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ENGINEERING OPERATIONS REPORT

NERVA MASS PROPERTIES COMPUTER METHODOLOGY

DRA

PROJECT 187

30 MARCH 1972

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NERVA MASS PROPERTIES COMPUTER METHODOLOGY

I. INTRODUCTION

This report documents the computer codes that were used for the weight, center of gravity, (C.G.), and mass moment of inertia calculations and documentation for the NERVA. The report covers Programs E15301, for basic weights calculations and 12001B, used primarily for summation and documentation.

II. SUMMARY/CONCLUSIONS

The two programs, E15301 and 12001B, are the basic tools used for weights work on the NERVA program. Used in conjunction with one another, they allow for rapid weights estimates for new concepts or changes while allowing for orderly documentation, which is a necessity in any effective weights effort.

Program E15301 requires that each component be resolved into a collection of standard shapes. Separate subroutines then process geometric and material density data for each entry. The master program then performs all calculations necessary to combine these results into a total weight, C.G. and moment of inertia for the component. The program is the same as the program COSMIC 400. The program was operational on the 1108 computer at the termination of the NERVA program.

Program 12001B is an Aerojet developed program. The program accepts previously calculated weight and C.G. data for individual components. The program sums weights and calculates center of gravities and moments of inertia for systems of up to four levels of assemblies. The output identifies the engine parts in a format usable directly in a formal report. The program has the option of recording the history of part and weight changes. The current ANSC version is for an IBM 360 computer.

III. TECHNICAL DISCUSSION

The rapid and numerous design concepts generated during the study of the NERVA placed a heavy burden on personnel responsible for weights analysis and weights control. The work was accomplished in an expeditious and efficient manner by using computer codes for routine calculations and for orderly documentation.

Computer Code E15301 is the basic tool for the initial calculation of weights data for a component. The general plan of the code requires that each component be resolved into a collection of standard shapes and that the minimum number of dimensional parameters defining each be submitted as input data. Only a single punched card is required for each geometric shape. Separate subroutines then process the data for each geometric shape resulting in the weight, C.G., and three moments of inertia for each. The main program then combines the results into a total weight package for the component.

There are 37 different geometric shapes currently in the program. They include (1) solids of revolution symmetrical about two principal axes; (2) solids of revolution symmetric about one axis; and (3) shapes which are not solids of revolutions such as rectangular prisms and wedges. Provision is also made for inclusion of independently produced formula for nonstandard shapes.

The program output is a columnized list of the weight, C.G., and moment of inertia for each geometric shape by defined number. The data from all the geometric shapes associated with one component are also combined. A typical input/output is included as Appendix A.

The original program was produced by North American Rockwell. It was obtained through COSMIC under the identification number 400.

Program 12001B was written to sum weights, and calculate centers of gravity and moments of inertia for a system comprised of major assemblies, assemblies, sub-assemblies and parts. The individual weights calculations must have been made previously. Each part name is printed along with its appropriate weight information. Summations can be made at each of the assembly levels listed above. The percent of the weight estimated, calculated and actual is included in the format. Breakout between gimbaled and non-gimbaled components can also be made.

The data are presented in a format usable directly in a formal report. The computer output sheets are used as documentation for the detailed engine weights. They serve in this manner as a working history of weight changes during engine development. Appendix D is a sample output sheet.

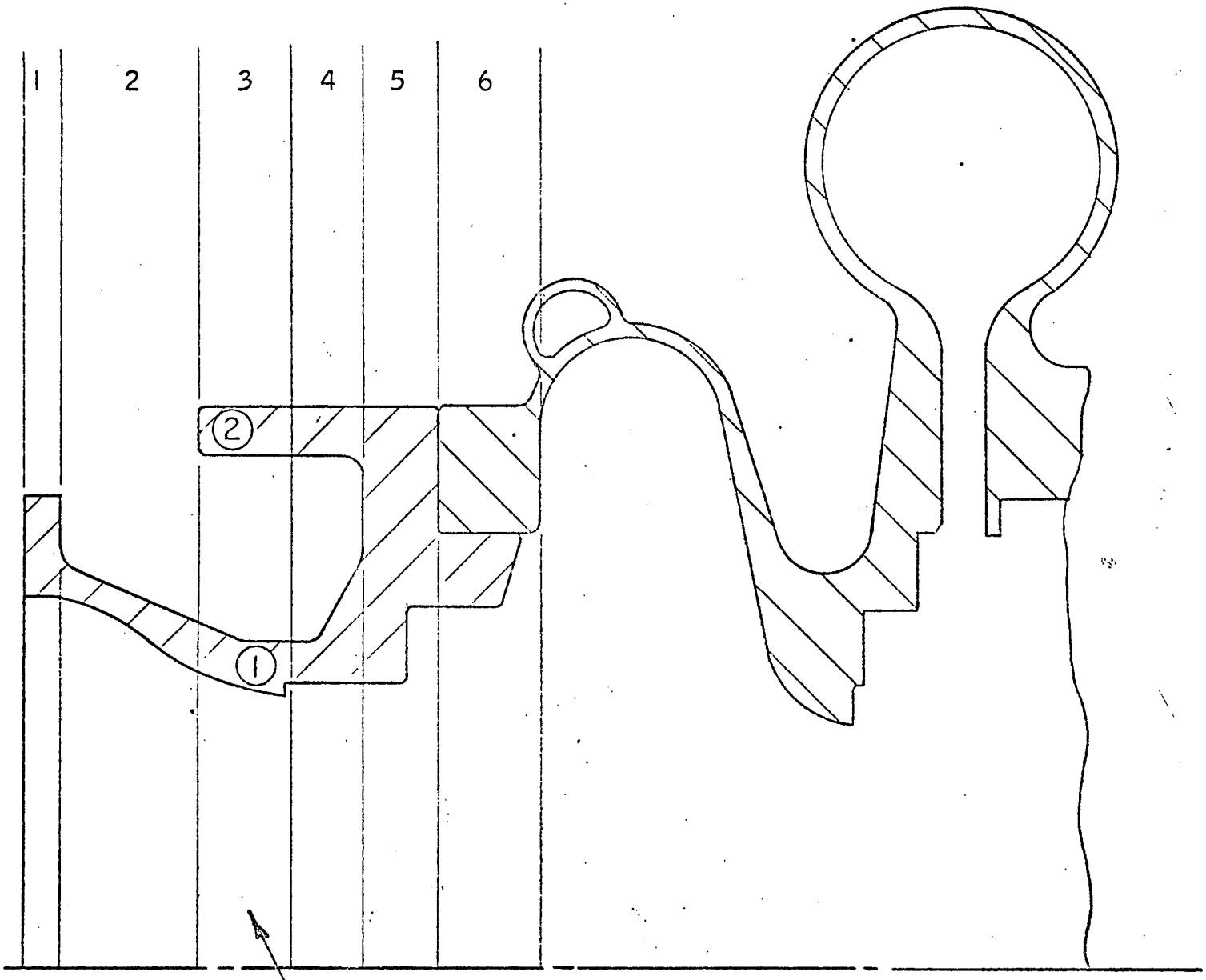
The program listings and Users' Manuals are included as Appendices B and C, and E and F, for Programs E15301 and 12001B, respectively.

Additional weights calculations were performed by hand or by use of calculation formula set-up on the General Electric teletype time share computer. These calculations are special in nature and of limited application and are not documented.

APPENDIX A

PROGRAM E15301

SAMPLE INPUT/OUTPUT



TYPICAL BREAKDOWN INTO BAYS
FOR SIMPLE GEOMETRIC SHAPES (TWO INPUTS
REQUIRED FOR BAY 3—SEE INPUT / OUTPUT LISTINGS)

TPA HOUSING

LISTING OF INPUT DATA CARDS FOR MASS PROPERTIES

PROGRAM E15301

1 HOUSING TPA 12-28-70 MIROPIENKO

1 1 1	.025	.29	1	4.75	.0		.05
1 1 1	.215	.29	1	6.0	4.75		.43
2111 2	.43	.29	1	5.2	4.8		-.75
.6	1.75						
2111 3	2.14	.29	1	4.36	3.75		.21
1.1	1.08						
1 1 3	2.38	.29	1	7.88	7.18		1.04
1100 4	4.3	.29	-1	4.85	4.55	3.5	1.05
1103 4	4.3	.29	-1	5.8	4.9	4.85	.3
1 1 4	3.75	.29	1	7.88	7.18		1.05
1 1 5	4.8	.29	1	7.88	3.45		1.
1 1 6	5.95	.29	1	5.7	3.7		.4
1109 6	5.75	.29	-1	5.7	5.25	5.0	.48
1 1 6	5.95	.29	1	7.35	5.75		1.28
1108 7	7.2	.18	-1	7.9	7.1	5.85	.62
1 2 7	7.0	.29		8.25	.5	.37	
1 1 8	7.68	.29	1	5.8	2.0		.3
2110 8	7.22	.29	1	5.73	5.4		.6
.3	.6						
1108 8	7.8	.29	-1	7.5	7.05	5.73	.6
2111 8	7.2	.15	1	7.9	7.05		.2
.65	.6						
110810	7.8	.29	1	7.45	7.0	2.0	.55
211114	7.8	.18	1	8.1	7.4		-.2
.9	.52						
211110	7.7	.29	1	8.2	8.0		-.15
.15	.7						
110812	8.35	.29	1	6.9	3.8	2.0	.55
211112	8.35	.12	1	7.9	7.0		-.6
5.5	.55						
211112	8.35	.29	1	8.15	7.9		-.6
.25	.55						
110813	8.9	.29	1	3.7	2.8	2.0	.64
211113	8.9	.12	1	7.3	3.5		-3.3
.3	.64						
211113	8.9	.29	1	7.65	7.35		-1.5
2.	.64						
110814	9.55	.29	1	2.8	2.35		.7
211114	9.55	.29	1	5.85	3.95		-.9
1.7	.7						
110915	11.0	.29	-1	5.05	3.5	3.15	.72
110815	11.0	.29	-1	6.8	5.05	5.05	.4
1 116	11.2	.29	1	5.5	3.7		.45
1 116	11.35	.29	1	8.15	5.5		.78
1 217	11.95	.29	1	9.8	1.6	1.45	
1 118	12.60	.29	1	8.1	5.95		.6
1 119	13.15	.29	1	7.7	2.4		.55
1 120	14.2	.29	1	2.9	2.15		1.3
110820	13.4	.29	1	3.7	2.97	2.9	1.3
1 120	14.25	.29	1	7.6	5.15		1.5
1 120	14.6	.29	1	8.95	7.6		.8
1 121	15.25	.29	1	2.9	2.15		.63
1 121	15.25	.29	1	7.6	5.15		.63
110922	15.55	.29	1	2.9	2.05	1.8	1.2
1 122	16.1	.29	1	6.35	6.05		1.2
1 123	17.1	.29	1	2.9	1.85		.7
211123	16.72	.29	1	8.6	6.0		-1.65
1.9	.7						
1 123	16.8	.29	1	13.0	8.4		.15
1 123	17.2	.29	1	13.0	12.85		.55
1 124	18.2	.29	1	2.9	1.95		1.54
211024	18.1	.29	1	3.5	2.9		.9
1.55	.9						
211124	17.45	.29	1	5.55	5.05		-1.5
.1	1.5						
1 124	18.2	.29	1	13.0	12.85		1.55
1 126	19.7	.29	1	3.5	2.		1.4
1 126	19.45	.29	1	4.2	4.1		.9
1 126	19.3	.29	1	7.0	5.1		1.3
1 126	19.6	.29	1	13.0	12.85		1.
1 128	22.15	.29	1	5.75	5.3		3.3
211128	20.0	.29	1	7.0	6.5		1.8
.3	1.7						
1 128	20.6	.29	1	13.0	8.8		.15
1 128	20.75	.29	1	13.0	12.85		1.5
1 129	24.8	.29	1	4.1	1.25		.25
1 129	24.4	.29	1	3.15	2.4		.5
1 129	24.5	.29	1	4.15	3.15		.25
1 129	24.0	.29	1	4.2	4.0		.8
1 129	24.1	.29	1	7.05	5.0		1.6
1 130	28.8	.29	1	.2	.0		2.2
1 130	27.35	.29	1	.3	.0		.75
1 130	26.2	.29	1	.5	.0		1.5
1 130	25.3	.29	1	.5	.3		.45
1 130	28.42	.29	1	.48	.4		2.9
1 130	26.0	.29	1	.7	.5		.5
1 130	25.8	.29	1	3.5	.7		.3
110730	25.7	.29	1	3.8	1.	.9	4.15
110830	24.9	.29	1	4.05	3.8	3.5	.8
1 130	27.4	.29	1	5.2	5.		5.
1 131	32.3	.29	1	.15	.0		4.8
1 131	35.5	.29	1	.5	.0		1.75
1 131	32.3	.29	1	.48	.4		4.8
1 131	36.3	.29	1	5.3	.0		.2
1 131	33.1	.29	1	5.3	5.1		6.3
1 132	36.75	.29	1	1.0	0.0		.7
1 132	37.6	.29	1	.2	.0		1.0
1 132	37.3	.29	1	1.	.5		.45
1 132	37.9	.29	1	.65	.45		.7
.1 132	38.35	.29	1	.65	.0		.2

Typical Input for Bay 3

RESULTS - INDIVIDUAL ENTRIES

K	N	WEIGHT	YBAR	XBAR	ZBAR	DELTA Y	DELTA X	DELTA Z
1	1	.10277917+01	.00	.02	5000.00	.57976016+01	.11594775+02	.57976016+01
1	1	.52642294+01	.00	.21	5000.00	.77152722+02	.15414322+03	.77152722+02
2	111	.72490157+01	.00	1.34	.00	.77640430+02	.15161361+03	.77640430+02
3	111	.67904795+01	.00	2.73	.00	.56615599+02	.11194664+03	.56615599+02
3	1	.99685909+01	.00	2.38	.00	.28469315+03	.56758570+03	.28469315+03
4	108	.99208660+01	.00	3.80	.00	.81909244+02	.16209829+03	.23775107+03
4	108	.14122737+01	.00	4.20	.00	.18971834+02	.37928392+02	.11365722+03
4	1	.10684635+02	.00	3.75	.00	.28744815+03	.57304325+03	.28744815+03
5	1	.45727927+02	.00	4.80	.00	.84974187+03	.16918624+04	.84974187+03
6	1	.68511854+01	.00	5.95	.00	.79188284+02	.15819387+03	.79188284+02
6	109	.27197019+01	.00	5.49	.00	.39944606+02	.79786323+02	.23135676+03
6	1	.24442697+02	.00	5.95	.00	.53548531+03	.10642961+04	.53548531+03
7	108	.77415787+01	.00	6.92	.00	.17649758+03	.35251044+03	.55907637+03
7	2	.53412672+01	.00	7.00	.00	.18306158+03	.18306158+03	.18306158+03
8	1	.66760951+01	.00	7.68	.00	.57059378+02	.11401568+03	.57059378+02
8	110	.15107684+01	.00	7.59	.00	.23599038+02	.47135662+02	.23599038+02
8	108	.10997654+02	.00	7.52	.00	.23654016+03	.47242614+03	.76879621+03
8	111	.32319496+01	.00	7.49	.00	.94126865+02	.18806084+03	.94126865+02
10	108	.24161019+02	.00	8.07	.00	.34061776+03	.68001891+03	.68534532+03
10	111	.35727449+01	.00	8.07	.00	.10342121+03	.20668210+03	.10342121+03
10	111	.17947180+01	.00	8.03	.00	.58096777+02	.11604805+03	.58096777+02
12	108	.12739226+02	.00	8.57	.00	.11828057+03	.23599380+03	.24067706+03
12	111	.75018552+01	.00	8.67	.00	.14016926+03	.28001126+03	.14016926+03
12	111	.13354371+01	.00	8.62	.00	.57900189+02	.11570285+03	.57900189+02
13	108	.34658176+01	.00	9.17	.00	.14679944+02	.29110955+02	.34186967+02
13	111	.47933165+01	.00	9.12	.00	.62012190+02	.12378888+03	.62012190+02
13	111	.89941167+01	.00	9.28	.00	.15425766+03	.30804591+03	.15425766+03
14	108	.42359487+01	.00	9.98	.00	.72884523+01	.14233491+02	.14576905+02
14	111	.15348448+02	.00	9.88	.00	.11058776+03	.22033515+03	.11058776+03
15	109	.94609416+01	.00	10.63	.00	.86909938+02	.17300190+03	.21475562+03
15	108	.35928207+01	.00	10.97	.00	.57965667+02	.11586887+03	.23469874+03
16	1	.67892332+01	.00	11.20	.00	.74698294+02	.14915945+03	.74698294+02
16	1	.25765201+02	.00	11.35	.00	.62254977+03	.12424930+04	.62254977+03
17	2	.25685216+02	.00	11.95	.00	.13072337+04	.25546354+04	.13072337+04
18	1	.16512541+02	.00	12.60	.00	.41748864+03	.83398653+03	.41748864+03
19	1	.25623027+02	.00	13.15	.00	.43689566+03	.87241900+03	.43689566+03
20	1	.44657469+01	.00	14.20	.00	.15247186+02	.29230861+02	.15247186+02
20	105	.32669026+01	.00	13.86	.00	.16910593+02	.33128812+02	.78601291+02
20	1	.42667943+02	.00	14.25	.00	.90748689+03	.17989654+04	.90748689+03
20	1	.16284326+02	.00	14.60	.00	.56211777+03	.11224985+04	.56211777+03
21	1	.21739075+01	.00	15.25	.00	.71547645+01	.14165725+02	.71547645+01
21	1	.17929356+02	.00	15.25	.00	.37837575+03	.75556548+03	.37837575+03
22	109	.51374780+01	.00	16.17	.00	.16160318+02	.31093045+02	.40864396+02
22	1	.49669802+01	.00	16.10	.00	.78701151+02	.15642623+03	.78701151+02
23	1	.31807448+01	.00	17.10	.00	.95389211+01	.18818081+02	.95389211+01
23	111	.19181193+02	.00	17.04	.00	.44573485+03	.88999008+03	.44576485+03
23	1	.13452740+02	.00	16.80	.00	.80579981+03	.16113692+04	.80570981+03
23	1	.19425533+01	.00	17.20	.00	.16234509+03	.32459222+03	.16234509+03
24	1	.69649051+01	.00	18.20	.00	.21014479+02	.39473762+02	.21014479+02
24	110	.42561037+01	.00	18.38	.00	.22185502+02	.43177167+02	.22185502+02
24	111	.39312320+01	.00	18.00	.00	.46553793+02	.91898468+02	.46553793+02
24	1	.54755958+01	.00	18.20	.00	.45847620+03	.91475983+03	.45847620+03
26	1	.10522765+02	.00	19.70	.00	.44467450+02	.85497464+02	.44467450+02
26	1	.68856323+00	.00	19.45	.00	.59072888+01	.11722702+02	.59072888+01
25	1	.27228906+02	.00	19.30	.00	.51444481+03	.10212201+04	.51444481+03

Typical Output for the Two Bay 3 Entries

LISTING OF OUTPUT DATA FOR MASS PROPERTIES PROGRAM E15301

26		.3532642E+01	.00	19.60	.00	.295[illegible]22+03	.5901676E+03	.2053782E+03
26		.1494934E+02	.00	22.15	.00	.242[illegible]204+03	.4571011E+03	.2421220E+03
28	111	.9442549E+01	.00	20.81	.00	.2809267E+03	.5571679E+03	.2809267E+03
26	1	.1251252E+02	.00	20.60	.00	.7709200E+03	.1541793E+04	.7709200E+03
28	1	.5296563E+01	.00	20.75	.00	.4436193E+03	.8852515E+03	.4436193E+03
29	1	.3472654E+01	.00	24.80	.00	.1596934E+02	.3190250E+02	.1596934E+02
29	1	.1896147E+01	.00	24.40	.00	.7473586E+01	.1486817E+02	.7473586E+01
29	1	.1662057E+01	.00	24.50	.00	.1129208E+02	.2256683E+02	.1129208E+02
29	1	.1195313E+01	.00	24.00	.00	.1011633E+02	.2010516E+02	.1011633E+02
29	1	.3600481E+02	.00	24.10	.00	.6801689E+03	.1344974E+04	.6801689E+03
30	1	.8017344E-01	.00	28.80	.00	.3313935E-01	.1603468E-02	.3313935E-01
30	1	.6149967E-01	.00	27.35	.00	.4266332E-02	.2767350E-02	.4266332E-02
30	1	.3417482E+00	.00	26.20	.00	.8541205E-01	.4270602E-01	.8541205E-01
30	1	.6655966E-01	.00	25.30	.00	.6682638E-02	.1115139E-01	.6682638E-02
30	1	.1486023E+00	.00	28.42	.00	.1485105E+00	.3630766E-01	.1485105E+00
30	1	.1093274E+00	.00	26.00	.00	.2250322E-01	.4045114E-01	.2250322E-01
30	1	.3214226E+01	.00	25.80	.00	.1026141E+02	.2047462E+02	.1026141E+02
30	107	.1777026E+01	.00	27.36	.00	.8899200E+01	.1330104E+02	.8899200E+01
30	108	.2305771E+01	.00	25.26	.00	.1610863E+02	.3107900E+02	.8785925E+02
30	1	.9292531E+01	.00	27.40	.00	.1402598E+03	.2417994E+03	.1402598E+03
31	1	.9839863E-01	.00	32.30	.00	.1894712E+00	.1105940E-02	.1894712E+00
31	1	.3985695E+00	.00	35.50	.00	.1266352E+00	.4992369E-01	.1266352E+00
31	1	.3078603E+00	.00	32.30	.00	.6211505E+00	.6009544E-01	.6211505E+00
31	1	.5118346E+01	.00	36.30	.00	.3596064E+02	.7188716E+02	.3596064E+02
31	1	.1193855E+02	.00	33.10	.00	.2009557E+03	.3229379E+03	.2009557E+03
32	1	.6377433E+00	.00	36.75	.00	.1854770E+00	.3188716E+00	.1854770E+00
32	1	.3644247E-01	.00	37.60	.00	.3401297E-02	.7288495E-03	.3401297E-02
32	1	.3074033E+00	.00	37.30	.00	.1012773E+00	.1921771E+00	.1012773E+00
32	1	.1403035E+00	.00	37.40	.00	.2765148E-01	.4384485E-01	.2765148E-01
32	1	.7868472E-01	.00	38.35	.00	.8388127E-02	.1626302E-01	.8388127E-02

RESULTS - SUB GROUPS

GROUP	WEIGHT	YBAR	XBAR	ZBAR	DELTA Y	DELTA X	DELTA Z
1	.6292021E+01	.00	.18	5000.00	.8298136E+02	.1657379E+03	.8298136E+02
2	.7249515E+01	.00	1.34	.00	.7764043E+02	.1516136E+03	.7764043E+02
3	.1677907E+02	.00	2.52	.00	.3419062E+03	.6795323E+03	.3419062E+03
4	.2091727E+02	.00	3.80	.00	.3885764E+03	.7730699E+03	.6391037E+03
5	.4572792E+02	.00	4.80	.00	.8497919E+03	.1691862E+04	.8497419E+03
6	.3401358E+02	.00	5.91	.00	.6551396E+03	.1302276E+04	.8465517E+03
7	.1301284E+02	.00	6.95	.00	.3595903E+03	.5351720E+03	.7421591E+03
8	.2261116E+02	.00	7.57	.00	.4114619E+03	.8216382E+03	.9437179E+03
10	.2952848E+02	.00	8.07	.00	.5021379E+03	.1002749E+04	.8469655E+03
12	.2217571E+02	.00	8.61	.00	.3164037E+03	.6317079E+03	.4389002E+03
13	.1079325E+02	.00	9.21	.00	.2310392E+03	.4609457E+03	.2505462E+03
14	.1458784E+02	.00	9.80	.00	.1178762E+03	.2345686E+03	.1251647E+03
15	.1366256E+02	.00	10.70	.00	.1450243E+03	.2888707E+03	.4496041E+03
16	.3269543E+02	.00	11.32	.00	.6973649E+03	.1391652E+04	.6973649E+03
17	.2566521E+02	.00	11.95	.00	.1307233E+04	.2556354E+04	.1307233E+04
18	.1051254E+02	.00	12.60	.00	.4174864E+03	.8339853E+03	.4174864E+03
19	.2662302E+02	.00	13.15	.00	.4368856E+03	.8724190E+03	.4368856E+03
20	.6672407E+02	.00	14.31	.00	.1594004E+04	.2983823E+04	.1565695E+04
21	.2010326E+02	.00	15.25	.00	.3955305E+03	.7697312E+03	.3955305E+03
22	.9204552E+01	.00	16.14	.00	.9487274E+02	.1875192E+03	.1195768E+03
23	.3775631E+02	.00	16.97	.00	.1423999E+04	.2844769E+04	.1423999E+04
24	.2012141E+02	.00	18.20	.00	.5485151E+03	.1089309E+04	.5485151E+03
25	.4196487E+02	.00	19.43	.00	.8615272E+03	.1708608E+04	.8615272E+03
28	.4220397E+02	.00	21.22	.00	.1757956E+04	.3441322E+04	.1757956E+04
29	.4423581E+02	.00	24.18	.00	.7268064E+03	.1434416E+04	.7268064E+03
30	.1743210E+02	.00	26.80	.00	.1895834E+03	.3076892E+03	.2613440E+03

← Summation of Bay 3 Data

OUTPUT DATA CONT.

31	.1786175I+02	.00	34.05	.00	.2766[illegible]+03	.3949610+03	.27662191+03
32	.1196957+01	.00	37.15	.00	.6322[illegible]+00	.5718855D+00	.63228979+00

TOTAL

0	.6830841+03	.00	13.52	46.06	.1559033D+09	.1558811G+09	.54011707+05

← Data for Input to Program 12001B for the TPA

DATA CARDS IGNORED - FIRST IS LISTED BELOW

APPENDIX B

PROGRAM E15301

LISTING

CODE	ΔI_X (ROLL)	ΔI_Y (PITCH)	ΔI_Z (YAW)	INPUT REQUIRED	OTHER
7	CYLINDER ABOUT AXES OTHER THAN AXIS OF CYLINDER. 74, 75, 76, 77, 78, 79 NOT ALLOWED.				
		$L = \sqrt{X^2 + Y^2 + Z^2}$			
7 1 (Solid)	$W\left\{\left[1 + \left(\frac{X}{L}\right)^2\right]\left(\frac{R^2}{4}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{X}{L}\right)^2\right]\right\}$			X,Y,Z,R	
	Input: W, X, Y, Z, R	$W\left[1 + \left(\frac{Y}{L}\right)^2\right]\left(\frac{R^2}{4}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{Y}{L}\right)^2\right]\}$			X = difference between X coordinates
			$W\left\{\left[1 + \left(\frac{Z}{L}\right)^2\right]\left(\frac{R^2}{4}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{Z}{L}\right)^2\right]\right\}$		
7 2 (Thin Wall)	$W\left\{\left[1 + \left(\frac{X}{L}\right)^2\right]\left(\frac{R^2}{2}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{X}{L}\right)^2\right]\right\}$			X,Y,Z,R	
	Input: W, X, Y, Z, R	$W\left\{\left[1 + \left(\frac{Y}{L}\right)^2\right]\left(\frac{R^2}{2}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{Y}{L}\right)^2\right]\right\}$			Y = difference between Y coordinates
			$W\left\{\left[1 + \left(\frac{Z}{L}\right)^2\right]\left(\frac{R^2}{2}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{Z}{L}\right)^2\right]\right\}$		
7 3 (Thick Wall)	$W\left\{\left[1 + \left(\frac{X}{L}\right)^2\right]\left(\frac{R^2 + r^2}{4}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{X}{L}\right)^2\right]\right\}$			X,Y,Z,R,r	
		$W\left\{\left[1 + \left(\frac{Y}{L}\right)^2\right]\left(\frac{R^2 + r^2}{4}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{Y}{L}\right)^2\right]\right\}$			Z = difference between Z coordinates
			$W\left\{\left[1 + \left(\frac{Z}{L}\right)^2\right]\left(\frac{R^2 + r^2}{4}\right) + \left(\frac{L^2}{12}\right)\left[1 - \left(\frac{Z}{L}\right)^2\right]\right\}$		

```
@9 RUN FYEE,428999,2,200     LIST E15301          16 MAY 72   21:51:14.366

@ CTL CLS=N                                       16 MAY 72   21:51:14.366

@ CTL UN=E15301                                   16 MAY 72   21:51:14.366

@R    ASG X=AN4155                                16 MAY 72   21:51:14.440
      AN4155 ASSIGNED UNIT  2

@N    HDG                                         16 MAY 72   21:51:14.449
```

```
@     XQT CUR                                          16 MAY 72   21:51:14.451
   1.      PEF X                                                   21:51:14
   2.      IN X                                                    21:51:16
     END OF FILE -- UNIT X
   3.      LIST 1                                                  21:51:20
```

13

```
@ ELT DELTA,1,710420, 60418

000001          CDELTAV                                                                 00004045
000002               SUBROUTINE DELTA                                                   00004050
000003          C    COMPUTES DELTA VALUES IN COMMON REFERENCE AXIS SYSTEM              00004055
000004               IMPLICIT REAL*8 (A-H,O-Z)                                          00004060
000005               DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00004065
000006              1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00004070
000007              2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                 00004075
000008               COMMON  PI                                                         00004080
000009               COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1        00004085
000010               COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T          00004090
000011               COMMON  J      , N      , K      , M      , Y      , X          00004095
000012               COMMON  Z      , RHO    , A1     , B1     , C1     , A2         00004100
000013               COMMON  B2     , C2     , R1     , R2     , R3     , H          00004105
000014               COMMON  B      , A      , AL     , WT     , YBT    , XBT        00004110
000015               COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT       00004115
000016               COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT       00004120
000017               COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB         00004125
000018               COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ        00004130
000019               COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ        00004135
000020               COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3        00004140
000021               COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3        00004145
000022               COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S       00004150
000023               COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S       00004155
000024               COMMON  E      , V      , PY     , PX     , PZ                 00004160
000025                    IF(N-200) 100,200,200                                       00004165
000026          100 DY1= CL1S*DPY + (1.0D0-CL1S) * DPX                                00004170
000027              DX1= CM1S*DPY + (1.0D0-CM1S) * DPX                                00004175
000028              DZ1= CN1S*DPY + (1.0D0-CN1S) * DPX                                00004180
000029              RETURN                                                            00004185
000030          200 DY1= CL1S*DPY +CL2S*DPX +CL3S*DPZ                                 00004190
000031              DX1= CM1S*DPY +CM2S*DPX +CM3S*DPZ                                 00004195
000032              DZ1= CN1S*DPY +CN2S*DPX +CN3S*DPZ                                 00004200
000033              RETURN                                                            00004205
000034              END                                                               00004210
```

```
@ ELT DIRC,1,710420, 60419

000001          CDIRCOS                                                                 00003755
000002                SUBROUTINE DIRC                                                   00003760
000003          C     COMPUTES DIRECTION COSINES AND C.G.                               00003765
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00003770
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00003775
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00003780
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00003785
000008                COMMON  PI                                                       00003790
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00003795
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00003800
000011                COMMON  J       , N       , K       , M       , Y       , X     00003805
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00003810
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00003815
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00003820
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00003825
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00003830
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00003835
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00003840
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00003845
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00003850
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00003855
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00003860
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00003865
000024                COMMON  E       , V       , PY      , PX      , PZ            00003870
000025                D1=DSQRT(A1**2 +B1**2 +C1**2)                                    00003875
000026                CL1 =A1/ D1                                                      00003880
000027                CM1 =B1/ D1                                                      00003885
000028                CN1 =C1/ D1                                                      00003890
000029                CL1S= CL1**2                                                     00003895
000030                CM1S= CM1**2                                                     00003900
000031                CN1S= CN1**2                                                     00003905
000032                     IF(N-200) 100,200,200                                       00003910
000033           100  YBR= Y + CL1*S                                                  00003915
000034                XBR= X+ CM1 *S                                                   00003920
000035                ZBR = Z+ CN1 *S                                                  00003925
000036                RETURN                                                           00003930
000037           200  A3= B1*C2 -C1*B2                                                00003935
000038                B3= C1*A2 - A1*C2                                                00003940
000039                C3= A1*B2 - B1*A2                                                00003945
000040                D2=DSQRT(A2**2 +B2**2 +C2**2)                                    00003950
000041                D3=DSQRT(A3**2 +B3**2 +C3**2)                                    00003955
000042                CL2 = A2/D2                                                      00003960
000043                CL2S= CL2**2                                                     00003965
000044                CM2 = B2/D2                                                      00003970
000045                CM2S= CM2**2                                                     00003975
000046                CN2 = C2/D2                                                      00003980
000047                CN2S= CN2**2                                                     00003985
000048                CL3 = A3/D3                                                      00003990
000049                CL3S= CL3**2                                                     00003995
000050                CM3 = B3/D3                                                      00004000
000051                CM3S = CM3**2                                                    00004005
000052                CN3 = C3/D3                                                      00004010
000053                CN3S= CN3**2                                                     00004015
000054                YBR= Y+S*CL2                                                     00004020
000055                XBR= X+S*CM2                                                     00004025
000056                ZBR= Z+S*CN2                                                     00004030
```

```
000057          RETURN                                          00004035
000058          END                                             00004040
```

```
@ ELT E15301,1,710423, 61857

1COSMIC ENGINE TEST CASE ONE TALBOTT 16JAN67
 1105 1  0    20     0    1     0   -1      0    10
 1 01 1  0    36     0    1     0    1      0    10     9          32
 1107 1  0    52     0    1     0    1      0    10     2      906 18
 1 02 2  0    45     0    1     0    1      0    15     5     48
 2202 3 115  275    0   29     0    0      1                      15
     7           3                      1           0           0
 1101 4  0    35    24   29     0   -1      0     2     1           5
 2202 4  0    41    24   29     0    1      0                      12
     8           4                      0           0           1
 1 01 4  0    635   24   29     0    1      0     2     15         33
 1 01 4  0    90     7   29     0    0      1     2     15         14
 2201 4  0    80    14   29     1    0      0    10     2     15
                            45          0           1           1
71 01 4  0    41    24  -29     0    1      0     10     0          12
```

```
@ ELT FOR1,1,710420, 60420

000001          C1FOR                                                                   00002420
000002                SUBROUTINE FOR1                                                   00002425
000003          C           FORMULA 1 - HOLLOW CYLINDER                                 00002430
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00002435
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00002440
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00002445
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00002450
000008                COMMON  PI                                                        00002455
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00002460
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00002465
000011                COMMON  J       , N       , K       , M       , Y       , X     00002470
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00002475
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00002480
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00002485
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00002490
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00002495
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00002500
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00002505
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00002510
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00002515
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00002520
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00002525
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00002530
000024                COMMON  E       , V       , PY      , PX      , PZ              00002535
000025                W1= P1*RHO*H*(R1**2-R2**2)                                        00002540
000026                S=0.0D0                                                           00002545
000027                CALL DIRC                                                         00002550
000028                DPY= .5D0*W1*(R1**2 +R2**2)                                       00002555
000029                DPX= W1/12.0D0*(3.0D0*(R1**2+R2**2) +H**2)                        00002560
000030                DPZ= DPX                                                          00002565
000031                CALL DELTA                                                        00002570
000032                RETURN                                                            00002575
000033                END                                                               00002580
```

```
@ ELT FOR101,1,710420, 60422

000001          C101FOR                                                                 00004525
000002                SUBROUTINE FOR101                                                 00004530
000003          C           FORMULA 101 - FRUSTRUM 'OF A SOLID CONE                     00004535
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00004540
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00004545
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00004550
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00004555
000008                COMMON  PI                                                       00004560
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00004565
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00004570
000011                COMMON  J       , N       , K       , M       , Y       , X    00004575
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00004580
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00004585
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00004590
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00004595
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00004600
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00004605
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00004610
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00004615
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00004620
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00004625
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00004630
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00004635
000024                COMMON  E       , V       , PY      , PX      , PZ           00004640
000025                E= R1**2  +R1*R2 +R2**2                                          00004645
000026                F=(R1-R2) /R1                                                    00004650
000027                G= E*(R1**2 +R2**2) - (R1*R2)**2                                 00004655
000028                U= F**2 -3.0D0*F +3.0D0                                          00004660
000029                P= .15D0/U*(F**4-5.0D0*F**3 +10.0D0*F*F -10.0D0*F +5.0D0)        00004665
000030                Q=1.0D0/U**2*(.1D0*U*(6.0D0*F**2-15.0D0*F+10.0D0) -.0625D0*(3.0D0*00004670
000031               1F*F-8.0D0*F+6.0)**2)                                             00004675
000032                W1= RHO *E*PI *H/3.0D0                                           00004680
000033                S= .25D0*H/E *(R1*R1+2.0D0*R1*R2 +3.0D0* R2*R2)                  00004685
000034                CALL DIRC                                                        00004690
000035                DPY =  .3D0 *W1 /E * G                                           00004695
000036                DPX= W1 *(P*R1**2 +Q*H**2)                                       00004700
000037                DPZ = DPX                                                        00004705
000038                CALL DELTA                                                       00004710
000039                RETURN                                                           00004715
000040                END                                                              00004720
```

```
@ ELT FOR102,1,710420, 60424

000001          C102FOR                                                                 00004725
000002                SUBROUTINE FOR102                                                 00004730
000003          C           FORMULA 102 - OUTSIDE FILLET OF REVOLUTION                  00004735
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00004740
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00004745
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00004750
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00004755
000008                COMMON  PI                                                       00004760
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00004765
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00004770
000011                COMMON  J       , N       , K       , M       , Y       , X    00004775
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00004780
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00004785
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00004790
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00004795
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00004800
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00004805
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00004810
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00004815
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00004820
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00004825
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00004830
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00004835
000024                COMMON  E       , V       , PY      , PX      , PZ           00004840
000025                E= RHO *R2**2                                                    00004845
000026                W1= E*(1.3483832D0*R1 +.30118575D0*R2)                           00004850
000027                T= E*R2 /W1*(1.0471976D0*R1 +.26179939D0*R2)                     00004855
000028                S= R2-T                                                          00004860
000029                CALL DIRC                                                        00004865
000030                DPY= E*(1.3483832D0*R1**3 +.90355662D0*R1*R1*R2 +.3440474D0 *R1* 00004870
000031               1R2*R2 +.05835682D0*R2**3)                                        00004875
000032                DPX= .5D0*DPY +E* R2*R2*(.8606946D0 *R1 +.23237608D0*R2) -W1*T*T 00004880
000033                DPZ= DPX                                                         00004885
000034                CALL DELTA                                                       00004890
000035                RETURN                                                           00004895
000036                END                                                              00004900
```

@ ELT FOR103,1,710420, 60426

```
000001          C103FOR                                                                 00004905
000002                SUBROUTINE FOR103                                                 00004910
000003          C           FORMULA 103 - INSIDE FILLET OF REVOLUTION                   00004915
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00004920
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00004925
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00004930
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00004935
000008                COMMON  PI                                                        00004940
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00004945
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00004950
000011                COMMON  J       , N       , K       , M       , Y       , X     00004955
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00004960
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00004965
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00004970
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00004975
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00004980
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00004985
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00004990
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00004995
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00005000
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00005005
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00005010
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00005015
000024                COMMON  E       , V       , PY      , PX      , PZ            00005020
000025                E= RHO *R2**2                                                     00005025
000026                W1= E*(1.3483832D0*R1 +1.0471976D0*R2)                            00005030
000027                S= E*R2 /W1 *(.30118575D0*R1 +.26179939D0 *R2)                    00005035
000028                CALL DIRC                                                         00005040
000029                DPY= E*(1.3483832D0 *R1**3 +3.1415927D0*R1*R1*R2 +2.5820838D0 *R1*00005045
000030               1R2*R2+.7330382 9D0*R2**3)                                         00005050
000031                DPX= .5D0*DPY +E*R2*R2*(.11468258D0*R1 + .10471976D0 *R2) -W1*S*S 00005055
000032                DPZ=DPX                                                           00005060
000033                CALL DELTA                                                        00005065
000034                RETURN                                                            00005070
000035                END                                                               00005075
```

```
@ ELT FOR104,1,710420, 60428

000001          C104FOR                                                                 00005080
000002                SUBROUTINE FOR104                                                 00005085
000003          C           FORMULA 104 - SOLID SPHERICAL SEGMENT, 2 BASES              00005090
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00005095
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00005100
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00005105
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00005110
000008                COMMON  PI                                                       00005115
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00005120
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00005125
000011                COMMON  J       , N       , K       , M       , Y       , X    00005130
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00005135
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00005140
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00005145
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00005150
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00005155
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00005160
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00005165
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00005170
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00005175
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00005180
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00005185
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00005190
000024                COMMON  E       , V       , PY      , PX      , PZ           00005195
000025                E= PI*RHO*H                                                      00005200
000026                W1= E*(R1*R1-(3.0D0*B*B +3.0D0*B*H +H*H) /3.0D0)                 00005205
000027                T= E/W1 *(R1**2 *(B+.5D0*H) -B**3 -1.5D0*B*B*H -B*H*H -.25D0*H**3)00005210
000028                S= T-B                                                           00005215
000029                CALL DIRC                                                        00005220
000030                DPY= .5D0*E*(R1**4 +B**4 +2.0D0*B**3*H +2.0D0*B**2*H**2 +B*H**3 + 00005225
000031               1.2D0*H**4-2.0D0/3.0D0*R1**2*(3.0D0*B*B+3.0D0*B*H+H**2))          00005230
000032                DPX= E *(.25D0*R1**4 + R1**2 /6.0D0*( 3.0D0*B*B +3.0D0*B*H +H*H) 00005235
000033               1-.75*B*(B**3+2.0D0*B*B*H+2.0D0*B*H*H+H**3)-.15D0*H**4)-W1*T*T     00005240
000034                DPZ=DPX                                                          00005245
000035                CALL DELTA                                                       00005250
000036                RETURN                                                           00005255
000037                END                                                              00005260
```

```
@ ELT FOR105,1,710420, 60430

000001          C105FOR                                                                 00005265
000002                SUBROUTINE FOR105                                                 00005270
000003          C           FORMULA 105 - SOLID HEMISPHERE                              00005275
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00005280
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00005285
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00005290
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00005295
000008                COMMON  PI                                                        00005300
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00005305
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00005310
000011                COMMON  J       , N       , K       , M       , Y       , X     00005315
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00005320
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00005325
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00005330
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00005335
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00005340
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00005345
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00005350
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00005355
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00005360
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00005365
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00005370
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00005375
000024                COMMON  E       , V       , PY      , PX      , PZ            00005380
000025                W1= 2.0D0/3.0D0*PI*RHO*R1**3                                      00005385
000026                S = .375D0 *R1                                                    00005390
000027                CALL DIRC                                                         00005395
000028                DPY= .4D0*W1*R1**2                                                00005400
000029                DPX= .259375D0 *W1 *R1**2                                         00005405
000030                DPZ=DPX                                                           00005410
000031                CALL DELTA                                                        00005415
000032                RETURN                                                            00005420
000033                END                                                               00005425
```

@ ELT FOR106,1,710420, 60431

```
C106FOR
      SUBROUTINE FOR106
C           FORMULA 106 - OUTER QUARTER OF SOLID TORUS
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION        HOL(12), W(100), YB(100), XB(100), ZB(100),     DY
     1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100),
     2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)
      COMMON  PI
      COMMON  W1    , YBR   , XBR   , ZBR   , DY1   , DX1
      COMMON  DZ1   , DPY   , DPX   , DPZ   , S     , T
      COMMON  J     , N     , K     , M     , Y     , X
      COMMON  Z     , RHO   , A1    , B1    , C1    , A2
      COMMON  B2    , C2    , R1    , R2    , R3    , H
      COMMON  B     , A     , AL    , WT    , YBT   , XBT
      COMMON  ZBT   , DYT   , DXT   , DZT   , SWYT  , SWXT
      COMMON  SWZT  , SWYST , SWXST , SWZST , SDYT  , SDXT
      COMMON  SDZT  , HOL   , W     , YB    , XB    , ZB
      COMMON  DY    , DX    , DZ    , SWY   , SWX   , SWZ
      COMMON  SWYS  , SWXS  , SWZS  , SDY   , SDX   , SDZ
      COMMON  D1    , D2    , D3    , CL1   , CL2   , CL3
      COMMON  CM1   , CM2   , CM3   , CN1   , CN2   , CN3
      COMMON  A3    , B3    , C3    , CL1S  , CL2S  , CL3S
      COMMON  CM1S  , CM2S  , CM3S  , CN1S  , CN2S  , CN3S
      COMMON  E     , V     , PY    , PX    , PZ
      E= .5D0*PI *RHO *R2**2
      W1= E*(PI*R1 +4.0D0/3.0D0*R2)
      S= .5D0*R2 *(8.0D0*R1 +3.0D0*R2) / (3.0D0*PI*R1 +4.0D0*R2 )
      CALL DIRC
      DPY= E*( PI*R1**3 +4.0D0*R1*R1*R2 +.75D0*PI*R1*R2*R2 +8.0D0*R2**3
     1/15.0D0)
      DPX= .5D0*DPY +E*R2**2 *(.25D0*PI*R1 +4.0D0/15.0D0*R2) -W1*S*S
      DPZ=DPX
      CALL DELTA
      RETURN
      END
```

```
@ ELT FOR107,1,710420, 60433

000001          C107FOR                                                                 00005605
000002                SUBROUTINE FOR107                                                 00005610
000003          C       FORMULA 107 - FRUSTRUM OF A HOLLOW CONE                         00005615
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00005620
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00005625
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00005630
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00005635
000008                COMMON  PI                                                       00005640
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00005645
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00005650
000011                COMMON  J       , N       , K       , M       , Y       , X    00005655
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00005660
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00005665
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00005670
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00005675
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00005680
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00005685
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00005690
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00005695
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00005700
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00005705
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00005710
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00005715
000024                COMMON  E       , V       , PY      , PX      , PZ           00005720
000025                U1= R1-R2                                                        00005725
000026                T= R2-R3                                                         00005730
000027                Q= U1 / H                                                        00005735
000028                E= PI * RHO * T                                                  00005740
000029                E1= E *(2.0D0*R1 -T)                                             00005745
000030                E2= 2.0D0*E *U1                                                  00005750
000031                E3= .5D0 *E /Q                                                   00005755
000032                E4= 2.0D0*E3 /Q**2                                               00005760
000033                W1= E * H *(R1+R3)                                               00005765
000034                S= H/3.0D0*(3.0D0*E1 -2.0D0*E2) / (2.0D0*E1 -E2)                 00005770
000035                B= R1 -Q*S                                                       00005775
000036                U2= R1**2 -R2**2                                                 00005780
000037                U3= R1**3 -R2**3                                                 00005785
000038                U4= R1**4 -R2**4                                                 00005790
000039                CALL DIRC                                                        00005795
000040                DPY= E3 *(U4 -2.0D0*T*U3 +2.0D0*T*T*U2 - T**3 *U1)               00005800
000041                DPX= .5D0*DPY +E4 *(.5D0*U4 -(4.0D0*B+T) /3.0D0*U3 +B*(B+T) *U2 -B00005805
000042               1*B*T*U1)                                                         00005810
000043                DPZ= DPX                                                         00005815
000044                CALL DELTA                                                       00005820
000045                RETURN                                                           00005825
000046                END                                                              00005830
```

```
@ ELT FOR108,1,710420, 60435

000001          C108FOR                                                                 00005835
000002                SUBROUTINE FOR108                                                 00005840
000003          C        FORMULA 108 - ANNULAR FRUSTRUM - CYLINDRICAL HOLE              00005845
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00005850
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00005855
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00005860
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00005865
000008                COMMON  PI                                                       00005870
000009                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1       00005875
000010                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T         00005880
000011                COMMON  J      , N      , K      , M      , Y      , X         00005885
000012                COMMON  Z      , RHO    , A1     , B1     , C1     , A2        00005890
000013                COMMON  B2     , C2     , R1     , R2     , R3     , H         00005895
000014                COMMON  B      , A      , AL     , WT     , YBT    , XBT       00005900
000015                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT      00005905
000016                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT      00005910
000017                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB        00005915
000018                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ       00005920
000019                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ       00005925
000020                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3       00005930
000021                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3       00005935
000022                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S      00005940
000023                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S      00005945
000024                COMMON  E      , V      , PY     , PX     , PZ                00005950
000025                CALL FOR101                                                      00005955
000026                WF= W1                                                           00005960
000027                YBF= YBR                                                         00005965
000028                XBF= XBR                                                         00005970
000029                ZBF= ZBR                                                         00005975
000030                DYF = DY1                                                        00005980
000031                DXF = DX1                                                        00005985
000032                DZF = DZ1                                                        00005990
000033                R1= R3                                                           00005995
000034                R2=0.0D0                                                         00006000
000035                RHO= -RHO                                                        00006005
000036                Y= Y+.5D0*H *CL1                                                 00006010
000037                X= X+.5D0*H *CM1                                                 00006015
000038                Z= Z+.5D0*H *CN1                                                 00006020
000039                CALL FOR1                                                        00006025
000040                WC=W1                                                            00006030
000041                YBC = YBR                                                        00006035
000042                XBC = XBR                                                        00006040
000043                ZBC = ZBR                                                        00006045
000044                DYC = DY1                                                        00006050
000045                DXC = DX1                                                        00006055
000046                DZC = DZ1                                                        00006060
000047                W1= WC+WF                                                        00006065
000048                YBR= (WF*YBF +WC*YBC) / W1                                       00006070
000049                XBR= (WF*XBF +WC*XBC) / W1                                       00006075
000050                ZBR= (WF*ZBF +WC*ZBC) / W1                                       00006080
000051                DY1= WF*(XBF**2 +ZBF**2) + WC*(XBC**2 +ZBC**2) +DYF + DYC -W1*(XBR00006085
000052               1**2 +ZBR**2)                                                     00006090
000053                DX1= WF*(YBF**2 +ZBF**2) +WC*(YBC**2 +ZBC**2) +DXF +DXC  -W1*( YBR00006095
000054               1**2 +ZBR**2)                                                     00006100
000055                DZ1= WF*(XBF**2 +YBF**2) + WC*(XBC**2 + YBC**2) +DZF +DZC - W1*(XB00006105
000056               1R**2 + YBR**2)                                                   00006110
```

```
000057                RETURN                                    00006115
000058                END                                       00006120
```

```
@ ELT FOR109,1,710420, 60436

000001      C109FOR                                                                  00006125
000002            SUBROUTINE FOR109                                                  00006130
000003      C        FORMULA 109 - ANNULAR CYLINDER - CONICAL HOLE                   00006135
000004            IMPLICIT REAL*8 (A-H,O-Z)                                          00006140
000005            DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00006145
000006           1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00006150
000007           2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00006155
000008            COMMON  PI                                                        00006160
000009            COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1        00006165
000010            COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T          00006170
000011            COMMON  J      , N      , K      , M      , Y      , X          00006175
000012            COMMON  Z      , RHO    , A1     , B1     , C1     , A2         00006180
000013            COMMON  B2     , C2     , R1     , R2     , R3     , H          00006185
000014            COMMON  B      , A      , AL     , WT     , YBT    , XBT        00006190
000015            COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT       00006195
000016            COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT       00006200
000017            COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB         00006205
000018            COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ        00006210
000019            COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ        00006215
000020            COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3        00006220
000021            COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3        00006225
000022            COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S       00006230
000023            COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S       00006235
000024            COMMON  E      , V      , PY     , PX     , PZ                  00006240
000025            ER2 = R2                                                          00006245
000026            EY = Y                                                            00006250
000027            EX = X                                                            00006255
000028            EZ = Z                                                            00006260
000029            R2=0.0D0                                                          00006265
000030            S= .5D0*H                                                         00006270
000031            CALL DIRC                                                         00006275
000032            Y=YBR                                                             00006280
000033            X=XBR                                                             00006285
000034            Z=ZBR                                                             00006290
000035            CALL FOR1                                                         00006295
000036            WC= W1                                                            00006300
000037            YBC = YBR                                                         00006305
000038            XBC = XBR                                                         00006310
000039            ZBC = ZBR                                                         00006315
000040            DYC = DY1                                                         00006320
000041            DXC = DX1                                                         00006325
000042            DZC = DZ1                                                         00006330
000043            RHO = -RHO                                                        00006335
000044            R1 = ER2                                                          00006340
000045            R2= R3                                                            00006345
000046            Y = EY                                                            00006350
000047            X = EX                                                            00006355
000048            Z = EZ                                                            00006360
000049            CALL FOR101                                                       00006365
000050            WF = W1                                                           00006370
000051            YBF = YBR                                                         00006375
000052            XBF = XBR                                                         00006380
000053            ZBF = ZBR                                                         00006385
000054            DYF = DY1                                                         00006390
000055            DXF = DX1                                                         00006395
000056            DZF = DZ1                                                         00006400
```

```
000057                W1 = WC+WF                                                    00006405
000058                YBR= (WF*YBF + WC*YBC) / W1                                   00006410
000059                XBR= (WF*XBF + WC*XBC) / W1                                   00006415
000060                ZBR= (WF*ZBF + WC*ZBC) / W1                                   00006420
000061                DY1= WF*(XBF**2 +ZBF**2) +WC*(XBC**2 +ZBC**2) + DYF + DYC -W1*(XBR00006425
000062               1**2 +ZBR**2)                                                  00006430
000063                DX1 = WF*( YBF**2 +ZBF**2) + WC*(YBC**2 +ZBC**2) + DXF + DXC - W1 00006435
000064               1*( YBR**2 + ZBR**2)                                          00006440
000065                DZ1 = WF*( XBF**2 + YBF**2) + WC*(XBC**2 +YBC**2) +DZF +DZC -W1* 00006445
000066               1(XBR**2 +YBR**2)                                             00006450
000067                RETURN                                                        00006455
000068                END                                                           00006460
```

```
@ ELT FOR110,1,710420, 60439

000001          C110FOR                                                                 00006465
000002                SUBROUTINE FOR110                                                 00006470
000003          C       FORMULA 110 - TRAPEZOID OF REVOLUTION                           00006475
000004          C         PARALLEL SIDES PARALLEL TO AXIS OF REVOLUTION                 00006480
000005                IMPLICIT REAL*8 (A-H,O-Z)                                         00006485
000006                DIMENSION TW(4),TYB(4),TXB(4),TZB(4),TDY(4),TDX(4),TDZ(4)         00006490
000007                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00006495
000008               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00006500
000009               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00006505
000010                COMMON  PI                                                       00006510
000011                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1       00006515
000012                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T         00006520
000013                COMMON  J      , N      , K      , M      , Y      , X         00006525
000014                COMMON  Z      , RHO    , A1     , B1     , C1     , A2        00006530
000015                COMMON  B2     , C2     , R1     , R2     , R3     , H         00006535
000016                COMMON  B      , A      , AL     , WT     , YBT    , XBT       00006540
000017                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT      00006545
000018                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT      00006550
000019                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB        00006555
000020                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ       00006560
000021                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ       00006565
000022                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3       00006570
000023                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3       00006575
000024                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S      00006580
000025                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S      00006585
000026                COMMON  E      , V      , PY     , PX     , PZ                00006590
000027          C         STORE ORIGINAL INPUT                                        00006595
000028                EA=A1                                                           00006600
000029                EB=B1                                                           00006605
000030                EC=C1                                                           00006610
000031                EY=Y                                                            00006615
000032                EX=X                                                            00006620
000033                EZ=Z                                                            00006625
000034                ERO=RHO                                                         00006630
000035                ER1=R1                                                          00006635
000036                ER2=R2                                                          00006640
000037                EH=H                                                            00006645
000038          C         DETERMINE TYPE                                              00006650
000039                IF(H-A) 10, 40, 60                                              00006655
000040             10 IF(H-B) 20, 20, 30                                              00006660
000041             20 L=1                                                             00006665
000042                GO TO 90                                                        00006670
000043             30 L=3                                                             00006675
000044                GO TO 90                                                        00006680
000045             40 IF(H-B) 50, 50, 30                                              00006685
000046             50 L=2                                                             00006690
000047                GO TO 90                                                        00006695
000048             60 IF(H-B) 50, 50, 70                                              00006700
000049             70 L=4                                                             00006705
000050          C         SET-UP INPUT FOR SECTION 1                                  00006710
000051             90 S=.5D0*A                                                        00006715
000052                R2=0.0D0                                                        00006720
000053                H=A                                                             00006725
000054                CALL DIRC                                                       00006730
000055                Y=YBR                                                           00006735
000056                X=XBR                                                           00006740
```

```
000057                Z=ZBR                                                00006745
000058                I=1                                                  00006750
000059             98 CALL FOR1                                            00006755
000060           C       STORE RESULTS                                     00006760
000061            100 TW(I) = W1                                           00006765
000062                TYB(I)= YBR                                          00006770
000063                TXB(I)= XBR                                          00006775
000064                TZB(I)= ZBR                                          00006780
000065                TDY(I)= DY1                                          00006785
000066                TDX(I)= DX1                                          00006790
000067                TDZ(I)= DZ1                                          00006795
000068                GO TO (110,130,120,140), I                           00006800
000069           C       SET-UP INPUT FOR SECTION 3                        00006805
000070            110 Y=EY                                                 00006810
000071                X=EX                                                 00006815
000072                Z=EZ                                                 00006820
000073                S= EH-.5D0*B                                         00006825
000074                R1= ER2                                              00006830
000075                H=B                                                  00006835
000076                CALL DIRC                                            00006840
000077                Y=YBR                                                00006845
000078                X=XBR                                                00006850
000079                Z=ZBR                                                00006855
000080                RHO= -ERO                                            00006860
000081                I=3                                                  00006865
000082                GO TO 98                                             00006870
000083           C       SET-UP INPUT FOR SECTION 2                        00006875
000084            120 Y=EY                                                 00006880
000085                X=EX                                                 00006885
000086                Z=EZ                                                 00006890
000087                GO TO (122,122,124,124), L                           00006895
000088            122 A1= -EA                                              00006900
000089                B1= -EB                                              00006905
000090                C1= -EC                                              00006910
000091                H= B-EH                                              00006915
000092                RHO= ERO                                             00006920
000093                GO TO 126                                            00006925
000094            124 H= EH-B                                              00006930
000095                RHO = -ERO                                           00006935
000096            126 R1 = ER1                                             00006940
000097                R2 = ER2                                             00006945
000098                I=2                                                  00006950
000099            128 CALL FOR101                                          00006955
000100                GO TO 100                                            00006960
000101            130 Y=EY                                                 00006965
000102                X=EX                                                 00006970
000103                Z=EZ                                                 00006975
000104                A1= EA                                               00006980
000105                B1= EB                                               00006985
000106                C1= EC                                               00006990
000107                S=A                                                  00006995
000108                CALL DIRC                                            00007000
000109                Y=YBR                                                00007005
000110                X=XBR                                                00007010
000111                Z=ZBR                                                00007015
000112                GO TO (132,134,132,134), L                           00007020
000113            132 A1= -EA                                              00007025
000114                B1= -EB                                              00007030
000115                C1= -EC                                              00007035
000116                H= A-EH                                              00007040
```

```
000117                RHO= -ERO                                          00007045
000118                GO TO 136                                          00007050
000119           134  H=EH-A                                             00007055
000120                RHO = ERO                                          00007060
000121           136  R1= ER1                                            00007065
000122                R2= ER2                                            00007070
000123                I=4                                                00007075
000124                GO TO 128                                          00007080
000125           C         COMBINE SECTIONS                              00007085
000126           140  W1= TW(1)                                          00007090
000127                YM= TW(1)* TYB(1)                                  00007095
000128                XM= TW(1)* TXB(1)                                  00007100
000129                ZM= TW(1)* TZB(1)                                  00007105
000130                YM2 = YM * TYB(1)                                  00007110
000131                XM2 = XM * TXB(1)                                  00007115
000132                ZM2 = ZM * TZB(1)                                  00007120
000133                YD= TDY(1)                                         00007125
000134                XD = TDX(1)                                        00007130
000135                ZD = TDZ(1)                                        00007135
000136                DO 150 I=2,4                                       00007140
000137                W1=W1+ TW(I)                                       00007145
000138                YM= YM + TW(I) * TYB(I)                            00007150
000139                XM= XM + TW(I) * TXB(I)                            00007155
000140                ZM= ZM + TW(I) * TZB(I)                            00007160
000141                YM2 = YM2 + TW(I) * TYB(I)**2                      00007165
000142                XM2 = XM2 + TW(I) * TXB(I)**2                      00007170
000143                ZM2 = ZM2 + TW(I) * TZB(I)**2                      00007175
000144                YD = YD + TDY(I)                                   00007180
000145                XD = XD + TDX(I)                                   00007185
000146           150  ZD = ZD + TDZ(I)                                   00007190
000147                YBR= YM / W1                                       00007195
000148                XBR= XM / W1                                       00007200
000149                ZBR= ZM / W1                                       00007205
000150                DY1 = XM2 +ZM2 + YD -W1*(XBR**2 +ZBR**2)           00007210
000151                DX1 = YM2 +ZM2 + XD -W1*(YBR**2 +ZBR**2)           00007215
000152                DZ1 = XM2 +YM2 + ZD -W1*(YBR**2 +XBR**2)           00007220
000153                RETURN                                             00007225
000154                END                                                00007230
```

```
@ ELT FOR111,1,710420, 60441

000001          C111FOR                                                                 00007235
000002                SUBROUTINE FOR111                                                 00007240
000003          C       FORMULA 111 - TRAPEZOID OF REVOLUTION                           00007245
000004          C          PARALLEL SIDES NORMAL TO AXIS OF REVOLUTION                  00007250
000005                IMPLICIT REAL*8 (A-H,O-Z)                                         00007255
000006                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00007260
000007               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00007265
000008               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00007270
000009                COMMON  PI                                                       00007275
000010                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00007280
000011                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00007285
000012                COMMON  J       , N       , K       , M       , Y       , X    00007290
000013                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00007295
000014                COMMON  B2      , C2      , R1      , R2      , R3      , H    00007300
000015                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00007305
000016                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00007310
000017                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00007315
000018                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00007320
000019                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00007325
000020                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00007330
000021                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00007335
000022                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00007340
000023                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00007345
000024                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00007350
000025                COMMON  E       , V       , PY      , PX      , PZ           00007355
000026          C     STORE ORIGINAL INPUT                                            00007360
000027                ER1=R1                                                          00007365
000028                ER2=R2                                                          00007370
000029                EH=H                                                            00007375
000030                EA=A1                                                           00007380
000031                EB=B1                                                           00007385
000032                EC=C1                                                           00007390
000033                EY=Y                                                            00007395
000034                EX=X                                                            00007400
000035                EZ=Z                                                            00007405
000036                IF(H) 20, 20, 30                                                00007410
000037             20 R2= ER1 + EH                                                    00007415
000038                GO TO 40                                                        00007420
000039             30 S=A                                                          00007425
000040                CALL DIRC                                                       00007430
000041                Y=YBR                                                           00007435
000042                X=XBR                                                           00007440
000043                Z=ZBR                                                           00007445
000044                A1= -EA                                                         00007450
000045                B1=-EB                                                          00007455
000046                C1=-EC                                                          00007460
000047                R1= ER1 + EH                                                    00007465
000048                R2= ER1                                                         00007470
000049             40 H=A                                                          00007475
000050                CALL FOR101                                                     00007480
000051                TW= W1                                                          00007485
000052                TYB= YBR                                                        00007490
000053                TXB= XBR                                                        00007495
000054                TZB= ZBR                                                        00007500
000055                TDY= DY1                                                        00007505
000056                TDX = DX1                                                       00007510
```

```
000057                TDZ = DZ1                                          00007515
000058          C     COMPUTE INNER CONE RESULTS                         00007520
000059                RHO= -RHO                                          00007525
000060                P= ER1 +EH -B                                      00007530
000061                Y= EY                                              00007535
000062                X= EX                                              00007540
000063                Z= EZ                                              00007545
000064                A1= EA                                             00007550
000065                B1= EB                                             00007555
000066                C1= EC                                             00007560
000067                IF(P-ER2) 60,60,50                                 00007565
000068             50 S=A                                                00007570
000069                CALL DIRC                                          00007575
000070                Y= YBR                                             00007580
000071                X= XBR                                             00007585
000072                Z= ZBR                                             00007590
000073                A1= -EA                                            00007595
000074                B1= -EB                                            00007600
000075                C1= -EC                                            00007605
000076                R1= P                                              00007610
000077                R2= ER2                                            00007615
000078                GO TO 70                                           00007620
000079             60 R1= ER2                                            00007625
000080                R2= P                                              00007630
000081             70 H= A                                               00007635
000082                CALL FOR101                                        00007640
000083          C           COMBINE FRUSTRUMS                            00007645
000084                YM= TW*TYB +W1*YBR                                 00007650
000085                XM= TW*TXB +W1*XBR                                 00007655
000086                ZM= TW*TZB +W1*ZBR                                 00007660
000087                YM2= TW*TYB**2 + W1*YBR**2                         00007665
000088                XM2= TW*TXB**2 + W1*XBR**2                         00007670
000089                ZM2 = TW*TZB**2 + W1*ZBR**2                        00007675
000090                YD= TDY +DY1                                       00007680
000091                XD= TDX +DX1                                       00007685
000092                ZD= TDZ +DZ1                                       00007690
000093                W1= TW+W1                                          00007695
000094                YBR= YM / W1                                       00007700
000095                XBR= XM / W1                                       00007705
000096                ZBR= ZM / W1                                       00007710
000097                DY1= XM2 +ZM2 +YD - W1*(XBR**2 + ZBR**2)           00007715
000098                DX1= YM2 +ZM2 +XD - W1*(YBR**2 + ZBR**2)           00007720
000099                DZ1= XM2 +YM2 +ZD - W1*(YBR**2 + XBR**2)           00007725
000100                RETURN                                             00007730
000101                END                                                00007735
```

```
@ ELT FOR112,1,710420, 60442

000001          C112FOR                                                                 00007740
000002                SUBROUTINE FOR112                                                 00007745
000003          C        FORMULA 112 - INNER QUARTER OF SOLID TORUS                     00007750
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00007755
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00007760
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00007765
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00007770
000008                COMMON  PI                                                       00007775
000009                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1       00007780
000010                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T         00007785
000011                COMMON  J      , N      , K      , M      , Y      , X         00007790
000012                COMMON  Z      , RHO    , A1     , B1     , C1     , A2        00007795
000013                COMMON  B2     , C2     , R1     , R2     , R3     , H         00007800
000014                COMMON  B      , A      , AL     , WT     , YBT    , XBT       00007805
000015                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT      00007810
000016                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT      00007815
000017                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB        00007820
000018                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ       00007825
000019                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ       00007830
000020                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3       00007835
000021                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3       00007840
000022                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S      00007845
000023                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S      00007850
000024                COMMON  E      , V      , PY     , PX     , PZ                 00007855
000025                NN=N                                                             00007860
000026                N=112                                                            00007865
000027          C        CYLINDER                                                      00007870
000028                S= .5D0*R2                                                       00007875
000029                CALL DIRC                                                        00007880
000030                Y=YBR                                                            00007885
000031                X=XBR                                                            00007890
000032                Z=ZBR                                                            00007895
000033                H=R2                                                             00007900
000034                R2=R1-H                                                          00007905
000035                CALL FOR1                                                        00007910
000036                WC=W1                                                            00007915
000037                YC=YBR                                                           00007920
000038                XC=XBR                                                           00007925
000039                ZC=ZBR                                                           00007930
000040                CY=DY1                                                           00007935
000041                CX=DX1                                                           00007940
000042                CZ=DZ1                                                           00007945
000043          C           FILLET                                                    00007950
000044                RHO = -RHO                                                       00007955
000045                S=.500*H                                                         00007960
000046                CALL DIRC                                                        00007965
000047                Y=YBR                                                            00007970
000048                X=XBR                                                            00007975
000049                Z=ZBR                                                            00007980
000050                A1= -A1                                                          00007985
000051                B1= -B1                                                          00007990
000052                C1= -C1                                                          00007995
000053                R1=R2                                                            00008000
000054                R2=H                                                             00008005
000055                CALL FOR102                                                      00008010
000056                WF= W1                                                           00008015
```

```
000057                YF= YBR                                                00008020
000058                XF= XBR                                                00008025
000059                ZF= ZBR                                                00008030
000060                FY= DY1                                                00008035
000061                FX= DX1                                                00008040
000062                FZ= DZ1                                                00008045
000063          C        RESTORE INPUT                                       00008050
000064                RHO= -RHO                                              00008055
000065                R1= R1+H                                               00008060
000066                S=H                                                    00008065
000067                CALL DIRC                                              00008070
000068                Y=YBR                                                  00008075
000069                X=XBR                                                  00008080
000070                Z=ZBR                                                  00008085
000071                A1= -A1                                                00008090
000072                B1=-B1                                                 00008095
000073                C1=-C1                                                 00008100
000074                N=NN                                                   00008105
000075          C        COMBINE CYLINDER AND FILLET                         00008110
000076                W1= WC+WF                                              00008115
000077                YM= WC*YC + WF*YF                                      00008120
000078                XM= WC*XC + WF*XF                                      00008125
000079                ZM= WC*ZC + WF*ZF                                      00008130
000080                YM2 = WC*YC**2 +WF*YF**2                               00008135
000081                XM2=  WC*XC**2 +WF*XF**2                               00008140
000082                ZM2=  WC*ZC**2 +WF*ZF**2                               00008145
000083                YD= CY+FY                                              00008150
000084                XD= CX+FX                                              00008155
000085                ZD= CZ+FZ                                              00008160
000086                YBR= YM / W1                                           00008165
000087                XBR= XM / W1                                           00008170
000088                ZBR= ZM /W1                                            00008175
000089                DY1= XM2 +ZM2 +YD -W1*(XBR**2 + ZBR**2)                00008180
000090                DX1= YM2+ZM2 +XD -W1* (YBR**2 +ZBR**2)                 00008185
000091                DZ1= XM2+YM2 + ZD -W1*(YBR**2 +XBR**2)                 00008190
000092                RETURN                                                 00008195
000093                END                                                    00008200
```

@ ELT FOR113,1,710420, 60444

```
000001          C113FOR                                                                 00008205
000002                SUBROUTINE FOR113                                                 00008210
000003          C        FORMULA 113 - INNER QUARTER, TOROIDAL SHELL                    00008215
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00008220
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00008225
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00008230
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00008235
000008                COMMON  PI                                                       00008240
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00008245
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00008250
000011                COMMON  J       , N       , K       , M       , Y       , X    00008255
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00008260
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00008265
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00008270
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00008275
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00008280
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00008285
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00008290
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00008295
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00008300
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00008305
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00008310
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00008315
000024                COMMON  E       , V       , PY      , PX      , PZ           00008320
000025                NN=N                                                             00008325
000026                N=113                                                            00008330
000027                ER2=R2                                                           00008335
000028                IF(NN-115) 112,106,112                                           00008340
000029              112 CALL FOR112                                                    00008345
000030                GO TO 120                                                        00008350
000031              106 CALL FOR106                                                    00008355
000032              120 WC=W1                                                          00008360
000033                YC=YBR                                                           00008365
000034                XC=XBR                                                           00008370
000035                ZC=ZBR                                                           00008375
000036                CY=DY1                                                           00008380
000037                CX=DX1                                                           00008385
000038                CZ=DZ1                                                           00008390
000039                R2=R3                                                            00008395
000040                RHO= -RHO                                                        00008400
000041                IF(NN-115) 212,206,212                                           00008405
000042              212 CALL FOR112                                                    00008410
000043                GO TO 220                                                        00008415
000044              206 CALL FOR106                                                    00008420
000045              220 WF=W1                                                          00008425
000046                YF= YBR                                                          00008430
000047                XF= XBR                                                          00008435
000048                ZF= ZBR                                                          00008440
000049                FY= DY1                                                          00008445
000050                FX= DX1                                                          00008450
000051                FZ= DZ1                                                          00008455
000052          C        RESTORE INPUT                                                 00008460
000053                R2=ER2                                                           00008465
000054                RHO= -RHO                                                        00008470
000055                N=NN                                                             00008475
000056          C        COMBINE PARTS                                                 00008480
```

```
000057                  W1=WC+WF                                        00008485
000058                  YM=WC*YC + WF*YF                                00008490
000059                  XM=WC*XC + WF*XF                                00008495
000060                  ZM=WC*ZC + WF*ZF                                00008500
000061                  YM2= WC* YC**2 + WF* YF**2                      00008505
000062                  XM2= WC* XC**2 + WF* XF**2                      00008510
000063                  ZM2= WC* ZC**2 + WF* ZF**2                      00008515
000064                  YD= CY+FY                                       00008520
000065                  XD= CX+FX                                       00008525
000066                  ZD= CZ+FZ                                       00008530
000067                  YBR= YM /W1                                     00008535
000068                  XBR= XM / W1                                    00008540
000069                  ZBR= ZM / W1                                    00008545
000070                  DY1= XM2 +ZM2 +YD -W1*( XBR**2 + ZBR**2)        00008550
000071                  DX1= YM2 +ZM2 +XD -W1*( YBR**2 + ZBR**2)        00008555
000072                  DZ1= YM2 + XM2 +ZD -W1*( YBR**2 + XBR**2)       00008560
000073                  RETURN                                          00008565
000074                  END                                             00008570
```

```
@ ELT FOR114,1,710420, 60446

000001          C114FOR                                                                 00008575
000002                SUBROUTINE FOR114                                                 00008580
000003          C        FORMULA 114 - HOLLOW SPHERICAL SEGMENT                         00008585
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00008590
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00008595
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00008600
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00008605
000008                COMMON  PI                                                       00008610
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00008615
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00008620
000011                COMMON  J       , N       , K       , M       , Y       , X    00008625
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00008630
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00008635
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00008640
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00008645
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00008650
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00008655
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00008660
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00008665
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00008670
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00008675
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00008680
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00008685
000024                COMMON  E       , V       , PY      , PX      , PZ           00008690
000025                NN=N                                                             00008695
000026                N=114                                                            00008700
000027                B=R3                                                             00008705
000028                ER1=R1                                                           00008710
000029                CALL FOR104                                                      00008715
000030                WC=W1                                                            00008720
000031                YC= YBR                                                          00008725
000032                XC=XBR                                                           00008730
000033                ZC= ZBR                                                          00008735
000034                CY=DY1                                                           00008740
000035                CX=DX1                                                           00008745
000036                CZ=DZ1                                                           00008750
000037                R1=R2                                                            00008755
000038                RHO = -RHO                                                       00008760
000039                CALL FOR104                                                      00008765
000040                WF=W1                                                            00008770
000041                YF=YBR                                                           00008775
000042                XF=XBR                                                           00008780
000043                ZF=ZBR                                                           00008785
000044                FY=DY1                                                           00008790
000045                FX=DX1                                                           00008795
000046                FZ=DZ1                                                           00008800
000047          C         RESTORE INPUT                                              00008805
000048                R1= ER1                                                          00008810
000049                RHO = -RHO                                                       00008815
000050                N=NN                                                             00008820
000051          C        COMBINE PARTS                                               00008825
000052                W1=WC+WF                                                         00008830
000053                YM= WC*YC +WF*YF                                                 00008835
000054                XM= WC*XC +WF*XF                                                 00008840
000055                ZM= WC*ZC +WF*ZF                                                 00008845
000056                YM2= WC*YC**2 +WF*YF**2                                          00008850
```

```
000057                XM2= WC*XC**2 +WF*XF**2                                00008855
000058                ZM2= WC*ZC**2 +WF*ZF**2                                00008860
000059                YD= CY+FY                                              00008865
000060                XD= CX+FX                                              00008870
000061                ZD= CZ+FZ                                              00008875
000062                YBR= YM / W1                                           00008880
000063                XBR= XM / W1                                           00008885
000064                ZBR= ZM / W1                                           00008890
000065                DY1= XM2 + ZM2 +YD -W1*( XBR**2 + ZBR**2)              00008895
000066                DX1= YM2 + ZM2 +XD -W1*( YBR**2 + ZBR**2)              00008900
000067                DZ1 =YM2 + XM2 +ZD -W1*( YBR**2 + XBR**2)              00008905
000068                RETURN                                                 00008910
000069                END                                                    00008915
```

```
@ ELT FOR115,1,710420, 60447

000001          C115FOR                                                                 00008920
000002                SUBROUTINE FOR115                                                 00008925
000003          C       FORMULA 115 - OUTER QUARTER, TOROIDAL SHELL                     00008930
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00008935
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00008940
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00008945
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00008950
000008                COMMON  PI                                                       00008955
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00008960
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00008965
000011                COMMON  J       , N       , K       , M       , Y       , X    00008970
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00008975
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00008980
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00008985
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00008990
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00008995
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00009000
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00009005
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00009010
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00009015
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00009020
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00009025
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00009030
000024                COMMON  E       , V       , PY      , PX      , PZ           00009035
000025                NN=N                                                             00009040
000026                N=115                                                            00009045
000027                CALL FOR113                                                      00009050
000028                N=NN                                                             00009055
000029                RETURN                                                           00009060
000030                END                                                              00009065
```

@ ELT FOR116,1,710420, 60448

```
000001          C116FOR                                                                 00009070
000002                SUBROUTINE FOR116                                                 00009075
000003          C       FORMULA 116 - AXIAL SEGMENT OF SOLID TORUS                      00009080
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00009085
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00009090
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00009095
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00009100
000008                COMMON  PI                                                       00009105
000009                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1       00009110
000010                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T         00009115
000011                COMMON  J      , N      , K      , M      , Y      , X         00009120
000012                COMMON  Z      , RHO    , A1     , B1     , C1     , A2        00009125
000013                COMMON  B2     , C2     , R1     , R2     , R3     , H         00009130
000014                COMMON  B      , A      , AL     , WT     , YBT    , XBT       00009135
000015                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT      00009140
000016                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT      00009145
000017                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB        00009150
000018                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ       00009155
000019                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ       00009160
000020                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3       00009165
000021                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3       00009170
000022                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S      00009175
000023                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S      00009180
000024                COMMON  E      , V      , PY     , PX     , PZ                 00009185
000025                NN=N                                                             00009190
000026                N=116                                                            00009195
000027                H=H-R2                                                           00009200
000028                AL=DATAN2(DSQRT(R2**2-H**2),DABS(H))                             00009205
000029                E1=.5D0*PI*RHO*R1*R2**2                                          00009210
000030                E2= PI-.5D0*(2.0D0*AL-DSIN(2.0D0*AL))                            00009215
000031                E3= 2.0D0*(DSIN(AL))**3                                          00009220
000032                IF(H) 20,30,30                                                   00009225
000033             20 E2= PI-E2                                                        00009230
000034             30 W1= 4.0D0*E1*E2                                                  00009235
000035                S= R2*E3 /(3.0D0*E2)                                             00009240
000036                CALL DIRC                                                        00009245
000037                DPY= E1*(E2 *(4.0D0*R1**2 +3.0D0*R2**2) +H*R2*E3)                00009250
000038                DPX= .5D0*E1*(E2*(4.0D0*R1**2 +5.0D0*R2**2) -H*R2*E3) -W1*S**2   00009255
000039                DPZ=DPX                                                          00009260
000040                CALL DELTA                                                       00009265
000041                N=NN                                                             00009270
000042                H=H+R2                                                           00009275
000043                RETURN                                                           00009280
000044                END                                                              00009285
```

```
@ ELT FOR117,1,710420, 60450

000001          C117FOR                                                                 00009290
000002                SUBROUTINE FOR117                                                 00009295
000003          C       FORMULA 117 - AXIAL SEGMENT OF HOLLOW TORUS                     00009300
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00009305
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00009310
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00009315
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00009320
000008                COMMON  PI                                                       00009325
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00009330
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00009335
000011                COMMON  J       , N       , K       , M       , Y       , X     00009340
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00009345
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00009350
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00009355
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00009360
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00009365
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00009370
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00009375
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00009380
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00009385
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00009390
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00009395
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00009400
000024                COMMON  E       , V       , PY      , PX      , PZ              00009405
000025                NN=N                                                             00009410
000026                N=117                                                            00009415
000027                EH=H                                                             00009420
000028                ER2=R2                                                           00009425
000029                CALL FOR116                                                      00009430
000030                WC= W1                                                           00009435
000031                YC= YBR                                                          00009440
000032                XC= XBR                                                          00009445
000033                ZC= ZBR                                                          00009450
000034                CY= DY1                                                          00009455
000035                CX= DX1                                                          00009460
000036                CZ= DZ1                                                          00009465
000037                H= H-R2+R3                                                       00009470
000038                R2=R3                                                            00009475
000039                RHO= -RHO                                                        00009480
000040                CALL FOR116                                                      00009485
000041                WF=W1                                                            00009490
000042                YF= YBR                                                          00009495
000043                XF= XBR                                                          00009500
000044                ZF= ZBR                                                          00009505
000045                FY=DY1                                                           00009510
000046                FX=DX1                                                           00009515
000047                FZ=DZ1                                                           00009520
000048                W1= WC +WF                                                       00009525
000049                YM= WC*YC +WF*YF                                                 00009530
000050                XM= WC*XC +WF*XF                                                 00009535
000051                ZM= WC*ZC +WF*ZF                                                 00009540
000052                YM2= WC*YC**2 + WF*YF**2                                         00009545
000053                XM2= WC*XC**2 + WF*XF**2                                         00009550
000054                ZM2= WC*ZC**2 + WF*ZF**2                                         00009555
000055                YD= CY+FY                                                        00009560
000056                XD= CX+FX                                                        00009565
```

```
000057                ZD= CZ+FZ                                          00009570
000058                YBR= YM / W1                                       00009575
000059                XBR= XM / W1                                       00009580
000060                ZBR= ZM / W1                                       00009585
000061                DY1= XM2+ZM2 +YD -W1*( XBR**2 +ZBR**2)             00009590
000062                DX1= YM2+ZM2 +XD -W1*( YBR**2 +ZBR**2)             00009595
000063                DZ1= YM2+XM2 +ZD -W1*( YBR**2 +XBR**2)             00009600
000064                N=NN                                               00009605
000065                RH0=-RH0                                           00009610
000066                H=EH                                               00009615
000067                R2=ER2                                             00009620
000068                RETURN                                             00009625
000069                END                                                00009630
```

```
@ ELT FOR118,1,710420, 60452

000001          C118FOR                                                                 00009635
000002                SUBROUTINE FOR118                                                 00009640
000003          C       FORMULA 118 - RADIAL  SEGMENT OF SOLID TORUS                    00009645
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00009650
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00009655
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00009660
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00009665
000008                COMMON  PI                                                       00009670
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00009675
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00009680
000011                COMMON  J       , N       , K       , M       , Y       , X     00009685
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00009690
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00009695
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00009700
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00009705
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00009710
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00009715
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00009720
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00009725
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00009730
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00009735
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00009740
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00009745
000024                COMMON  E       , V       , PY      , PX      , PZ            00009750
000025                NN=N                                                             00009755
000026                N=118                                                            00009760
000027                EH=H                                                             00009765
000028                H=H-R2                                                           00009770
000029                T= 2.0D0*DSQRT(R2**2 -H**2)                                      00009775
000030                AL=DATAN2(.5D0*T,DABS(H))                                        00009780
000031                E1=.5D0*PI*RHO*R1*R2**2                                          00009785
000032                E2= PI-.5D0*(2.0D0*AL -DSIN(2.0D0*AL))                           00009790
000033                E3= 2.0D0/R1*R2/15.0D0*(DSIN(AL))**3                             00009795
000034                IF(H) 20,30,30                                                   00009800
000035             20 E2= PI-E2                                                        00009805
000036             30 W1= .8*D0E1*( 5.0D0*E2 +E3)                                      00009810
000037                S=0.0D0                                                          00009815
000038                CALL DIRC                                                        00009820
000039                DPY= E1*( E2*(4.0D0*R1**2 +3.0D0*R2**2) +E3*(60.0D0*R1**2 -45.0D0*00009825
000040               1R1*H +12.0D0* H**2 +8.0D0*R2**2))                                00009830
000041                DPX= .5D0*DPY +E1*( E2*R2**2 +E3*(T**2 +5.0D0*R1*H))             00009835
000042                DPZ=DPX                                                          00009840
000043                CALL DELTA                                                       00009845
000044                N=NN                                                             00009850
000045                H=EH                                                             00009855
000046                RETURN                                                           00009860
000047                END                                                              00009865
```

```
@ ELT FOR119,1,710420, 60453

000001          C119FOR                                                                 00009870
000002                SUBROUTINE FOR119                                                 00009875
000003          C       FORMULA 119 - RADIAL SEGMENT OF HOLLOW TORUS                    00009880
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00009885
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00009890
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00009895
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00009900
000008                COMMON  PI                                                       00009905
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00009910
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00009915
000011                COMMON  J       , N       , K       , M       , Y       , X    00009920
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00009925
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00009930
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00009935
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00009940
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00009945
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00009950
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00009955
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00009960
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00009965
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00009970
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00009975
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00009980
000024                COMMON  E       , V       , PY      , PX      , PZ           00009985
000025                NN=N                                                            00009990
000026                N=119                                                           00009995
000027                EH=H                                                            00010000
000028                ER2=R2                                                          00010005
000029                CALL FOR118                                                     00010010
000030                WC= W1                                                          00010015
000031                CY= DY1                                                         00010020
000032                CX= DX1                                                         00010025
000033                CZ= DZ1                                                         00010030
000034                H= H-R2+R3                                                      00010035
000035                R2 = R3                                                         00010040
000036                RHO= -RHO                                                       00010045
000037                CALL FOR118                                                     00010050
000038                W1=W1 +WC                                                       00010055
000039                DY1= DY1+CY                                                     00010060
000040                DX1= DX1+CX                                                     00010065
000041                DZ1= DZ1+CZ                                                     00010070
000042                N=NN                                                            00010075
000043                RHO =-RHO                                                       00010080
000044                H= EH                                                           00010085
000045                R2= ER2                                                         00010090
000046                RETURN                                                          00010095
000047                END                                                             00010100
```

```
@ ELT FOR120,1,710420, 60455

000001          C120FOR                                                                 00010105
000002                SUBROUTINE FOR120                                                 00010110
000003          C           FORMULA 120 - RADIAL SECTOR OF SOLID TORUS          10-23-62 00010115
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00010120
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00010125
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00010130
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00010135
000008                COMMON  PI                                                        00010140
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00010145
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00010150
000011                COMMON  J       , N       , K       , M       , Y       , X     00010155
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00010160
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00010165
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00010170
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00010175
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00010180
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00010185
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00010190
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00010195
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00010200
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00010205
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00010210
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00010215
000024                COMMON  E       , V       , PY      , PX      , PZ              00010220
000025                NN=N                                                              00010225
000026                N=120                                                             00010230
000027                PHI = PI*R3 /180.0D0                                              00010235
000028                ALF = PI*H / 360.0D0                                              00010240
000029                Q= 2.0D0*PI*RHO *R2**2                                            00010245
000030                T1 = PHI-ALF                                                      00010250
000031                T2= PHI +ALF                                                      00010255
000032                SN1 =DSIN(T1)                                                     00010260
000033                SN2 =DSIN(T2)                                                     00010265
000034                CS1 =DCOS(T1)                                                     00010270
000035                CS2 =DCOS(T2)                                                     00010275
000036                E1= CS2-CS1                                                       00010280
000037                E2= SN2-SN1                                                       00010285
000038                E3= .5D0*(SN2**2 -SN1**2)                                         00010290
000039                E4= .5D0*(SN2*CS2 - SN1*CS1)                                      00010295
000040                E5= (CS2**3 -CS1**3) /3.0D0                                       00010300
000041                W1= Q*(R1*ALF -E1*R2/3.0D0)                                       00010305
000042                S= Q/W1*R2 *(E2*R1/3.0D0+ E3*R2/4.0D0)                            00010310
000043                G1= .75D0*(ALF-E4)                                                00010315
000044                G2= .2D0*(E5-E1)                                                  00010320
000045                G3= ALF*S**2 *R1                                                  00010325
000046                G4= -S/3.0D0*(2.0D0*E2*R1 +E1*S)                                  00010330
000047                G5= .25D0 *(R1*(ALF+E4) -2.0D0*E3*S)                              00010335
000048                G6= -.2D0 *E5                                                     00010340
000049                CALL DIRC                                                         00010345
000050                DPY= Q*(ALF*R1**3 - E1*R1**2 *R2 +G1*R1*R2**2 + G2*R2**3 )        00010350
000051                DPX= .5D0*DPY +Q*(G3+G4*R2 +G5*R2**2 +G6*R2**3 )                  00010355
000052                DPZ= DPX                                                          00010360
000053                CALL DELTA                                                        00010365
000054                N=NN                                                              00010370
000055                RETURN                                                            00010375
000056                END                                                               00010380
```

```
@ ELT FOR121,1,710420, 60456

000001          C121FOR                                                                 00010385
000002                SUBROUTINE FOR121                                                 00010390
000003          C       FORMULA 121 - RADIAL SECTOR OF A HOLLOW TORUS                   00010395
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00010400
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00010405
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00010410
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00010415
000008                COMMON  PI                                                       00010420
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00010425
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00010430
000011                COMMON  J       , N       , K       , M       , Y       , X    00010435
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00010440
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00010445
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00010450
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00010455
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00010460
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00010465
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00010470
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00010475
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00010480
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00010485
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00010490
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00010495
000024                COMMON  E       , V       , PY      , PX      , PZ           00010500
000025          C           SAVE INPUT                                                00010505
000026                NN= N                                                           00010510
000027                N= 121                                                          00010515
000028                ER2 = R2                                                        00010520
000029                ER3 = R3                                                        00010525
000030          C           OUTER SECTOR                                              00010530
000031                R3= AL                                                          00010535
000032                CALL FOR120                                                     00010540
000033                WC= W1                                                          00010545
000034                YC= YBR                                                         00010550
000035                XC= XBR                                                         00010555
000036                ZC= ZBR                                                         00010560
000037                CY= DY1                                                         00010565
000038                CX= DX1                                                         00010570
000039                CZ= DZ1                                                         00010575
000040          C           INNER SECTOR                                              00010580
000041                RHO = -RHO                                                      00010585
000042                R2 = ER3                                                        00010590
000043                CALL FOR120                                                     00010595
000044                WF= W1                                                          00010600
000045                YF= YBR                                                         00010605
000046                XF= XBR                                                         00010610
000047                ZF= ZBR                                                         00010615
000048                FY= DY1                                                         00010620
000049                FX= DX1                                                         00010625
000050                FZ= DZ1                                                         00010630
000051          C           RESTORE INPUT                                             00010635
000052                R2 = ER2                                                        00010640
000053                R3= ER3                                                         00010645
000054                RHO= -RHO                                                       00010650
000055                N= NN                                                           00010655
000056          C           COMBINE PARTS                                             00010660
```

```
000057                  W1= WC +WF                                          00010665
000058                  YM= WC*YC + WF*YF                                   00010670
000059                  XM= WC*XC + WF*XF                                   00010675
000060                  ZM= WC*ZC + WF*ZF                                   00010680
000061                  YM2= WC*YC**2 + WF*YF**2                            00010685
000062                  XM2= WC*XC**2 + WF*XF**2                            00010690
000063                  ZM2= WC*ZC**2 + WF*ZF**2                            00010695
000064                  YD= CY+FY                                           00010700
000065                  XD= CX+FX                                           00010705
000066                  ZD= CZ+FZ                                           00010710
000067                  YBR= YM / W1                                        00010715
000068                  XBR= XM / W1                                        00010720
000069                  ZBR= ZM / W1                                        00010725
000070                  DY1= XM2 +ZM2 +YD -W1*(XBR*XBR + ZBR*ZBR)           00010730
000071                  DX1= YM2 +ZM2 +XD -W1*(YBR*YBR + ZBR*ZBR)           00010735
000072                  DZ1= XM2 +YM2 +ZD -W1*(XBR*XBR + YBR*YBR)           00010740
000073                  RETURN                                              00010745
000074                  END                                                 00010750
```

```
@ ELT FOR122,1,710420, 60458

000001          C122FOR                                                                 00010755
000002                SUBROUTINE FOR122                                                 00010760
000003          C      FORMULA 122 - AXIAL SEGMENT OF HOLLOW ELLIPTICAL SPHEROID        00010765
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00010770
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00010775
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00010780
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00010785
000008                COMMON  PI                                                       00010790
000009                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1       00010795
000010                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T         00010800
000011                COMMON  J      , N      , K      , M      , Y      , X         00010805
000012                COMMON  Z      , RHO    , A1     , B1     , C1     , A2        00010810
000013                COMMON  B2     , C2     , R1     , R2     , R3     , H         00010815
000014                COMMON  B      , A      , AL     , WT     , YBT    , XBT       00010820
000015                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT      00010825
000016                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT      00010830
000017                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB        00010835
000018                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ       00010840
000019                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ       00010845
000020                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3       00010850
000021                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3       00010855
000022                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S      00010860
000023                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S      00010865
000024                COMMON  E      , V      , PY     , PX     , PZ                00010870
000025          C       PRELIMINARY COMPUTATIONS                                        00010875
000026                G=R1-R3                                                           00010880
000027                C=R2-H                                                            00010885
000028                F=R2-R3                                                           00010890
000029                TL= H-R3                                                          00010895
000030                TM= G/F                                                           00010900
000031                TN= R1/R2                                                         00010905
000032                D= (R1+G)*(R1-G)                                                  00010910
000033                U= (TN+TM) * (TN-TM)                                              00010915
000034                E1=(F*F+F*C +C*C) /3.0                                            00010920
000035                E2=(R2*R2 + R2*F +F*F) /3.0                                       00010925
000036                E3=(3.0D0*E1 *F*F +C**3 *(F+C))/5.0D0                             00010930
000037                E4=(3.0D0 *E2 *R2*R2 +F**3 *(R2+F)) /5.0D0                        00010935
000038                TJ= R1*R1 +G*G                                                    00010940
000039                TK= TN*TN + TM*TM                                                 00010945
000040                Q= R3*(R1*R1*E2-TN*TN*E4)                                         00010950
000041                P1= (D*E1-U*E3) *TL                                               00010955
000042                P2= R3 *(R1*R1 -TN*TN *E2)                                        00010960
000043                P3= (D-U*E1) * TL                                                 00010965
000044          C       WEIGHT, C.G., AND DELTA VALUES                                  00010970
000045                W1= PI*RHO *(P2+P3)                                               00010975
000046                S= 0.25D0 /(P2+P3) *(TL*(F+C) *(2.0D0*D -U * (F*F +C*C)) +R3 *(R2+00010980
000047               1F)*(2.0D0*R1*R1 -TN*TN *(F*F +R2*R2))) -C                         00010985
000048                CALL DIRC                                                         00010990
000049                DPY= 0.5D0 *PI*RHO*(TJ*P3 -TK*P1 +R1*R1*P2 -Q*TN*TN)              00010995
000050                DPX= 0.5D0*DPY +PI*RHO *(P1+Q) -W1 *(S+C)**2                      00011000
000051                DPZ= DPX                                                          00011005
000052                CALL DELTA                                                        00011010
000053                RETURN                                                            00011015
000054                END                                                               00011020
```

```
@ ELT FOR123,1,710420, 60460

000001                SUBROUTINE FOR123                                                    00011025
000002          C     FORMULA 123- CIRCULAR OGIVE OF REVOLUTION                            00011030
000003                IMPLICIT REAL*8 (A-H,O-Z)                                            00011035
000004                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00011040
000005               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00011045
000006               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                  00011050
000007                COMMON  PI                                                          00011055
000008                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1     00011060
000009                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T       00011065
000010                COMMON  J       , N       , K       , M       , Y       , X       00011070
000011                COMMON  Z       , RHO     , A1      , B1      , C1      , A2      00011075
000012                COMMON  B2      , C2      , R1      , R2      , R3      , H       00011080
000013                COMMON  B       , A       , AL      , WT      , YBT     , XBT     00011085
000014                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT    00011090
000015                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT    00011095
000016                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB      00011100
000017                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ     00011105
000018                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ     00011110
000019                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3     00011115
000020                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3     00011120
000021                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S    00011125
000022                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S    00011130
000023                COMMON  E       , V       , PY      , PX      , PZ                00011135
000024                REAL * 8 M,K,L                                                      00011140
000025          C      PRELIMINARY COMPUTATIONS                                          00011145
000026                M= (R2-R3)/H                                                        00011150
000027                K=0.5D0*(H - (R2*R2-R3*R3)/H)                                       00011155
000028                                B= (M*K-R2 +DSQRT  (( R2-M*K)**2 -(R2*R2 +K*K - R1* 00011160
000029               1R1)*(1.0D0+M*M))) /(1.0D0+M*M)                                      00011165
000030                A = M*B -K                                                          00011170
000031                L = A + H                                                           00011175
000032                C = R1*R1 + B*B                                                     00011180
000033                F =DSQRT(R1*R1-L*L)                                                 00011185
000034                G =DSQRT(R1*R1-A*A)                                                 00011190
000035                E = L*F -A*G + R1*R1*(DATAN2(L,F)  -DATAN2(A,G))                    00011195
000036                U = B* (A*G**3 -L*F**3 +0.5D0*R1*R1 *E)                             00011200
000037                P3 = H*(3.0D0*A*L + H*H)/3.0D0                                      00011205
000038                P5 = H*(L**4 + A*L**3 +L*L*A*A +  L*A**3 +A**4)/5.0D0               00011210
000039                W1 = PI*RHO*(C*H-B*E-P3)                                            00011215
000040                S = (PI*RHO/W1)* (0.5D0*C*H*(L+A)   -0.25D0*H*(2.0D0*A*(2.0D0*L*L-00011220
000041               1A*H) +H**3) - (2.0D0*B/3.0D0)*(G**3 -F**3)) -A                      00011225
000042                CALL DIRC                                                           00011230
000043          C      COMPUTE DELTA VALUES                                              00011235
000044                DPY =0.5D0* PI*RHO*( H*(C*C + 4.0D0* R1*R1*B*B) -2.0D0*P3*(C +2.0 00011240
000045               1*B*B) + P5 -2.0D0*B*C*E +U)                                         00011245
000046                DPX =0.5D0*DPY -W1*(A+S)**2 + PI*   RHO*(C*P3 -P5-0.5D0*U)          00011250
000047          C      COMPUTE DELTA VALUES IN COMMON  REFERENCE AXIS SYSTEM             00011255
000048                CALL DELTA                                                          00011260
000049                RETURN                                                              00011265
000050                END                                                                 00011270
```

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@ ELT FOR124,1,710420, 60461

000001                SUBROUTINE FOR124                                                    00013830
000002          C          FORMULA 124  SOLID HALF ELLIPSE                               00013835
000003                IMPLICIT REAL*8 (A-H,O-Z)                                          00013840
000004                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00013845
000005               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00013850
000006               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00013855
000007                COMMON  PI                                                         00013860
000008                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1    00013865
000009                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T      00013870
000010                COMMON  J       , N       , K       , M       , Y       , X      00013875
000011                COMMON  Z       , RHO     , A1      , B1      , C1      , A2     00013880
000012                COMMON  B2      , C2      , R1      , R2      , R3      , H      00013885
000013                COMMON  B       , A       , AL      , WT      , YBT     , XBT    00013890
000014                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT   00013895
000015                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT   00013900
000016                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB     00013905
000017                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ    00013910
000018                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ    00013915
000019                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3    00013920
000020                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3    00013925
000021                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S   00013930
000022                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S   00013935
000023                COMMON  E       , V       , PY      , PX      , PZ               00013940
000024                W1 = 2.D0 * PI * RHO * R1 * R1 * R2 / 3.D0                         00013945
000025                S  = .375D0 * R2                                                   00013950
000026                CALL DIRC                                                          00013955
000027                DPY = .4D0 * W1 * R1 * R1                                          00013960
000028                DPX = W1 / 320.D0 * (64.D0 * R1 * R1 + 19.D0 * R2 * R2)            00013965
000029                DPZ = DPX                                                          00013970
000030                CALL DELTA                                                         00013975
000031                RETURN                                                             00013980
000032                END                                                                00013985
```

```
@ ELT FOR2,1,710420, 60462

000001          C2FOR                                                                   00002585
000002                SUBROUTINE FOR2                                                   00002590
000003          C           FORMULA 2 - HOLLOW TORUS                                    00002595
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00002600
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00002605
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00002610
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00002615
000008                COMMON  PI                                                       00002620
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00002625
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00002630
000011                COMMON  J       , N       , K       , M       , Y       , X    00002635
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00002640
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00002645
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00002650
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00002655
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00002660
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00002665
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00002670
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00002675
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00002680
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00002685
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00002690
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00002695
000024                COMMON  E       , V       , PY      , PX      , PZ           00002700
000025                E= 2.0D0*PI**2 *RHO * R1                                        00002705
000026                W1= E*(R2**2 -R3**2)                                            00002710
000027                S=0.0D0                                                         00002715
000028                CALL DIRC                                                       00002720
000029                DPY = W1*R1**2 +.75D0*E *(R2**4 -R3**4)                         00002725
000030                DPX = .5D0*W1*R1**2 +.625D0 *E *(R2**4 -R3**4)                  00002730
000031                DPZ = DPX                                                       00002735
000032                CALL DELTA                                                      00002740
000033                RETURN                                                          00002745
000034                END                                                             00002750
```

@ ELT FOR201,1,710420, 60463

```
000001          C201FOR                                                                 00011275
000002                SUBROUTINE FOR201                                                 00011280
000003          C           FORMULA 201 - SECTOR OF A HOLLOW TORUS                      00011285
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00011290
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00011295
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00011300
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00011305
000008                COMMON  PI                                                        00011310
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00011315
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00011320
000011                COMMON  J       , N       , K       , M       , Y       , X     00011325
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00011330
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00011335
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00011340
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00011345
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00011350
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00011355
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00011360
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00011365
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00011370
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00011375
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00011380
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00011385
000024                COMMON  E       , V       , PY      , PX      , PZ              00011390
000025                AL= PI*AL /180.0D0                                                00011395
000026                A= R2**2 +R3**2                                                   00011400
000027                E= 2.0D0/AL *(DSIN(AL))**2 *(2.0D0*R1**2 +A +A**2 /(8.0D0*R1**2)) 00011405
000028                W1= 2.0D0*PI*RHO*R1*AL *(R2*R2-R3*R3)                             00011410
000029                S=DSIN(AL) /AL *(R1+ .25D0*A/R1)                                  00011415
000030                CALL DIRC                                                         00011420
000031                DPY=W1*.25D0 /AL *(4.0D0*R1**2*AL +3.0D0*A*AL -E)                 00011425
000032                DPX= .0625D0*W1 /AL *(4.0D0*R1**2 *(2.0D0*AL-DSIN(2.0D0*AL)) +A*(100011430
000033               10.0D0*AL -3.0D0*DSIN(2.0D0*AL)))                                  00011435
000034                DPZ= .0625D0*W1 /AL *(4.0D0*R1**2 *(2.0D0*AL +DSIN(2.0D0*AL)) + A*00011440
000035               1(10.0D0*AL+3.0D0*DSIN(2.0D0*AL)) -4.0D0*E)                        00011445
000036                CALL DELTA                                                        00011450
000037                RETURN                                                            00011455
000038                END                                                               00011460
```

@ ELT FOR202,1,710420, 60465

```
000001          C202FOR                                                                 00011465
000002                SUBROUTINE FOR202                                                 00011470
000003          C           FORMULA 202 - RECTANGULAR PRISM                             00011475
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00011480
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00011485
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00011490
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00011495
000008                COMMON  PI                                                        00011500
000009                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1       00011505
000010                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T         00011510
000011                COMMON  J      , N      , K      , M      , Y      , X         00011515
000012                COMMON  Z      , RHO    , A1     , B1     , C1     , A2        00011520
000013                COMMON  B2     , C2     , R1     , R2     , R3     , H         00011525
000014                COMMON  B      , A      , AL     , WT     , YBT    , XBT       00011530
000015                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT      00011535
000016                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT      00011540
000017                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB        00011545
000018                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ       00011550
000019                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ       00011555
000020                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3       00011560
000021                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3       00011565
000022                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S      00011570
000023                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S      00011575
000024                COMMON  E      , V      , PY     , PX     , PZ                00011580
000025                W1= RHO *A*B*H                                                    00011585
000026                S=0.0D0                                                           00011590
000027                CALL DIRC                                                         00011595
000028                DPY=W1/12.0D0*(A*A +B*B)                                          00011600
000029                DPX=W1/12.0D0*(B*B +H*H)                                          00011605
000030                DPZ=W1/12.0D0*(A*A +H*H)                                          00011610
000031                CALL DELTA                                                        00011615
000032                RETURN                                                            00011620
000033                END                                                               00011625
```

@ ELT FOR203,1,710420, 60466

```
000001          C203FOR                                                                 00011630
000002                SUBROUTINE FOR203                                                 00011635
000003          C           FORMULA 203 - SECTOR OF OUTER HALF-TORUS                    00011640
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00011645
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00011650
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00011655
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00011660
000008                COMMON  PI                                                        00011665
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00011670
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00011675
000011                COMMON  J       , N       , K       , M       , Y       , X     00011680
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00011685
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00011690
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00011695
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00011700
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00011705
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00011710
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00011715
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00011720
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00011725
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00011730
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00011735
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00011740
000024                COMMON  E       , V       , PY      , PX      , PZ            00011745
000025                AL= PI*AL /180.0D0                                                00011750
000026                A= 1.0D0/(PI*R1 +4.0D0*R2 /3.0D0)                                 00011755
000027                E1 = (AL-DSIN(AL)*DCOS(AL)) /(4.0D0*AL)                           00011760
000028                E2 = (AL+DSIN(AL)*DCOS(AL)) /(2.0D0*AL)                           00011765
000029                W1= RHO *AL * R2**2 /A                                            00011770
000030                S= (4.0D0*A*DSIN(AL)) /(3.0D0*AL) *(.75D0*PI*R1*R1+.1875D0*PI*R2*R00011775
000031               12+2.0D0*R1*R2)                                                    00011780
000032                CALL DIRC                                                         00011785
000033                DPY= A*W1*(PI*R1**3 +.75D0*PI*R1*R2*R2 +4.0D0*R1*R1*R2 +8.0D0/15.000011790
000034               1D0*R2**3) -W1*S*S                                                 00011795
000035                DPX= A*W1*( 2.0D0*PI*E1*R1**3 + PI*(.25D0+1.5D0*E1)*R1*R2*R2 +2.0 00011800
000036               1D0*E1*R1*R1*R2 +(4.0D0+E1) /15.0D0*R2**3 )                        00011805
000037                DPZ= A*W1*(PI*E2*R1**3 +PI*(.25D0+.75D0*E2) *R1*R2*R2 +4.0D0*E2*R100011810
000038               1*R1*R2 +(4.0D0+8.0D0*E2) /15.0D0*R2**3) -W1*S*S                    00011815
000039                CALL DELTA                                                        00011820
000040                RETURN                                                            00011825
000041                END                                                               00011830
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@ ELT FOR204,1,710420, 60468

000001          C204FOR                                                                 00011835
000002                SUBROUTINE FOR204                                                 00011840
000003          C      FORMULA 204 - TRUNCATED UNGULA OF A CYLINDER                       00011845
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00011850
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00011855
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00011860
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00011865
000008                COMMON  PI                                                        00011870
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00011875
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00011880
000011                COMMON  J       , N       , K       , M       , Y       , X     00011885
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00011890
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00011895
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00011900
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00011905
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00011910
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00011915
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00011920
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00011925
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00011930
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00011935
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00011940
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00011945
000024                COMMON  E       , V       , PY      , PX      , PZ              00011950
000025                F= R1-A                                                           00011955
000026                P=DSQRT(R1**2 -F**2)                                              00011960
000027                ALF=DATAN2(P, F)                                                  00011965
000028                SA=DSIN(ALF)                                                      00011970
000029                S2A=DSIN(2.0D0*ALF)                                               00011975
000030                CA=DCOS(ALF)                                                      00011980
000031                IF(A-B) 10,20,10                                                  00011985
000032             10 E= H/(A-B)                                                        00011990
000033                Q=DSQRT(B*(2.0D0*R1 -B))                                          00011995
000034                G= R1-B                                                           00012000
000035                BET =DATAN2(Q,G)                                                  00012005
000036                C= RHO*E*R1**3                                                    00012010
000037                S3A=DSIN(3.0D0*ALF)                                               00012015
000038                S4A=DSIN(4.0D0*ALF)                                               00012020
000039                SB=DSIN(BET)                                                      00012025
000040                S2B=DSIN(2.0D0*BET)                                               00012030
000041                S3B=DSIN(3.0D0*BET)                                               00012035
000042                S4B=DSIN(4.0D0*BET)                                               00012040
000043                C2A=DCOS(2.0D0*ALF)                                               00012045
000044                C3A=DCOS(3.0D0*ALF)                                               00012050
000045                CB=DCOS(BET)                                                      00012055
000046                C2B=DCOS(2.0D0*BET)                                               00012060
000047                C3B=DCOS(3.0D0*BET)                                               00012065
000048                U= 2.0D0/15.0D0*C*R1**2 *(SA**5 -SB**5)                           00012070
000049          C      COMPUTE WEIGHT                                                   00012075
000050                W1= C*(SA-SB-ALF*CA +BET*CB-1.0D0/3.0D0* (SA**3 - SB**3))        00012080
000051          C        Y AXIS COMPONENT OF C.G.                                       00012085
000052                S= C*E /8.0D0*R1/W1 *(S2A-S2B-2.0D0*ALF*C2A +2.0D0*BET*C2B -ALF +B00012090
000053               1ET +.25D0* (S4A-S4B)) -E*F                                        00012095
000054          C      COMPUTE X AXIS COMPONENT OF C.G.                                 00012100
000055                V=0.0D0                                                           00012105
000056          C      COMPUTE Z AXIS COMPONENT OF C.G.                                 00012110
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```
000057                T=2.0D0/3.0D0*C/W1*R1*(.375D0*(ALF-BET)- .25D0*(S2A-S2B) +1.0D0/3200012115
000058               1.0D0*(S4A-S4B))                                              00012120
000059          C     DIRECTION COSINES AND C.G.                                    00012125
000060                CALL SPEDIR                                                   00012130
000061          C     PRODUCTS OF INERTIA                                           00012135
000062                PY=0.0D0                                                      00012140
000063                PX= E*(U-W1*T*F) -W1*S*T                                      00012145
000064                PZ=0.0D0                                                      00012150
000065          C     COMPUTE DELTA VALUES                                          00012155
000066                DPZ= C*(ZIRT(ALF,E,R1,F) - ZIRT( BET,E,R1,F)) -W1*S*S         00012160
000067                DPX= DPZ -W1*T*T +U                                           00012165
000068                DPY= .5D0*(W1*R1*R1 +U) -W1*T*T                               00012170
000069          C     ROTATE DELTA VALUES TO COMMON REFERENCE ORIENTATION            00012175
000070                CALL SPEDEL                                                   00012180
000071                RETURN                                                        00012185
000072             20 C=2.0D0*ALF - S2A                                             00012190
000073                S= .5D0*H                                                     00012195
000074                V= 0.0D0                                                      00012200
000075                T= 4.0D0/3.0D0*R1/C *SA**3                                    00012205
000076                CALL SPEDIR                                                   00012210
000077                E= RHO *C*.5D0*R1**2                                          00012215
000078                G= .25D0*R1**2 *(1.0D0-T/R1*CA)                               00012220
000079                U= .25D0*R1**2 *(1.0D0+3.0D0*T/R1 *CA) -T**2                  00012225
000080                W1= E*H                                                       00012230
000081                DPY= W1*(G+U)                                                 00012235
000082                DPX= W1/12.0D0*(12.0D0*U +H**2)                               00012240
000083                DPZ= W1/12.0D0*(12.0D0*G +H**2)                               00012245
000084                CALL DELTA                                                    00012250
000085                RETURN                                                        00012255
000086                END                                                           00012260
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@ ELT FOR205,1,710420, 60470

000001          C205FOR                                                                 00012370
000002                SUBROUTINE FOR205                                                 00012375
000003          C        FORMULA 205 - SOLID TAPERED TORUS                              00012380
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00012385
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00012390
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00012395
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100),               00012400
000008               3C(10),P(5)                                                        00012405
000009                COMMON  PI                                                        00012410
000010                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00012415
000011                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00012420
000012                COMMON  J       , N       , K       , M       , Y       , X     00012425
000013                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00012430
000014                COMMON  B2      , C2      , R1      , R2      , R3      , H     00012435
000015                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00012440
000016                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00012445
000017                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00012450
000018                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00012455
000019                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00012460
000020                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00012465
000021                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00012470
000022                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00012475
000023                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00012480
000024                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00012485
000025                COMMON  E       , V       , PY      , PX      , PZ              00012490
000026          C           PRELIMINARY COMPUTATIONS                                    00012495
000027                G=R2-R3                                                           00012500
000028                Q=R1+R3                                                           00012505
000029                F1=3.0D0-12.0D0/PI**2                                             00012510
000030                F2=5.0D0-30.0D0/PI**2                                             00012515
000031                P(1) = R2+R3                                                      00012520
000032                DO 10 I=2,5                                                       00012525
000033             10 P(I) = P(I-1) *R2 +R3**I                                          00012530
000034          C          VOLUME AND WEIGHT                                          00012535
000035                V= PI**2 *(2.0D0*Q*R3*R3 +R3*(2.0D0*Q+R3) *G +2.0D0/3.0D0*G*G*(Q+200012540
000036               1.0D0*G) +.5D0*G**3)                                               00012545
000037                W1= RHO * V                                                       00012550
000038                S= 2.0D0*G /V *(4.0D0*Q*Q*R3 +4.0D0*Q*R3*R3 +R3**3 +G*(2.0D0*Q*Q +00012555
000039               18.0D0*Q*R3+3.0D0*R3*R3)+G*G*F1*(2.0D0*Q+3.0D0*R3)+G**3*F2)         00012560
000040                CALL DIRC                                                         00012565
000041                DPY=PI**2 *RHO/12.0D0*(8.0D0*R1**3 *P(2) +18.0D0*R1*(R1*P(3) +P(4)00012570
000042               1) +7.0D0*P(5)) -W1*S*S                                            00012575
000043                F=G/PI                                                            00012580
000044                C(1)= 1.5D0*Q*R3*R3 *(4.0D0*Q*Q +5.0D0*R3*R3)                     00012585
000045                C(2)= .75D0*R3*G *(8.0D0*Q**3 +12.0D0*Q*Q*R3 +20.0D0*Q*R3*R3 +5.0D00012590
000046               10*R3**3)                                                          00012595
000047                C(3)= G*G*(2.0D0*Q**3 +12.0D0*Q*Q*R3 +21.0D0*Q*R3*R3 +10.0D0*R3**300012600
000048               1)                                                                 00012605
000049                C(4)= .75D0 *G**3 *(6.0D0*Q*Q +22.0D0*Q*R3 +17.0D0*R3**2 )        00012610
000050                C(5)= .3D0 *G**4 *(17.0D0*Q +28.0D0*R3)                           00012615
000051                C(6)= 2.25D0 *G**5                                                00012620
000052                C(7)= .75D0*F*F*(4.0D0*Q**3 +24.0D0*Q*Q*R3 +30.0D0*Q*R3*R3 +12.0D000012625
000053               1*R3**3 -45.0D0*Q* *F*F-60.0D0*F*F*R3)                             00012630
000054                C(8)= 1.125D0 *G*F*F *(12.0D0*Q*Q +36.0D0*Q*R3 +22.0D0*R3*R3 -35.000012635
000055               1D0*F*F)                                                           00012640
000056                C(9)= 7.5D0 *(G*F)**2 *(3.0D0*Q +4.0D0*R3)                        00012645
```

```
000057          C(10) = 13.125D0 *G *(G*F) **2                          00012650
000058          U1= C(1)+C(2)+C(3)+C(4)+C(5)+C(6)                       00012655
000059          U2= C(7)+C(8)+C(9)+C(10)                                00012660
000060          DPZ= PI**2 *RHO /6.0D0*(U1+U2) -W1*S*S                  00012665
000061          DPX= PI**2 *RHO /6.0D0*(U1-U2)                          00012670
000062          CALL DELTA                                              00012675
000063          RETURN                                                  00012680
000064          END                                                     00012685
```

```
@ ELT FOR206,1,710420, 60472

000001          C206FOR                                                                 00012690
000002          C     SUBROUTINE FOR206 - HOLLOW TAPERED TORUS                          00012695
000003                SUBROUTINE FOR206                                                 00012700
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00012705
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00012710
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00012715
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00012720
000008                COMMON  PI                                                       00012725
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00012730
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00012735
000011                COMMON  J       , N       , K       , M       , Y       , X     00012740
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00012745
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00012750
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00012755
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00012760
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00012765
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00012770
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00012775
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00012780
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00012785
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00012790
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00012795
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00012800
000024                COMMON  E       , V       , PY      , PX      , PZ              00012805
000025                NN=N                                                             00012810
000026                N=206                                                            00012815
000027                ER1=R1                                                           00012820
000028                ER2=R2                                                           00012825
000029                ER3=R3                                                           00012830
000030                CALL FOR205                                                      00012835
000031                WC=W1                                                            00012840
000032                YC=YBR                                                           00012845
000033                XC=XBR                                                           00012850
000034                ZC=ZBR                                                           00012855
000035                CY=DY1                                                           00012860
000036                CX=DX1                                                           00012865
000037                CZ=DZ1                                                           00012870
000038                R1=R1+B                                                          00012875
000039                R2=R2-B                                                          00012880
000040                R3=R3-B                                                          00012885
000041                RHO=-RHO                                                         00012890
000042                CALL FOR205                                                      00012895
000043                WF=W1                                                            00012900
000044                YF=YBR                                                           00012905
000045                XF=XBR                                                           00012910
000046                ZF=ZBR                                                           00012915
000047                FY=DY1                                                           00012920
000048                FX=DX1                                                           00012925
000049                FZ=DZ1                                                           00012930
000050          C         RESTORE INPUT                                              00012935
000051                R1=ER1                                                           00012940
000052                R2=ER2                                                           00012945
000053                R3=ER3                                                           00012950
000054                RHO=-RHO                                                         00012955
000055                N=NN                                                             00012960
000056          C                                                                      00012965
```

```
000057          C          COMBINE PARTS                                  00012970
000058                     W1=WC+WF                                       00012975
000059                     YM=WC*YC +WF*YF                                00012980
000060                     XM=WC*XC +WF*XF                                00012985
000061                     ZM=WC*ZC +WF*ZF                                00012990
000062                     YM2=WC*YC**2 +WF*YF**2                         00012995
000063                     XM2=WC*XC**2 +WF*XF**2                         00013000
000064                     ZM2=WC*ZC**2 +WF*ZF**2                         00013005
000065                     YD= CY+FY                                      00013010
000066                     XD= CX+FX                                      00013015
000067                     ZD= CZ+FZ                                      00013020
000068                     YBR= YM / W1                                   00013025
000069                     XBR= XM / W1                                   00013030
000070                     ZBR= ZM / W1                                   00013035
000071                     DY1= XM2 +ZM2 +YD -W1*(XBR**2 +ZBR**2)         00013040
000072                     DX1= YM2 +ZM2 +XD -W1*(YBR**2 +ZBR**2)         00013045
000073                     DZ1= YM2 +XM2 +ZD -W1*(YBR**2 +XBR**2)         00013050
000074                     RETURN                                         00013055
000075                     END                                            00013060
```

@ ELT FOR207,1,710420, 60474

```
000001          C207FOR                                                                 00013065
000002          C       FORMULA 207 - SECTOR OF HOLLOW TAPERED DISC                     00013070
000003                  SUBROUTINE FOR207                                               00013075
000004                  IMPLICIT REAL*8 (A-H,O-Z)                                       00013080
000005                  DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00013085
000006                 1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00013090
000007                 2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)              00013095
000008                  COMMON  PI                                                      00013100
000009                  COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1 00013105
000010                  COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T   00013110
000011                  COMMON  J       , N       , K       , M       , Y       , X   00013115
000012                  COMMON  Z       , RHO     , A1      , B1      , C1      , A2  00013120
000013                  COMMON  B2      , C2      , R1      , R2      , R3      , H   00013125
000014                  COMMON  B       , A       , AL      , WT      , YBT     , XBT 00013130
000015                  COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00013135
000016                  COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00013140
000017                  COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB  00013145
000018                  COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ 00013150
000019                  COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ 00013155
000020                  COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3 00013160
000021                  COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3 00013165
000022                  COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00013170
000023                  COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00013175
000024                  COMMON  E       , V       , PY      , PX      , PZ          00013180
000025          C           PRELIMINARY COMPUTATIONS                                    00013185
000026                  AL=AL*PI/180.0D0                                                00013190
000027                  C1A = B-A                                                       00013195
000028                  C2A = R2+R1                                                     00013200
000029                  C3=R1-R2                                                        00013205
000030                  Q = C1A/C3                                                      00013210
000031                  C4=B+Q *R2                                                      00013215
000032                  C5= R1**2 +R2**2                                                00013220
000033                  C6= C5 + R1*R2                                                  00013225
000034          C           VOLUME AND WEIGHT                                           00013230
000035                  V = C3/3.D0 *AL *(3.D0*C2A*C4 -2.D0*Q *C6)                      00013235
000036                  W1= RHO *V                                                      00013240
000037          C           C.G. AND DIRECTION COSINES                                  00013245
000038                  S = C3/6.D0*DSIN(AL) / V *(4.D0*C4*C6 -3.D0*Q*C2A*C5)           00013250
000039                  CALL DIRC                                                       00013255
000040                  T1=.5D0*B                                                       00013260
000041                  T2=.5D0*A                                                       00013265
000042                  P1= T1-T2                                                       00013270
000043                  E=(R1-R2)/P1                                                    00013275
000044                  U=R2+E*T1                                                       00013280
000045                  P2=T1*T1 -T2*T2                                                 00013285
000046                  P3= T1**3 -T2**3                                                00013290
000047                  P4= T1**4 -T2**4                                                00013295
000048                  P5= T1**5 -T2**5                                                00013300
000049                  C=DSIN(AL)*DCOS(AL)                                             00013305
000050                  F1=2.0D0/3.0D0*(R1*R1*T2**3 -R2*R2*T1**3)                       00013310
000051                  F2= .5D0*(R1**4*T2 -R2**4*T1)                                   00013315
000052                  F3=(10.0D0*U*U*P3 -15.0D0*U*E*P4 +6.0D0*E*E*P5) /15.0D0         00013320
000053                  F4=.1D0*(5.0D0*U**4*P1 -10.0D0*U**3*E*P2 +10.0D0*U*U*E*E*P3 -5.0D000013325
000054                 1*U*E**3*P4 +E**4*P5)                                            00013330
000055                  F5= RHO *(F1+F3)                                                00013335
000056                  F6= RHO *(F2+F4)                                                00013340
```

```
000057                F7= .2D0*P1*(R1**4 +R1**3*R2 +R1*R1*R2*R2 +R1*R2**3 +R2**4)      00013345
000058          C        MOMENTS OF INERTIA                                            00013350
000059                DPZ= AL*(F5+F6) +C*F6 -W1*S*S                                    00013355
000060                DPX= AL*(F5+F6) -C*F6                                            00013360
000061                DPY= RHO*AL*(2.0D0*F2 +F7) -W1*S*S                               00013365
000062                CALL DELTA                                                       00013370
000063                RETURN                                                           00013375
000064                END                                                              00013380
```

@ ELT FOR208,1,710420, 60476

```
000001          C208FOR                                                                 00013385
000002          C       FOR208 - SECTOR OF WEDGE OF REVOLUTION                          00013390
000003                SUBROUTINE FOR208                                                 00013395
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00013400
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00013405
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00013410
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00013415
000008                COMMON  PI                                                        00013420
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00013425
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00013430
000011                COMMON  J       , N       , K       , M       , Y       , X     00013435
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00013440
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00013445
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00013450
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00013455
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00013460
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00013465
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00013470
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00013475
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00013480
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00013485
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00013490
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00013495
000024                COMMON  E       , V       , PY      , PX      , PZ              00013500
000025                AL= AL *PI/180.0D0                                                00013505
000026                C1A = R1-R2                                                       00013510
000027                C2A = R1+R2                                                       00013515
000028                C3= AL *B                                                         00013520
000029                C4= R1* R2                                                        00013525
000030                E=DSIN(AL) / (2.0D0*AL)                                           00013530
000031                C5=DSIN(2.0D0*AL) /(2.0D0*AL)                                     00013535
000032                C6= 2.0D0*R1**2 -R2**2                                            00013540
000033                C7= RHO *AL *B                                                    00013545
000034                C8= R2 *R1 *R1                                                    00013550
000035                C9= 2.0D0*R1 -3.0D0*R2                                            00013555
000036          C        VOLUME AND WEIGHT                                            00013560
000037                VL = C1A *C3 /3.D0*(C2A+R1)                                       00013565
000038                W1= RHO *VL                                                       00013570
000039          C        C.G. AND DIRECTION COSINES                                   00013575
000040                V = E * (R1**3 *(C1A+C9) +R2**4) / (R1**2 *C9 +R2**3)             00013580
000041                S= .25D0*B*(C6-2.0D0*C4 +R1*R1) /(C6-C4)                          00013585
000042                T=0.0D0                                                           00013590
000043                CALL SPEDIR                                                       00013595
000044          C        PRODUCTS OF INERTIA                                          00013600
000045                PX=0.0D0                                                          00013605
000046                PY=0.0D0                                                          00013610
000047                PZ= RHO /30.0D0*B**2 /C1A*DSIN(AL)* (3.0D0*R1**3 *C9 +R2*R2 *(R1*R00013615
000048               11 +R1 *R2+R2*R2)) -W1*V*S                                         00013620
000049          C         DELTA VALUES                                                00013625
000050                F=.1D0 *C7/C1A*(R1**4 *(4.0D0*R1 -5.0D0*R2) +R2**5 )              00013630
000051                G =F*(.5D0*(1.D0-C5)+B*B /(3.D0*C1A*C1A) ) -C7*B*B*C8 /           00013635
000052               1 (3.D0*C1A)                                                       00013640
000053                P= G +C5 *F                                                       00013645
000054                DPY =F-W1*V*V                                                     00013650
000055                DPX = G -W1*S*S                                                   00013655
000056                DPZ = P -W1*(V*V +S*S)                                            00013660
```

```
000057                CALL SPEDEL                                00013665
000058                RETURN                                     00013670
000059                END                                        00013675
```

```
@ ELT FOR3,1,710420, 60477

000001          C3FOR                                                                   00002755
000002                SUBROUTINE FOR3                                                   00002760
000003          C             FORMULA 3 - SOLID SPHERE                                  00002765
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00002770
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00002775
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00002780
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00002785
000008                COMMON  PI                                                       00002790
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1  00002795
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T    00002800
000011                COMMON  J       , N       , K       , M       , Y       , X    00002805
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2   00002810
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H    00002815
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT  00002820
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT 00002825
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT 00002830
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB   00002835
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ  00002840
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ  00002845
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3  00002850
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3  00002855
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S 00002860
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S 00002865
000024                COMMON  E       , V       , PY      , PX      , PZ           00002870
000025                W1= 4.0D0/3.0D0*PI *RHO * R1**3                                  00002875
000026                YBR=Y                                                            00002880
000027                XBR=X                                                            00002885
000028                ZBR=Z                                                            00002890
000029                DY1= .4D0 *W1 * R1**2                                            00002895
000030                DX1= DY1                                                         00002900
000031                DZ1= DY1                                                         00002905
000032                RETURN                                                           00002910
000033                END                                                              00002915
```

@ ELT FOR5,1,710420, 60480

```
000001          C5FOR                                                                   00003095
000002                SUBROUTINE FOR5                                                   00003100
000003          C       FORMULA 5 - INNER HALF-TORUS, SOLID                             00003105
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00003110
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00003115
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00003120
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00003125
000008                COMMON  PI                                                        00003130
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00003135
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00003140
000011                COMMON  J       , N       , K       , M       , Y       , X     00003145
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00003150
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00003155
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00003160
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00003165
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00003170
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00003175
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00003180
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00003185
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00003190
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00003195
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00003200
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00003205
000024                COMMON  E       , V       , PY      , PX      , PZ              00003210
000025                ER3=R3                                                          00003215
000026                R3=0.0D0                                                        00003220
000027                CALL FOR2                                                       00003225
000028                WC= W1                                                          00003230
000029                CY=DY1                                                          00003235
000030                CX=DX1                                                          00003240
000031                CZ=DZ1                                                          00003245
000032                RHO= -RHO                                                       00003250
000033                CALL FOR4                                                       00003255
000034                W1= WC +W1                                                      00003260
000035                DY1= CY +DY1                                                    00003265
000036                DX1= CX+DX1                                                     00003270
000037                DZ1= CZ +DZ1                                                    00003275
000038          C       RESTORE INPUT                                                 00003280
000039                RHO= -RHO                                                       00003285
000040                R3= ER3                                                         00003290
000041                RETURN                                                          00003295
000042                END                                                             00003300
```

```
@ ELT FOR500,1,710420, 60481

000001          C500FOR                                                                 00013680
000002                SUBROUTINE FOR500                                                 00013685
000003          C           FORMULA 500 - MISC. SHAPES                                  00013690
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00013695
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00013700
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00013705
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00013710
000008                COMMON  PI                                                        00013715
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00013720
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00013725
000011                COMMON  J       , N       , K       , M       , Y       , X     00013730
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00013735
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00013740
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00013745
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00013750
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00013755
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00013760
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00013765
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00013770
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00013775
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00013780
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00013785
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00013790
000024                COMMON  E       , V       , PY      , PX      , PZ              00013795
000025                S=0.0D0                                                           00013800
000026                YBR=Y                                                             00013805
000027                XBR=X                                                             00013810
000028                ZBR=Z                                                             00013815
000029                RETURN                                                            00013820
000030                END                                                               00013825
```

```
@ ELT FOR6,1,710420, 60482

000001          C6FOR                                                                   00003305
000002                SUBROUTINE FOR6                                                   00003310
000003          C       FORMULA 6 - INNER HALF, TOROIDAL SHELL                          00003315
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00003320
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00003325
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00003330
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00003335
000008                COMMON  PI                                                        00003340
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00003345
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00003350
000011                COMMON  J       , N       , K       , M       , Y       , X     00003355
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00003360
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00003365
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00003370
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00003375
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00003380
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00003385
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00003390
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00003395
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00003400
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00003405
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00003410
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00003415
000024                COMMON  E       , V       , PY      , PX      , PZ            00003420
000025                NN=N                                                            00003425
000026                N=6                                                             00003430
000027                ER2=R2                                                          00003435
000028                CALL FOR5                                                       00003440
000029                WC=W1                                                           00003445
000030                CY=DY1                                                          00003450
000031                CX=DX1                                                          00003455
000032                CZ=DZ1                                                          00003460
000033                RHO = -RHO                                                      00003465
000034                R2=R3                                                           00003470
000035                CALL FOR5                                                       00003475
000036                W1= WC+W1                                                       00003480
000037                DY1= CY+DY1                                                     00003485
000038                DX1= CX+DX1                                                     00003490
000039                DZ1= CZ+DZ1                                                     00003495
000040          C     RESTORE INPUT                                                   00003500
000041                R2=ER2                                                          00003505
000042                RHO = -RHO                                                      00003510
000043                N=NN                                                            00003515
000044                RETURN                                                          00003520
000045                END                                                             00003525
```

```
@ ELT FOR7,1,710420, 60484

000001          C7FOR                                                                   00003530
000002                SUBROUTINE FOR7                                                   00003535
000003          C        FORMULA 7 - OUTER HALF, TOROIDAL SHELL                         00003540
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00003545
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00003550
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00003555
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)               00003560
000008                COMMON  PI                                                       00003565
000009                COMMON  W1     , YBR    , XBR    , ZBR    , DY1    , DX1      00003570
000010                COMMON  DZ1    , DPY    , DPX    , DPZ    , S      , T        00003575
000011                COMMON  J      , N      , K      , M      , Y      , X        00003580
000012                COMMON  Z      , RHO    , A1     , B1     , C1     , A2       00003585
000013                COMMON  B2     , C2     , R1     , R2     , R3     , H        00003590
000014                COMMON  B      , A      , AL     , WT     , YBT    , XBT      00003595
000015                COMMON  ZBT    , DYT    , DXT    , DZT    , SWYT   , SWXT     00003600
000016                COMMON  SWZT   , SWYST  , SWXST  , SWZST  , SDYT   , SDXT     00003605
000017                COMMON  SDZT   , HOL    , W      , YB     , XB     , ZB       00003610
000018                COMMON  DY     , DX     , DZ     , SWY    , SWX    , SWZ      00003615
000019                COMMON  SWYS   , SWXS   , SWZS   , SDY    , SDX    , SDZ      00003620
000020                COMMON  D1     , D2     , D3     , CL1    , CL2    , CL3      00003625
000021                COMMON  CM1    , CM2    , CM3    , CN1    , CN2    , CN3      00003630
000022                COMMON  A3     , B3     , C3     , CL1S   , CL2S   , CL3S     00003635
000023                COMMON  CM1S   , CM2S   , CM3S   , CN1S   , CN2S   , CN3S     00003640
000024                COMMON  E      , V      , PY     , PX     , PZ               00003645
000025                NN=N                                                             00003650
000026                N=7                                                              00003655
000027                ER2=R2                                                           00003660
000028                CALL FOR4                                                        00003665
000029                WC=W1                                                            00003670
000030                CY=DY1                                                           00003675
000031                CX=DX1                                                           00003680
000032                CZ=DZ1                                                           00003685
000033                RHO = -RHO                                                       00003690
000034                R2=R3                                                            00003695
000035                CALL FOR4                                                        00003700
000036                W1=WC+W1                                                         00003705
000037                DY1= CY+DY1                                                      00003710
000038                DX1= CX+DX1                                                      00003715
000039                DZ1= CZ+DZ1                                                      00003720
000040          C          RESTORE INPUT                                             00003725
000041                R2= ER2                                                          00003730
000042                RHO= -RHO                                                        00003735
000043                N=NN                                                             00003740
000044                RETURN                                                           00003745
000045                END                                                              00003750
```

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@ ELT MAIN,1,710615, 33810

000001
000002          E15301
000003          E15301
000004          E15301
000005          C                                                    E15301                    00000000
000006          C                                                                              00000005
000007          C                                                                              00000010
000008          C                                                                              00000015
000009          C     PLACED ON PRODUCTION 17 OCTOBER 1967                                     00000020
000010          C                                                                              00000025
000011          COSMIC NO.   400                                                               00000030
000012          C     WEIGHT, CENTER OF GRAVITY AND MOMENT OF INERTIA                          00000035
000013          CMP062                                                                         00000040
000014          C     PROPOSAL WEIGHT, CG, MI COMPUTATION PROGRAM                              00000045
000015          C     DECK 7R-062  2-7-62 R. HUFF 596-111                                      00000050
000016          C                                                                              00000055
000017                IMPLICIT REAL*8 (A-H,O-Z)                                              00000060
000018                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00000065
000019               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100),      00000070
000020               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                     00000075
000021                COMMON  PI                                                             00000080
000022                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1        00000085
000023                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T          00000090
000024                COMMON  J       , N       , K       , M       , Y       , X          00000095
000025                COMMON  Z       , RHO     , A1      , B1      , C1      , A2         00000100
000026                COMMON  B2      , C2      , R1      , R2      , R3      , H          00000105
000027                COMMON  B       , A       , AL      , WT      , YBT     , XBT        00000110
000028                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT       00000115
000029                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT       00000120
000030                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB         00000125
000031                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ        00000130
000032                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ        00000135
000033                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3        00000140
000034                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3        00000145
000035                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S       00000150
000036                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S       00000155
000037                COMMON  E       , V       , PY      , PX      , PZ                   00000160
000038              200 READ (5,505,END=1000) (HOL(I), I=1,12)                               00000165
000039                WRITE (6,505)(HOL(I), I=1,12)                                          00000170
000040                WRITE (6,55)                                                           00000175
000041          C     CLEAR COMMON                                                           00000180
000042                PI      = 0.0D0                                                        00000185
000043                W1      = 0.0D0                                                        00000190
000044                YBR     = 0.0D0                                                        00000195
000045                XBR     = 0.0D0                                                        00000200
000046                ZBR     = 0.0D0                                                        00000205
000047                DY1     = 0.0D0                                                        00000210
000048                DX1     = 0.0D0                                                        00000215
000049                DZ1     = 0.0D0                                                        00000220
000050                DPY     = 0.0D0                                                        00000225
000051                DPX     = 0.0D0                                                        00000230
000052                DPZ     = 0.0D0                                                        00000235
000053                S       = 0.0D0                                                        00000240
000054                T       = 0.0D0                                                        00000245
000055                J       = 0.0D0                                                        00000250
000056                N       = 0.0D0                                                        00000255
```

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000057                K      = 0.0D0                                    00000260
000058                M      = 0.0D0                                    00000265
000059                Y      = 0.0D0                                    00000270
000060                X      = 0.0D0                                    00000275
000061                Z      = 0.0D0                                    00000280
000062                RHO    = 0.0D0                                    00000285
000063                A1     = 0.0D0                                    00000290
000064                B1     = 0.0D0                                    00000295
000065                C1     = 0.0D0                                    00000300
000066                A2     = 0.0D0                                    00000305
000067                B2     = 0.0D0                                    00000310
000068                C2     = 0.0D0                                    00000315
000069                R1     = 0.0D0                                    00000320
000070                R2     = 0.0D0                                    00000325
000071                R3     = 0.0D0                                    00000330
000072                H      = 0.0D0                                    00000335
000073                B      = 0.0D0                                    00000340
000074                A      = 0.0D0                                    00000345
000075                AL     = 0.0D0                                    00000350
000076                WT     = 0.0D0                                    00000355
000077                YBT    = 0.0D0                                    00000360
000078                XBT    = 0.0D0                                    00000365
000079                ZBT    = 0.0D0                                    00000370
000080                DYT    = 0.0D0                                    00000375
000081                DZT    = 0.0D0                                    00000380
000082                SWYT   = 0.0D0                                    00000385
000083                SWXT   = 0.0D0                                    00000390
000084                SWZT   = 0.0D0                                    00000395
000085                SWYST  = 0.0D0                                    00000400
000086                SWXST  = 0.0D0                                    00000405
000087                SWZST  = 0.0D0                                    00000410
000088                SDYT   = 0.0D0                                    00000415
000089                SDXT   = 0.0D0                                    00000420
000090                SDZT   = 0.0D0                                    00000425
000091                DO 2  I=1,12                                      00000430
000092              2 HOL(I)=0.0D0                                      00000435
000093                DO 4 I=1,100                                      00000440
000094                W(I)     = 0.0D0                                  00000445
000095                YB(I)    = 0.0D0                                  00000450
000096                XB(I)    = 0.0D0                                  00000455
000097                ZB(I)    = 0.0D0                                  00000460
000098                DY(I)    = 0.0D0                                  00000465
000099                DX(I)    = 0.0D0                                  00000470
000100                DZ(I)    = 0.0D0                                  00000475
000101                SWY(I)   = 0.0D0                                  00000480
000102                SWX(I)   = 0.0D0                                  00000485
000103                SWZ(I)   = 0.0D0                                  00000490
000104                SWYS(I)  = 0.0D0                                  00000495
000105                SWXS(I)  = 0.0D0                                  00000500
000106                SWZS(I)  = 0.0D0                                  00000505
000107                SDY(I)   = 0.0D0                                  00000510
000108                SDX(I)   = 0.0D0                                  00000515
000109                SDZ(I)   = 0.0D0                                  00000520
000110              4 CONTINUE                                          00000525
000111                D1     = 0.0D0                                    00000530
000112                D2     = 0.0D0                                    00000535
000113                D3     = 0.0D0                                    00000540
000114                CL1    = 0.0D0                                    00000545
000115                CL2    = 0.0D0                                    00000550
000116                CL3     = 0.0D0                                   00000555
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000117              CM1      = 0.0D0                                          00000560
000118              CM2      = 0.0D0                                          00000565
000119              CM3      = 0.0D0                                          00000570
000120              CN1      = 0.0D0                                          00000575
000121              CN2      = 0.0D0                                          00000580
000122              CN3      = 0.0D0                                          00000585
000123              A3       = 0.0D0                                          00000590
000124              B3       = 0.0D0                                          00000595
000125              C3       = 0.0D0                                          00000600
000126              CL1S     = 0.0D0                                          00000605
000127              CL2S     = 0.0D0                                          00000610
000128              CL3S     = 0.0D0                                          00000615
000129              CM1S     = 0.0D0                                          00000620
000130              CM2S     = 0.0D0                                          00000625
000131              CM3S     = 0.0D0                                          00000630
000132              CN1S     = 0.0D0                                          00000635
000133              CN2S     = 0.0D0                                          00000640
000134              CN3S     = 0.0D0                                          00000645
000135              E        = 0.0D0                                          00000650
000136              PI= 3.141592700                                           00000655
000137              I=1                                                       00000660
000138          300 READ (5,15)J,M,N,K,Y,X,Z,RHO,A1,B1,C1,R1,R2,R3,H          00000665
000139                  IF(N-500) 310, 320, 999                               00000670
000140          310     IF(M-2) 340, 330, 999                                 00000675
000141          320 READ (5,35)W1, DY1, DX1, DZ1                              00000680
000142              GO TO 500                                                 00000685
000143          330 READ (5,25)B,A,AL,A2,B2,C2                                00000690
000144          340       IF(N-100) 460,999,410                               00000695
000145          410     IF(N-200) 420,999,430                                 00000700
000146          420 L=N-100                                                   00000705
000147              GO TO 470                                                 00000710
000148          430       IF(N-500) 440,500,999                               00000715
000149          440 L=N-200                                                   00000720
000150              GO TO 480                                                 00000725
000151          460 GO TO (601,602,603,604,605,606,607,608,609,610,611,612,613,614,61500000730
000152             1,616,617,618,619,620,621,622,623,624,625,626,627,628,629,630),N   00000735
000153          470 GO TO (701,702,703,704,705,706,707,708,709,710,711,712,713,714,71500000740
000154             1,716,717,718,719,720,721,722,723,724,725,726,727,728,729,730,731,700000745
000155             232,733,734,735,736,737,738,739,740,741,742,743,744,745,746,747,74800000750
000156             3,749,750),L                                                00000755
000157          480 GO TO (801,802,803,804,805,806,807,808,809,810,811,812,813,814,81500000760
000158             1,816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,800000765
000159             232,833,834,835,836,837,838,839,840,841,842,843,844,845,846,847,84800000770
000160             3,849,850),L                                                00000775
000161          601 CALL FOR1                                                 00000780
000162              GO TO 350                                                 00000785
000163          602 CALL FOR2                                                 00000790
000164              GO TO 350                                                 00000795
000165          603 CALL FOR3                                                 00000800
000166              GO TO 350                                                 00000805
000167          604 CALL FOR4                                                 00000810
000168              GO TO 350                                                 00000815
000169          605 CALL FOR5                                                 00000820
000170              GO TO 350                                                 00000825
000171          606 CALL FOR6                                                 00000830
000172              GO TO 350                                                 00000835
000173          607 CALL FOR7                                                 00000840
000174              GO TO 350                                                 00000845
000175        C     ROUTINES FOR8 TO FOR30 DELETED.
000176          608 CONTINUE                                                  00000850
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000177                GO TO 350                                         00000855
000178           609 CONTINUE                                           00000860
000179                GO TO 350                                         00000865
000180           610 CONTINUE                                           00000870
000181                GO TO 350                                         00000875
000182           611 CONTINUE                                           00000880
000183                GO TO 350                                         00000885
000184           612 CONTINUE                                           00000890
000185                GO TO 350                                         00000895
000186           613 CONTINUE                                           00000900
000187                GO TO 350                                         00000905
000188           614 CONTINUE                                           00000910
000189                GO TO 350                                         00000915
000190           615 CONTINUE                                           00000920
000191                GO TO 350                                         00000925
000192           616 CONTINUE                                           00000930
000193                GO TO 350                                         00000935
000194           617 CONTINUE                                           00000940
000195                GO TO 350                                         00000945
000196           618 CONTINUE                                           00000950
000197                GO TO 350                                         00000955
000198           619 CONTINUE                                           00000960
000199                GO TO 350                                         00000965
000200           620 CONTINUE                                           00000970
000201                GO TO 350                                         00000975
000202           621 CONTINUE                                           00000980
000203                GO TO 350                                         00000985
000204           622 CONTINUE                                           00000990
000205                GO TO 350                                         00000995
000206           623 CONTINUE                                           00001000
000207                GO TO 350                                         00001005
000208           624 CONTINUE                                           00001010
000209                GO TO 350                                         00001015
000210           625 CONTINUE                                           00001020
000211                GO TO 350                                         00001025
000212           626 CONTINUE                                           00001030
000213                GO TO 350                                         00001035
000214           627 CONTINUE                                           00001040
000215                GO TO 350                                         00001045
000216           628 CONTINUE                                           00001050
000217                GO TO 350                                         00001055
000218           629 CONTINUE                                           00001060
000219                GO TO 350                                         00001065
000220           630 CONTINUE                                           00001070
000221                GO TO 350                                         00001075
000222           701 CALL FOR101                                        00001080
000223                GO TO 350                                         00001085
000224           702 CALL FOR102                                        00001090
000225                GO TO 350                                         00001095
000226           703 CALL FOR103                                        00001100
000227                GO TO 350                                         00001105
000228           704 CALL FOR104                                        00001110
000229                GO TO 350                                         00001115
000230           705 CALL FOR105                                        00001120
000231                GO TO 350                                         00001125
000232           706 CALL FOR106                                        00001130
000233                GO TO 350                                         00001135
000234           707 CALL FOR107                                        00001140
000235                GO TO 350                                         00001145
000236           708 CALL FOR108                                        00001150
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000237                GO TO 350                                        00001155
000238           709 CALL FOR109                                       00001160
000239                GO TO 350                                        00001165
000240           710 CALL FOR110                                       00001170
000241                GO TO 350                                        00001175
000242           711 CALL FOR111                                       00001180
000243                GO TO 350                                        00001185
000244           712 CALL FOR112                                       00001190
000245                GO TO 350                                        00001195
000246           713 CALL FOR113                                       00001200
000247                GO TO 350                                        00001205
000248           714 CALL FOR114                                       00001210
000249                GO TO 350                                        00001215
000250           715 CALL FOR115                                       00001220
000251                GO TO 350                                        00001225
000252           716 CALL FOR116                                       00001230
000253                GO TO 350                                        00001235
000254           717 CALL FOR117                                       00001240
000255                GO TO 350                                        00001245
000256           718 CALL FOR118                                       00001250
000257                GO TO 350                                        00001255
000258           719 CALL FOR119                                       00001260
000259                GO TO 350                                        00001265
000260           720 CALL FOR120                                       00001270
000261                GO TO 350                                        00001275
000262           721 CALL FOR121                                       00001280
000263                GO TO 350                                        00001285
000264           722 CALL FOR122                                       00001290
000265                GO TO 350                                        00001295
000266           723 CALL FOR123                                       00001300
000267                GO TO 350                                        00001305
000268           724 CALL FOR124                                       00001310
000269                GO TO 350                                        00001315
000270      C         FOR125 TO FOR150 REMOVED.
000271           725 CONTINUE                                          00001320
000272                GO TO 350                                        00001325
000273           726 CONTINUE                                          00001330
000274                GO TO 350                                        00001335
000275           727 CONTINUE                                          00001340
000276                GO TO 350                                        00001345
000277           728 CONTINUE                                          00001350
000278                GO TO 350                                        00001355
000279           729 CONTINUE                                          00001360
000280                GO TO 350                                        00001365
000281           730 CONTINUE                                          00001370
000282                GO TO 350                                        00001375
000283           731 CONTINUE                                          00001380
000284                GO TO 350                                        00001385
000285           732 CONTINUE                                          00001390
000286                GO TO 350                                        00001395
000287           733 CONTINUE                                          00001400
000288                GO TO 350                                        00001405
000289           734 CONTINUE                                          00001410
000290                GO TO 350                                        00001415
000291           735 CONTINUE                                          00001420
000292                GO TO 350                                        00001425
000293           736 CONTINUE                                          00001430
000294                GO TO 350                                        00001435
000295           737 CONTINUE                                          00001440
000296                GO TO 350                                        00001445
```

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000297          738 CONTINUE                                                00001450
000298              GO TO 350                                               00001455
000299          739 CONTINUE                                                00001460
000300              GO TO 350                                               00001465
000301          740 CONTINUE                                                00001470
000302              GO TO 350                                               00001475
000303          741 CONTINUE                                                00001480
000304              GO TO 350                                               00001485
000305          742 CONTINUE                                                00001490
000306              GO TO 350                                               00001495
000307          743 CONTINUE                                                00001500
000308              GO TO 350                                               00001505
000309          744 CONTINUE                                                00001510
000310              GO TO 350                                               00001515
000311          745 CONTINUE                                                00001520
000312              GO TO 350                                               00001525
000313          746 CONTINUE                                                00001530
000314              GO TO 350                                               00001535
000315          747 CONTINUE                                                00001540
000316              GO TO 350                                               00001545
000317          748 CONTINUE                                                00001550
000318              GO TO 350                                               00001555
000319          749 CONTINUE                                                00001560
000320              GO TO 350                                               00001565
000321          750 CONTINUE                                                00001570
000322              GO TO 350                                               00001575
000323          801 CALL FOR201                                             00001580
000324              GO TO 350                                               00001585
000325          802 CALL FOR202                                             00001590
000326              GO TO 350                                               00001595
000327          803 CALL FOR203                                             00001600
000328              GO TO 350                                               00001605
000329          804 CALL FOR204                                             00001610
000330              GO TO 350                                               00001615
000331          805 CALL FOR205                                             00001620
000332              GO TO 350                                               00001625
000333          806 CALL FOR206                                             00001630
000334              GO TO 350                                               00001635
000335          807 CALL FOR207                                             00001640
000336              GO TO 350                                               00001645
000337          808 CALL FOR208                                             00001650
000338              GO TO 350                                               00001655
000339      C       FOR206
000340      C       FOR209 TO FOR250 REMOVED.
000341          809 CONTINUE                                                00001660
000342              GO TO 350                                               00001665
000343          810 CONTINUE                                                00001670
000344              GO TO 350                                               00001675
000345          811 CONTINUE                                                00001680
000346              GO TO 350                                               00001685
000347          812 CONTINUE                                                00001690
000348              GO TO 350                                               00001695
000349          813 CONTINUE                                                00001700
000350              GO TO 350                                               00001705
000351          814 CONTINUE                                                00001710
000352              GO TO 350                                               00001715
000353          815 CONTINUE                                                00001720
000354              GO TO 350                                               00001725
000355          816 CONTINUE                                                00001730
000356              GO TO 350                                               00001735
```

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000357          817 CONTINUE                                                    00001740
000358              GO TO 350                                                   00001745
000359          818 CONTINUE                                                    00001750
000360              GO TO 350                                                   00001755
000361          819 CONTINUE                                                    00001760
000362              GO TO 350                                                   00001765
000363          820 CONTINUE                                                    00001770
000364              GO TO 350                                                   00001775
000365          821 CONTINUE                                                    00001780
000366              GO TO 350                                                   00001785
000367          822 CONTINUE                                                    00001790
000368              GO TO 350                                                   00001795
000369          823 CONTINUE                                                    00001800
000370              GO TO 350                                                   00001805
000371          824 CONTINUE                                                    00001810
000372              GO TO 350                                                   00001815
000373          825 CONTINUE                                                    00001820
000374              GO TO 350                                                   00001825
000375          826 CONTINUE                                                    00001830
000376              GO TO 350                                                   00001835
000377          827 CONTINUE                                                    00001840
000378              GO TO 350                                                   00001845
000379          828 CONTINUE                                                    00001850
000380              GO TO 350                                                   00001855
000381          829 CONTINUE                                                    00001860
000382              GO TO 350                                                   00001865
000383          830 CONTINUE                                                    00001870
000384              GO TO 350                                                   00001875
000385          831 CONTINUE                                                    00001880
000386              GO TO 350                                                   00001885
000387          832 CONTINUE                                                    00001890
000388              GO TO 350                                                   00001895
000389          833 CONTINUE                                                    00001900
000390              GO TO 350                                                   00001905
000391          834 CONTINUE                                                    00001910
000392              GO TO 350                                                   00001915
000393          835 CONTINUE                                                    00001920
000394              GO TO 350                                                   00001925
000395          836 CONTINUE                                                    00001930
000396              GO TO 350                                                   00001935
000397          837 CONTINUE                                                    00001940
000398              GO TO 350                                                   00001945
000399          838 CONTINUE                                                    00001950
000400              GO TO 350                                                   00001955
000401          839 CONTINUE                                                    00001960
000402              GO TO 350                                                   00001965
000403          840 CONTINUE                                                    00001970
000404              GO TO 350                                                   00001975
000405          841 CONTINUE                                                    00001980
000406              GO TO 350                                                   00001985
000407          842 CONTINUE                                                    00001990
000408              GO TO 350                                                   00001995
000409          843 CONTINUE                                                    00002000
000410              GO TO 350                                                   00002005
000411          844 CONTINUE                                                    00002010
000412              GO TO 350                                                   00002015
000413          845 CONTINUE                                                    00002020
000414              GO TO 350                                                   00002025
000415          846 CONTINUE                                                    00002030
000416              GO TO 350                                                   00002035
```

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000417          847 CONTINUE                                                    00002040
000418              GO TO 350                                                   00002045
000419          848 CONTINUE                                                    00002050
000420              GO TO 350                                                   00002055
000421          849 CONTINUE                                                    00002060
000422              GO TO 350                                                   00002065
000423          850 CONTINUE                                                    00002070
000424              GO TO 350                                                   00002075
000425          500 CALL FOR500                                                 00002080
000426          350 WRITE (6,65)K,N,W1,YBR,XBR,ZBR,DY1,DX1,DZ1                  00002085
000427            C WEIGHT SUMS                                                 00002090
000428              WT=WT +W1                                                   00002095
000429              W(K) = W(K) +W1                                             00002100
000430            C FIRST MOMENT SUMS                                           00002105
000431              SWYT = SWYT +W1*YBR                                         00002110
000432              SWY(K) = SWY(K) + W1*YBR                                    00002115
000433              SWXT = SWXT + W1 * XBR                                      00002120
000434              SWX(K) = SWX(K) + W1*XBR                                    00002125
000435              SWZT = SWZT + W1* ZBR                                       00002130
000436              SWZ(K) = SWZ(K) + W1* ZBR                                   00002135
000437            C SECOND MOMENT SUMS                                          00002140
000438              SWYST = SWYST +W1*YBR **2                                   00002145
000439              SWYS(K) = SWYS(K) + W1*YBR**2                               00002150
000440              SWXST = SWXST + W1*XBR **2                                  00002155
000441              SWXS(K) = SWXS(K) + W1* XBR**2                              00002160
000442              SWZST = SWZST + W1 *ZBR**2                                  00002165
000443              SWZS(K) = SWZS(K) + W1* ZBR**2                              00002170
000444            C DELTA SUMS                                                  00002175
000445              SDYT = SDYT + DY1                                           00002180
000446              SDY(K) = SDY(K) +DY1                                        00002185
000447              SDXT = SDXT + DX1                                           00002190
000448              SDX(K) = SDX(K) +DX1                                        00002195
000449              SDZT = SDZT + DZ1                                           00002200
000450              SDZ(K) = SDZ(K) + DZ1                                       00002205
000451                  IF(J) 370, 360, 370                                     00002210
000452          360 I=I+1                                                       00002215
000453              GO TO 300                                                   00002220
000454          370 WRITE (6,75)                                                00002225
000455              DO 390 I=1,100                                              00002230
000456                  IF(W(I)) 380,390,380                                    00002235
000457          380 YB(I) = SWY(I) /W(I)                                        00002240
000458              XB(I) = SWX(I) /W(I)                                        00002245
000459              ZB(I) = SWZ(I) /W(I)                                        00002250
000460              DY(I) = SWXS(I) + SWZS(I) +SDY(I) -W(I) *(XB(I)**2 + ZB(I)**2)  00002255
000461              DX(I) = SWYS(I) + SWZS(I) +SDX(I) -W(I) *(YB(I)**2 + ZB(I)**2)  00002260
000462              DZ(I) = SWXS(I) + SWYS(I) + SDZ(I) -W(I) *(YB(I)**2 + XB(I)**2)  00002265
000463              WRITE (6,85)I,W(I),YB(I),XB(I),ZB(I),DY(I),DX(I),DZ(I)      00002270
000464          390 CONTINUE                                                    00002275
000465              WRITE (6,95)                                                00002280
000466              YBT = SWYT /WT                                              00002285
000467              XBT = SWXT /WT                                              00002290
000468              ZBT = SWZT /WT                                              00002295
000469              DYT = SWXST + SWZST +SDYT -WT*(XBT**2 + ZBT**2)             00002300
000470              DXT = SWYST + SWZST +SDXT -WT*(YBT**2 + ZBT**2)             00002305
000471              DZT = SWXST + SWYST +SDZT -WT*(YBT**2 + XBT**2)             00002310
000472              L=0                                                         00002315
000473              WRITE (6,85)L, WT, YBT, XBT, ZBT, DYT, DXT, DZT             00002320
000474              GO TO 200                                                   00002325
000475          999 WRITE (6,45)I                                               00002330
000476         1000 CALL EXIT                                                   00002335
```

```
000477                STOP                                                    00002340
000478            505 FORMAT(12A6)                                            00002345
000479             15 FORMAT(2I1,I3,I2,F5.2,2F6.2,F6.4,7F6.3 )                00002350
000480             25 FORMAT(6E12.6)                                          00002355
000481             35 FORMAT(4F12.4)                                          00002360
000482             45 FORMAT(33H0  INCORRECT VALUE FOR N OR M IN I3, 9HTH ENTRY. )  00002365
000483             55 FORMAT(1H0 40X, 28HRESULTS - INDIVIDUAL ENTRIES // 4X, 1HK 3X, 1HN00002370
000484               1 7X, 6HWEIGHT 8X, 4HYBAR 5X, 4HXBAR 5X, 4HZBAR 8X, 7HDELTA Y 10X, 00002375
000485               27HDELTA X 10X, 7HDELTA Z )                              00002380
000486             65 FORMAT(2I5,E17.8,3F9.2,3E17.8)                          00002385
000487             75 FORMAT(1H0 44X, 20HRESULTS - SUB GROUPS // 5X, 5HGROUP 6X, 6HWEIGH00002390
000488               1T 8X, 4HYBAR 5X, 4HXBAR 5X, 4HZBAR 8X, 7HDELTA Y 10X, 7HDELTA X  00002395
000489               210X, 7HDELTA Z)                                         00002400
000490             85 FORMAT(I8, E19.8, 3F9.2, 3E17.8 )                       00002405
000491             95 FORMAT(1H0 52X, 5HTOTAL //)                             00002410
000492                END                                                     00002415
```

```
@ ELT SPEDEL,1,710420, 60490

000001          CSPDLTV                                                                 00004215
000002                SUBROUTINE SPEDEL                                                 00004220
000003          C      COMPUTES ROTATED DELTA VALUES WHEN PROD. OF I NOT ZERO.          00004225
000004                IMPLICIT REAL*8 (A-H,O-Z)                                         00004230
000005                DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00004235
000006               1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00004240
000007               2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00004245
000008                COMMON  PI                                                        00004250
000009                COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1   00004255
000010                COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T     00004260
000011                COMMON  J       , N       , K       , M       , Y       , X     00004265
000012                COMMON  Z       , RHO     , A1      , B1      , C1      , A2    00004270
000013                COMMON  B2      , C2      , R1      , R2      , R3      , H     00004275
000014                COMMON  B       , A       , AL      , WT      , YBT     , XBT   00004280
000015                COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT  00004285
000016                COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT  00004290
000017                COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB    00004295
000018                COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ   00004300
000019                COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ   00004305
000020                COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3   00004310
000021                COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3   00004315
000022                COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S  00004320
000023                COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S  00004325
000024                COMMON  E       , V       , PY      , PX      , PZ              00004330
000025                DY1= CL1S*DPY +CL2S*DPX + CL3S*DPZ -2.0D0*(PY*CL2*CL3 +PX*CL1*CL3 00004335
000026               1+PZ*CL1*CL2)                                                      00004340
000027                DX1= CM1S*DPY +CM2S*DPX +CM3S*DPZ -2.0D0*(PY*CM2*CM3 +PX*CM1*CM3 +00004345
000028               1PZ*CM1*CM2)                                                       00004350
000029                DZ1= CN1S*DPY +CN2S*DPX +CN3S*DPZ -2.0D0*(PY*CN2*CN3 + PX*CN1*CN3 00004355
000030               1+PZ*CN1*CN2)                                                      00004360
000031                RETURN                                                            00004365
000032                END                                                               00004370
```

@ ELT SPEDIR,1,710420, 60491

```
CSPDRCO                                                                 00004375
      SUBROUTINE SPEDIR                                                 00004380
C      COMPUTES DIRECTION COSINES AND C.G.                              00004385
      IMPLICIT REAL*8 (A-H,O-Z)                                         00004390
      DIMENSION       HOL(12), W(100), YB(100), XB(100), ZB(100),     DY00004395
     1(100), DX(100), DZ(100), SWY(100), SWX(100), SWZ(100), SWYS(100), 00004400
     2SWXS(100), SWZS(100), SDY(100), SDX(100), SDZ(100)                00004405
      COMMON  PI                                                        00004410
      COMMON  W1      , YBR     , XBR     , ZBR     , DY1     , DX1     00004415
      COMMON  DZ1     , DPY     , DPX     , DPZ     , S       , T       00004420
      COMMON  J       , N       , K       , M       , Y       , X       00004425
      COMMON  Z       , RHO     , A1      , B1      , C1      , A2      00004430
      COMMON  B2      , C2      , R1      , R2      , R3      , H       00004435
      COMMON  B       , A       , AL      , WT      , YBT     , XBT     00004440
      COMMON  ZBT     , DYT     , DXT     , DZT     , SWYT    , SWXT    00004445
      COMMON  SWZT    , SWYST   , SWXST   , SWZST   , SDYT    , SDXT    00004450
      COMMON  SDZT    , HOL     , W       , YB      , XB      , ZB      00004455
      COMMON  DY      , DX      , DZ      , SWY     , SWX     , SWZ     00004460
      COMMON  SWYS    , SWXS    , SWZS    , SDY     , SDX     , SDZ     00004465
      COMMON  D1      , D2      , D3      , CL1     , CL2     , CL3     00004470
      COMMON  CM1     , CM2     , CM3     , CN1     , CN2     , CN3     00004475
      COMMON  A3      , B3      , C3      , CL1S    , CL2S    , CL3S    00004480
      COMMON  CM1S    , CM2S    , CM3S    , CN1S    , CN2S    , CN3S    00004485
      COMMON  E       , V       , PY      , PX      , PZ                00004490
      CALL DIRC                                                         00004495
      YBR= Y + S*CL1 +V*CL2 + T*CL3                                     00004500
      XBR= X + S*CM1 +V*CM2 + T*CM3                                     00004505
      ZBR= Z + S*CN1 +V*CN2 + T*CN3                                     00004510
      RETURN                                                            00004515
      END                                                               00004520
```

```
@ ELT ZIRT,1,710420, 60493

000001            CZRT204                                                    00012265
000002                  FUNCTION ZIRT(T,E,R,F)                               00012270
000003            C      COMPUTES PART OF DELTA Z IN FOR204                  00012275
000004                  IMPLICIT REAL*8 (A-H,O-Z)                            00012280
000005                  REAL * 8 T,E,R,F                                     00012285
000006                  O=.25D0*R*R*(1.0D0+E*E) +E*E*F*F                     00012290
000007                  W=.2D0*R*R*(1.0D0/6.0D0-E*E)                         00012295
000008                  X=.25D0 *E *E *R *F                                  00012300
000009                  Y= 2.0D0*W/3.0D0-(5.0D0/12.0D0*R*R +E*E*E*F) /3.0 D0 00012305
000010                  Z= E*E *R*R /36.0D0                                  00012310
000011                  S=DSIN(T)                                            00012315
000012                  C=DCOS(T)                                            00012320
000013                  P=DSIN(2.0D0*T)                                      00012325
000014                  Q=DCOS(2.0D0*T)                                      00012330
000015                  U=DSIN(3.0D0*T)                                      00012335
000016                  V=DCOS(3.0D0*T)                                      00012340
000017                  G=DSIN(4.0D0*T)                                      00012345
000018                  ZIRT=O*(S-T*C)+Y*S**3+X*(T-.25D0*G-P+2.0D0*T*Q)+W*S**3*C**2+Z*  00012350
000019                 1( U-3.0D0*T*V )                                      00012355
000020                  RETURN                                               00012360
000021                  END                                                  00012365

    4.        TRI X                                                          21:51:28

    5.                                                                       21:51:28

      END CUR
```

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<***Δ***1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***8***Δ***9***Δ***0***Δ***1***Δ***2***Δ***3*
**********ISD-28.08:INFORMATION-SYSTEMS-DESIGN:15-MAY-1972**********
Δ1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***0***Δ***1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***0***Δ
[ ]#Δ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[ ]#Δ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[ ]#Δ

16 MAY 72 N 21:51:28 IDENT=FYEE ACCOUNT=428999 CARDS IN= 11, OUT= 0

PAGES= 73, LINES= 2883. TIME=00:00:14 (HMS)

*** USER NOTICES - MAY 16, 1972 ***
****

ISD'S 1108 WILL BE UNAVAILABLE FOR TERMINAL SERVICE FROM 7:00 - 7:30 TOMORROW MORNING (5/17/72) IN ADDITION TO THE NORMALLY SCHEDULED DOWN TIME, TO MAKE EQUIPTMENT REPAIRS.

****

(1) ISD 1108 TERMINAL SERVICE WILL BE AVAILABLE AS SCHEDULED BELOW UNLESS OTHERWISE SPECIFIED IN A USER NOTICE.

MON : 07:00 - 24:00
TUE - FRI : 00:00 - 03:00 ; 07:00 - 24:00
SAT : 00:00 - 22:00
SUN : 04:00 - 22:00

(2) RON/I TELEPHONE NUMBERS

10 CHAR/SEC 415-635-1051 (4 PORTS)

**** 415-635-9559 IS NOW AVAILABLE FOR USE AS A 30 CHAR/SEC LOW SPEED PORT.
**** ON 5/17/72, 415-562-4294 WILL BE TAKEN OUT OF SERVICE AS A LOW SPEED PORT.

(3) EFFECTIVE MONDAY - FRIDAY TURNAROUND TIME SHOULD BE REDUCED BETWEEN THE HOURS OF 10:30 - 11:30 AND 14:00 - 17:00 FOR USERS SUBMITTING NON-TAPE JOBS WITH RUN TIMES ESTIMATED AT LESS THAN 6 MINUTES.

(4) THE 1004 DIAL-UP PHONE NUMBERS ARE LISTED BELOW.

415-562-0809 AND 415-562-0810

(5) ATTENTION RON/I USERS:

BEGINNING MAY 15, A MAJOR REVISION TO THE RON/I SYSTEM WILL TAKE PLACE. ALL COMMANDS WILL REQUIRE AT LEAST 2 CHARACTERS. THE SIGN-ON REQUIRES YOUR 6 CHARACTER ACCOUNT NUMBER IN ADDITION TO YOUR SITE CODE (@@SITEA0,123456). THE RON/I MANUAL IS AVAILABLE FROM THE ISD DOCUMENT LIBRARY.

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<***Δ****1****Δ****2****Δ****3****Δ****4****Δ****5****Δ****6****Δ****7****Δ****8****Δ****9****Δ****0****Δ****1****Δ****2****Δ****3*
**********************************ISD-28.08:INFORMATION-SYSTEMS-DESIGN:15-MAY-1972**********************************
***Δ***1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***0***Δ***1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***0***Δ
[ ]#Δ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[ ]#Δ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[ ]#Δ

16 MAY 72 N 21:51:28   IDENT=FYEE    ACCOUNT=428999  CARDS IN=   11, OUT=    0

  PAGES=   73, LINES=  2883. TIME=00:00:14 (HMS)
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\\EOF\

APPENDIX C

PROGRAM E15301

USERS' MANUAL

PROPOSAL WEIGHT, C. G., AND MOMENT OF INERTIA COMPUTATIONS

Program E15301

(Addendum)

Aerojet-General Corporation
Computing Sciences
Sacramento, California

by

J. A. Budzenski

7 May 1969

APPROVED

Harvey Bader

H. J. Bader, Manager
Engineering Analysis
and Programming

Aerojet-General Corporation
Computing Sciences Division
Sacramento, California

Proposal Weight, C. G., And Moment of Inertia Computations

Program E15301

J. A. Budzenski
7 February 1967

Cosmic Number 400 (Program For Estimating Proposal Weight - Center of Gravity and Moment of Inertia of Rocket Engines and Their Components), an IBM 7094 program from North American has been adapted to the IBM 360 FORTRAN Level H without changes in logic.

DOCUMENTATION

Documentation for the program has been prepared by R. J. Huff of North American and is attached as Enclosure 1. Note enclosed is a new data format sheet.

For added information please see Ken Talbott, Department 7730, Building 2019, Extension 5-7627, Department Manager G. S. Kaveney.

FUTURE EXPANSION

Subroutines are available for new configurations. In order to incorporate a new subroutine you must submit a problem statement to Computing Sciences Division.

CUSTOMER INSTRUCTIONS	KEYPUNCH INSTRUCTIONS	CUSTOMER	DATE
1. ENTER DATA LEGIBLY WITHIN SPACES PROVIDED 2. DISTINGUISH BETWEEN 1 vs I, 0 vs O, 2 vs Z, U vs V, S vs 5	X PUNCH 1 CARD PER HAND POSTED LINE ITEM PUNCH ALL LINES WHETHER POSTED OR NOT, IF NECESSARY PROVIDE BLANK CARDS PUNCH ALL LINES THAT ARE HAND POSTED PAD INCLUDING SPACES ALL SPACES MAY BE IGNORED ALL SPACES MAY BE IGNORED EXCEPT ON 1 CARD ALL SPACES MAY BE IGNORED EXCEPT (specify cols.) ALL SIGNS AND DECIMALS MUST BE PUNCHED DO NOT PUNCH ZEROS AND SIGNS SHOWN AFTER LAST HANDWRITTEN VALUE ENTRY x Use 360 Characters x Sequence 79-80	JOB NO.: E15301	PROGRAMMER: J. Budzenski
3 Symbol explaination for first card J = Last item indicator (7 if last, blank if not) M = Number of cards for this entry (1 or 2) N = Formula number K = Sub-group number (must not be blank or zero) 4 "Δ" Indicates assumed location of decimal point		TITLE: Proposal Weight, C.G., And Moment of Inertia Computations	
		FORM APPROVED (KEYPUNCH)	DATE

Title Card - One for each case.

1. Typical first card format for individual item.
2. Typical second card format for individual entry - when required.
3. Typical second card format for formula 500 only.

Line	Cols 1–20	Cols 21–40	Cols 41–60	Cols 61–78	Cols 79–80
1					E15301
2	J M N K y Δ	x Δ z	Δ ρ a Δ	b Δ C Δ R Δ r Δ r Δ H Δ	
3	B Δ	A Δ	α Δ	d Δ e Δ f Δ	
4	w Δ	Δy Δ	Δ Δ	Δz Δ	
Last					E15301

89

EP 0400

PROGRAM for ESTIMATING PROPOSAL WEIGHT-CENTER of GRAVITY and MOMENT of INERTIA of ROCKET ENGINES and THEIR COMPONENTS

(North American)

PREPARED BY:

R.J. Huff
Weight Control Analysis
D596-111

JUNE 1962

30.10.01

WEIGHT CONTROL IBM 7094 PROGRAM DESCRIPTION

TITLE	Proposal weight, C.G., and Moment of Inertia Computations
DECK NO.	7R-062
LOCATION	EDPM File
DATE	15 June 1965
PROGRAMMER	R.J. Huff, 596-109

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PROPOSAL WT., C.G., M.I. PROGRAM 7R-062

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REGION 30

PROPOSAL WT., C.G., MI PROGRAM 7R-062

TABLE OF CONTENTS (Cont'd.)

REGION 30

PROPOSAL WT., C.G., M.I. PROGRAM 7R-062

TABLE OF CONTENTS (CONT'D.)

REGION 30

PROPOSAL WT., C.G., M.I. PROGRAM 7R-062

ABSTRACT

Details of the mechanics and use of an IBM 7090 program designed to allow rapid weight, C.G. and M.I. evaluation of engine or component layouts from a minimum of data input are presented. Each case consists of a composite of assumed common geometrical shapes.

INTRODUCTION

The increasing flow of proposal layouts into the Weight Control Unit for weight, C.G., and M.I. analysis has placed a serious burden on the reduced manpower available. In general, the approach to each of these tasks is identical; i.e., the layout is broken up into parts, each of which takes a standard geometric shape. Values of weight, C.G. and moment of inertia for each part are computed by hand from existing formulas, and the results are then combined. It is the aim of the present program to expedite this process by eliminating this hand-computation.

General Program Plan

The general plan of the program requires that each component be resolved into a collection of standard shapes, and that the minimum number of dimensional parameters defining each be submitted as input data. Separate subroutines then process the data for each entry, resulting in a weight, center of gravity, and three properly oriented delta values for each, with respect to a reference coordinate system. The master program then performs all calculations necessary to combine these results into a total weight, C.G. and moments of inertia for the component.

By utilizing separate subroutines for different shapes, the program may be easily expanded in the future, should new shapes be found desirable. Input

data for each entry consists in general of the dimensions defining the shape, the density of material, the location of some identifying point in the common reference axis system, and direction number indicating the orientation (and sense) of one or more of the principal axes of the shape with respect to the common axis system. A number identifying the particular shape assumed must also be furnished with each input entry.

Facility for removing material from the total is provided by the density variable. To remove weight, a negative sign is attached to the density, the other parameters being written in the standard fashion.

Printed results for each case will consist of a list containing the weight, C.G. and inertia delta values of each entry, in addition to values for the entire combination.

Computations Performed by Subroutines

Each subroutine computes and furnishes to the main program the following information for an individual entry:

1. Weight (may be positive or negative)
2. C.G. The individual center of gravity is determined directly from the input, when the shape has symmetry such that the centroid may be fixed visually without calculation, or by computation. In the latter case, the location of some unique point on the shape is given as input, and the computed C.G. measured from this point.
3. Delta values about axes thru the centroid, and parallel to the common system reference axes. These values are computed in two steps. First, the moments of inertia of the shape about its

principal axes are computed using standard formulas based on the geometry of the shape. Secondly, the orientation of the system reference axes with respect to these principal axes is determined from the input data defining the direction numbers of the axis of revolution (for solids of revolution) and one of the remaining axes of the principal axis system for other shapes. The principal axes are then rotated into coincidence with the reference axis system, and delta values of the shape computed in the new configuration. These computations are simplified by the fact that products of inertia in the principal axis system are zero. Delta values will be negative when weight is negative.

Computations Performed by the Main Program

After processing each separate entry by means of the proper subroutines, the main program will contain, in storage, a complete set of weights, C.G.'s and deltas for all constituents. The main program then computes and stores the following sums:

$\sum w$			WEIGHTS
$\sum w\bar{y}$	$\sum w\bar{x}$	$\sum w\bar{z}$	1ST MOMENTS
$\sum w\bar{y}^2$	$\sum w\bar{x}^2$	$\sum w\bar{z}^2$	2ND MOMENTS
$\sum \Delta y$	$\sum \Delta x$	$\sum \Delta z$	DELTAS

These data are then combined to compute:

$W = \sum w$ — TOTAL WEIGHT

$\bar{Y} = \sum w\bar{y} / W$

$\bar{X} = \sum w\bar{x} / W$

$\bar{Z} = \sum w\bar{z} / W$

} CENTER OF GRAVITY

$$\Delta Y = \sum w \bar{x}^2 + \sum w \bar{z}^2 + \sum \Delta y - W\left[\bar{X}^2 + \bar{Z}^2\right]$$

$$\Delta X = \sum w \bar{y}^2 + \sum w \bar{z}^2 + \sum \Delta x - W\left[\bar{Y}^2 + \bar{Z}^2\right]$$

$$\Delta Z = \sum w \bar{x}^2 + \sum w \bar{y}^2 + \sum \Delta z - W\left[\bar{Y}^2 + \bar{X}^2\right]$$

Geometrical Shapes Included in Program

All geometrical shapes considered in this program fall into three major types, as follows:

Type I — Solids of revolution, symmetrical about both principal axes. This type requires only the direction of the axis of symmetry to be completely oriented.

Type II — Solids of revolution with only one axis of symmetry. This type is completely oriented when the positive direction of the axis of symmetry is specified, since the relation of this axis sense to the body is fixed by arbitrary convention.

Type III — Shapes which are not solids of revolution. This type requires the direction and sense of two principal axes, in order to be completely oriented.

Use of the Program

It is felt that this program could become one of the weight engineer's most useful tools. Proper write-up of the data will seem tedious and slow at first, but with familiarity and practice, will eventually result in substantial time saving. Suggestions for improvement or expansion will be incorporated as experience dictates.

30.11.01

CURRENT LIST - SHAPES INCLUDED IN PROGRAM

TYPE I

01	Hollow cylinder
02	Hollow torus
03	Solid sphere
04	Outer half-torus, solid
05	Inner half-torus, solid
06	Inner half-toroidal shell
07	Outer half-toroidal shell

CURRENT LIST - SHAPES INCLUDED IN PROGRAM

TYPE II

101	Frustrum of cone, solid
102	Outside fillet of revolution
103	Inside fillet of revolution
104	Solid spherical segment - 2 bases
105	Hemisphere, solid
106	Outer quarter of torus, solid
107	Frustrum of hollow cone
108	Annular frustrum - cylindrical hole
109	Annular cylinder, conical hole
110	Trapezoid of revolution
111	Trapezoid of revolution
112	Inner quarter of solid torus
113	Inner quarter, toroidal shell
114	Hollow spherical segment
115	Outer quarter, toroidal shell
116	Axial segment, solid torus
117	Axial segment, hollow torus
118	Radial segment, solid torus
119	Radial segment, hollow torus
120	Radial sector, solid torus
121	Radial sector, hollow torus
122	Axial segment of hollow elliptical spheroid

30.11.03

CURRENT LIST - SHAPES INCLUDED IN PROGRAM

TYPE III

201	Sector of hollow torus
202	Rectangular prism
203	Sector of outer half-torus, solid
204	Truncated ungula of cylinder
205	Solid tapered torus
206	Hollow tapered torus
207	Sector of hollow tapered disk
208	Sector of wedge of revolution

DATA WRITEUP

PRELIMINARY DATA RECORDING

As an aid in recording data measured from a layout or print, worksheets of the form shown on page 30.12.02 have been prepared. Data may be recorded initially on these sheets, and later transcribed in the proper format onto IBM data sheets.

Data required for each configuration is indicated by "X" on the enclosed sample worksheets. Each separate section of a drawing breakdown may be assigned a number (i) to avoid duplication or omission of parts. This number is not entered as data. The significance of each parameter symbol used is defined in the sketch of each geometrical shape in sections 30.2, 30.10, and 30.20. Units used must be consistent, i.e., linear dimensions in inches, density in lb/cu.in. Half angles are entered in degrees, conversion to radians being performed by the program. Direction numbers a, b, c refer uniformly to the Y principal axis, taken as the axis of revolution, when one exists.

SAMPLE WORKSHEET

DESCRIPTION -

Section								
Formula	N	01	02	03	04	05	06	07
Density	ρ	X	X	X	X	X	X	X
Location	Y	X	X	X	X	X	X	X
Location	X	X	X	X	X	X	X	X
Location	Z	X	X	X	X	X	X	X
Direction	a	X	X		X	X	X	X
Direction	b	X	X		X	X	X	X
Direction	c	X	X		X	X	X	X
Large Radius	R	X	X	X	X	X	X	X
Small Radius	r	X	X	X	X	X	X	X
Inside Radius	r_1		X				X	X
Height	H	X						
Dimension	B							
Dimension	A							
Half Angle	α							
Direction	d							
Direction	e							
Direction	f							
No: of Cards	M	1	1	1	1	1	1	1
Sub Group	K							

X Indicates required input

SAMPLE WORKSHEET

DESCRIPTION -

Section									
Formula	N	101	102	103	104	105	106	107	108
Density	D	X	X	X	X	X	X	X	X
Location	Y	X	X	X	X	X	X	X	X
Location	X	X	X	X	X	X	X	X	X
Location	Z	X	X	X	X	X	X	X	X
Direction	a	X	X	X	X	X	X	X	X
Direction	b	X	X	X	X	X	X	X	X
Direction	c	X	X	X	X	X	X	X	X
Large Radius	R	X	X	X	X	X	X	X	X
Small Radius	r	X	X	X			X	X	X
Inside Radius	r_i							X	X
Height	H	X			X			X	X
Dimension	B				X				
Dimension	A								
Half Angle	α								
Direction	d								
Direction	e								
Direction	f								
No. of Cards	M	1	1	1	2	1	1	1	1
Sub Group	K								

X Indicates required input

SAMPLE WORKSHEET

DESCRIPTION -

Section									
Formula	N	109	110	111	112	113	114	115	116
Density	P	X	X	X	X	X	X	X	X
Location	Y	X	X	X	X	X	X	X	X
Location	X	X	X	X	X	X	X	X	X
Location	Z	X	X	X	X	X	X	X	X
Direction	a	X	X	X	X	X	X	X	X
Direction	b	X	X	X	X	X	X	X	X
Direction	c	X	X	X	X	X	X	X	X
Large Radius	R	X	X	X	X	X	X	X	X
Small Radius	r	X	X	X	X	X	X	X	X
Inside Radius	Ri	X				X	X	X	
Height	H	X	X	X					X
Dimension	B		X	X					
Dimension	A		X	X					
Half Angle	∝								
Direction	d								
Direction	e								
Direction	f								
No. of cards	M	1	2	2	1	1	1	1	1
Sub Group	K								

X Indicates required input

SAMPLE WORKSHEET

DESCRIPTION Section			
Formula	N	124	
Density	ρ	X	
Locations	Y	X	
Location	X	X	
Location	Z	X	
Direction	a	X	
Direction	b	X	
Direction	c	x	
Large Radius	R	X	
Small Radius	r	X	
Inside Radius	r_i		
Height	H		
Dimension	B		
Dimension	A		
Half Angle	α		
Direction	d		
Direction	e		
Direction	f		
No. of Cards	M	1	
Sub Group	K		

X Indicates Required Input

30.12.05

SAMPLE WORKSHEET

DESCRIPTION

Section

Formula	N	117	118	119	120	121	122		
Density	ρ	X	X	X	X	X	X		
Location	Y	X	X	X	X	X	X		
Location	X	X	X	X	X	X	X		
Location	Z	X	X	X	X	X	X		
Direction	a	X	X	X	X	X	X		
Direction	b	X	X	X	X	X	X		
Direction	c	X	X	X	X	X	X		
Large Radius	R	X	X	X	X	X	X		
Small Radius	r	X	X	X	X	X	X		
Inside Radius	r_i	X		X	X	X	X		
Height	H	X	X	X	X	X	X		
Dimension	B								
Dimension	A								
Half Angle	α					X			
Direction	d								
Direction	e								
Direction	f								
No. of cards	M	1	1	1	1	2	1		
Group	K								

X Indicates required input

30.12.06

SAMPLE WORKSHEET

DESCRIPTION -

Section									
Formula	N	201	202	203	204	205	206	207	208
Density	ρ	X	X	X	X	X	X	X	X
Location	Y	X	X	X	X	X	X	X	X
Location	X	X	X	X	X	X	X	X	X
Location	Z	X	X	X	X	X	X	X	X
Direction	a	X	X	X	X	X	X	X	X
Direction	b	X	X	X	X	X	X	X	X
Direction	c	X	X	X	X	X	X	X	X
Large Radius	R	X		X	X	X	X	X	X
Small Radius	r	X		X		X	X	X	X
Inside Radius	r_i	X				X	X		
Height	H		X		X				
Dimension	B		X		X		X	X	X
Dimension	A		X		X			X	
Half Angle	α	X		X				X	X
Direction	d	X	X	X	X	X	X	X	X
Direction	e	X	X	X	X	X	X	X	X
Direction	f	X	X	X	X	X	X	X	X
No. of cards	M	2	2	2	2	2	2	2	2
Sub group	K								

X Indicates required input

Final Data Write-Up

When every part of the engine or component has been entered on the worksheets, data must be transcribed onto FORTRAN FIXED 10 DIGIT DECIMAL DATA forms as shown on the enclosed sample page. The first card for each case must contain a description of the case being analyzed. This identification is printed out along with the computed results. This card must have a "1" in column one, the descriptive material in columns 2 thru 72 being otherwise arbitrary.

Individual sections will require at most two data cards. The input integer M denotes the number of cards required in each instance. The First card of the final entry for each case is denoted by a "7" in Column one (J), which is otherwise left blank. One sub-level of breakdown has been provided; hence each entry must be assigned an integer (K) to classify it as a member of a particular sub-grouping. All items assigned the same value of K will be combined, and their composite weight, C.G., and inertia values printed. The value of K must never be zero or blank. In the event no sub-grouping is desired, a value of K=1 should be assigned each entry.

The assigned formula number of the particular shape assumed for each entry is entered as an integer in columns 3-5 of the first data card. All other data is placed in the format shown on the sample page. Dotted lines show the position assumed for the decimal point. Data not conforming to this format may be entered with a written decimal point (occupying one column).

The format of the second card is as shown on the sample. When using formula 500 (miscellaneous shapes not included in the program), the second card has the special format shown. Multiple cases may be run at the same time provided that all the above rules are followed. Data cards must all be numbered sequentially. All jobs should be referred to the Unit Programmer before submittal to Department 62.

FORTRAN FIXED TO ... DECIMAL DATA

DECK N ____ PROGRAMMER ____ DAT ____ PAGE ____ of ____ JOB NO. ____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 F-1 THRUST		— TYPICAL TITLE CARD — ONE FOR EACH CASE —
CHAMBER PRO		COLUMN 1 MUST CONTAIN '1'
POSED 3-7-6		
2		
	73 80	
D. JELINEK	1	
J M N K y		— TYPICAL FIRST CARD FOR INDIVIDUAL ITEM —
x y		J = LAST ITEM INDICATOR (7 IF LAST, BLANK IF NOT)
ρ a		M = NUMBER OF CARDS FOR THIS ENTRY (1 OR 2)
b c		N = FORMULA NUMBER
R r	73 80	K = SUB-GROUP NUMBER (MUST NOT BE BLANK OR ZERO)
? H	2	
B		— SECOND CARD FOR INDIVIDUAL ENTRY - WHEN REQUIRED —
A		
α		
d		
e	73 80	
f	3	
w		— SECOND CARD FOR FORMULA 500 ONLY —
Δy		
Δx		
Δz		
	73 80	
	3	

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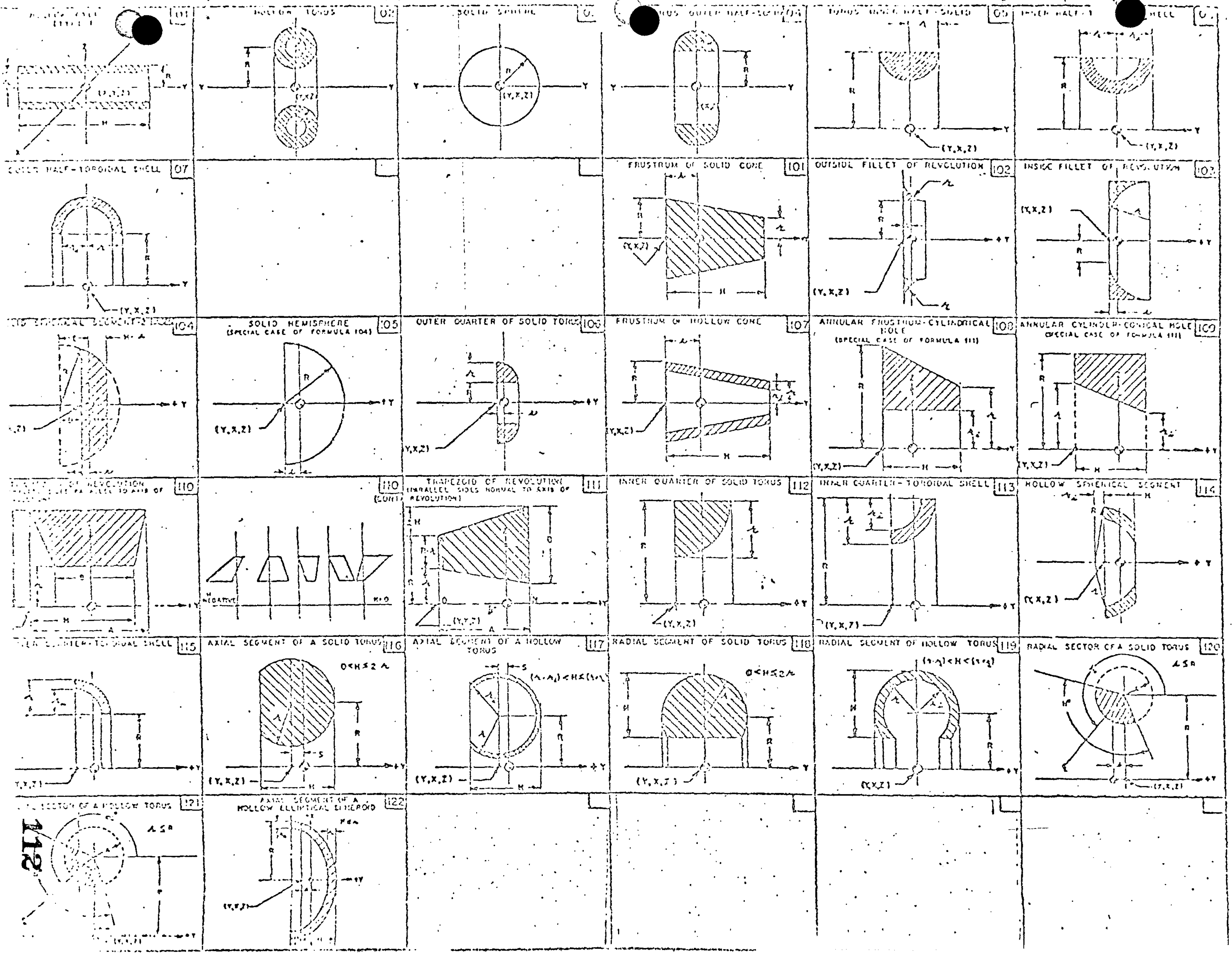
SAMPLE DATA FORMAT 7R-062

Ref 50530 Page 25

30.12.03



HOLLOW TORUS 02
SOLID SPHERE
TORUS OUTER HALF-SOLID
TORUS INNER HALF-SOLID 05
OUTER HALF-TOROIDAL SHELL 07
FRUSTUM OF SOLID CONE 101
OUTSIDE FILLET OF REVOLUTION 102
INSIDE FILLET OF REVOLUTION 103
SOLID HEMISPHERE (SPECIAL CASE OF FORMULA 104) 105
OUTER QUARTER OF SOLID TORUS 106
FRUSTUM OF HOLLOW CONE 107
ANNULAR FRUSTUM-CYLINDRICAL HOLE (SPECIAL CASE OF FORMULA 111) 108
ANNULAR CYLINDER-CONICAL HOLE (SPECIAL CASE OF FORMULA 111) 109
110 (CONT)
TRAPEZOID OF REVOLUTION (PARALLEL SIDES NORMAL TO AXIS OF REVOLUTION) 111
INNER QUARTER OF SOLID TORUS 112
INNER QUARTER-TOROIDAL SHELL 113
HOLLOW SPHERICAL SEGMENT 114
AXIAL SEGMENT OF A SOLID TORUS 116
AXIAL SEGMENT OF A HOLLOW TORUS 117
RADIAL SEGMENT OF SOLID TORUS 118
RADIAL SEGMENT OF HOLLOW TORUS 119
RADIAL SECTOR OF A SOLID TORUS 120
AXIAL SEGMENT OF A HOLLOW ELLIPTICAL SPHEROID 122

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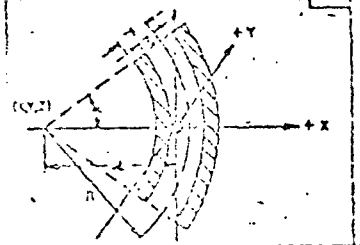
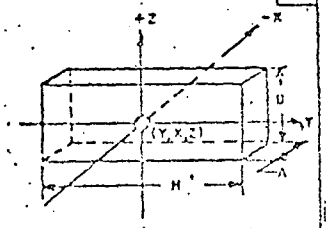
30.13.01

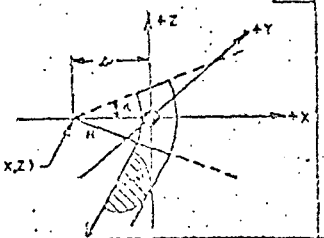
SECTOR OF HOLLOW TORUS 201



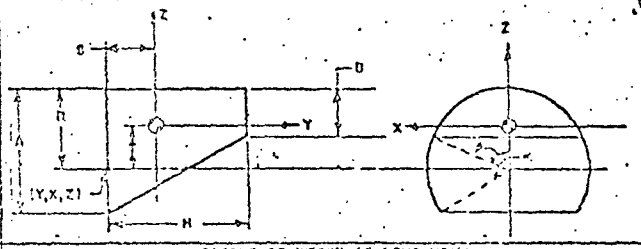
RECTANGULAR PRISM 202



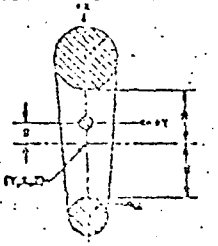
SECTOR OF OUTER HALF-TORUS 203



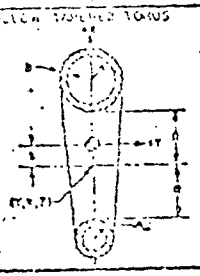
TRUNCATED UNGULA OF A CYLINDER 204



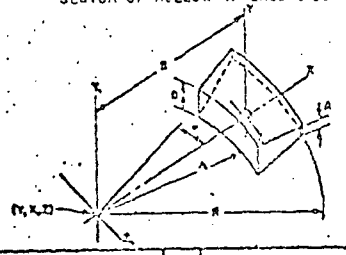
SOLID TAPERED TORUS 205



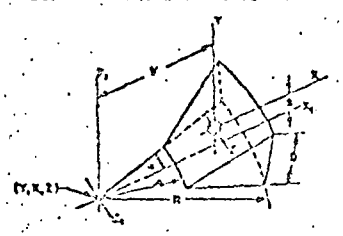
HOLLOW TAPERED TORUS 206



SECTOR OF HOLLOW TAPERED DISC 207



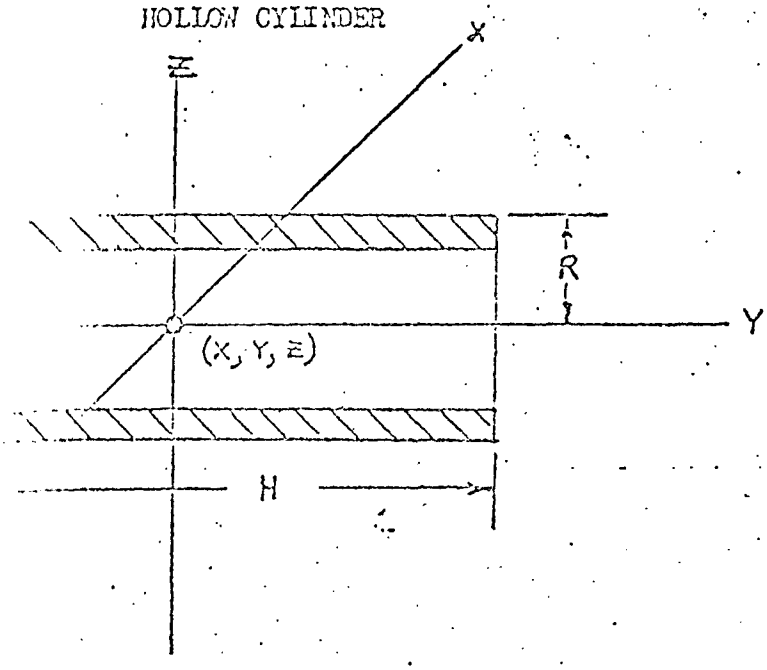
SECTOR OF WEDGE OF REVOLUTION 208



METRICAL CONFIGURATIONS

TYPE I

HOLLOW CYLINDER



: a, b, c

. . . . . $W = \rho \pi H (R^2 - r^2)$

eference axes:

$\lambda^2 = b^2/D$ $\delta^2 = c^2/D$

$\bar{x} = x$ $\bar{z} = z$

system:

$(r^2 + r^2) + R^2]$

FORMULA 01 (Cont'd.)

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2)\, \partial X$$

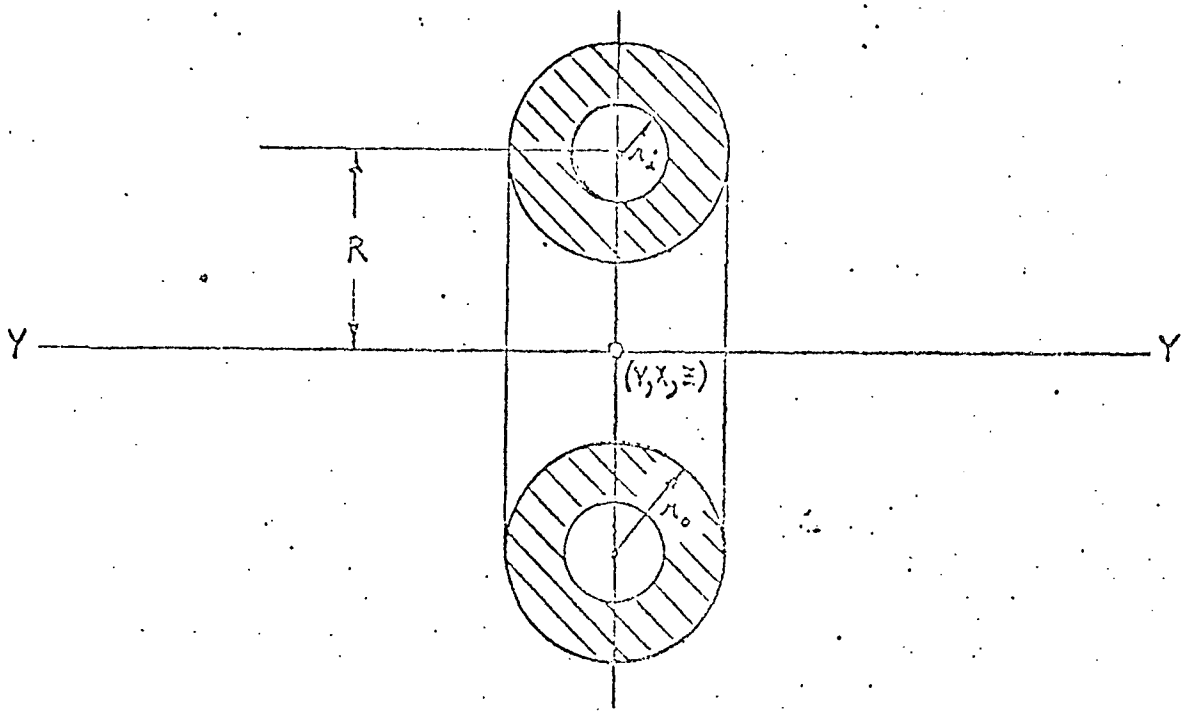
$$\Delta X = \mu^2 \partial Y + (1 - \mu^2)\, \partial X$$

$$\Delta Z = \nu^2 \partial Y + (1 - \nu^2)\, \partial X$$

Input data required:

n	= 01	Formula no.
ρ		Density
y	}	Centroid
x		
z		
a	}	Direction nos., Y axis
b		
c		
R		Outer radius
r		Inside radius
H		Length
m	= 1	No. of cards

FORMULA 02 HOLLOW TORUS



Direction numbers of Y axis: a, b, c

Let $K = 2\pi^2 \rho R$, $D = \left[a^2 + b^2 + c^2\right]^{1/2}$

Weight . . . . . $W = K (r^2 - r_i^2)$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

Center of gravity:

$\bar{y} = y$ $\bar{x} = x$ $\bar{z} = z$

Delta values in principal axis system:

$\delta Y = wR^2 + 0.75K (r^4 - r_i^4)$

$\delta X = \delta Z = 0.5\, wR^2 + 0.625\, K (r^4 - r_i^4)$

FORMULA 02 (Cont'd.)

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2) \partial X$$

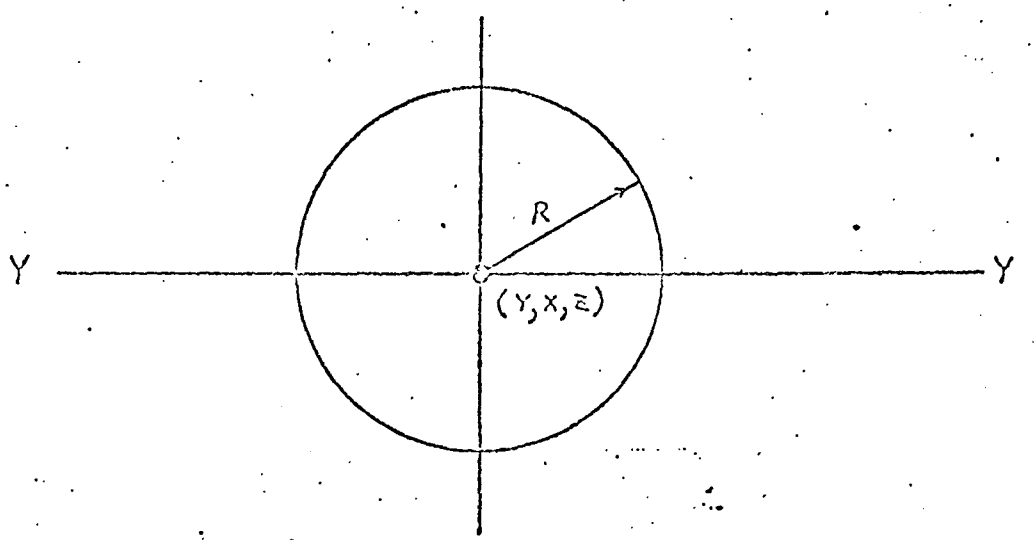
$$\Delta X = \mu^2 \partial Y + (1 - \mu^2) \partial X$$

$$\Delta Z = \nu^2 \partial Y + (1 - \nu^2) \partial X$$

Input data required:

n = 02		
ρ		Density
y, x, z		Centroid
a, b, c		Direction nos., Y axis
R		Radius of torus (to $\frac{r}{2}$)
r		Outer radius of section
r_i		Inner radius of section
m = 1		No. of cards

FORMULA 03 SOLID SPHERE



Weight . . . . . $W = 4/3\,\pi\rho\,R^3$

Center of Gravity: $\bar{y} = y$, $\bar{x} = x$, $\bar{z} = z$

Delta values in principal axis system:

$$\partial Y = \partial X = \partial Z = 0.4\,WR^2$$

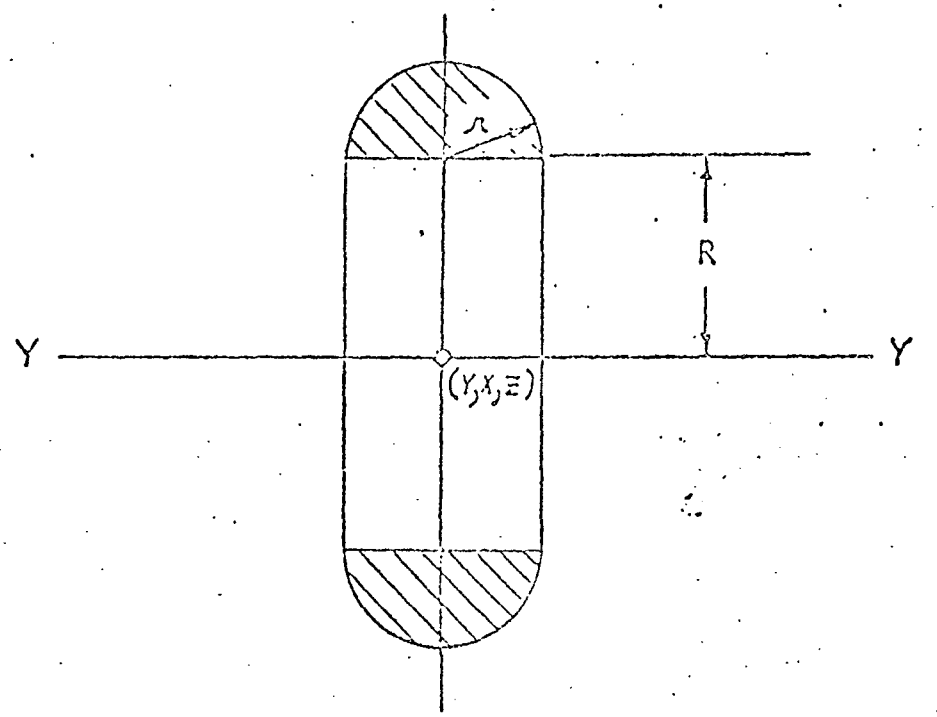
Delta values in common reference axis system:

$$\Delta Y = \partial Y \qquad \Delta X = \partial X \qquad \Delta Z = \partial Z$$

Input data required:

n = 03	
ρ	Density
y, x, z	Centroid
R	Radius

FORMULA 04 OUTER HALF - TORUS, SOLID



Direction numbers of Y axis: a, b, c

Let $K = \rho \pi r^2$, $D = \left[a^2 + b^2 + c^2\right]^{1/2}$

Weight: . . . . . $W = K\left[4/3\ r + \pi R\right]$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

Center of Gravity:

$\bar{y} = y$, $\bar{x} = x$, $\bar{z} = z$

Delta values in principal axis system:

$$\partial Y = K\left[\pi R^3 + 4R^2 r + 0.75\pi R r^2 + 8/15\ r^3\right]$$

$$\partial X = \partial Z = 0.5\,\partial Y + Kr^2\left[0.25\pi R + 4/15\ r\right]$$

FORMULA 04 (Cont'd.)

Delta values in the common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2) \partial X$$

$$\Delta X = \mu^2 \partial Y + (1 - \mu^2) \partial X$$

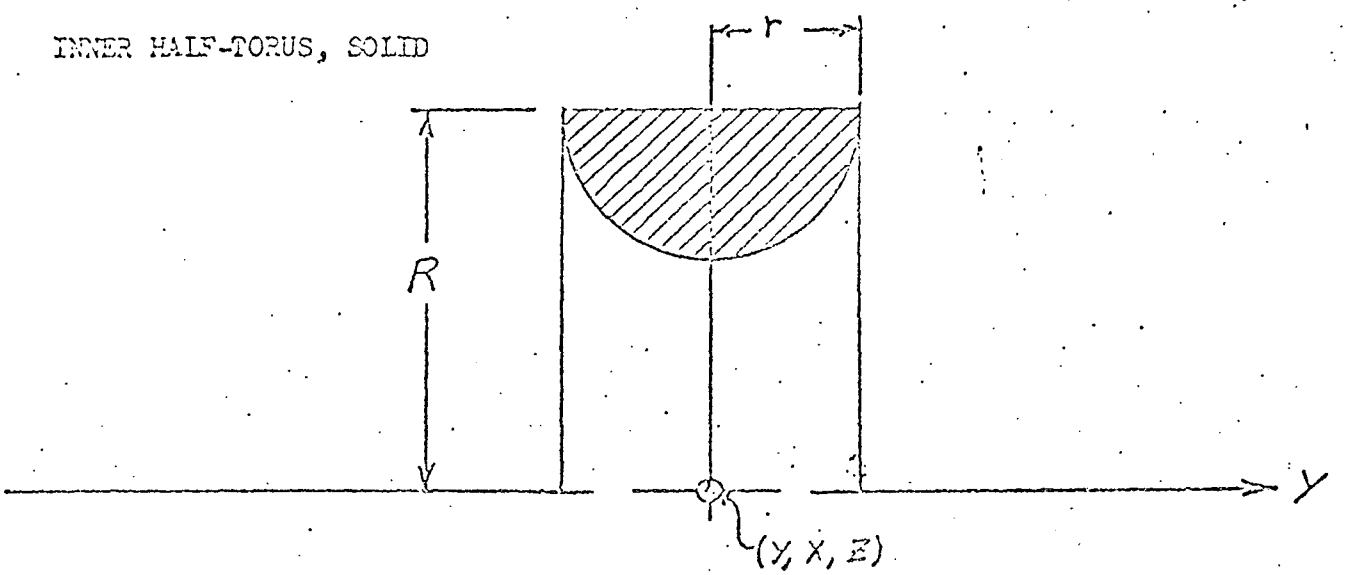
$$\Delta Z = \nu^2 \partial Y + (1 - \nu^2) \partial X$$

Input data required:

n = 04		
ρ		Density
y	}	Centroid
x		
z		
a	}	Direction Nos. - Y axis
b		
c		
R		Radius to Δ
r		Section radius
m = 1		No. of cards

FORMULA 05

INNER HALF-TORUS, SOLID



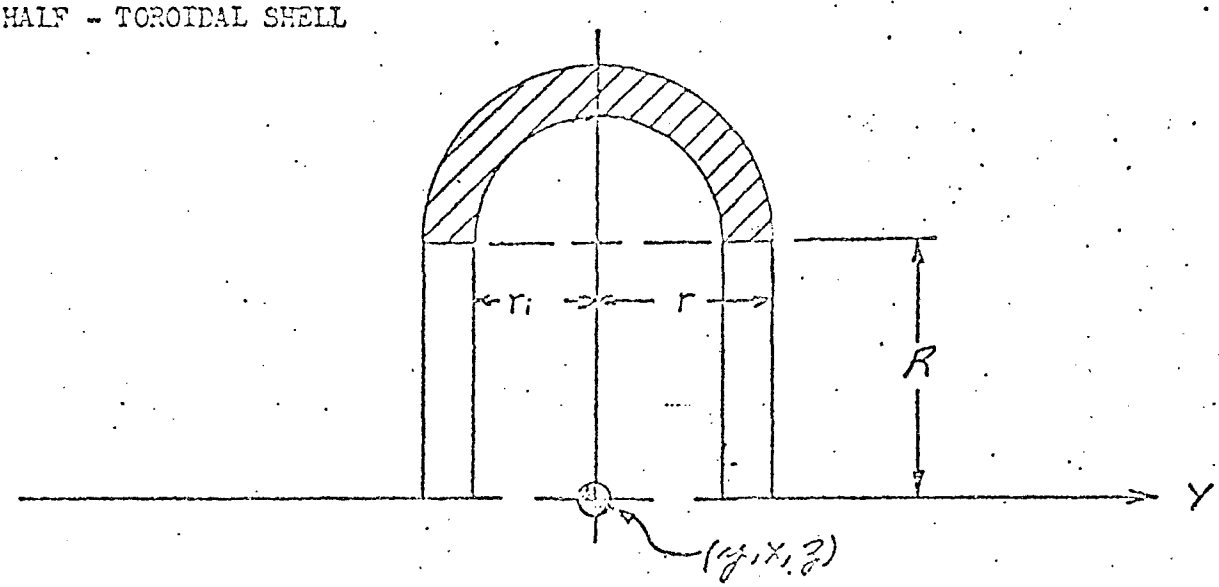
Results for this configuration are computed by deducting the outer half-torus (Formula 04) from the full torus (Formula 02) values.

Input data required:

N = 05	Formula number
M = 1	Number of cards
y, x, z	Location of geometrical center on Y axis
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to $\mathbb{C}$ of torus
r	Radius of section

FORMULA 07

OUTER HALF - TOROIDAL SHELL



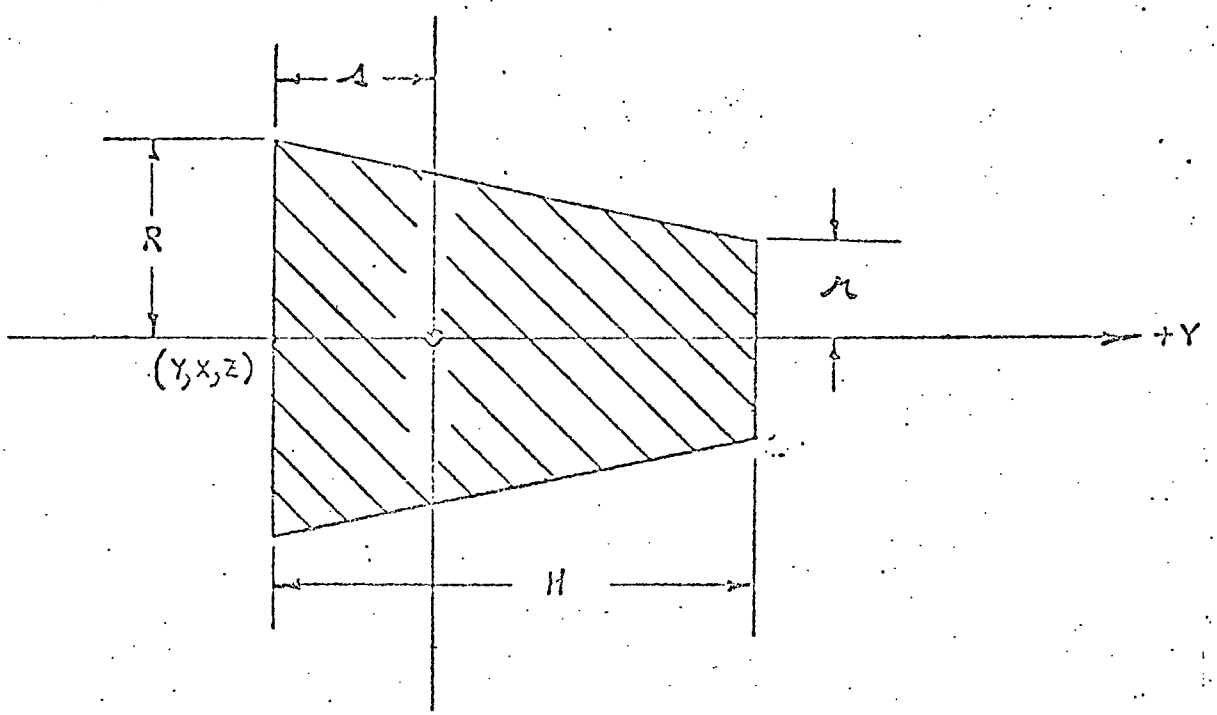
Results for this configuration are determined by deducting the solid half-torus of radius r_i (Formula 04) from the solid half-torus of radius r (Formula 04).

Input data required:

N = 07	Formula number
M = 1	Number of cards
y, x, z	Location of geometrical center on Y axis
ρ	Density
a, b, c	Direction numbers of Y axis
R	Radius to ϕ of torus
r	Outer radius of section
r_i	Inner radius of section

TYPE II

FORMULA 101 FRUSTRUM OF SOLID CONE



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$K = R^2 + Rr + r^2$

$A = (R - r) / R$

$M = A^2 - 3A + 3$

$P = \frac{3}{20 M} (A^4 - 5A^3 + 10A^2 - 10A + 5)$

$Q = \frac{1}{M^2} \left[0.1M (6A^2 - 15A + 10) - 0.0625 (3A^2 - 8A + 6)^2\right]$

Weight: . . . . . $W = \rho K \pi H / 3$

$= \frac{H}{4K} (R^2 + 2Rr + 3r^2)$

FORMULA 101(Cont'd.)

Direction cosines of Y axis with reference axes:

$$\lambda = a/D \qquad \mu = b/D \qquad \nu = c/D$$

Center of gravity:

$$\bar{y} = y + s\lambda \ , \qquad \bar{x} = x + s\mu \ , \qquad \bar{z} = z + s\nu$$

Delta values in principal axis system:

$$\partial Y = \frac{3w}{10}\left[\frac{R^5 - r^5}{R^3 - r^3}\right]$$

$$\partial X = \partial Z = w\left[PR^2 + QH^2\right]$$

Delta values in the common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2)\,\partial X$$

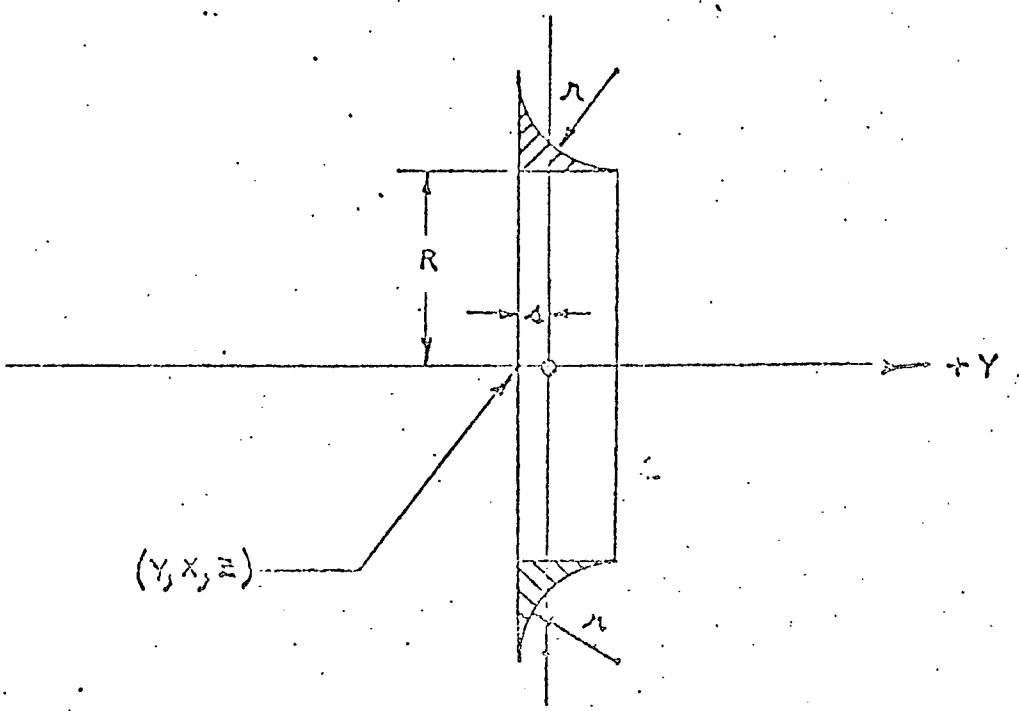
$$\Delta X = \mu^2 \partial Y + (1 - \mu^2)\,\partial X$$

$$\Delta Z = \nu^2 \partial Y + (1 - \nu^2)\,\partial X$$

Input data required:

n = 101		
ρ		Density
y	}	Center of large base
x		
z		
a	}	Direction numbers of Y axis in sense shown
b		
c		
R		Radius - large base
r		Radius - small base
H		Height
m = 1		No. of cards

FORMULA 102 OUTSIDE FILLET OF REVOLUTION



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$K = \rho r^2$

Weight: . . . . . $w = K\left[1.3483832R + 0.30118575r\right]$

$t = (Kr/w)\left[1.0471976R + 0.26179939r\right]$

$s = r - t$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

FORMULA 102 (Cont'd.)

Center of gravity:

$$\bar{y} = y + \lambda s \qquad \bar{x} = x + \mu s \qquad \bar{z} = z + \nu s$$

Delta values in principal axis system:

$$\partial Y = K\left[1.3483832R^3 + 0.90355662R^2r + 0.34404744Rr^2 + 0.055835682r^3\right]$$

$$\partial X = \partial Z = 0.5\,\partial Y + Kr^2\left[0.85069461R + 0.23237608r\right] = wt^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1-\lambda^2)\,\partial X$$

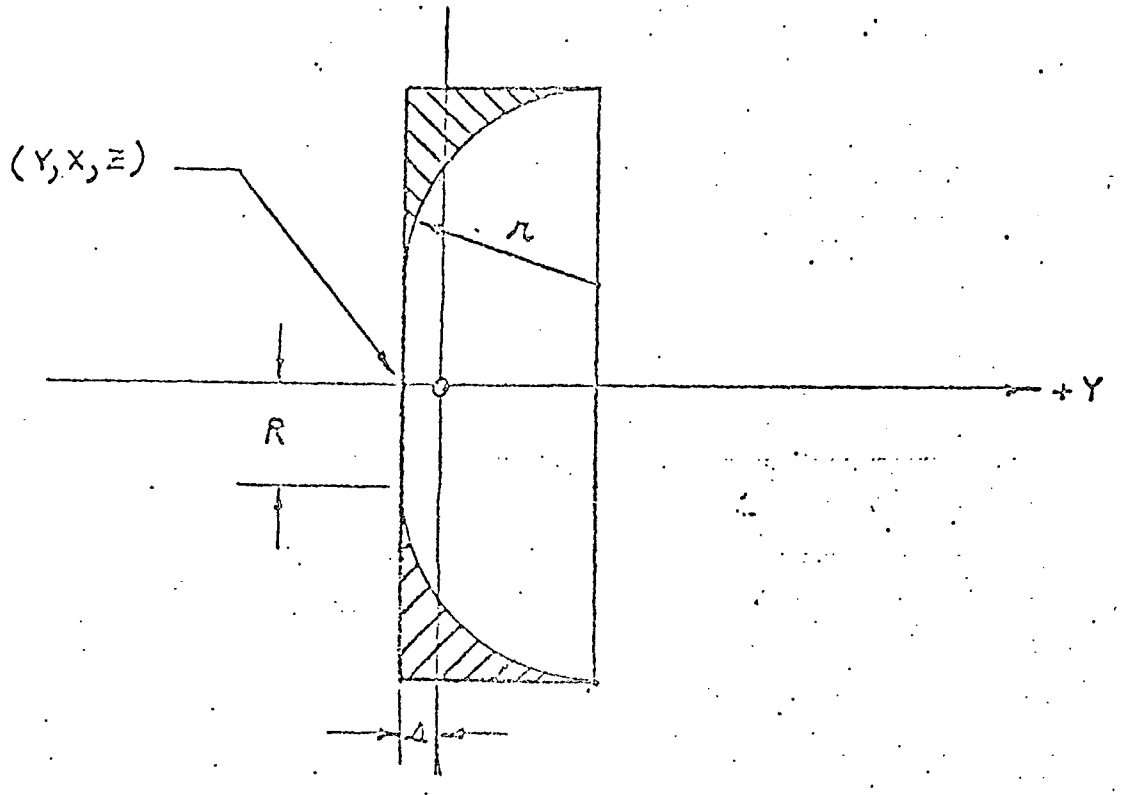
$$\Delta X = \mu^2 \partial Y + (1-\mu^2)\,\partial X$$

$$\Delta Z = \nu^2 \partial Y + (1-\nu^2)\,\partial X$$

Input data required:

n = 102	
ρ	Density
y, x, z	Center of base
a, b, c	Direction numbers of Y axis in the sense shown
R	Large radius
r	Fillet radius
m = 1	No. of cards

FORMULA 103 INSIDE FILLET OF REVOLUTION



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$K = \rho r^2$

Weight: . . . . . $w = K\left[1.3483832R + 1.0471976r\right]$

$s = \frac{Kr}{w}\left[0.30118575R + 0.26179939r\right]$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

Center of gravity:

$\bar{y} = y + \lambda s$ $\bar{x} = x + \mu s$ $\bar{z} = z + \nu s$

FORMULA 103(Cont'd.)

Delta values in principal axis system:

$$\partial Y = K\left[1.3483832R^3 + 3.1415927R^2r + 2.5820838Rr^2 + 0.73303829r^3\right]$$

$$\partial X = \partial Z = 0.5\,\partial Y + Kr^2\left[0.11468258R + 0.10471976r\right] - ws^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1-\lambda^2)\,\partial X$$

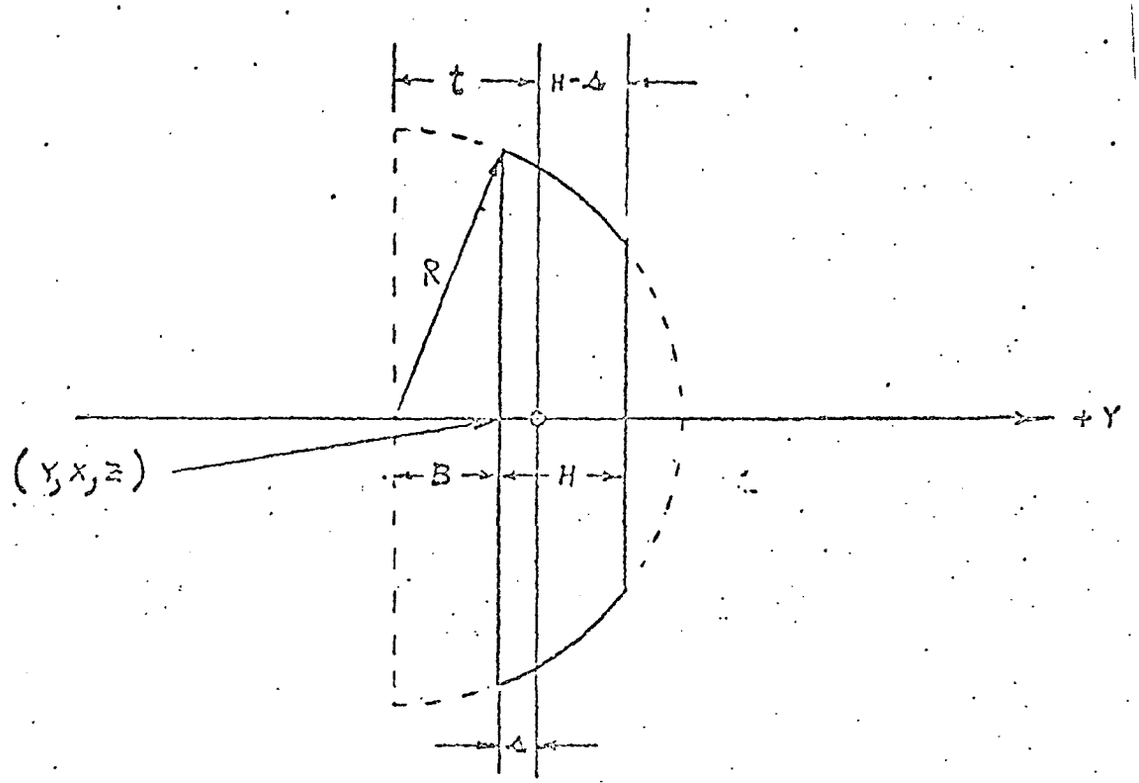
$$\Delta X = \mu^2 \partial Y + (1-\mu^2)\,\partial X$$

$$\Delta Z = \nu^2 \partial Y + (1-\nu^2)\,\partial X$$

Input data required:

n = 103	
ρ	Density
y, x, z	Center of base
a, b, c	Direction numbers of Y axis in the sense shown
R	Large radius
r	Fillet radius
n = 1	No. of cards

FORMULA 104 SOLID SPHERICAL SEGMENT - 2 BASES



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$K = \pi \rho H$

Weight: . . . . $w = K\left[R^2 - 1/3\ (3B^2 + 3BH + H^2)\right]$

$t = \frac{K}{w}\left[R^2(B + 0.5H) - B^3 - 1.5\ B^2H - BH^2 - 0.25H^3\right]$

$s = t - B$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

FORMULA 104 (Cont'd.)

Center of gravity:

$$\bar{y} = y + \lambda s \qquad \bar{x} = x + \mu s \qquad \bar{z} = z + \vartheta s$$

Delta values in principal axis system:

$$\partial Y = 0.5K \left[R^4 + B^4 + 2B^3H + 2B^2H^2 + BH^3 + 0.2H^4 - 2R^2/3 \, (3B^2 + 3BH + H^2) \right]$$

$$\partial X = \partial Z = K \left[0.25R^4 + R^2/6(3B^2 + 3BH + H^2) - 0.75B \, (B^3 + 2B^2H + 2BH^2 + H^3) - 0.15H^4 \right] - wt^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2) \, \partial X$$

$$\Delta X = \mu^2 \partial Y + (1 - \mu^2) \, \partial X$$

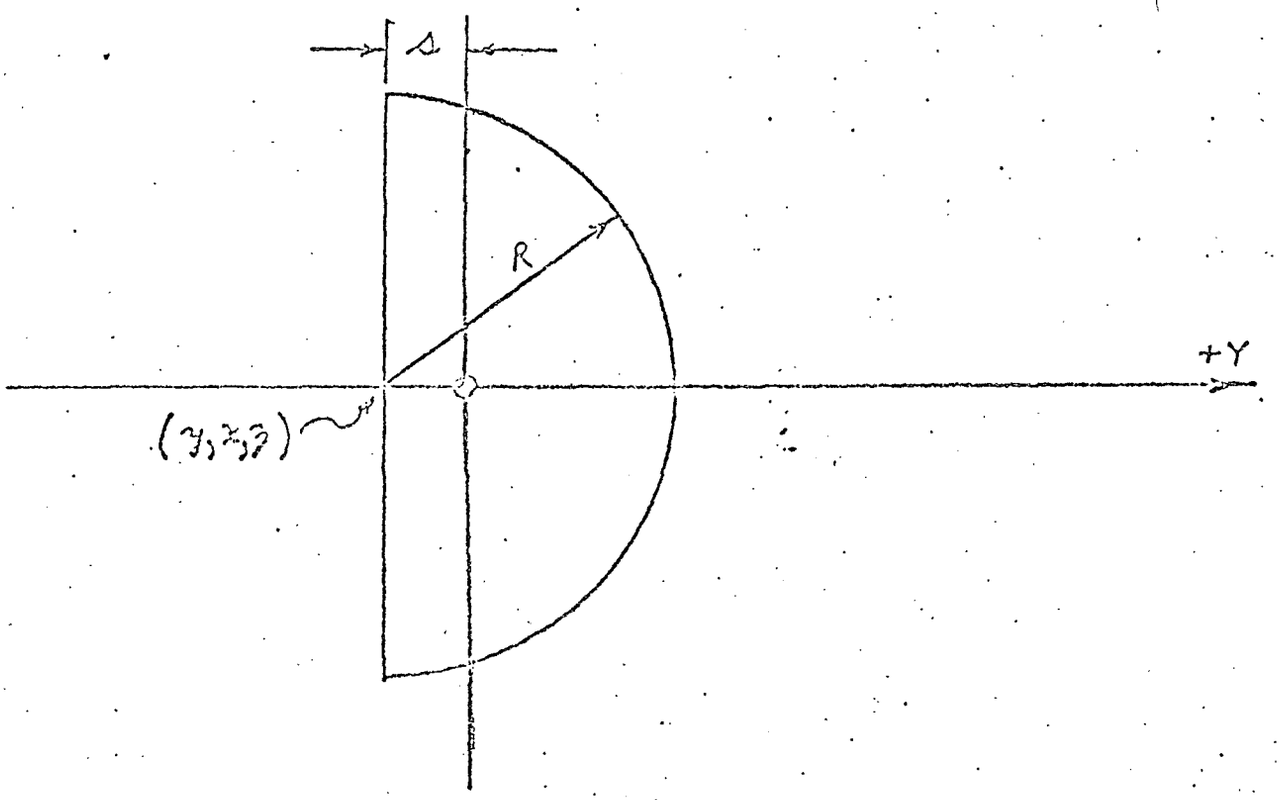
$$\Delta Z = \vartheta^2 \partial Y + (1 - \vartheta^2) \, \partial X$$

Input data required:

n = 104	
ρ	Density
y, x, z	Center of larger base
a, b, c	Direction numbers of Y axis in the sense shown
R	Radius of sphere
B	Distance - center of sphere to large base
H	Height of segment
m = 2	No. of cards

Formula 105

SOLID HEMISPHERE
(Special case of formula 104)



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

Weight:, . . $W = \frac{2\pi\rho R^3}{3}$

$s = \frac{3R}{8}$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

Center of gravity:

$\bar{y} = y + \lambda s$, $\bar{x} = x + \mu s$, $\bar{z} = z + \nu s$

FORMULA 105 (Cont'd.)

Delta values in principal axis system:

$$\partial Y = 0.4\, wR^2$$

$$\partial X = \partial Z = 0.259375\, wR^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2)\, \partial X$$

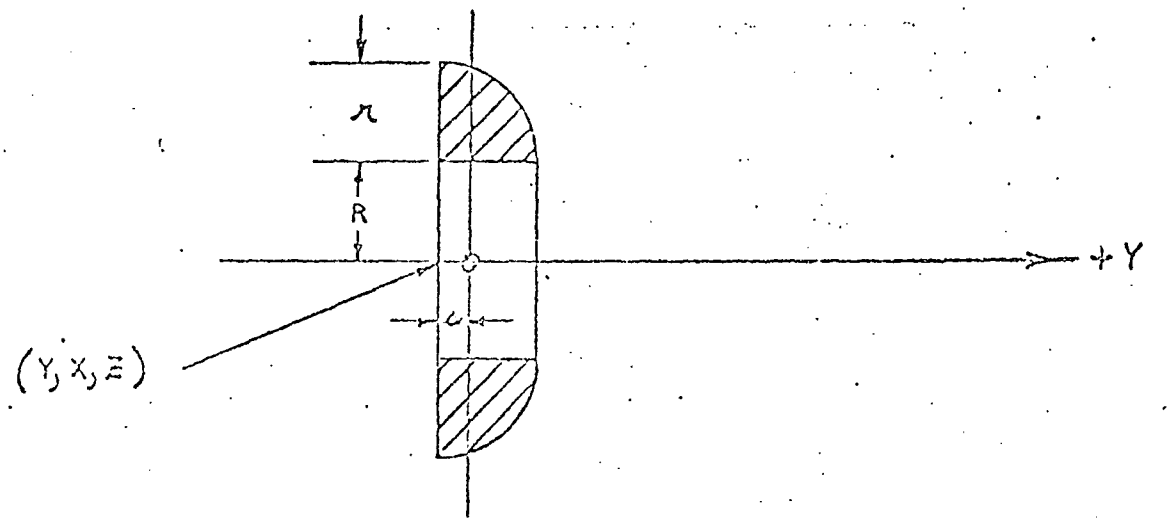
$$\Delta X = \mu^2 \partial Y + (1 - \mu^2)\, \partial X$$

$$\Delta Z = \nu^2 \partial Y + (1 - \nu^2)\, \partial X$$

Input data required:

n = 105		
ρ		Density
y	}	Center of sphere
x		
z		
a	}	Direction numbers of Y axis in sense shown
b		
c		
R		Radius
m = 1		No. of cards

Formula 106 Outer Quarter of Solid Torus



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$K = 0.5\pi\rho r^2$

Weight: $w = K(\pi R + 4r/3)$

$s = \dfrac{r(8R + 3r)}{2(3\pi R + 4r)}$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

Center of gravity:

$\bar{y} = y + \lambda s$, $\bar{x} = x + \mu s$, $\bar{z} = z + \nu s$

Delta values in principal axis system:

$$\delta Y = K\left[\pi R^3 + 4R^2 r + 0.75\pi R r^2 + 8 r^3/15\right].$$

$$\delta X = \delta Z = 0.5\,\delta Y + K r^2 (0.25\pi R + 4r/15) - ws^2$$

Delta values in common reference axis system

$$\Delta Y = \lambda^2 \delta Y + (1 - \lambda^2)\,\delta X$$

$$\Delta X = \mu^2 \delta Y + (1 - \mu^2)\,\delta X$$

$$\Delta Z = \nu^2 \delta Y + (1 - \nu^2)\,\delta X$$

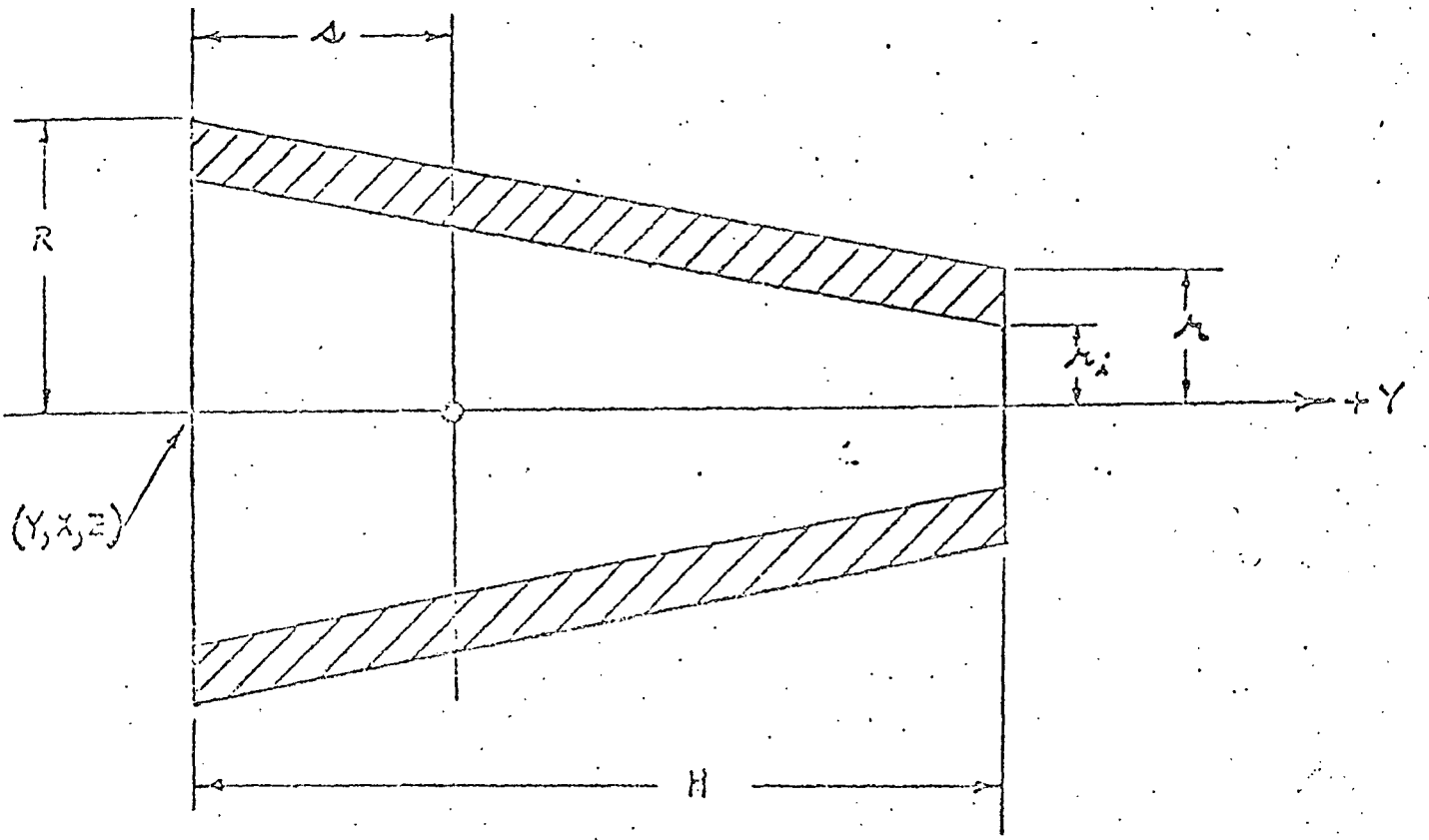
Formula 106 (cont'd)

Input data required:

n = 106	
ρ	density
y, x, z	center of torus
a, b, c	direction numbers of Y axis in the sense shown
R	Radius of torus
r	Radius of section
m=1	No. of cards

FRUSTRUM OF HOLLOW CONE

FORMULA 107



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$U_1 = R - r$

$t = r - r_i$

$q = u_1/\pi$

$E = \pi\rho t$

$K_1 = E(2R - t)$

$K_2 = 2EU_1$

$K_3 = .5E/q$

$K_4 = 2K_3/q^2$

Weight..... $W = EH(R + r_i)$

FORMULA 107 (Cont'd.)

$$s = H/3 \left[\frac{3K_1 - 2K_2}{2K_1 - K_2} \right]$$

$$B = R - qs$$

$$u_2 = R^2 - r^2$$

$$u_3 = R^3 - r^3$$

$$u_4 = R^4 - r^4$$

Direction cosines of Y axis with reference axes:

$$\lambda = a/D \qquad \mu = b/D \qquad \nu = c/D$$

Center of gravity:

$$\bar{y} = y + \lambda s \qquad \bar{x} = x + \mu s \qquad \bar{z} = z + \nu s$$

Delta values in principal axis system:

$$\partial Y = K_3 \left[u_4 - 2tu_3 + 2t^2 u_2 - t^3 u_1 \right]$$

$$\partial X = \partial Z = 0.5 \partial Y + K_4 \left[.5u_4 - \frac{4B + t}{3} u_3 + B(B + t)u_2 - B^2 t u_1 \right]$$

Formula 107 (cont'd)

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2)\, \partial x$$

$$\Delta X = \mu^2 \partial Y + (1 - \mu^2)\, \partial x$$

$$\Delta Z = \nu^2 \partial Y + (1 - \nu^2)\, \partial x$$

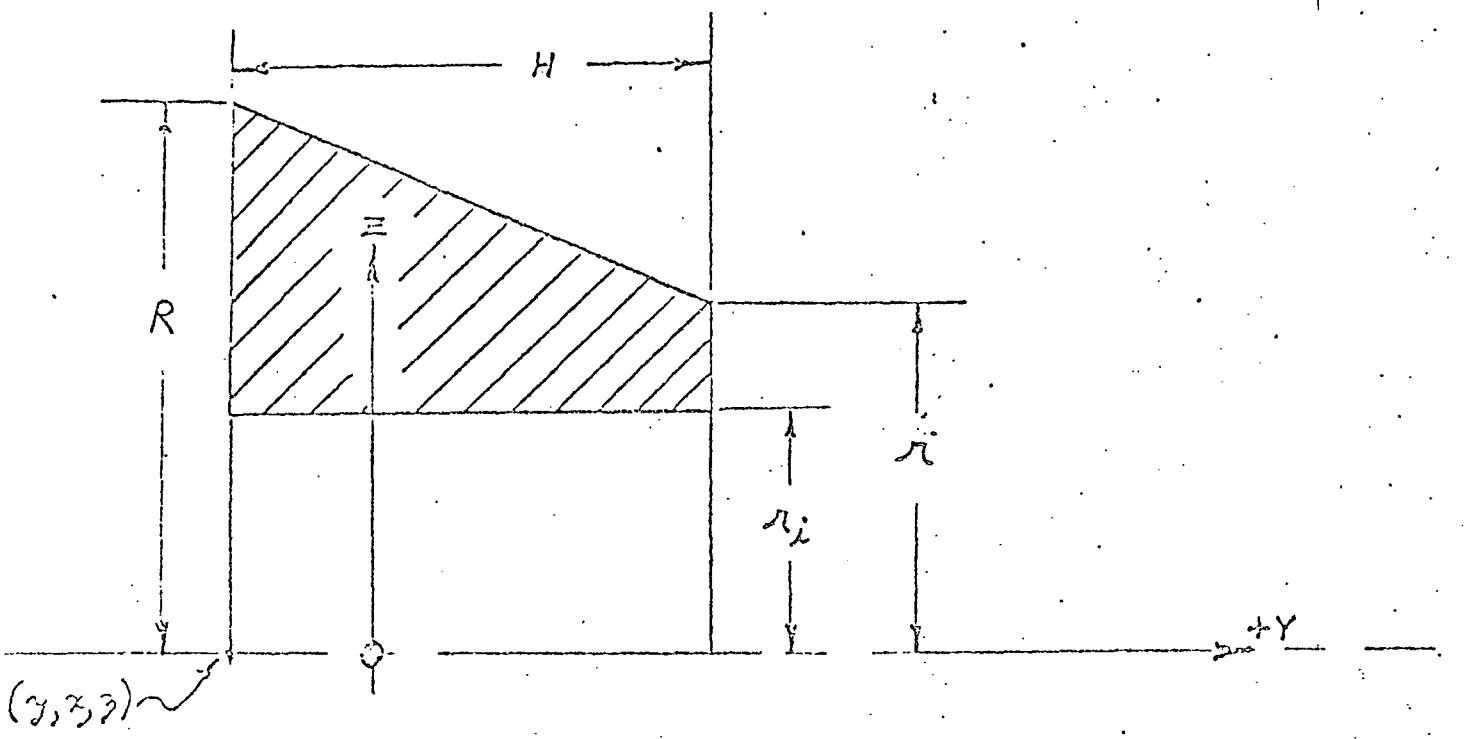
Input data required:

n = 107	
ρ	Density
y, x, z	Center of large base
a, b, c	Direction numbers of Y axis in sense shown
R	Outer radius - large base
r	Outer radius - small base
r_i	Inner radius - small base
H	Height
m = 1	No. of cards

FORMULA 103

ANNULAR FRUSTRUM - CYLINDRICAL HOLE

(Special Case of Formula 111)



Direction numbers of Y axis: a, b, c

Reference point (y, x, z) must be chosen such that the larger base is at the reference point. The + Y direction must go toward the body, as in the sketch.

Values for weight, C. G., and moments of inertia are obtained by treating this configuration as a solid frustrum minus an inner solid cylinder. Use is made of Formulas 101 and 01. Results are combined in the standard fashion.

FORMULA 108 - ANNULAR FRUSTRUM - CYLINDRICAL HOLE (Cont'd.)

Input data required:

m = 1 no. of cards

n = 108 Formula number

y, x, z } coordinates of reference point

ρ density

a, b, c } direction numbers of Y axis in sense shown.

R Max. outer radius

r Min. outer radius

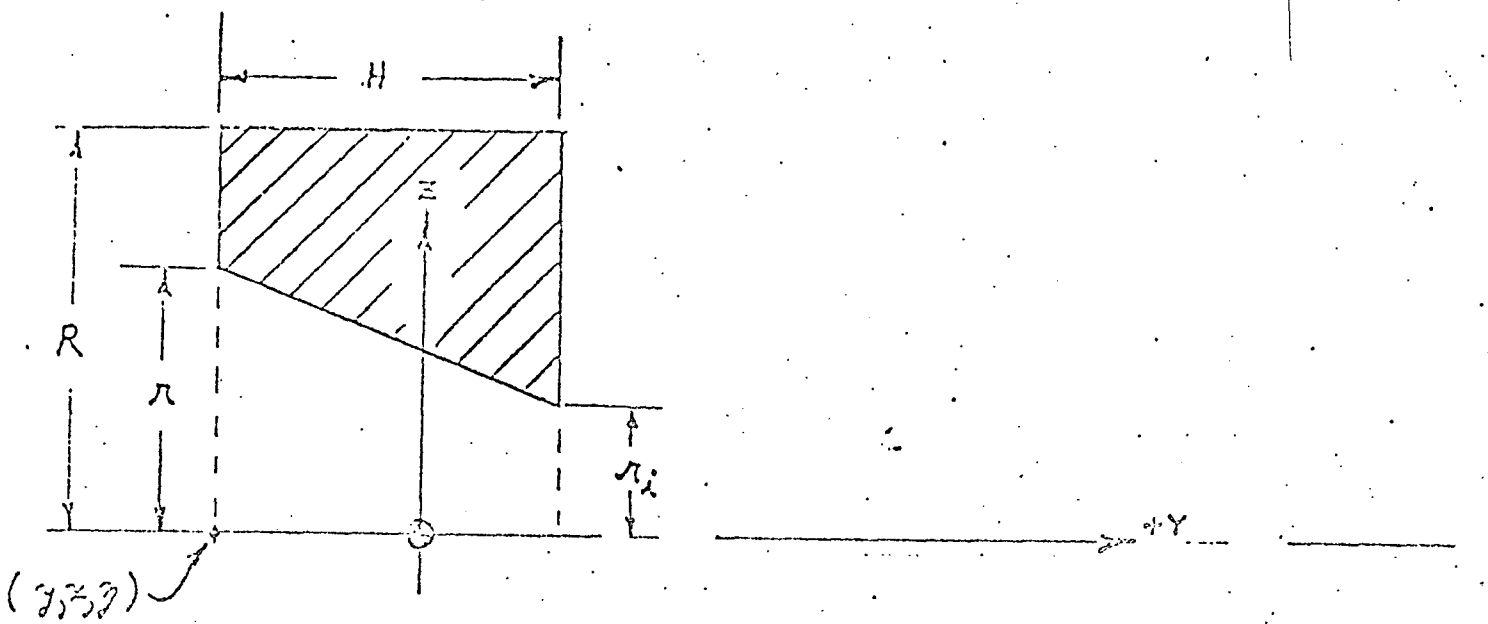
r_i Inner radius (of hole)

H Axial length

FORMULA 109

ANNULAR CYLINDER - CONICAL HOLE

(Special Case of Formula 111)



Direction numbers of Y axis: a, b, c

Reference point (y, x, z) must be chosen so that the larger inner radius is at the reference point. The positive Y direction must go toward the body, as in the sketch.

Values for weight, C. G., and moments of inertia are obtained by treating the configuration as a solid cylinder minus a solid frustrum, using Formulas 01 and 101. Results are combined in the standard fashion for composite shapes.

FORMULA 109 - ANNULAR CYLINDER - CONICAL HOLE (Cont'd.)

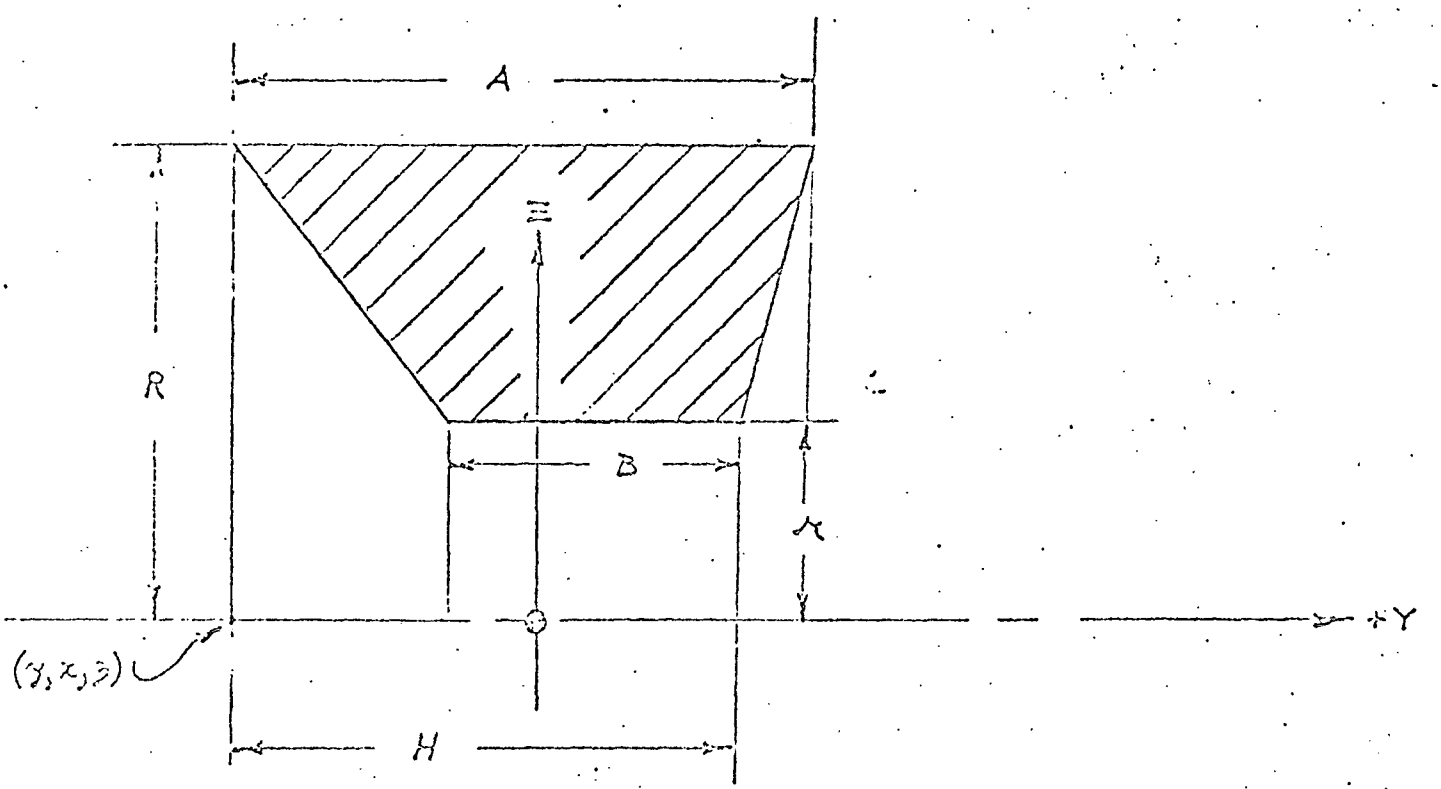
Input data required:

m = 1	no. of cards
n = 109	Formula number
y, x, z	coordinates locating center of small base
ρ	density
a, b, c	direction numbers of + Y axis
R	outer radius
r	larger inside radius
r_i	smaller inside radius
H	axial length

FORMULA 110

TRAPEZOID OF REVOLUTION

(Parallel sides parallel to axis of revolution)

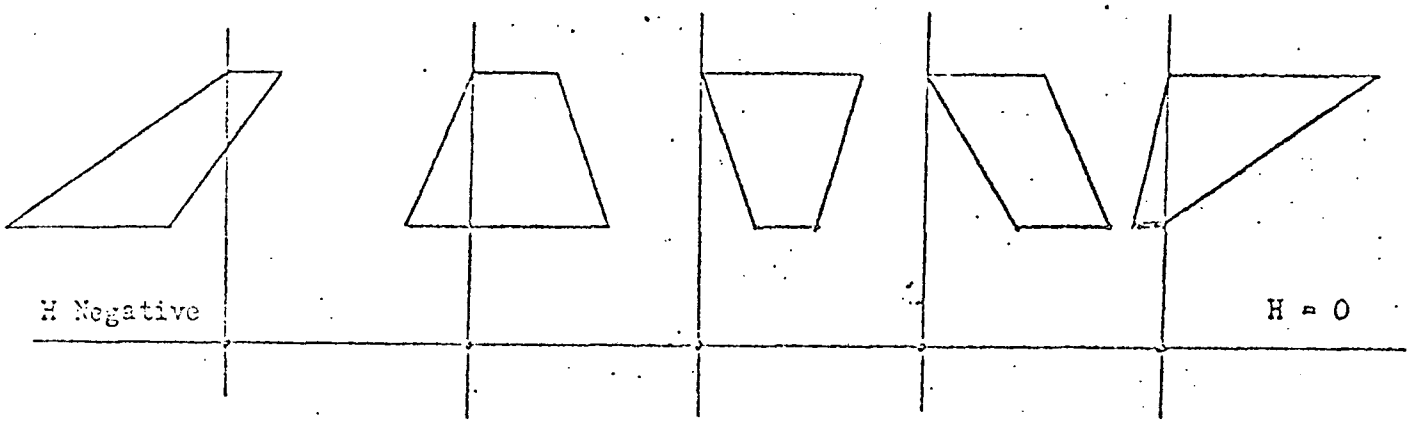


Identifying point (y, x, z) is located on the y axis, with y in a normal plane thru the upper left corner of the section, as shown in the sketch.

Direction numbers of Y axis: a, b, c

The distance H is measured in the + Y direction, from the upper left corner to the lower right corner of the trapezoid; i.e., H can be negative, as shown in Sketch (b).

FORMULA 110 - TRAPEZOID OF REVOLUTION (Cont'd.)



Sketch (b)

Reference points for trapezoidal configurations

Values for weight, C. G., and moments of inertia for this configuration are obtained by treating the body as an algebraic combination of two solid cylinders and two solid frustrums. The frustrums are added or deducted as required by the particular type of trapezoidal section involved. Results for each section are computed and combined in the standard fashion for composite bodies. Use is made of Formulas 01 and 101.

FORMULA 110 - TRAPEZOID OF REVOLUTION (Cont'd.)

Input data required:

m = 2 no. of cards

n = 110 Formula number

y, x, z } coordinates of reference point

ρ density

a, b, c } direction numbers, Y axis

R outer radius

r inner radius

H axial distance - upper left corner to lower right corner

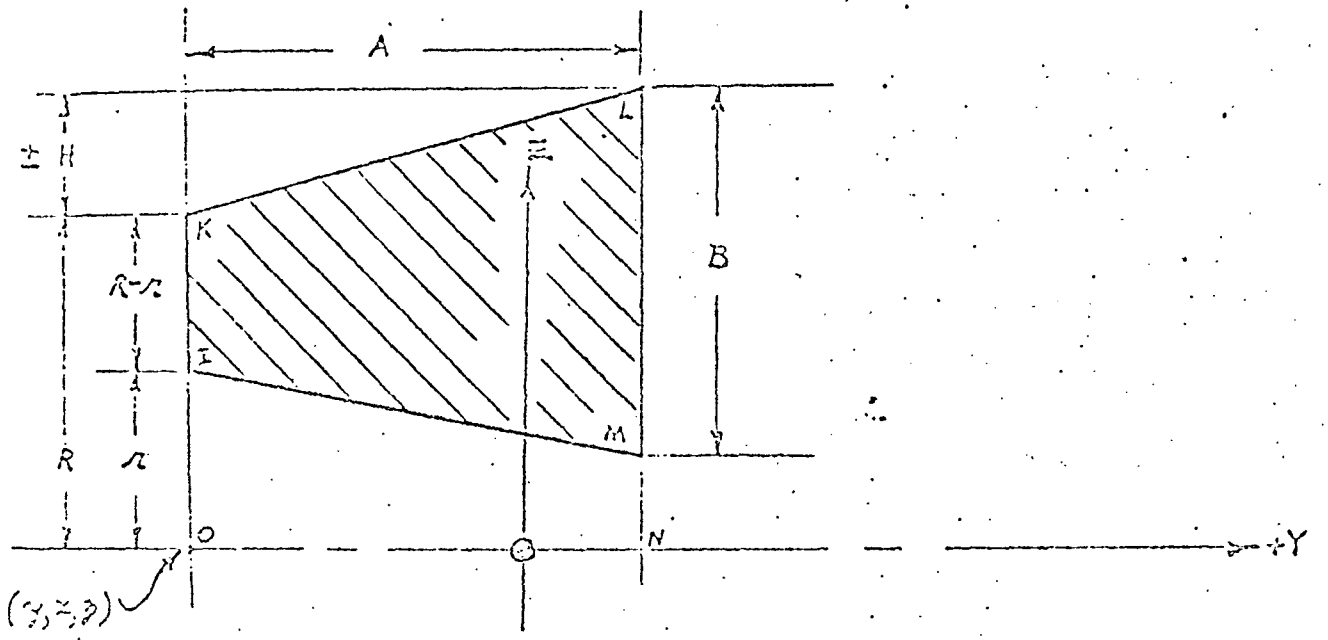
B axial length - inner base

A axial length - outer base

FORMULA 111

TRAPEZOID OF REVOLUTION

(Parallel Sides Normal to Axis of Revolution)



Identifying point y, x, z is located on the axis of revolution in the plane of one base of the trapezoid.

Direction numbers of Y axis: a, b, c

Other input data (see sketch):

ρ, R, r, A, B, H (Positive or negative, measured as length $\overline{NL} - \overline{OK}$)

Define $D = (a^2 + b^2 + c^2)^{\frac{1}{2}}$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$ $\mu = b/D$ $\nu = c/D$

FORMULA 111 - Trapezoid of Revolution (Cont'd.)

Values of weight, C. G., and delta values for this configuration are obtained through the use of the solid frustrum equations as follows:

(a) Compute and store results for outer frustrum OKLN using Formula 101:

Let $\rho_1 = \rho$, $H_1 = A$

(1) When H is zero or negative, let

$R_1 = R$ $\quad a_1 = a$ $\quad y_1 = y$

$r_1 = R + H$ $\quad b_1 = b$ $\quad x_1 = x$

$c_1 = c$ $\quad z_1 = z$

Using Formula 101, compute W_1, $\bar{y}_1$, $\bar{x}_1$, $\bar{z}_1$, ΔY_1, ΔX_1, ΔZ_1.

(2) When H is positive, let

$R_1 = R + H$ $\quad a_1 = -a$ $\quad y_1 = y + \lambda A$

$r_1 = R$ $\quad b_1 = -b$ $\quad x_1 = x + \mu A$

$c_1 = -c$ $\quad z_1 = z + \nu A$

Using Formula 101, compute W_1, $\bar{y}_1$, $\bar{x}_1$, $\bar{z}_1$, ΔY_1, ΔX_1, ΔZ_1.

(b) Reverse sign of density, compute and store results for inner frustrum OMNN using Formula 101:

Let $\rho_2 = -\rho$, $\quad P = R + H - B$, $\quad H_2 = A$

(1) When P is less than or equal to r, let

$R_2 = r$ $\quad a_2 = a$ $\quad y_2 = y$

$r_2 = P$ $\quad b_2 = b$ $\quad x_2 = x$

$c_2 = c$ $\quad z_2 = z$

Using Formula 101, compute W_2, $\bar{y}_2$, $\bar{x}_2$, $\bar{z}_2$, ΔY_2, ΔX_2, ΔZ_2.

FORMULA 111 - Trapezoid of Revolution (Cont'd.)

(2) When P is greater than r_1 let

$$R_2 = P \qquad a_2 = -a \qquad y_2 = y + \lambda A$$
$$r_2 = r \qquad b_2 = -b \qquad x_2 = x + \mu A$$
$$c_2 = -c \qquad z_2 = z + \nu A$$

Using Formula 101, compute W_2, $\bar{y}_2$, $\bar{x}_2$, $\bar{z}_2$, ΔY_2, ΔX_2, ΔZ_2.

(c) Combine frustrums:

$$YM = w_1\bar{y}_1 + w_2\bar{y}_2$$
$$XM = w_1\bar{x}_1 + w_2\bar{x}_2$$
$$ZM = w_1\bar{z}_1 + w_2\bar{z}_2$$

Weight $W = w_1 + w_2$

C.G. $\bar{y} = YM/W$

$\bar{x} = XM/W$

$\bar{z} = ZM/W$

Deltas $$\Delta Y = \sum_{i=1}^{2} \left[w_i (\bar{x}_i^2 + \bar{z}_i^2) + \Delta y_i \right] - W (\bar{x}^2 + \bar{z}^2)$$

$$\Delta X = \sum_{i=1}^{2} \left[w_i (\bar{y}_i^2 + \bar{z}_i^2) + \Delta x_i \right] - W (\bar{y}^2 + \bar{z}^2)$$

$$\Delta Z = \sum_{i=1}^{2} \left[w_i (\bar{y}_i^2 + \bar{x}_i^2) + \Delta z_i \right] - W (\bar{y}^2 + \bar{x}^2)$$

FORMULA 111 - Trapezoid of Revolution (Cont'd.)

Input data required:

m = 2 no. of cards

n = 111 Formula number

y, x, z } coordinates locating center of one base (reference)

ρ density

a, b, c } direction numbers of axis of revolution with sense shown.

R Outer radius - reference base

r Inner radius - reference base

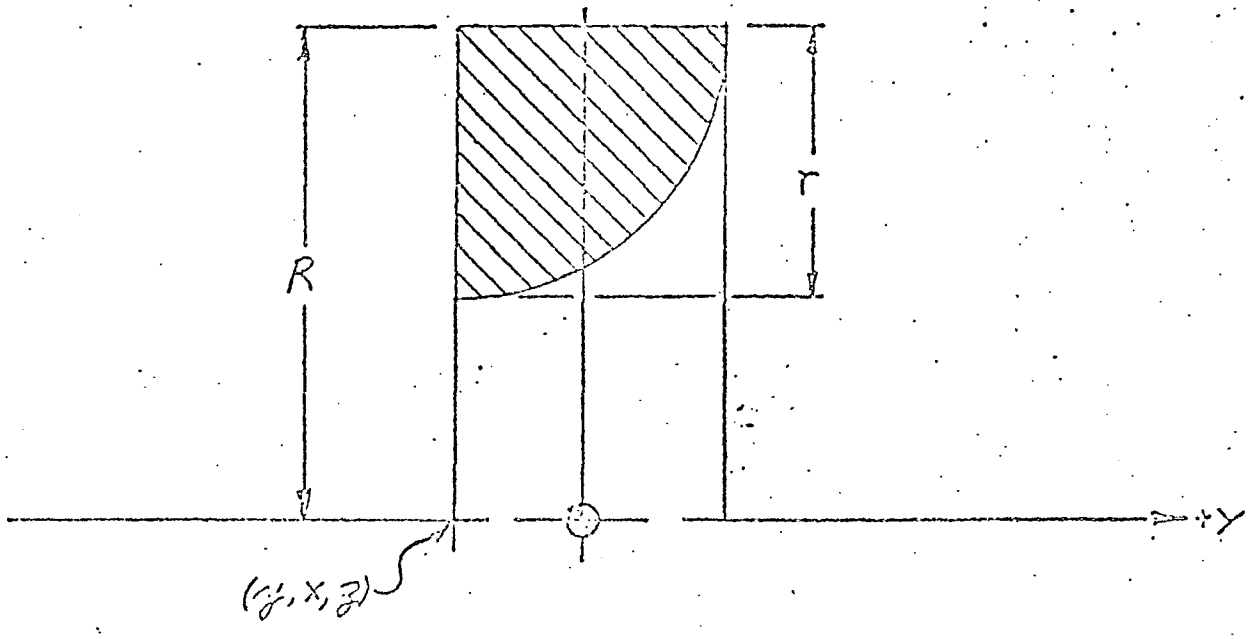
H Outer radius of opposite base minus R (+ or -)

B Height of opposite base

A Axial length (between parallel sides).

FORMULA 112

INNER QUARTER OF SOLID TORUS



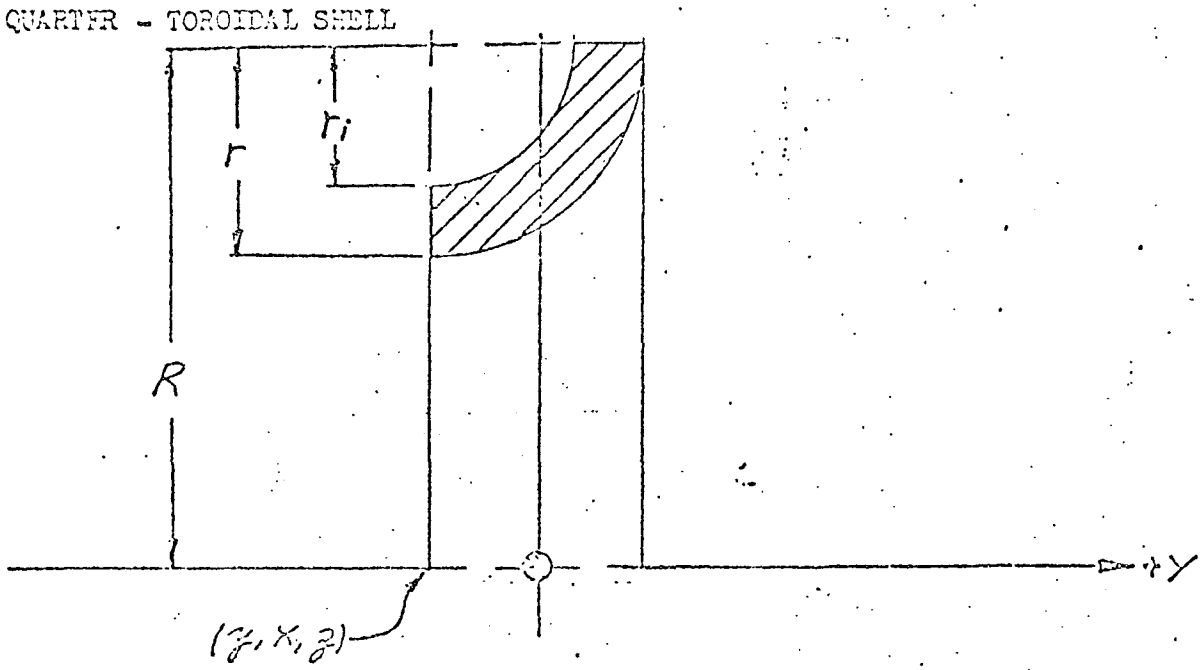
Results for this configuration are obtained by deducting an outside fillet of revolution (Formula 102) from a hollow cylinder (Formula 01).

Input data required:

N = 112	Formula number
M = 1	Number of cards
y, x, z	Location of geometrical center of torus on Y axis
ρ	Density
a, b, c	Direction numbers of Y axis
R	Radius to $\mathbb{C}$ of torus
r	Radius of section

FORMULA 113

INNER QUARTER - TOROIDAL SHELL



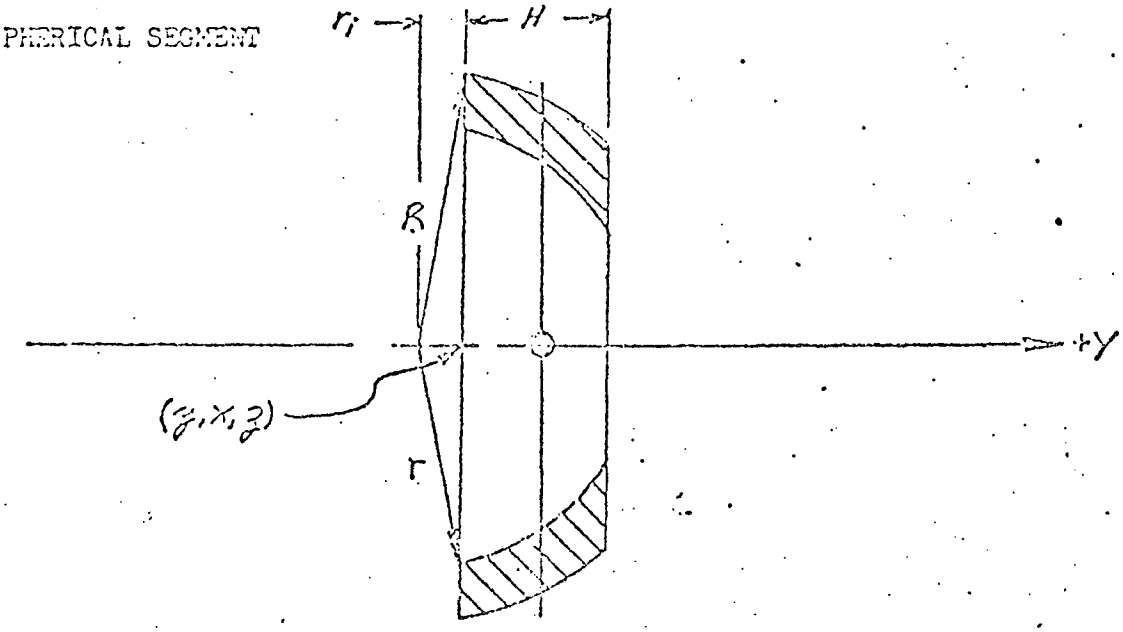
Results for this configuration are obtained by deducting the solid quarter-torus of radius r_i (Formula 112) from a solid quarter-torus of radius r (Formula 112).

Input data required:

N = 113	Formula number
M = 1	Number of cards
y, x, z	Location of geometrical of torus on Y axis
ρ	Density
a, b, c	Direction numbers of Y axis
R	Radius to torus $\mathbb{C}$
r	Outer section radius
r_i	Inner section radius

FORMULA 114

HOLLOW SPHERICAL SEGMENT



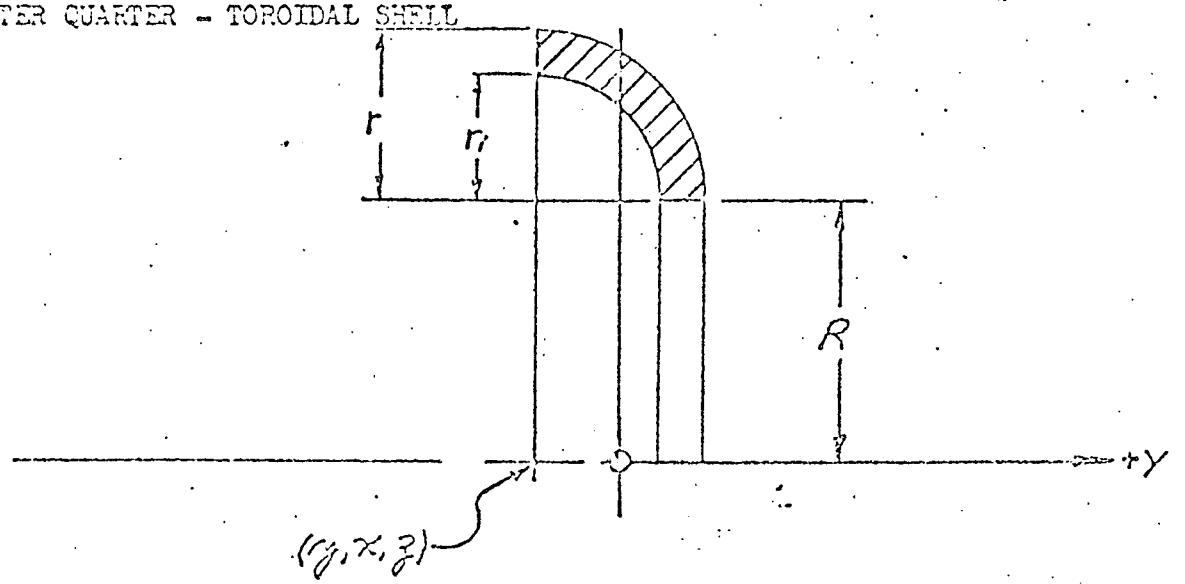
Results for this configuration are obtained by deducting the inner spherical segment of radius r (Formula 104) from the outer spherical segment of radius R (Formula 104).

Input data required:

N = 114	Formula number
M = 1	Number of cards
y, x, z	Location of center, large base
ρ	Density
a, b, c	Direction numbers of +Y axis, in sense shown
R	Outer spherical radius
r	Inner spherical radius
r_i	Distance, center of sphere to large base

FORMULA 115

OUTER QUARTER - TOROIDAL SHELL



Results for this configuration are obtained by deducting the solid quarter torus of radius r_i (Formula 106) from the solid quarter torus of radius r (Formula 106).

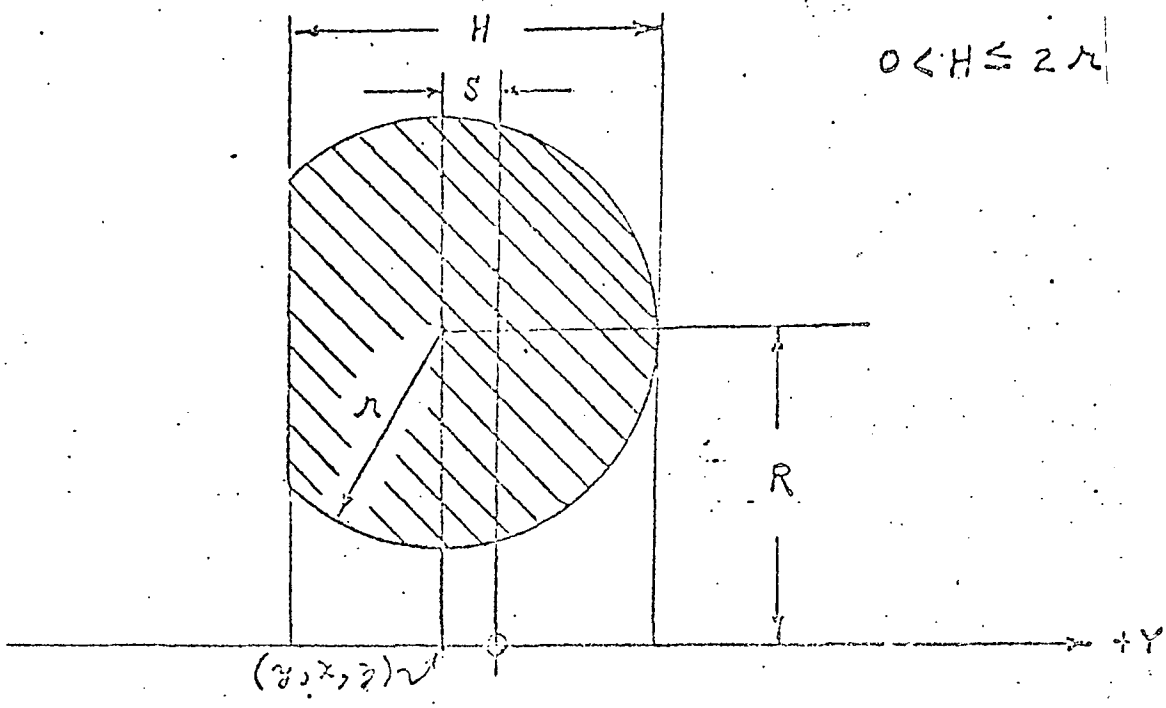
Input data required:

N = 115	Formula number
M = 1	Number of cards
y, x, z	Location of torus ℄ on Y axis
ρ	Density
a, b, c	Direction numbers of Y axis
R	Radius to torus ℄
r	Outer section radius
r_i	Inner section radius

E

FORMULA 116

Axial Segment of a Solid Torus



$0 < H \leq 2r$

Direction numbers of Y axis: a, b, c

Define:

$$D = (a^2 + b^2 + c^2)^{\frac{1}{2}}$$

$$h = H - r$$

$$\alpha = \text{Tan}^{-1}\left(\frac{\sqrt{r^2 - h^2}}{h}\right)$$

$$E_1 = .5\pi\rho Rr^2$$

$$E_3 = 2\,\text{Sin}^3\alpha$$

If $h \geq 0$: $E_2 = \pi - .5\,(2\alpha - \text{Sin}\,2\alpha)$

If $h < 0$:: $E_2 = .5\,(2\alpha - \text{Sin}\,2\alpha)$

Weight: $W = \frac{1}{4}E_1E_2$

$S = E_3r/(3E_2)$

Direction cosines of Y axis with reference axes:

$\lambda = a/D$, $\mu = b/D$, $\nu = c/D$

FORMULA 116 (Cont'd.)

Center of Gravity:

$$\bar{y} = y + \lambda S, \qquad \bar{x} = x + \mu S, \qquad \bar{z} = z + \delta S$$

Delta values in principal axis system:

$$\delta Y = E_1 \left[E_2 (4R^2 + 3r^2) + E_3 hr \right]$$

$$\delta X = \delta Z = .5 E_1 \left[E_2 (4R^2 + 5r^2) - E_3 hr \right] = WS^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \delta Y + (1 - \lambda^2) \delta X$$

$$\Delta X = \mu^2 \delta Y + (1 - \mu^2) \delta X$$

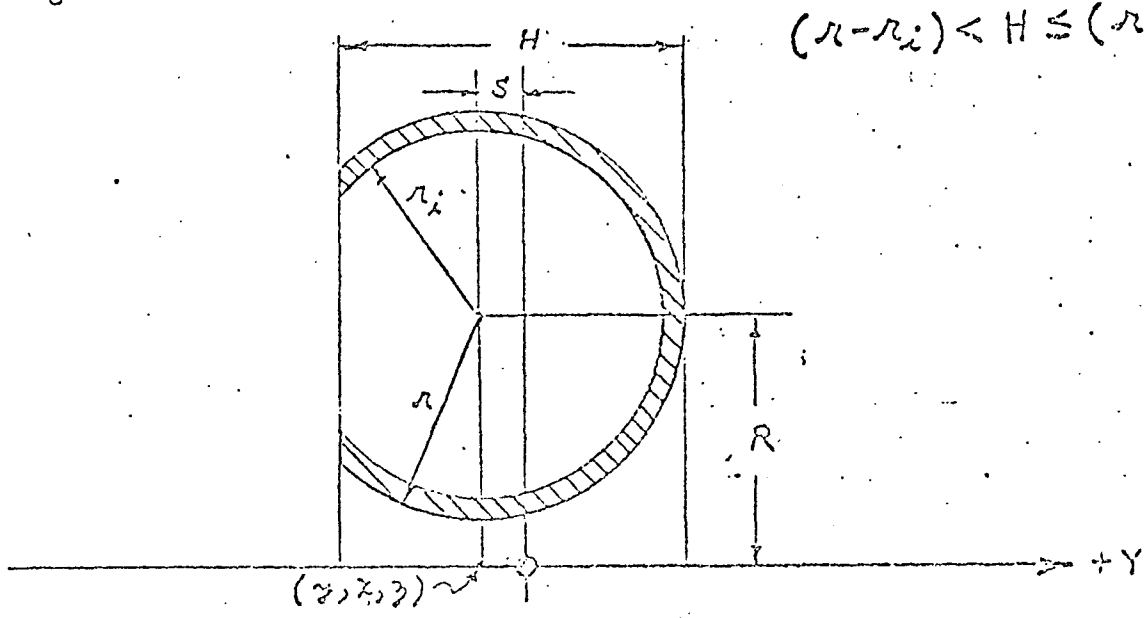
$$\Delta Z = \delta^2 \delta Y + (1 - \delta^2) \delta X$$

Input Data Required:

N = 116	Formula number
M = 1	Number of cards
y, x, z	Geometrical center of torus
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to torus section $\mathcal{L}$
r	Radius of section
H	Height of segment

FORMULA 117

Axial Segment of Hollow Torus



$$(r - r_i) < H \leq (r + r_i)$$

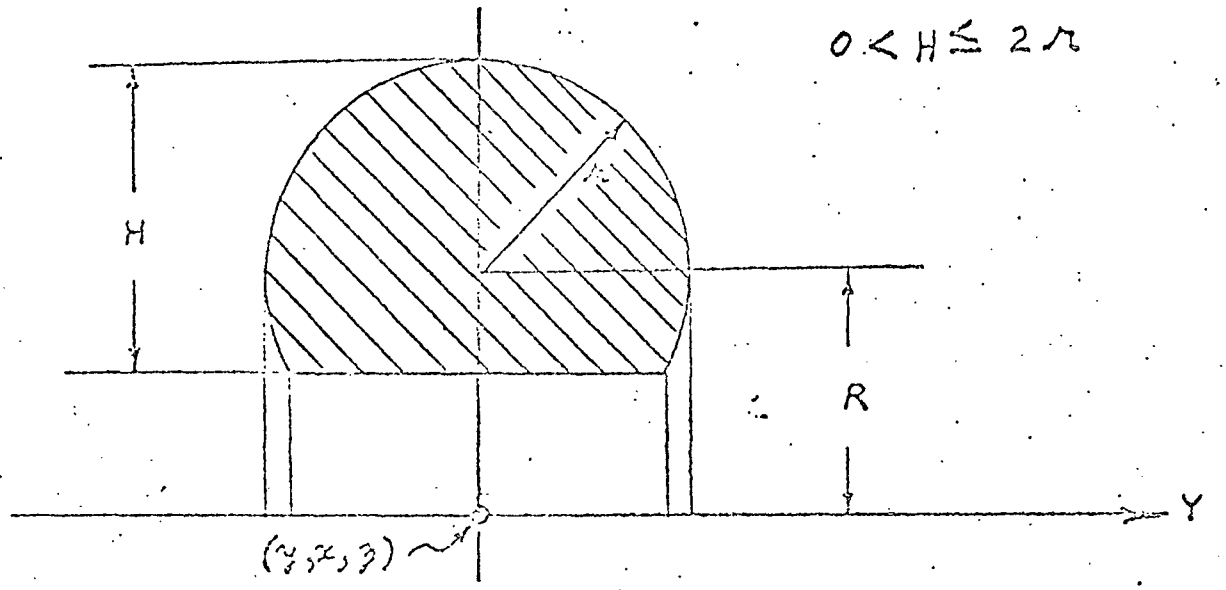
Results for this configuration are obtained by deducting the inner solid segment (Formula 116) from the total solid segment (Formula 116).

Input data required:

N = 117	Formula number
M = 1	Number of cards
y, x, z	Geometrical center of torus
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to torus section $\mathbb{C}$
r	Outer radius of section
r_i	Inner radius of section
H	Height of segment

FORMULA 118

Radial Segment of Solid Torus



Direction numbers of Y axis: a, b, c

Define:

$$D = (a^2 + b^2 + c^2)^{\frac{1}{2}}$$

$$h = H - r$$

$$T = 2(r^2 - h^2)^{\frac{1}{2}}$$

$$\alpha = \text{Tan}^{-1}\left[\frac{T}{2\,|h|}\right]$$

$$E_1 = .5\pi\rho\, Rr^2$$

$$E_3 = \frac{2r\,\sin^3\alpha}{15\,R}$$

If $h \geq 0$: $E_2 = \pi - .5\,(2\alpha - \text{Sin}\,2\alpha)$

If $h < 0$: $E_2 = .5\,(2\alpha - \text{Sin}\,2\alpha)$

Weight: $W = .8\,E_1\,(5E_2 + E_3)$

$S = 0$

FORMULA 118 (Cont'd.)

Direction cosines of Y axis with reference axes:

$$\lambda = a/D \,, \qquad \mu = b/D \,, \qquad \nu = c/D$$

Center of gravity:

$$\bar{y} = y \qquad \bar{x} = x \qquad \bar{z} = z$$

Delta values in principal axis system:

$$\delta Y = E_1 \left[E_2 (4R^2 + 3r^2) + E_3 (60R^2 - 45Rh + 12h^2 + 8r^2) \right]$$

$$\delta X = \delta z = .5\, \delta Y + E_1 \left[E_2 r^2 + E_3 (T^2 + 5Rh) \right]$$

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \delta Y + (1 - \lambda^2)\, \delta X$$

$$\Delta X = \mu^2 \delta Y + (1 - \mu^2)\, \delta X$$

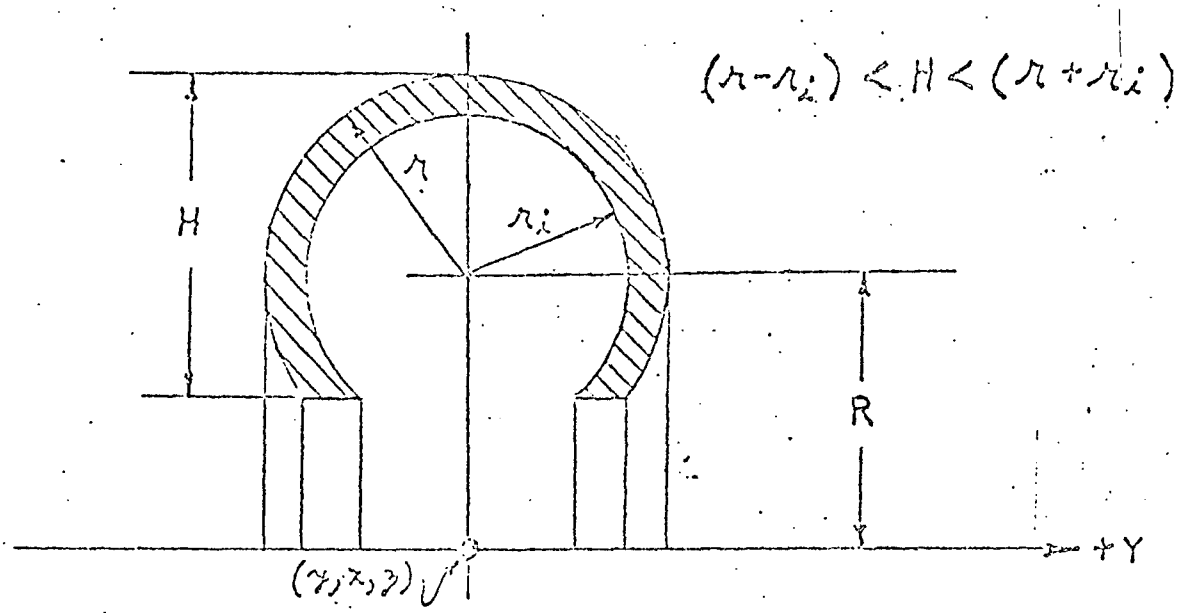
$$\Delta z = \delta^2 \delta Y + (1 - \delta^2)\, \delta X$$

Input Data required:

N = 118	Formula number
M = 1	Number of cards
y, x, z	Geometrical center of torus
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to torus section ξ
r	Radius of section
H	Height of segment

FORMULA 119

Radial Segment of Hollow Torus



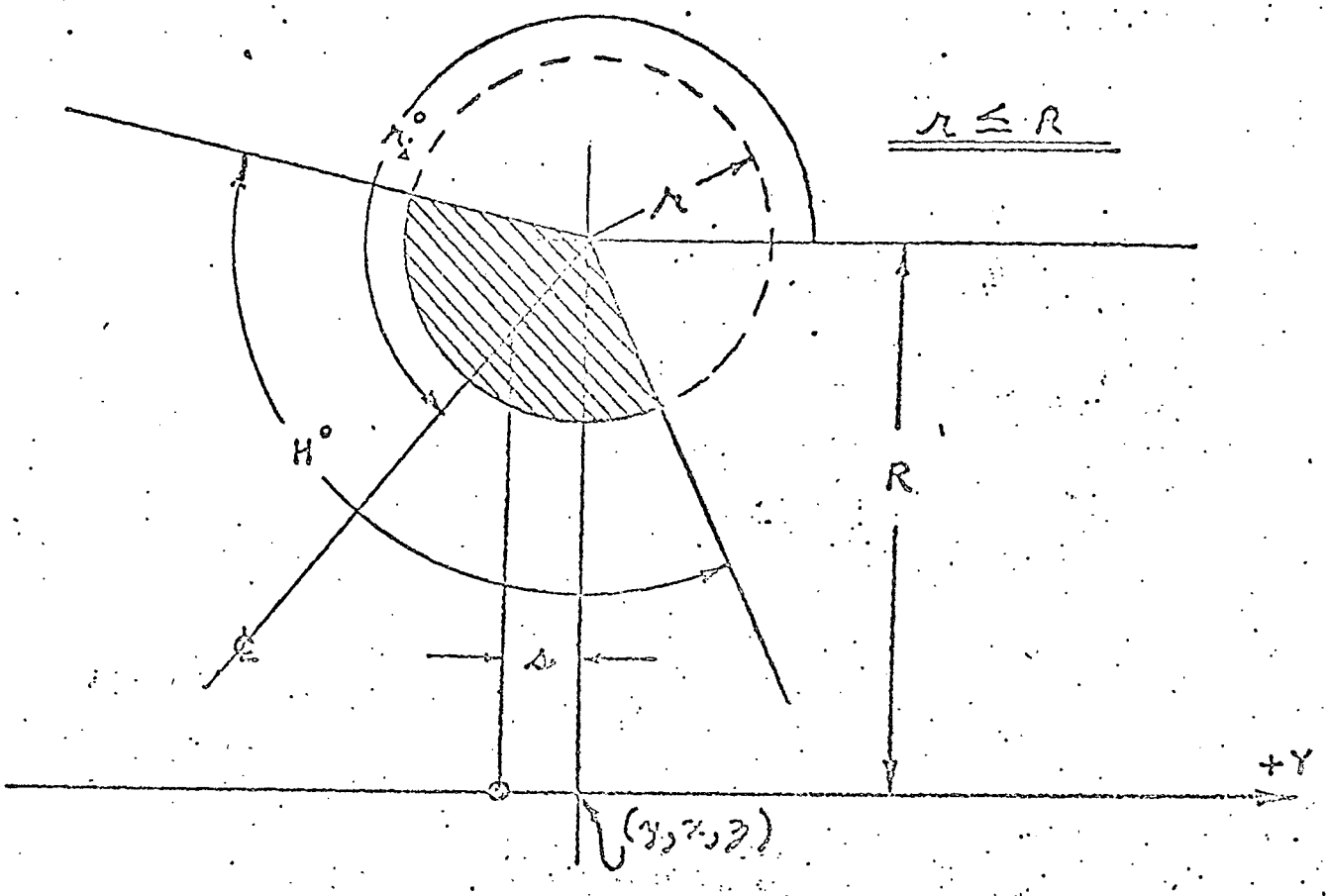
Results for this configuration are obtained by deducting the inner solid segment (Formula 118) from the total solid segment (Formula 118).

Input Data Required:

N = 119	Formula number
M = 1	Number of cards
y, x, z	Geometrical center of torus
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to torus $\mathbb{C}$
r	Outer radius of section
r_i	Inner radius of section
H	Height of segment

FORMULA 120

RADIAL SECTOR OF SOLID TORUS



Direction numbers of Y axis: a, b, c

Define: $D = \left[a^2 + b^2 + c^2\right]^{\frac{1}{2}}$

$\varphi = r_i \pi / 180$ median line angle, radians

$\alpha = H \pi / 360$ sector half-angle, radians

$K = 2\pi r^2 \varphi$

$\theta_1 = \varphi - \alpha$

$\theta_2 = \varphi + \alpha$

$E_1 = \text{Cos } \theta_2 - \text{Cos } \theta_1$

$E_2 = \text{Sin } \theta_2 - \text{Sin } \theta_1$

Formula 120 (Cont'd.)

$$E_3 = \tfrac{1}{2}(\sin^2 \theta_2 - \sin^2 \theta_1)$$

$$E_4 = \tfrac{1}{2}(\sin \theta_2 \cos \theta_2 - \sin \theta_1 \cos \theta_1)$$

$$E_5 = 1/3\ (\cos^3 \theta_2 - \cos^3 \theta_1)$$

Weight . . . $W = K\ (\alpha R - E_1\, r/3)$

$$s = \frac{Kr}{W}\left[\frac{E_2 R}{3} + \frac{E_3 r}{4}\right]$$

Define: $G_1 = 0.75\ (\alpha - E_4)$

$$G_2 = 0.2\ (E_5 - E_1)$$

$$G_3 = \alpha\, s^2 R$$

$$G_4 = -s/3\ \left[2E_2 R + E_1\, s\right]$$

$$G_5 = 0.25\left[R\ (\alpha + E_4) - 2E_3\, s\right]$$

$$G_6 = -0.2\, E_5$$

Direction cosines of Y axis with reference axes:

$$\lambda = a/D\ , \qquad \mu = b/D\ , \qquad \delta = c/D$$

Center of gravity:

$$\bar{y} = y + \lambda s\ ; \qquad \bar{x} = x + \mu s\ , \qquad \bar{z} = z + \delta s$$

Delta values in principal axis system:

$$\partial Y = K\left[\alpha R^3 - E_1 R^2 r + G_1 R r^2 + G_2 r^3\right]$$

$$\partial X = \partial Z = 0.5\,\partial Y + K\left[G_3 + G_4 r + G_5 r^2 + G_6 r^3\right]$$

FORMULA 120 (CONT'D).

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2)\, \partial X$$

$$\Delta X = \mu^2 \partial Y + (1 - \mu^2)\, \partial X$$

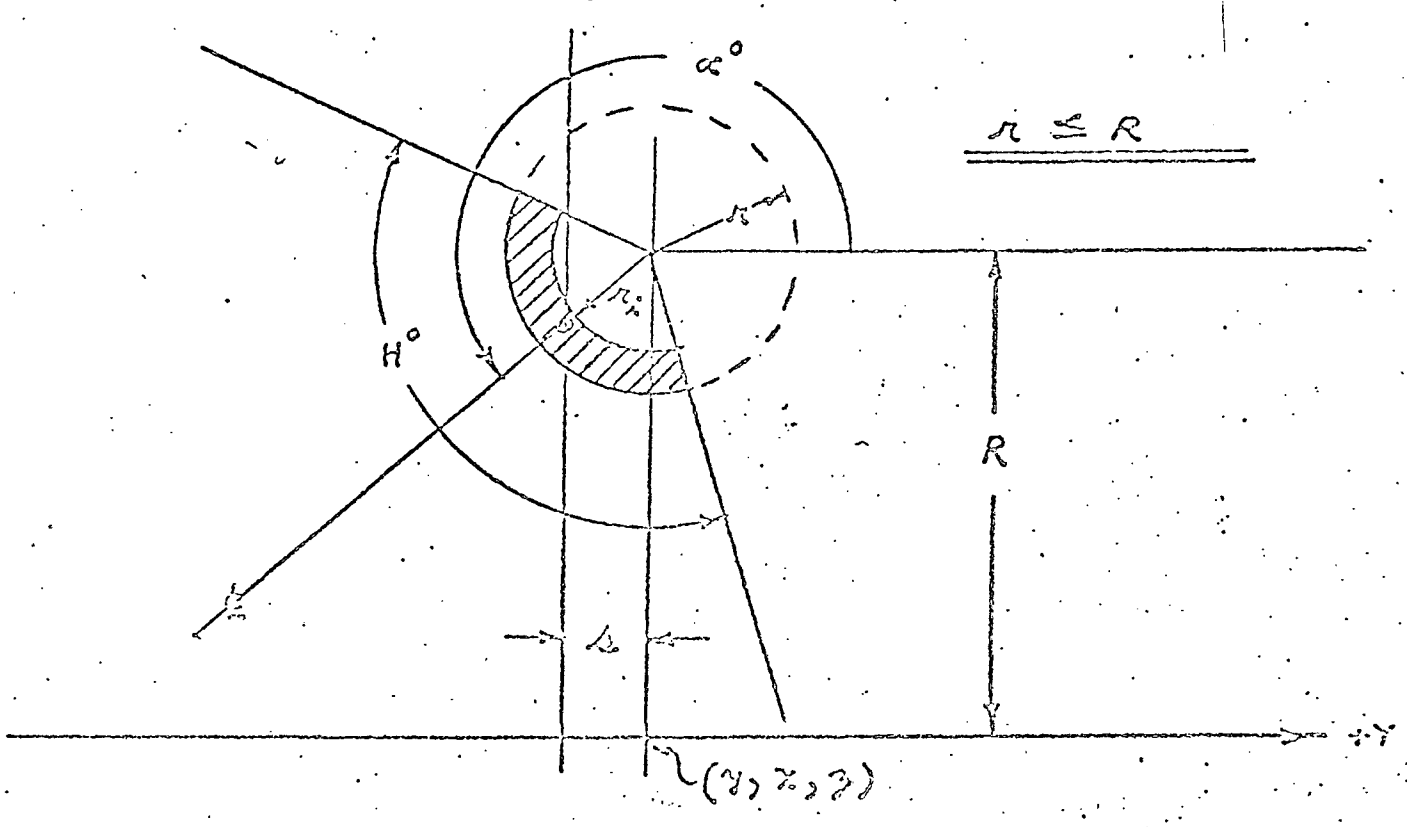
$$\Delta Z = \delta^2 \partial Y + (1 - \delta^2)\, \partial X$$

Input data required:

n = 120	Formula number
m = 1	Number of cards
y, x, z	Geometrical center of torus
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to torus section
r	Section radius
r_i	Sector median line angular position (degrees)
H	Angular width of sector, (degrees)

FORMULA 121

Radial Sector of a Hollow Torus



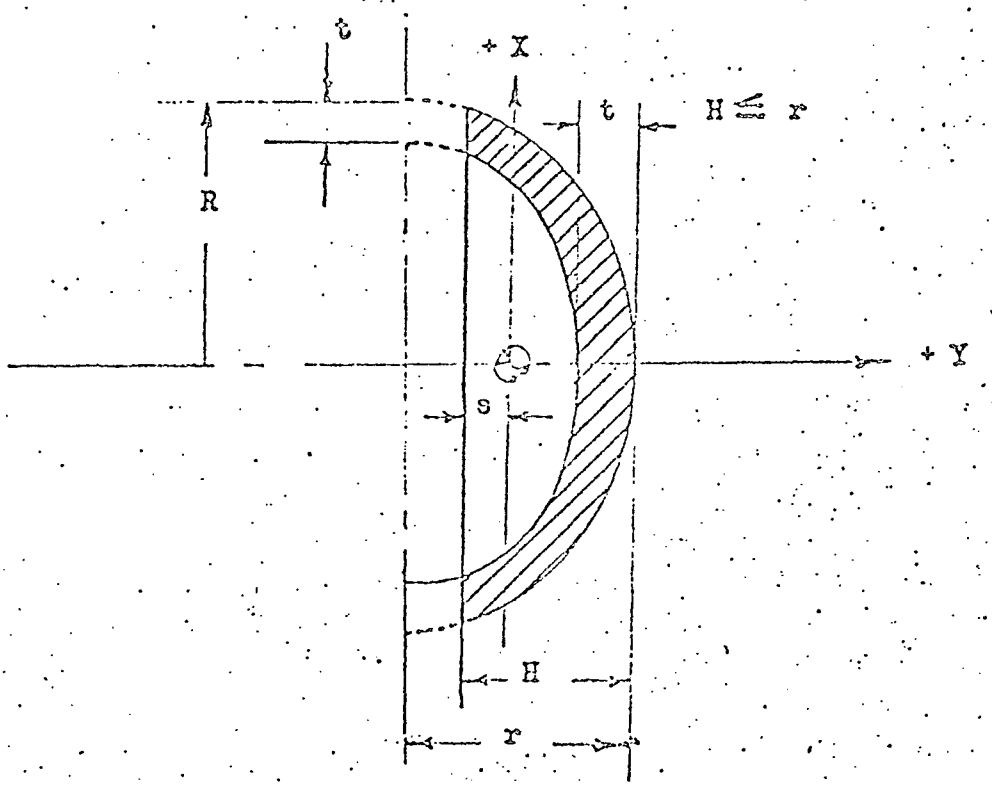
Results for this configuration are obtained by deducting the inner solid sector (Formula 120) with section radius r_1 from the total solid sector (Formula 120) with radius r.

Input data required:

n = 121	Formula number
m = 2	Number of cards
y, x, z	Geometrical center of torus
ρ	Density
a, b, c	Direction numbers, Y axis
R	Radius to torus section
r	Outer radius of section
r_1	Inner radius of section
H	Angular width of sector, degrees
α	Median line angle, measured from + Y direction, degrees

FORMULA 122

AXIAL SEGMENT of HOLLOW ELLIPTICAL SPHEROID*
(Generated by Concentric Ellipses with Semi-axes R, r and R-t, r-t)



Direction numbers of Y axis: a, b, c

Compute:

$G = R - t$ $\qquad$ $M = G/F$

$C = r - H$ $\qquad$ $N = R/r$

$F = r - t$ $\qquad$ $J = R^2 + G^2$

$L = H - t$ $\qquad$ $K = M^2 + N^2$

$D = (R + G)(R - G)$

$U = (N + M)(N - M)$

$E_1 = (F^2 + FC + C^2)/3$

* Note: This configuration does not have a constant shell thickness.

FORMULA 122 (cont'd)

$$E_2 = (r^2 + rF + F^2)/3$$

$$E_3 = 0.2(F^4 + F^3C + F^2C^2 + FC^3 + C^4)$$

$$E_4 = 0.2(F^4 + F^3r + F^2r^2 + Fr^3 + r^4)$$

$$Q = t\,(R^2E_2 - N^2E_4)$$

$$P_1 = L\,(DE_1 - UE_3)$$

$$P_2 = t\,(R^2 - N^2E_2)$$

$$P_3 = L\,(D - UE_1)$$

$$d = (a^2 + b^2 + c^2)^{\frac{1}{2}}$$

Weight: $W = \pi\rho\,(P_2 + P_3)$

$$s = \frac{\pi\rho}{4W}\left\{ L(F + C)\left[2D - U\,(F^2 + C^2)\right] + t\,(F + r)\left[2R^2 - N^2\,(F^2 + r^2)\right]\right\} - C$$

Direction cosines of Y axis with reference axes:

$$\lambda = a/d \qquad \mu = b/d \qquad \nu = c/d$$

Center of gravity:

$$\bar{y} = y + \lambda s \qquad \bar{x} = x + \mu s \qquad \bar{z} = z + \nu s$$

Delta values in principal axis system:

$$\partial Y = 0.5\,\pi\rho\left\{P_2R^2 + JP_3 - KP_1 - QN^2\right\}$$

$$\partial X = 0.5\,\partial Y + \pi\rho\,(P_1 + Q) - W(C + s)^2$$

$$\partial Z = \partial X$$

FORMULA 122 (cont'd)

Delta values in common reference axis system:

$$\Delta Y = \lambda^2 \partial Y + (1 - \lambda^2) \partial X$$

$$\Delta X = \mu^2 \, Y + (1 - \mu^2) \partial X$$

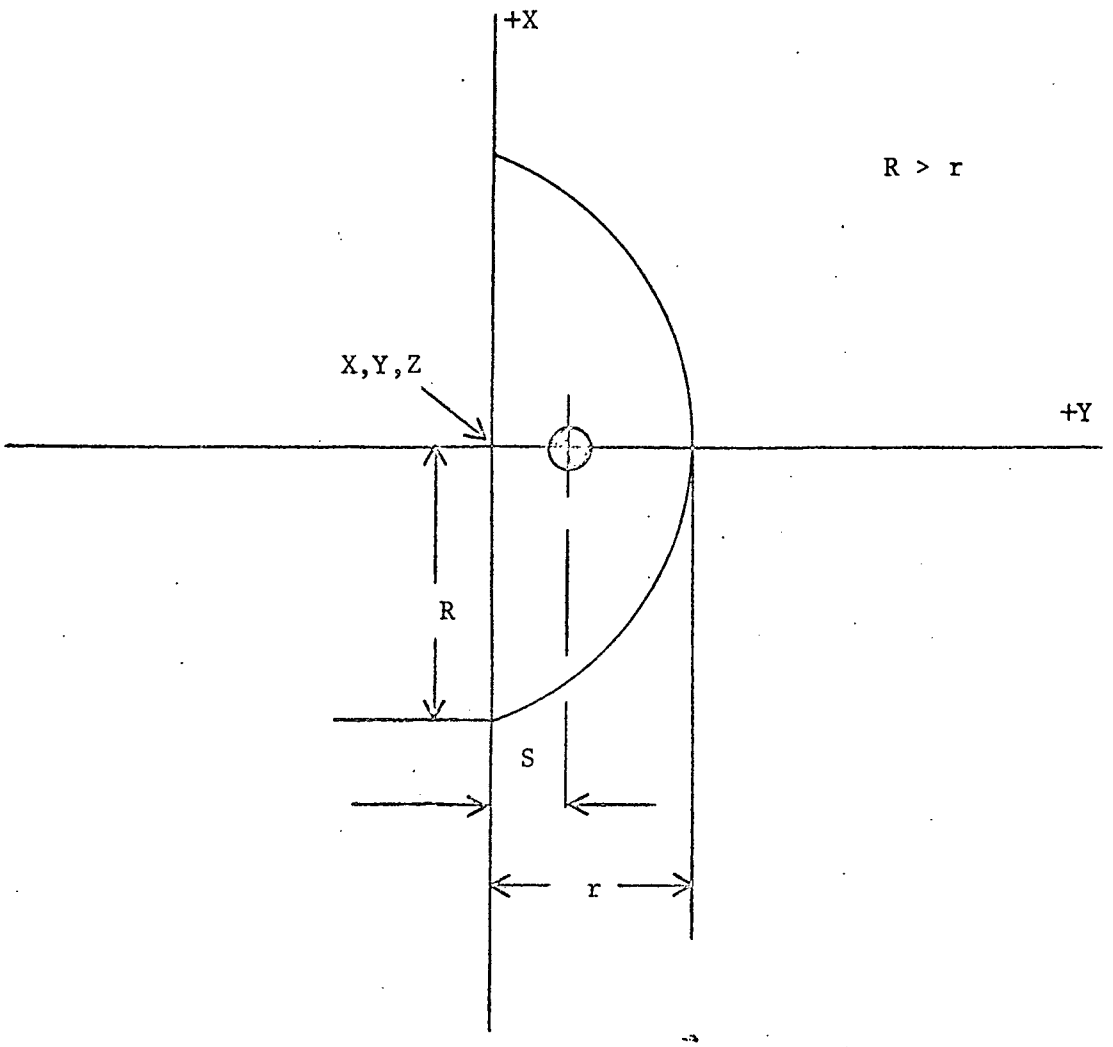
$$\Delta Z = \zeta^2 \partial Y + (1 - \zeta^2) \partial X$$

Input data required:

n	Formula Number = 122
m	Number of cards = 1
y, x, z	Geom. center - open end
ρ	Density
a, b, c	Direction No's. Y axis
R	Outer semi-major axis
r	Outer semi-minor axis
t *	Thickness
H	Axial height of segment

* Entered in location usually denoted r_i on data sheet

FORMULA 124 SOLID HALF ELLIPSE



DIRECTION NUMBERS OF Y AXIS: a, b, c

DEFINE: $D = (a^2 + b^2 + c^2)^{1/2}$

WEIGHT: $W = 2/3\ \pi\ \rho R^2 r$.

ELEMENT CENTER OF GRAVITY: $S = 0.375r$

DIRECTION COSINES OF Y AXIS WITH REFERENCE AXIS:

$$\lambda = a/D \quad , \quad \mu = b/D \quad , \quad S = c/D$$

CENTER OF GRAVITY:

$$\bar{y} = y + \lambda s \quad , \quad \bar{x} = x + \mu s \quad , \quad \bar{z} = z + Ss$$

FORMULA 124 (cont)

DELTA VALUES IN PRINCIPAL AXIS SYSTEM:

$$\delta y = 0.4WR^2 \quad , \quad \delta x = \delta z = W/320(64R^2+19r^2)$$

DELTA VALUES IN COMMON REFERENCE AXIS SYSTEM:

$$\Delta y = \lambda^2 \delta y + (1-\lambda^2)\delta x$$

$$\Delta x = \mu^2 \delta y + (1-\mu^2)\delta x$$

$$\Delta z = S^2 \delta y + (1-S^2)\delta x$$

INPUT DATA REQUIRED:

m = 1 number of cards

N = 124 Formula number

K = Subgroup

y, x, z } Center of base

R Major semi-axis

r Minor semi-axis

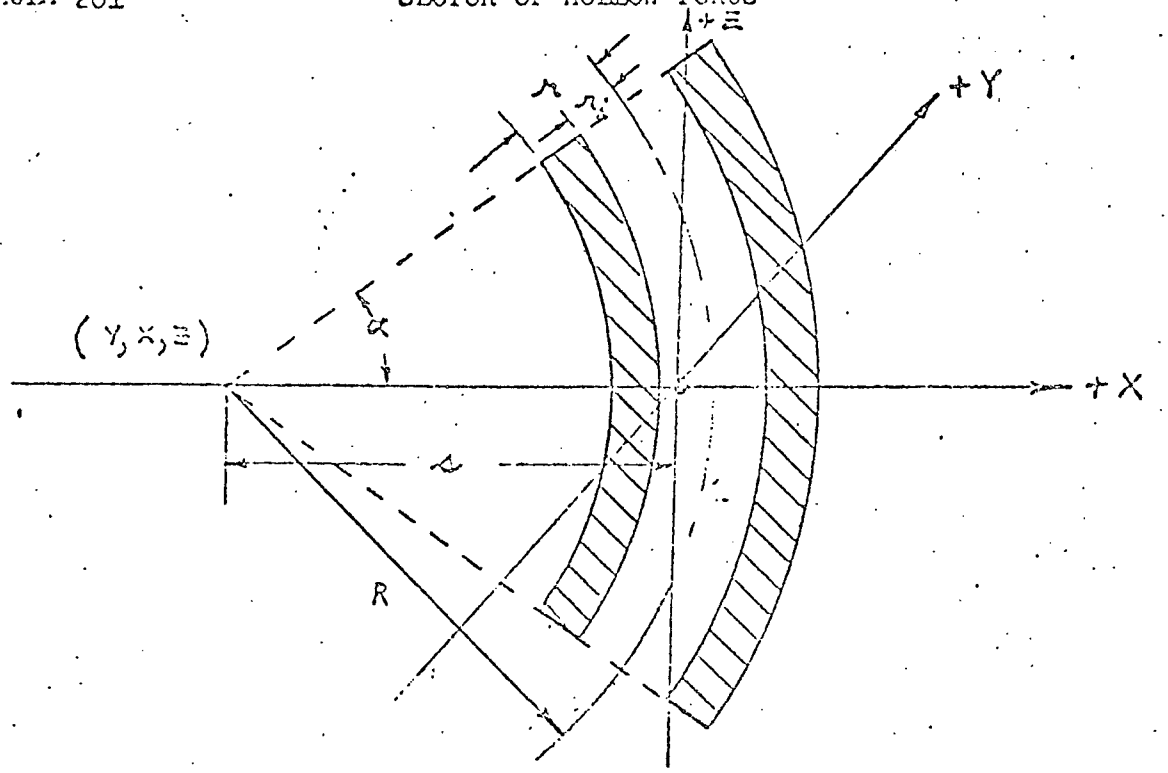
ρ Density

a, b, c } Direction numbers of Y axis (See figure)

TYPE III

FORMULA 201

SECTOR OF HOLLOW TORUS



Direction numbers of Y axis (parallel to axis of revolution): a, b, c

Direction numbers of X axis (thru center of revolution and C.G. of sector):

d, e, f

Direction numbers of Z axis:

$-g = ce - bf$, $-h = af - cd$, $-i = bd - ae$

Define:

$$D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$$

$$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$$

$$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$$

Convert α to radian measure: $\alpha = \pi\alpha/180$

FORMULATION (Cont'd.)

Define: $A = r^2 + r_i^2$

$$K = \frac{2 \sin^2 \alpha}{\alpha} \left[2R^2 + A + \frac{A^2}{8R^2} \right]$$

Weight: . . . . . $w = 2\pi\rho R \alpha (r^2 - r_i^2)$

$$s = \frac{\sin \alpha}{\alpha} \left[R + \frac{A}{4R} \right]$$

Direction cosines of Y axis with reference axes:

$$\lambda_1 = a/D_1, \qquad \mu_1 = b/D_1, \qquad \nu_1 = c/D_1$$

Direction cosines of X axis with reference axes:

$$\lambda_2 = d/D_2, \qquad \mu_2 = e/D_2, \qquad \nu_2 = f/D_2$$

Direction cosines of Z axis with reference axes:

$$\lambda_3 = g/D_3, \qquad \mu_3 = h/D_3, \qquad \nu_3 = i/D_3$$

Center of gravity:

$$\bar{y} = y + s\lambda_2, \qquad \bar{x} = x + s\mu_2, \qquad \bar{z} = z + s\nu_2$$

Delta values in principal axis system:

$$\delta Y = \frac{W}{4\alpha} \left[4R^2 \alpha + 3A\alpha - K \right]$$

$$\delta X = \frac{W}{16\alpha} \left[4R^2 (2\alpha - \sin 2\alpha) + A(10\alpha - 3 \sin 2\alpha) \right]$$

$$\delta Z = \frac{W}{16\alpha} \left[4R^2 (2\alpha + \sin 2\alpha) + A(10\alpha + 3 \sin 2\alpha) - 4K \right]$$

Delta values in common reference axis system:

$$\Delta Y = \lambda_1^2 \delta Y + \lambda_2^2 \delta X + \lambda_3^2 \delta Z$$

$$\Delta X = \mu_1^2 \delta Y + \mu_2^2 \delta X + \mu_3^2 \delta Z$$

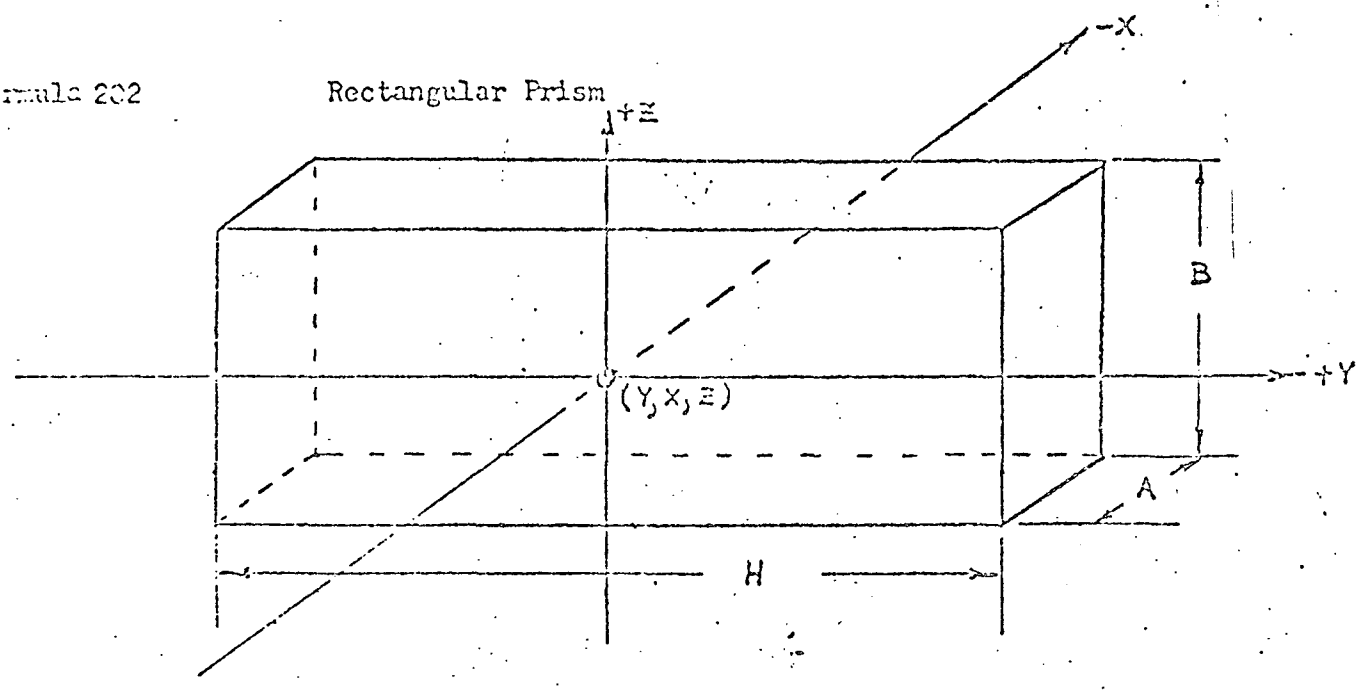
$$\Delta Z = \nu_1^2 \delta Y + \nu_2^2 \delta X + \nu_3^2 \delta Z$$

FORMULA 201 (Cont'd.)

Input data required:

n	= 201	
ρ		Density
x		Center of torus
a		
b		Direction numbers of Y axis
c		
d		
e		Direction numbers of X axis in the sense shown
f		
R		Radius to torus
r		Outer radius of torus section
r_i		Inner radius of torus section
α		Half-angle (degrees)
m	= 2	No. of cards

Formula 202 Rectangular Prism



Direction numbers of Y axis (parallel to longest dimension H):
a, b, c

Direction numbers of X axis (parallel to shortest dimension A):
d, e, f

Direction numbers of Z axis:

$-g = ce - bf$, $-h = af - cd$, $-i = bd - ae$

Define:

$D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$

$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$

$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$

Weight $W = \rho ABH$

Direction cosines of Y axis with reference axes:

$\lambda_1 = a/D_1$, $\mu_1 = b/D_1$, $\nu_1 = c/D_1$

Direction cosines of X axis with reference axes:

$\lambda_2 = d/D_2$, $\mu_2 = e/D_2$, $\nu_2 = f/D_2$

Direction cosines of Z axis with reference axes:

$\lambda_3 = g/D_3$, $\mu_3 = h/D_3$, $\nu_3 = i/D_3$

Center of gravity:

$\bar{y} = y$, $\bar{x} = x$, $\bar{z} = z$

Formula 202 (cont'd.)

Delta values in principal axis system

$$\partial Y = w/12 \left(A^2 + B^2\right)$$

$$\partial X = w/12 \left(B^2 + H^2\right)$$

$$\partial \Xi = w/12 \left(A^2 + H^2\right)$$

Delta values in common reference system:

$$\Delta Y = \lambda_1^2 \partial Y + \lambda_2^2 \partial X + \lambda_3^2 \partial \Xi$$

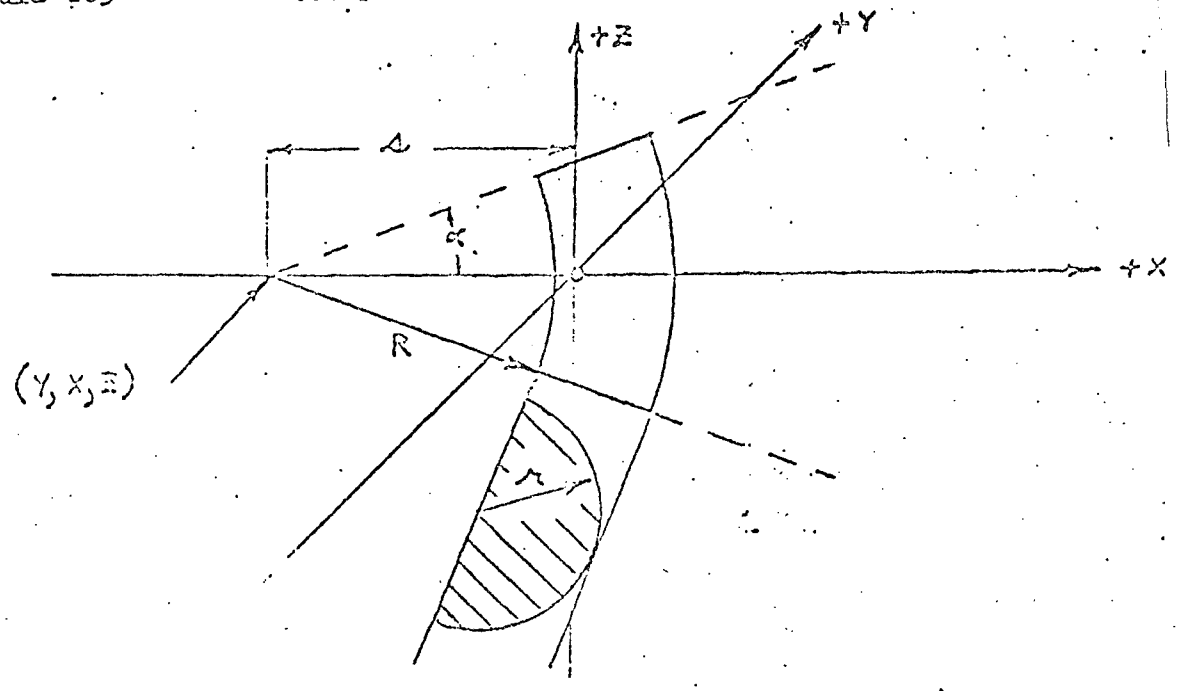
$$\Delta X = \mu_1^2 \partial Y + \mu_2^2 \partial X + \mu_3^2 \partial Z$$

$$\Delta \Xi = \nu_1^2 \partial Y + \nu_2^2 \partial X + \nu_3^2 \partial \Xi$$

Input data required:

n = 202	
ρ	density
y, x, z	location of centroid
a, b, c	direction numbers of Y axis
d, e, f	direction numbers of X axis
A, B, H	dimensions of prism
m = 2	No. of cards

Formula 203 Sector of Outer Half-Torus



Direction numbers of Y axis (parallel to axis of revolution):

a, b, c

Direction numbers of X axis (thru center of revolution and C. G. of sector):

d, e, f

Direction numbers of Z axis:

$-g = ce - bf$, $-h = af - cd$, $-i = bd - ae$

Define $D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$

$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$

$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$

Convert α to radian measure: $\alpha = \pi\alpha/180$

Define: $A = 1 / (\pi R + 4r/3)$

$K_1 = (\alpha - \sin\alpha \cos\alpha) / 4\alpha$

$K_2 = (\alpha + \sin\alpha \cos\alpha) / 2\alpha$

Weight: $w = \rho\alpha r^2/A$

$s = \frac{4A \sin\alpha}{3\alpha} \left[.757\pi R^2 + .1875\pi r^2 + 2Rr\right]$

Formula 203 (cont'd.)

Direction cosines of Y axis with reference axes:

$$\lambda_1 = a/D_1 \quad , \mu_1 = b/D_1 \quad , \nu_1 = c/D_1$$

Direction cosines of X axis with reference axes:

$$\lambda_2 = d/D_2 \quad , \mu_2 = e/D_2 \quad , \nu_2 = f/D_2$$

Direction cosines of Z axis with reference axes:

$$\lambda_3 = g/D_3 \quad , \mu_3 = h/D_3 \quad , \nu_3 = i/D_3$$

Center of gravity:

$$\bar{y} = y + \lambda_2 s \quad , \bar{x} = x + \mu_2 s \quad , \bar{z} = z + \nu_2 s$$

Delta values in principal axis system:

$$\delta Y = A\omega \left[\pi R^3 + .75\,\pi Rr^2 + 4 R^2 r + 8\, r^3/15 \right] - ws^2$$

$$\delta X = A\omega \left[2\pi K_1 R^3 + \pi (.25 + 1.5K_1) Rr^2 + 2 K_1 R^2 r + (4 + K_1)\, r^3/15 \right]$$

$$\delta Z = A\omega \left[\pi K_2 R^3 + \pi (.25 + .75 K_2) Rr^2 + 4K_2 R^2 r + (4 + 8K_2)\, r^3/15 \right] - ws^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda_1^2 \delta Y + \lambda_2^2 \delta X + \lambda_3^2 \delta Z$$

$$\Delta X = \mu_1^2 \delta Y + \mu_2^2 \delta X + \mu_3^2 \delta Z$$

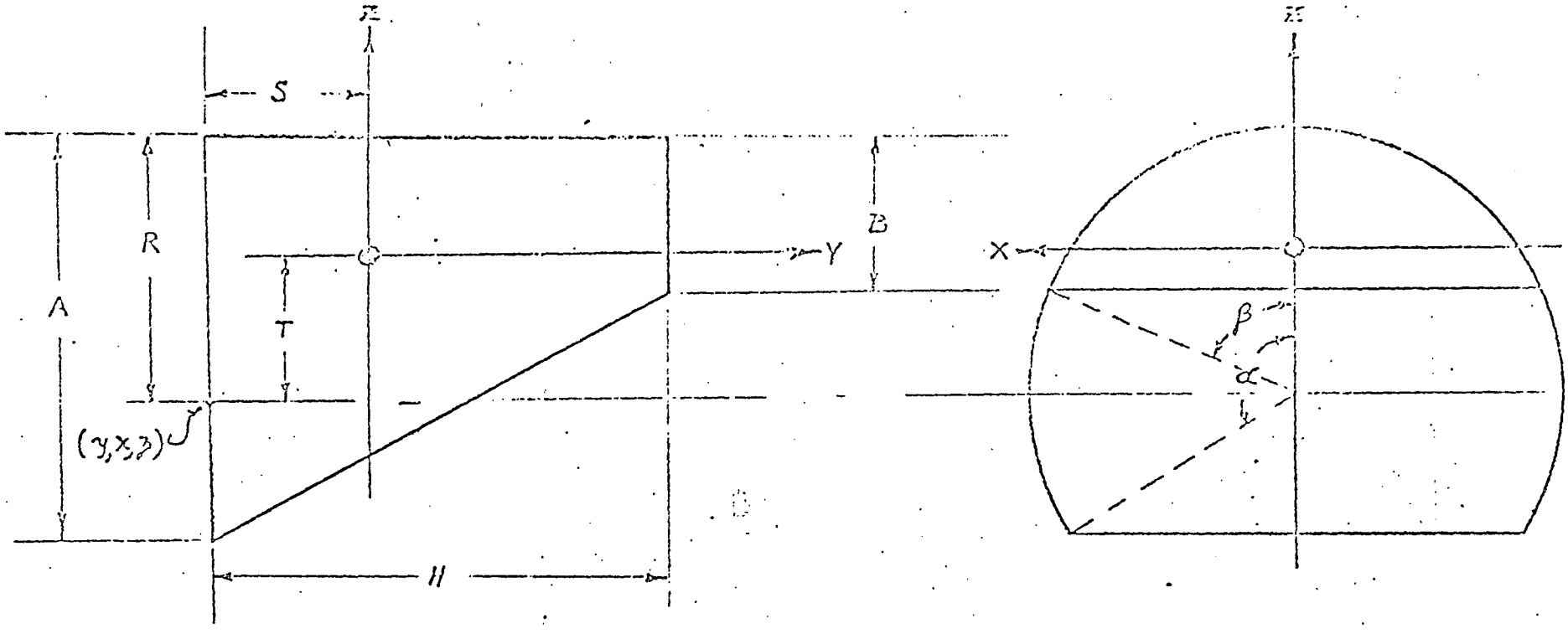
$$\Delta Z = \nu_1^2 \delta Y + \nu_2^2 \delta X + \nu_3^2 \delta Z$$

Input data required:

n = 203

ρ	density
y, x, z	center of torus
a, b, c	direction numbers of Y axis
d, e, f	direction numbers of X axis
R	Radius to torus ℄
r	radius of section
α	half-angle (degrees)

m = 2 No. of Cards



FORMULA 204

TRUNCATED UNGULA OF A CYLINDER

FORMULA 204 - Truncated Ungula of Cylinder (Cont'd.)

Direction numbers of Y axis (Parallel to axis of cylinder):

$a,\ b,\ c$

Direction numbers of X axis (Normal to Y axis, parallel to plane of diagonal cut, with sense chosen so that the positive Z axis in the right Handed system X, Y, Z will intersect the cylindrical surface):

$d,\ e,\ f$

Direction numbers of Z axis:

$g = bf - ce, \qquad h = cd - af, \qquad i = ae - bd$

Define: $D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$

$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$

$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$

Direction cosines of Y axis with reference axes:

$\lambda_1 = a/D_1 \qquad \mu_1 = b/D_1 \qquad \nu_1 = c/D_1$

Direction cosines of X axis with reference axes:

$\lambda_2 = d/D_2 \qquad \mu_2 = e/D_2 \qquad \nu_2 = f/D_2$

Direction cosines of Z axis with reference axes:

$\lambda_3 = g/D_3 \qquad \mu_3 = h/D_3 \qquad \nu_3 = i/D_3$

Define: $F = R - A$

$P = (R^2 - F^2)^{\frac{1}{2}}$

$\alpha = \mathrm{Tan}^{-1}(P/F)$

FORMULA 204 - Truncated Ungula of Cylinder (Cont'd.)

I. GENERAL CASE $A \neq B$

$$E = H/(A - B)$$

$$Q = (B\,(2R - B))^{\frac{1}{2}}$$

$$G = R - B$$

$$\beta = \mathrm{Tan}^{-1}\,(Q/G)$$

$$C = \rho ER^3$$

$$U = 2/15\,(CR^2)\,(\mathrm{Sin}^5\alpha - \mathrm{Sin}^5\beta)$$

Weight $$W = C\left\{\mathrm{Sin}\,\alpha - \mathrm{Sin}\,\beta - \alpha\,\mathrm{Cos}\,\alpha + \beta\,\mathrm{Cos}\,\beta - 1/3\,(\mathrm{Sin}^3\alpha - \mathrm{Sin}^3\beta)\right\}$$

Y axis component of CG:

$$S = \frac{CER}{2W}\left\{\mathrm{Sin}2\alpha - \mathrm{Sin}2\beta - 2\alpha\,\mathrm{Cos}2\alpha + 2\beta\,\mathrm{Cos}2\beta - \alpha + \beta + .25\,(\mathrm{Sin}4\alpha - \mathrm{Sin}4\beta)\right\} - EF$$

X axis component of C.G.: $V = 0$

Z axis component of C.G.:

$$T = \frac{2CR}{3W}\left\{.375\,(\alpha - \beta) - .25\,(\mathrm{Sin}2\alpha - \mathrm{Sin}2\beta) + 1/32\,(\mathrm{Sin}4\alpha - \mathrm{Sin}\,4\beta)\right\}$$

Center of Gravity:

$$\bar{y} = y + \lambda_1 S + \lambda_2 V + \lambda_3 T$$

$$\bar{x} = x + \mu_1 S + \mu_2 V + \mu_3 T$$

$$\bar{z} = z + \nu_1 S + \nu_2 V + \nu_3 T$$

Define:

$$C_1 = .25R^2\,(1 + E^2) + E^2F^2$$

$$C_2 = .2R^2\,(1/6 - E^2)$$

$$C_3 = .25\,E^2RF$$

$$C_4 = 1/3\,(2C_2 - 5R^2/12 - E^2F^2)$$

$$C_5 = E^2R^2/36$$

FORMULA 204 - Truncated Ungula of Cylinder (Cont'd.)

Products of Inertia about original y, x, z axes:

$$P_Y = 0$$

$$P_X = E\ (U - TFW) - WST$$

$$P_Z = 0$$

Delta values in original (symmetrical) axis system:

$$\begin{aligned}\partial Z = C\Big[& C_1 (\sin\alpha - \sin\beta - \alpha\cos\alpha + \beta\cos\beta) \\ & + C_2 (\sin^3\alpha\ \cos^2\alpha - \sin^3\beta\ \cos\beta) \\ & + C_3 (\alpha - \beta - .25 (\sin^4\alpha - \sin^4\beta) - \sin 2\alpha + \sin 2\beta \\ & \qquad + 2\alpha\cos 2\alpha - 2\beta\cos 2\beta) \\ & + C_4 (\sin^3\alpha - \sin^3\beta) \\ & + C_5 (\sin^3 3\alpha - \sin^3 3\beta - 3\alpha\cos 3\alpha + 3\beta\cos 3\beta)\Big] - WS^2\end{aligned}$$

$$\partial X = \partial Z - WT^2 + U$$

$$\partial Y = 0.5\ (WR^2 + U) - WT^2$$

Delta values rotated* to common reference axis system:

$$\Delta Y = \lambda_1^2 \partial Y + \lambda_2^2 \partial X + \lambda_3^2 \partial Z - 2\ (P_y \lambda_2 \lambda_3 + P_x \lambda_1 \lambda_3 + P_Z \lambda_1 \lambda_2)$$

$$\Delta X = \mu_1^2 \partial Y + \mu_2^2 \partial X + \mu_3^2 \partial Z - 2\ (P_y \mu_2 \mu_3 + P_x \mu_1 \mu_3 + P_Z \mu_1 \mu_2)$$

$$\Delta Z = \delta_1^2 \partial Y + \delta_2^2 \partial X + \delta_3^2 \partial Z - 2\ (P_y \delta_2 \delta_3 + P_x \delta_1 \delta_3 + P_Z \delta_1 \delta_2)$$

* Original axes are not principal axes; hence, products of inertia are required in rotation to new axis configuration.

FORMULA 204 - Truncated Ungula of Cylinder (Cont'd.)

II. SPECIAL CASE A = B

$$C = 2\alpha - \sin 2\alpha$$

$$S = 0.5H$$

$$V = 0$$

$$T = \frac{4R \sin^3 \alpha}{3C}$$

$$E = 0.5\rho CR^2$$

$$G = .25R^2 (1 - T \cos \alpha / R)$$

$$U = .25R^2 (1 + 3T \cos \alpha / R) - T^2$$

Weight $W = EH$

Delta values in original axis system:

$$\partial Y = W (G + U)$$

$$\partial X = W/12 (12U + H^2)$$

$$\partial Z = W/12 (12G + H^2)$$

Delta values rotated to common reference axis system:

$$\Delta Y = \lambda_1^2 \partial Y + \lambda_2^2 \partial X + \lambda_3^2 \partial Z$$

$$\Delta X = \mu_1^2 \partial Y + \mu_2^2 \partial X + \mu_3^2 \partial Z$$

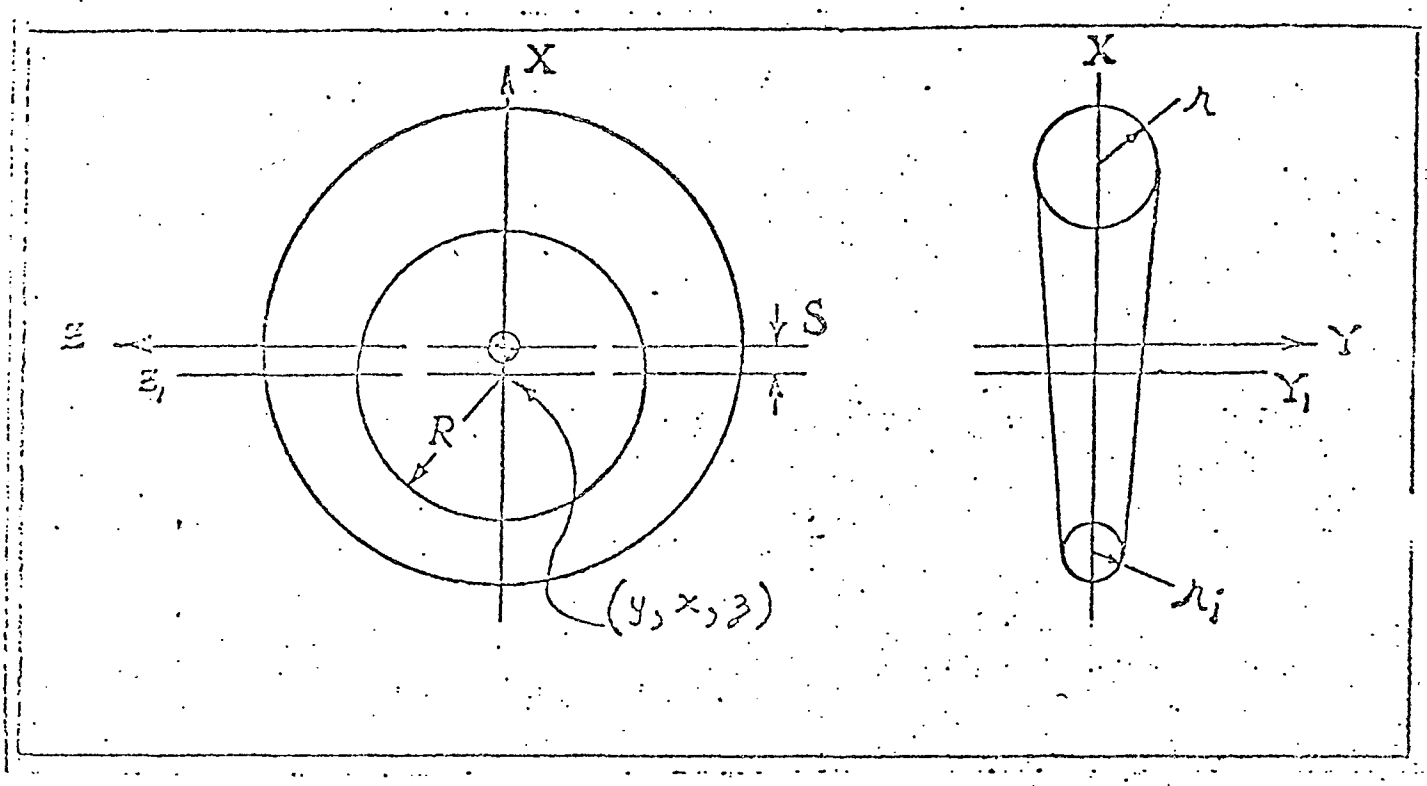
$$\Delta Z = \nu_1^2 \partial Y + \nu_2^2 \partial X + \nu_3^2 \partial Z$$

FORMULA 204 - Truncated Ungula of Cylinder (Cont'd.)

Input data required:

n	= 204
m	= 2
y, x, z	coordinates of reference point
ρ	density
a, b, c	Direction numbers of Y axis in sense shown.
R	Radius of cylinder
H	Axial length
A	Vertical height of base at reference point y
B	Vertical height of opposite base
d, e, f	Direction numbers of X axis in sense shown.

Formula 205 - Solid Tapered Torus



Direction numbers of Y axis (parallel to axis of revolution): a, b, c

Direction numbers of X axis (thru center, and point of maximum outer radius):

d, e, f

Direction numbers of Z axis:

$g = bf - ce, \quad h = ce - af, \quad i = ae - bd$

Define: $D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$

$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$

$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$

Formula 205, Cont'd

Direction cosines of Y axis with reference axes:

$$\lambda_1 = a/D_1, \quad \mu_1 = b/D_1, \quad \nu_1 = c/D_1$$

Direction cosines of X axis with reference axes:

$$\lambda_2 = d/D_2, \quad \mu_2 = e/D_2, \quad \nu_2 = f/D_2$$

Direction cosines of Z axis with reference axes:

$$\lambda_3 = g/D_3, \quad \mu_3 = h/D_3, \quad \nu_3 = i/D_3$$

Define:

$$G = r - r_i$$

$$Q = R + r_i$$

$$F_1 = 3 - 12/\pi^2$$

$$F_2 = 5 - 30/\pi^2$$

$$P_1 = r + r_i$$

$$P_2 = r P_1 + r_i^2$$

$$P_3 = r P_2 + r_i^3$$

$$P_4 = r P_3 + r_i^4$$

$$P_5 = r P_4 + r_i^5$$

Volume:

$$V = \pi^2 \left[2 Q r_i^2 + G r_i (2 Q + r_i) + \frac{2 G^2 (Q + 2 r_i)}{3} + .5 G^3 \right]$$

Formula 205, Cont'd

Weight: $W = \rho V$

Center of gravity:

$$S = \frac{2G}{V}\left\{4Q^2 r_i + 4Q r_i^2 + r_i^3 + G(2Q^2 + 8Q r_i + 3r_i^2) + G^2 F_1 (2Q + 3r_i) + G^3 F_2\right\}$$

$$\bar{y} = y + \lambda_2 S, \quad \bar{x} \quad x + \mu_2 S, \quad \bar{z} = z + \delta_2 S$$

Preliminary computations for moments of inertia

$F = G/7c$

$C_1 = 1.5\, Q\, r_i^2 (4Q^2 + 5r_i^2)$

$C_2 = .75\, r_i\, G\, (8Q^3 + 12Q^2 r_i + 20Q r_i^2 + 5r_i^3)$

$C_3 = G^2 (2Q^3 + 12Q^2 r_i + 21Q r_i^2 + 10 r_i^3)$

$C_4 = .75\, G^3 (5Q^2 + 22Q r_i + 17 r_i^2)$

$C_5 = .3\, G^4 (17Q + 28 r_i)$

$C_6 = 2.25\, G^5$

$C_7 = .75\, F^2 (4Q^3 + 24Q^2 r_i + 30Q r_i^2 + 12 r_i^3 - 45Q F^2 - 60 F^2 r_i)$

$C_8 = 1.125\, G\, F^2 (12Q^2 + 36Q r_i + 22 r_i^2 - 35 F^2)$

$C_9 = 7.5\, G^2 F^2 (3Q + 4 r_i)$

Formula 205, Cont'd

$$C_{10} = 13.125\, G^3 F^2$$

$$U_1 = C_1 + C_2 + C_3 + C_4 + C_5 + C_6$$

$$U_2 = C_7 + C_8 + C_9 + C_{10}$$

Delta values in principal axis system:

$$\partial Y = \frac{\pi^2 \rho}{12} \left\{ 8 R^3 P_2 + 18 R^2 P_3 + 18 R P_4 + 7 P_5 \right\} - W S^2$$

$$\partial X = \frac{\pi^2 \rho}{6} (U_1 - U_2)$$

$$\partial Z = \frac{\pi^2 \rho}{6} (U_1 + U_2) - W S^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda_1^2 \partial Y + \lambda_2^2 \partial X + \lambda_3^2 \partial Z$$

$$\Delta X = \mu_1^2 \partial Y + \mu_2^2 \partial X + \mu_3^2 \partial Z$$

$$\Delta Z = \delta_1^2 \partial Y + \delta_2^2 \partial X + \delta_3^2 \partial Z$$

Formula 205, Cont'd

Input data required:

$n = 205$

$m = 2$

y, x, z } Coordinates of geometrical center

ρ Density

a, b, c } Direction numbers, Y axis

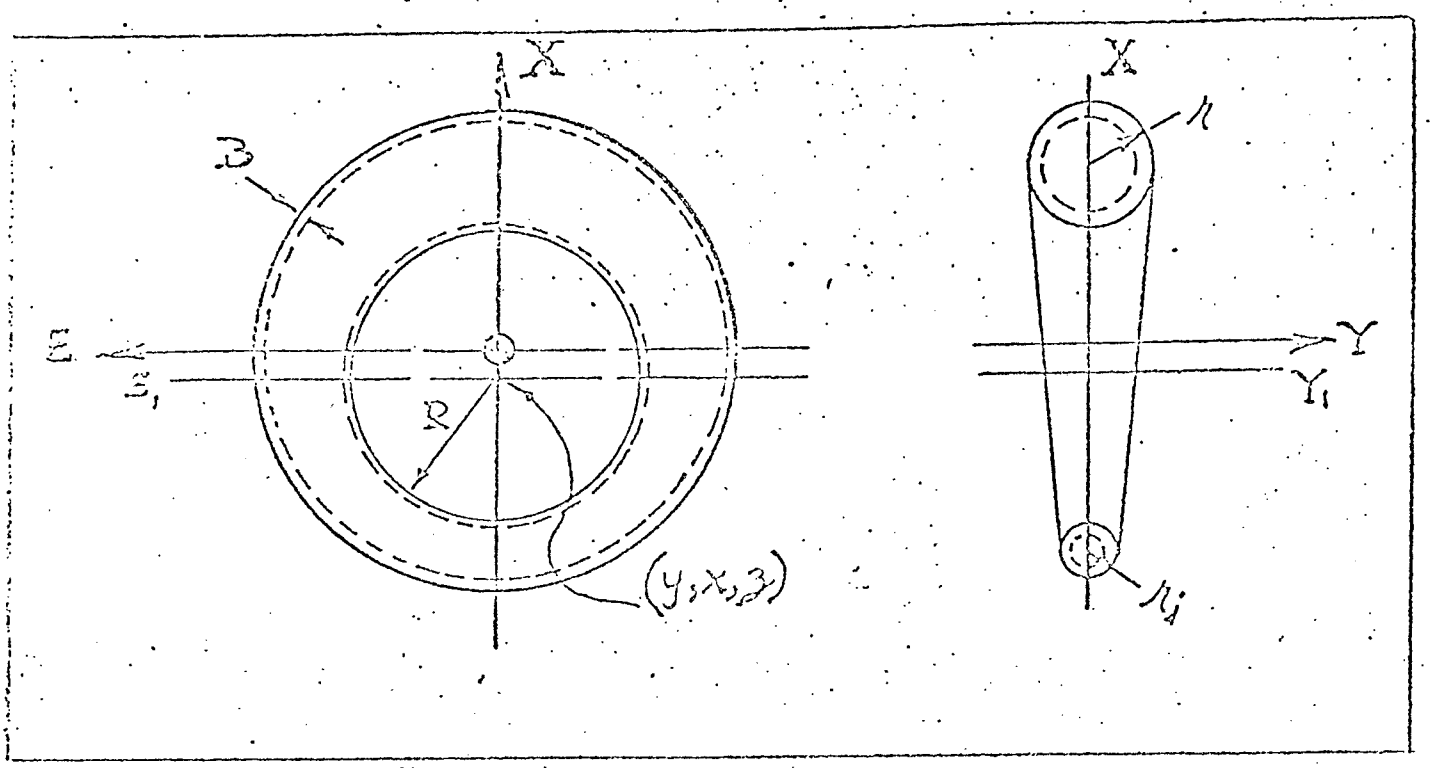
R Radius - geometrical to inner surface

r Largest section radius

r_i Smallest section radius

d, e, f } Direction numbers X axis

Formula 206 - Hollow Tapered Torus



Results for this configuration are obtained by deducting the inner solid torus of dimensions R + B, r - B, r_i - B, (Formula 205) from the solid outer torus of dimension R, r, r_i (Formula 205).

Input data required:

n = 206

m = 2

y, x, z — Location of geometrical center inner surface

ρ — Density

a, b, c — Direction numbers, Y axis

R — Radius, center to inner surface

r — Largest section outer radius

r_i — Smallest section outer radius

B — Wall thickness

d, e, f — Direction numbers, X axis

Formula 207, Cont'd

Convert α to radian measure: $\alpha = \pi\alpha/180$

Define:

$C_1 = B - A$ $\qquad$ $Q = C_1/C_3$ $\qquad$ $C_6 = C_5 + R\,r$

$C_2 = R + r$ $\qquad$ $C_4 = B + Q\,r$

$C_3 = R - r$ $\qquad$ $C_5 = R^2 + r^2$

Volume and Weight:

$$V = \frac{C_3\,\alpha}{3}\,(3C_2\,C_4 - 2Q\,C_6)$$

$$W = \rho V$$

Centroid:

$$S = \frac{C_3\,\mathrm{SIN}\,\alpha}{6V}\,(4\,C_4\,C_6 - 3Q\,C_2\,C_5)$$

Center of gravity in reference axis system:

$$\bar{Y} = y + \lambda_2 S\,,\quad \bar{X} = x + \mu_2 S\,,\quad \bar{Z} = z + \nu_2 S$$

Preliminary computations for delta values:

Define:

$T_1 = .5B$ $\qquad$ $P_2 = T_1^2 - T_2^2$

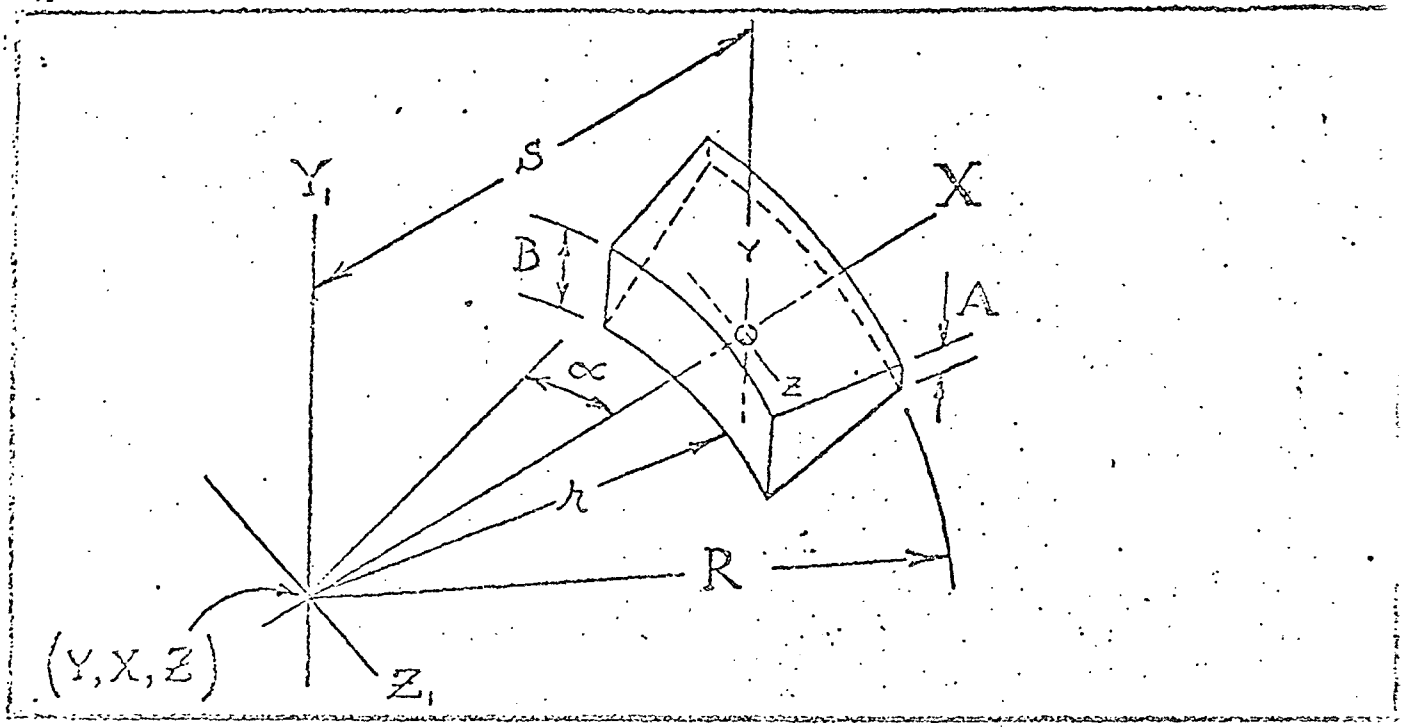
$T_2 = .5A$ $\qquad$ $P_3 = T_1^3 - T_2^3$

$P_1 = T_1 - T_2$ $\qquad$ $P_4 = T_1^4 - T_2^4$

$E = C_3/P_1$ $\qquad$ $P_5 = T_1^5 - T_2^5$

$U = r + ET_1$ $\qquad$ $C = \mathrm{SIN}\,\alpha\,\mathrm{COS}\,\alpha$

Formula 207 - Sector of Hollow Tapered Disc



Direction numbers of Y axis: a, b, c

Direction numbers of X axis (thru centroid): d, e, f

Direction numbers of Z axis: g = bf - ce, h = cd - af, i = ae - bd

Define:

$$D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$$

$$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$$

$$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$$

Direction cosines of Y axis with reference axes:

$$\lambda_1 = a/D_1, \quad \mu_1 = b/D_1, \quad \nu_1 = c/D_1$$

Direction cosines of X axis with reference axes:

$$\lambda_2 = d/D_2, \quad \mu_2 = e/D_2, \quad \nu_2 = f/D_2$$

Direction cosines of Z axis with reference axes:

$$\lambda_3 = g/D_3, \quad \mu_3 = h/D_3, \quad \nu_3 = i/D_3$$

Formula 207, Cont'd

$$F_1 = \frac{2}{3}\left(R^2 T_2^3 - r^2 T_1^3\right)$$

$$F_2 = .5\left(R^4 T_2 - r^4 T_1\right)$$

$$F_3 = \frac{1}{15}\left(10 U^2 P_3 - 15 UE P_4 + 6 E^2 P_5\right)$$

$$F_4 = \frac{1}{10}\left(5 U^4 P_1 - 10 U^3 E P_2 + 10 U^2 E^2 P_3 - 5 U E^3 P_4 + E^4 P_5\right)$$

$$F_5 = \rho\left(F_1 + F_3\right)$$

$$F_6 = \rho\left(F_2 + F_4\right)$$

$$F_7 = \frac{P_1}{5}\left(R^4 + R^3 r + R^2 r^2 + R r^3 + r^4\right)$$

Delta values in Principal Axis System:

$$\partial Y = \rho\alpha(2F_2 + F_7) - WS^2$$

$$\partial X = \alpha\left(F_5 + F_6\right) - CF_6$$

$$\partial Z = \alpha\left(F_5 + F_6\right) + CF_6 - WS^2$$

Delta values in common reference axis system:

$$\Delta Y = \lambda_1^2 \partial Y + \lambda_2^2 \partial X + \lambda_3^2 \partial Z$$

$$\Delta X = \mu_1^2 \partial Y + \mu_2^2 \partial X + \mu_3^2 \partial Z$$

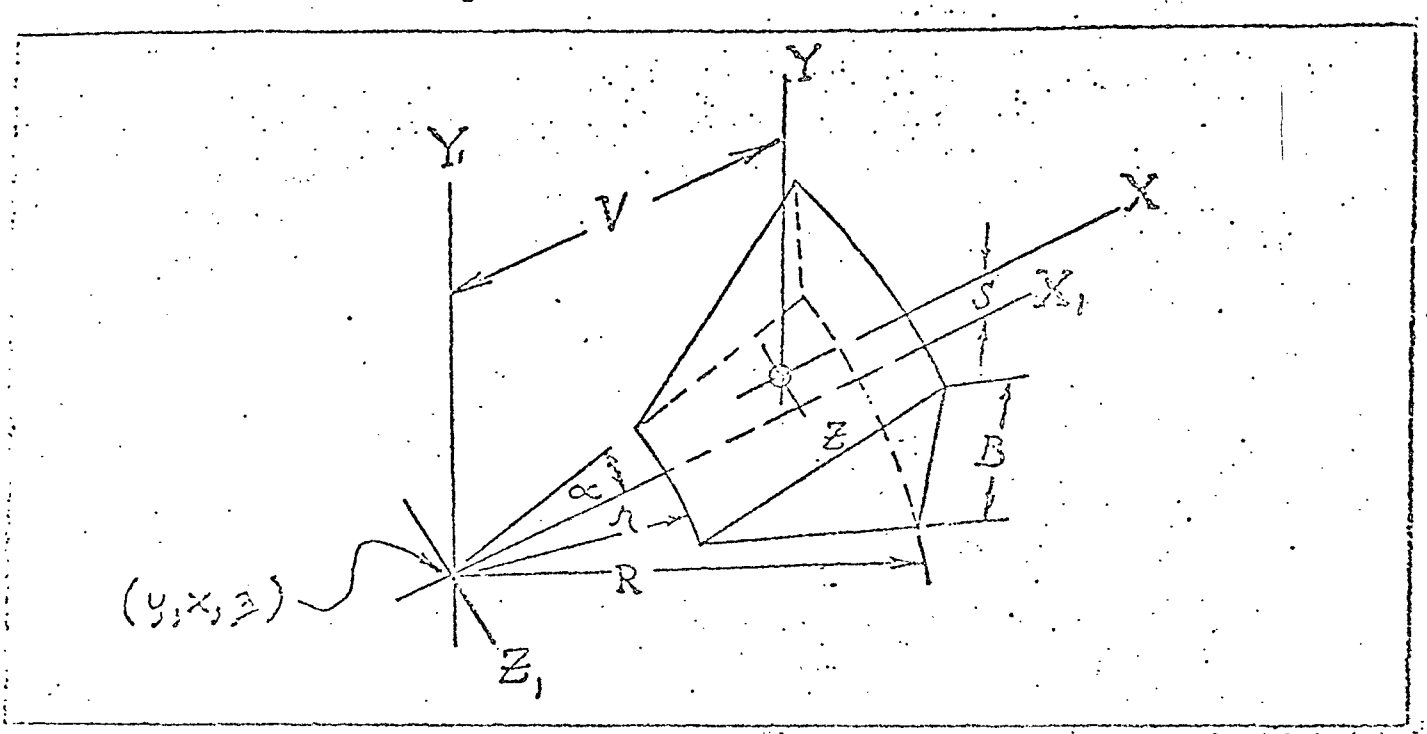
$$\Delta Z = \delta_1^2 \partial Y + \delta_2^2 \partial X + \delta_3^2 \partial Z$$

Formula 207, Cont'd

Input data required:

n = 207	
m = 2	
ρ	density
y, x, z	center of disc
a, b, c	direction numbers of Y axis
d, e, f	direction numbers of X axis
R	Radius to outer edge
r	Radius to inner edge
B	disc thickness - inner edge
A	disc thickness - outer edge
α	half-angle - degrees

Formula 208 - Sector of Wedge of Revolution



Shape generated by right triangle with one leg in the X_1 Z_1 plane, rotated thru 2α degrees about the Y_1 axis. Outer edge is parallel to Y_1.

Direction numbers of Y_1 axis: a, b, c

Direction numbers of X_1 axis (which bisects the sector): d, e, f

Direction numbers of Z_1 axis: $g = bf - ce$, $h = cd - af$, $i = ae - bd$

Define: $D_1 = (a^2 + b^2 + c^2)^{\frac{1}{2}}$

$D_2 = (d^2 + e^2 + f^2)^{\frac{1}{2}}$

$D_3 = (g^2 + h^2 + i^2)^{\frac{1}{2}}$

Formula 203, Cont'd

Direction cosines of Y axis with reference axes:

$$\lambda_1 = a/D_1, \quad \mu_1 = b/D_1, \quad \nu_1 = c/D_1$$

Direction cosines of X axis with reference axes:

$$\lambda_2 = d/D_2, \quad \mu_2 = e/D_2, \quad \nu_2 = f/D_2$$

Direction cosines of Z axis with reference axes:

$$\lambda_3 = g/D_3, \quad \mu_3 = h/D_3, \quad \nu_3 = i/D_3$$

Convert half-angle to radian measure: $\alpha = \pi\alpha/180$

Define:

$C_1 = R - r$

$C_2 = R + r$

$C_3 = \alpha B$

$C_4 = R r$

$C_5 = \dfrac{\text{SIN } (2\alpha)}{2\alpha}$

$C_6 = 2R^2 - r^2$

$E = \sin\alpha/2\alpha$

$C_7 = \rho\alpha B$

$C_8 = r R^2$

$C_9 = 2R - 3r$

Weight:

$$W = \rho\left\{\frac{C_1 C_3 (C_2 + R)}{3}\right\}$$

Formula 208, Cont'd

Y axis component of C.G.:

$$S = \frac{B}{4}\left[\frac{C_6 - 2C_4 + R^2}{C_6 - C_4}\right]$$

X axis component of C.G.:

$$V = B\left[\frac{R^3(C_1 + C_9) + r^4}{R^2 C_9 + r^3}\right]$$

Z axis component of C.G.: $T = 0$

$$\bar{y} = y + \lambda_1 S + \lambda_2 V$$

$$\bar{x} = x + \mu_1 S + \mu_2 V$$

$$\bar{z} = z + \delta_1 S + \delta_2 V$$

Products of inertia about centroidal axes:

$$P_x = P_y = 0$$

$$P_z = \frac{\rho B^2 \sin\alpha}{30 C_1}\left[3R^3 C_9 + r^2(C_2^2 - C_4)\right] - W V S$$

Formula 208, Cont'd

Define:

$$F = \frac{C_4}{10\,C_1}\left[R^4\,(4R - 5r) + r^5\right]$$

$$G = F\left[\frac{1 - C_5}{2} + \frac{B^2}{3\,C_1^{\,2}}\right] - \frac{B^2\,C_7\,C_8}{3\,C_1}$$

$$P = G + C_5\,F$$

Delta values about centroidal axes:

$$\Delta Y = F - W\,V^2$$

$$\Delta X = G - W\,S^2$$

$$\Delta Z = P - W\,(V^2 + S^2)$$

Delta values in common reference axis system:

$$\Delta Y = \lambda_1^2\,\Delta Y + \lambda_2^2\,\Delta X + \lambda_3^2\,\Delta Z - 2\,\lambda_1\lambda_2\,P_Z$$

$$\Delta X = \mu_1^2\,\Delta Y + \mu_2^2\,\Delta X + \mu_3^2\,\Delta Z - 2\,\mu_1\mu_2\,P_Z$$

$$\Delta Z = \nu_1^2\,\Delta Y + \nu_2^2\,\Delta X + \nu_3^2\,\Delta Z - 2\,\nu_1\nu_2\,P_Z$$

Formula 208, Cont'd

Input data required:

n = 208	
m = 2	
y, x, z	location of reference point
ρ	density
a, b, c	direction numbers of Y axis in sense shown
R	outer radius
r	inner radius
B	thickness at outer edge
α	half-angle, degrees
d, e, f	direction numbers of X axis in sense shown

Formula 500 — Misc. Shapes not covered by Program

Input data required:

n = 500 w =	weight (+ or -)
$\bar{Y}$ $\bar{X}$ $\bar{Z}$	centroid location
ΔY ΔX ΔZ	delta values in common reference axis system (+ or -)
n = 2	No. of Cards

APPENDIX D - 1

PROGRAM 12001B
SAMPLE OUTPUT SHEET

LAUNCH CONDITION WITH SHIELD

MASS PROPERTIES SUMMARY 0005 0001970 PAGE 1 - 1

MA	PART NAME	PART NO.	WEIGHT LB.	CENTER OF GRAVITY INCHES			GIMBALED INERTIA SLUG-FT. SQUARED			PERCENT		
				X	Y	Z	X-X	Y-Y	Z-Z	EST.	CAL.	ACT.
2	PROPELLANT FEED SY	1138623 A	5488.0	45.4	-.7	.3	1270.84	1707.56	1782.82	100		
3	NUCLEAR SUBSYSTEM	939J740	15524.0	143.8	.0	.0	1212.00	51514.03	51514.03		100	
4	NOZZLE ASSY SUBSYS	1138200	2233.0	246.8	.1	-.1	453.28	26236.53	26235.82	63	37	
5	INST + CONTROL SUB		518.0	59.2	.0	.0	118.02	401.73	401.73	100		
6	THRUST STR SUBSYS		895.0	52.6	2.9	-2.9	99.05	347.26	347.12	84	16	
7	PV + CLOSURE SUBSY	1138808NC	1808.0	137.3	.0	.0	270.29	5618.50	5618.50		100	
8	DESTRUCT SUBSYSTEM	1219421 B	597.0	378.2	.0	.0	44.59	16321.49	16321.49	100		
9	EXT SHIELD SUBSYS	1138352NC	9675.0	76.0	.0	.0	2475.95	7104.99	7104.99	100		
10	GIMBAL ASSY SUBSYS	1137978 A	565.0	18.6	8.5	-8.5	1.21	1.23	.27	1	99	
11	GROWTH CONTINGENCY		271.0	111.9	-.4	.6	46.90	534.05	534.03	100		
	1137400 D/MOD ENGINE MODULE DRY		37574.0	116.05	.10	-.15	5992.15	109787.36	109860.81	50	50	
	1137400 D/MOD ENGINE MODULE PROP.		85.0	85.00	.00	.00	12.41	131.81	131.81	100		
	1137400 D/MOD ENGINE MODULE WET		37659.0	115.98	.10	-.15	6004.56	109919.18	109992.62	50	50	
21	NOICE		600.0	-1290.0	130.0	130.0	.00	.00	.00	100		
22	PSOV INSTALLATION		327.0	-17.6	.0	.0	.00	.00	.00	100		
23	COOLDOWN MODULE		248.0	-19.9	-54.6	-11.1	.00	.00	.00	100		
	STAGE MOUNTED COMPONENTS	DRY	1175.0	-667.8	54.9	64.0	.00	.00	.00	100		
	STAGE MOUNTED COMPONENTS	PROP.	15.0	-14.0	.0	.0	.00	.00	.00	100		
	STAGE MOUNTED COMPONENTS	WET	1190.0	-659.5	54.2	63.2	.00	.00	.00	100		
	GIMBALED COMPONENTS DRY		36682.1	118.59	-.06	.00	5992.15	109787.36	109860.81			
	GIMBALED COMPONENTS PROP.		85.0	85.00	.00	.00	12.41	131.81	131.81			
	GIMBALED COMPONENTS WET		36767.1	118.51	-.06	.00	6004.56	109919.18	109992.62			

	WEIGHT LB.	CENTER OF GRAVITY INCHES			INERTIA ABOUT ENGINE C. G. SLUG-FT. SQUARED			PERCENT		
		X	Y	Z	X-X	Y-Y	Z-Z	EST.	CAL.	ACT.
TOTAL ENGINE DRY	38749.0	92.28	1.76	1.79	10705.87	295303.13	295532.37	51	49	
TOTAL ENGINE PROP.	100.0	70.15	.00	.00	14.07	89.34	89.34	100		
TOTAL ENGINE WET	38849.0	92.23	1.76	1.79	10720.07	295403.07	295632.31	51	49	

APPENDIX E

PROGRAM 12001B

LISTING

PAGE 1

R CUR (Mass Properties Program 12001B) 16 MAY 72 14:00:47.866
Listing

1. PEF A 14:00:48

2. KEYWRD : 14:00:49

3. IN A 14:00:49

END OF FILE -- UNIT A

4. TRI A 14:00:52

5. TOC 14:00:52

ELEMENT TABLE

ASPCID		SYMBOLIC	24 FEB 72	12:35:09	0	00136670	14	14
CALC		SYMBOLIC	20 FEB 72	01:44:38	0	00137174	14	205
CRDIN		SYMBOLIC	24 FEB 72	08:44:41	0	00144662	14	494
DATA		SYMBOLIC	24 FEB 72	11:11:23	0	00162266	14	29
HEADER		SYMBOLIC	20 FEB 72	01:44:46	0	00163114	14	13
MAIN		SYMBOLIC	06 MAR 72	09:46:39	0	00163402	14	72
MASIN		SYMBOLIC	24 FEB 72	08:44:52	0	00165362	14	153
MATL		SYMBOLIC	20 FEB 72	01:44:53	0	00171520	14	75
MISSUM		SYMBOLIC	20 FEB 72	01:44:57	0	00173552	14	174
PRINT		SYMBOLIC	06 MAR 72	09:16:20	0	00200356	14	505
ASPCID	CODE	RELOCATABLE	24 FEB 72	12:35:09	0	00216214	14	8
					1	00216374	24	1
CALC	CODE	RELOCATABLE	20 FEB 72	01:44:38	0	00216424	14	136
					1	00222204	24	1
CRDIN	CODE	RELOCATABLE	24 FEB 72	08:44:41	0	00222234	14	161
					1	00226552	24	1
HEADER	CODE	RELOCATABLE	20 FEB 72	01:44:46	0	00226602	14	9
					1	00227000	24	1
MAIN	CODE	RELOCATABLE	06 MAR 72	09:46:39	0	00227030	14	12
					1	00227300	24	1
MASIN	CODE	RELOCATABLE	24 FEB 72	08:44:52	0	00227330	14	47
					1	00230552	24	1
MATL	CODE	RELOCATABLE	20 FEB 72	01:44:53	0	00230602	14	19
					1	00231214	24	1
MISSUM	CODE	RELOCATABLE	20 FEB 72	01:44:57	0	00231244	14	44
					1	00232414	24	1
PRINT	CODE	RELOCATABLE	06 MAR 72	09:16:20	0	00232444	14	289
					1	00242362	24	1

ENTRY POINT TABLE

ASPCID (ASPCID/CODE)	1	000014	CALC (CALC/CODE)	1	001773	CRDIN (CRDIN/CODE)	1	002714
HEADER (HEADER/CODE)	1	000023	MASIN (MASIN/CODE)	1	000632	MATL (MATL/CODE)	1	000255
MISSUM (MISSUM/CODE)	1	000676	PRINT (PRINT/CODE)	1	003240			

BLOCK TABLE EMPTY

COBOL LIBRARY TABLE EMPTY

PROCEDURE NAME TABLE EMPTY

6. LIST 1 14:00:52

```
.@ ELT ASPCID,1,720224, 45309

000001                SUBROUTINE ASPCID
000002                WRITE(6,10)
000003             10 FORMAT( '1'
000004               1   50X 'AEROJET SOLID PROPULSION COMPANY'
000005               2 / 54X 'SACRAMENTO CALIFORNIA'
000006               3// 20X '*** PROGRAM COMMENTS ***'
000007               4 / 20X 'PROGRAM NUMBER-NEW SD003A OLD 12001 '
000008               5 / 20X 'PROGRAM TITLE- WEIGHT, BALANCE, AND INERTIA          '
000009               6 / 20X 'PROGRAM WRITTEN JUNE 1970 BY R.V. ALEXANDER    '
000010               7 / 20X '    CONVERSION FROM IBM 7094 TO UNIVAC'
000011               7 / 20X 'MODIFIED MAR 72 BY W. REUSS'                              *NEW
000012               8 )
000013                RETURN
000014                END
```

```
0 ELT CALC,1,720220,  6278

000001                SUBROUTINE CALC(DELIX,DELIY,DELIZ,MIC,X,Y,Z,R,S,W)
000002          C *** SUBROUTINE FOR CALCULATION OF PART MOM. OF I ABOUT OWN C.G.
000003                G(W,R,S,H)=W/4.*(R*R+S*S)+W*H*H/12.*(1.+2.*R*S/(R+S)**2)
000004                IF (MIC .GE. 20) GO TO 10
000005          C *** PARALLELOPIPED (SOLID ONLY).
000006                N=MIC-10
000007                GO TO (1,9,9,1,9,9,1),N
000008              1 DELIX=W/12.*(Y*Y+Z*Z)
000009                DELIY=W/12.*(X*X+Z*Z)
000010                DELIZ=W/12.*(X*X+Y*Y)
000011                GO TO 99
000012             10 IF (MIC .GE. 30) GO TO 20
000013          C *** FRUSTRUM OF A CONE
000014                D=R**4+R**3*S+R*R*S*S+R*S**3+S**4
000015                E=R*R+R*S+S*S
000016                F=R**4+4.*R**3*S+10.*R*R*S*S+4.*R*S**3+S**4
000017                N=MIC-20
000018                GO TO (2,3,9,4,5,9,6,7),N
000019              2 DELIX=.2*W*(R**5-S**5)/(R*R*R-S*S*S)
000020                DELIY=.15*W*(D/E+X*F/4./E/E)
000021                DELIZ=DELIY
000022                GO TO 99
000023              3 DELIX=W/2.*(R*R+S*S)
000024                DELIY=G(W,R,S,X)
000025                DELIZ=DELIY
000026                GO TO 99
000027              4 DELIX=.15*W*(D/E+Y*F/(4.*E*E))
000028                DELIY=.3*W*(R**5-S**5) /(R**3-S**3)
000029                DELIZ=DELIX
000030                GO TO 99
000031              5 DELIX=G(W,R,S,Y)
000032                DELIY=.5*W*(R*R+S*S)
000033                DELIZ=DELIX
000034                GO TO 99
000035              6 DELIX=.15*W*(D/E+Z*F/(4.*E*E))
000036                DELIY=DELIX
000037                DELIZ=.3*W*(R**5-S**5)/(R**3-S**3)
000038                GO TO 99
000039              7 DELIX=G(W,R,S,Z)
000040                DELIY=DELIX
000041                DELIZ=.5*W*(R*R+S*S)
000042                GO TO 99
000043             20 IF (MIC .GE. 40) GO TO 30
000044          C *** SPHERE CODES
000045                N=MIC-30
000046                IF (R .EQ. 0.) R=X/2.
000047                GO TO (8,11,12,9),N
000048              8 DELIX=.4*W*R*R
000049                DELIY=DELIX
000050                DELIZ=DELIX
000051                GO TO 99
000052             11 DELIX=.666667*W*R*R
000053                DELIY=DELIX
000054                DELIZ=DELIX
000055                GO TO 99
000056             12 A=(R**5-S**5)/(R**3-S**3)
```

```
000057                DELIX=.4*W*A
000058                DELIY=DELIX
000059                DELIZ=DELIX
000060                GO TO 99
000061             30 IF (MIC .GE. 50) GO TO 40
000062          C *** TORUS CODES
000063                N=MIC-40
000064                GO TO (13,14,9,15,16,9,17,18,9),N
000065             13 IF (S .EQ. 0.) S=X/2.
000066                DELIX=.25*W*(4.*R*R+3.*S*S)
000067                DELIY=W/8.*(4.*R*R+5.*S*S)
000068                DELIZ=DELIY
000069                GO TO 99
000070             14 IF (S .EQ. 0.) S=X/2.
000071                DELIX=W*(R*R+1.5*S*S)
000072                DELIY=W*(R*R/2.+1.25*S*S)
000073                DELIZ=DELIY
000074                GO TO 99
000075             15 IF (S .EQ. 0.) S=Y/2.
000076                DELIX=W/8.*(4.*R*R+5.*S*S)
000077                DELIY=.25*W*(4.*R*R+3.*S*S)
000078                DELIZ=DELIX
000079                GO TO 99
000080             16 IF (S .EQ. 0.) S=Y/2.
000081                DELIX=W*(R*R/2.+1.25*S*S)
000082                DELIY=W*(R*R+1.5*S*S)
000083                DELIZ=DELIX
000084                GO TO 99
000085             17 IF (S .EQ. 0.) S=Z/2.
000086                DELIY=W/8.*(4.*R*R+5.*S*S)
000087                DELIY=DELIX
000088                DELIZ=.25*W*(4.*R*R+3.*S*S)
000089                GO TO 99
000090             18 IF (S .EQ. 0.) S=Z/2.
000091                DELIX=W*(R*R/2.+1.25*S*S)
000092                DELIY=DELIX
000093                DELIZ=W*(R*R+1.5*S*S)
000094                GO TO 99
000095             40 IF (MIC .GE. 60) GO TO 50
000096          C *** HEMISPHERE CODES
000097                IF (R .EQ. 0.)
000098               1WRITE(6,19) MIC
000099             19 FORMAT (1H1,20X,'  R NOT INPUT FOR HEMISPHERE, CODE=',I2)
000100                N=MIC-50
000101                P=R*R*W
000102                A=.4*P
000103                B=.666667*P
000104                C=.416667*P
000105                D=.26*P
000106                GO TO (41,42,9,43,44,9,45,46,9),N
000107             41 DELIX=A
000108                DELIY=D
000109                DELIZ=D
000110                GO TO 99
000111             42 DELIX=B
000112                DELIY=C
000113                DELIZ=C
000114                GO TO 99
000115             43 DELIX=D
000116                DELIY=A
```

```
000117                DELIZ=D
000118                GO TO 99
000119             44 DELIX=C
000120                DELIY=B
000121                DELIZ=C
000122                GO TO 99
000123             45 DELIX=D
000124                DELIY=D
000125                DELIZ=A
000126                GO TO 99
000127             46 DELIX=C
000128                DELIY=C
000129                DELIZ=B
000130                GO TO 99
000131             50 IF (MIC .GE. 70) GO TO 60
000132           C *** CYLINDER CODES
000133                N=MIC-60
000134                A=3.*(R*R+S*S)+X*X
000135                B=3.*(R*R+S*S)+Y*Y
000136                C=3.*(R*R+S*S)+Z*Z
000137                GO TO (21,22,23,24,25,26,27,28,29),N
000138             21 DELIX=.5*W*R*R
000139                DELIY=W/12.*(3*R*R+X*X)
000140                DELIZ=DELIY
000141                GO TO 99
000142             22 DELIX=W*R*R
000143                DELIY=W/12.*(6.*R*R+X*X)
000144                DELIZ=DELIY
000145                GO TO 99
000146             23 DELIX=.5*W*(R*R+S*S)
000147                DELIY=W*A/12.
000148                DELIZ=DELIY
000149                GO TO 99
000150             24 DELIX=W/12.*(3.*R*R+Y*Y)
000151                DELIY=.5*W*R*R
000152                DELIZ=DELIX
000153                GO TO 99
000154             25 DELIX=W/12.*(6.*R*R+Y*Y)
000155                DELIY=W*R*R
000156                DELIZ=DELIX
000157                GO TO 99
000158             26 DELIX=W/12.*B
000159                DELIY=.5*W*(R*R+S*S)
000160                DELIZ=DELIX
000161                GO TO 99
000162             27 DELIX=W/12.*(3.*R*R+Z*Z)
000163                DELIY=DELIX
000164                DELIZ=.5*W*R*R
000165                GO TO 99
000166             28 DELIX=W/12.*(6.*R*R+Z*Z)
000167                DELIY=DELIX
000168                DELIZ=W*R*R
000169                GO TO 99
000170             29 DELIX=W/12.*C
000171                DELIY=DELIX
000172                DELIZ=.5*W*(R*R+S*S)
000173                GO TO 99
000174             60 IF (MIC .GT. 80) GO TO 9
000175           C *** CYLINDER ABOUT AXIS OTHER THAN OWN.
000176                N=MIC-70
```

```
000177                A=SQRT(X*X+Y*Y+Z*Z)
000178                B=1.+(X/A)**2
000179                C=1.+(Y/A)**2
000180                D=1.+(Z/A)**2
000181                F=A*A/12.
000182                P=1.-(X/A)**2
000183                Q=1.-(Y/A)**2
000184                T=1.-(Z/A)**2
000185                GO TO (31,32,33,9),N
000186             31 E=R*R/4.
000187                DELIX=W*(B*E+F*P)
000188                DELIY=W*(C*E+F*Q)
000189                DELIZ=W*(D*E+F*T)
000190                GO TO 99
000191             32 E=.5*R*R
000192                DELIX=W*(B*E+F*P)
000193                DELIY=W*(C*E+F*Q)
000194                DELIZ=W*(D*E+F*T)
000195                GO TO 99
000196             33 H=.25*(R*R+S*S)
000197                DELIX=W*(B*H+F*P)
000198                DELIY=W*(C*H+F*Q)
000199                DELIZ=W*(D*H+F*T)
000200                GO TO 99
000201              9 WRITE (6,34) MIC
000202             34 FORMAT (1H1,' ERROR ON INERTIA CODE INPUT, CODE=',I2)
000203             99 CONTINUE
000204                RETURN
000205                END
```

@ ELT CRDIN,1,720224, 31431

```
000001                SUBROUTINE CRDIN
000002          C *** CALCULATIONS FOR ALL CARD INPUT DATA FOR ALL EXCEPT FIRST CARD
000003          C ***     WHICH WILL BE A MAJOR ASSEMBLY. PRINTING OF 'DETAILED WEIGHT
000004          C ***     STATEMENT' IS ALSO CONTROLLED HERE.
000005                COMMON  DX,DY,DZ,G,GIMX,GIMY,GIMZ,IA,IAFLG,IAM,IASUB,IP,IPFL1,
000006               1IPFL2,IPSF,MIC,NI,NLINE,TGC,TIOX,TIOY,TIOZ,TMC,TPSC,TPRT1,TPRT2,
000007               2TPRT3,TPRT4,TPRT5,TPRTN1,TPRTN2,TPRTN3,TRL,TRS,TW,TWC,TX,TX1,
000008               3TY,TY1,TZ,TZ1,WTHF,M,
000009               4MPF(10),IMA(40),PSC(40),WC(40),GC(40),CM(40),PRT1(40),PRT2(40),
000010               5PRT3(40),PRT4(40),PRT5(40),WX(40),WGX(40),WXX(40),WGXX(40),WY(40),
000011               6WYY(40),WGY(40),WGYY(40),WZ(40),WGZ(40),WZZ(40),WGZZ(40),W(40),
000012               7WG(40),XIO(40),XGIO(40),YIO(40),YGIO(40),ZIO(40),ZGIO(40),X(40),
000013               8XG(40),Y(40),YG(40),Z(40),ZG(40),WXZ(40),WGXZ(40),TIX(40),TGIX(40)
000014               9,TIY(40),TGIY(40),TIZ(40),TGIZ(40),PW(3,40),TPW(3,9),
000015               AWXM(9),WGXM(9),WXXM(9),WGXXM(9),WYM(9),WGYM(9),WYYM(9),WGYYM(9),
000016               BWZM(9),WGZM(9),WZZM(9),WGZZM(9),WM(9),WGM(9),XIOM(9),XGIOM(9),
000017               CYIOM(9),YGIOM(9),ZIOM(9),ZGIOM(9),XM(9),XGM(9),YM(9),YGM(9),ZM(9),
000018               DZGM(9),WXZM(9),WGXZM(9),TIXM(9),TGIXM(9),TIYM(9),TGIYM(9),TIZM(9),
000019               ETGIZM(9),WXY(40),WYZ(40),WGXY(40),WGYZ(40),WXYM(9) ,WYZM(9),
000020               FAA,AB,AC,AD,AE,AF,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,
000021               GAW,AX,AY,AZ,WGXYM(9),WGYZM(9),WTMTL(26)
000022                NJ=0
000023                NK=0
000024                I=1
000025                J=1
000026                K=1
000027          C *** ZERO OUT DATA FOR TEMP2 (SUB-ASSEMBLY).
000028                BSW=0.
000029                BSWX=0.
000030                BSWXX=0.
000031                BSWY=0.
000032                BSWYY=0.
000033                BSWZ=0.
000034                BSWZZ=0.
000035                BWXZ=0.
000036                BWXY=0.
000037                BWYZ=0.
000038                BTIOX=0.
000039                BTIOY=0.
000040                BTIOZ=0.
000041                BGSW=0.
000042                BGSWX=0.
000043                BGSWXX=0.
000044                BGSWY=0.
000045                BGSWYY=0.
000046                BGSWZ=0.
000047                BGSWZZ=0.
000048                BGWXZ=0.
000049                BGWXY=0.
000050                BGWYZ=0.
000051                BGTIOX=0.
000052                BGTIOY=0.
000053                BGTIOZ=0.
000054                ZSW=0.
000055                ZSWX=0.
000056                ZSWXX=0.
```

```
000057              ZSWY=0.
000058              ZSWYY=0.
000059              ZSWZ=0.
000060              ZSWZZ=0.
000061              ZWXZ=0.
000062              ZWXY=0.
000063              ZWYZ=0.
000064              ZTIOX=0.
000065              ZTIOY=0.
000066              ZTIOZ=0.
000067              ZGSW=0.
000068              ZGSWX=0.
000069              ZGSWXX=0.
000070              ZGSWY=0.
000071              ZGSWYY=0.
000072              ZGSWZ=0.
000073              ZGSWZZ=0.
000074              ZGWXZ=0.
000075              ZGWXY=0.
000076              ZGWYZ=0.
000077              ZGTIOX=0.
000078              ZGTIOY=0.
000079              ZGTIOZ=0.
000080            1 READ(5,5) IAM,IA,IASUB,IP,     TWC,TGC,TMC,TPRT1,TPRT2,TPRT3,
000081             1TPRT4,    ,TPRTN1,TPRTN2,TPRTN3,TW,TX,TY,TZ,MIC,TX1,TY1,TZ1,TRL,      MAR72
000082             2TRS,TIOX,TIOY,TIOZ
000083            5 FORMAT(A2,3A1,4A4,2A4,A1,F8.1,F5.1,2F4.1,I2,3X,2F4.1,F3.1,           MAR72
000084             1F4.1,F3.1,T60,3F7.0)
000085              TPRT5=6H                                                             MAR72
000086              IF(IAM .LT. 88) M=IAM
000087              CALL MATL
000088              IF (IP  .GE. K) GO TO 6
000089              IF (NK .EQ. 1) GO TO 2
000090           20 IF (IASUB .GE. J) GO TO 3
000091              IF (NJ .EQ. 1) GO TO 4
000092           30 IF (IA  .GE. I) GO TO 7
000093              IF (IAM .EQ. 88) GO TO 88
000094        C *** THIS CARD SHOULD BE A PART CARD, BUT IS NOT.
000095              WRITE (6,8) IAM,MIC,TIOX
000096            8 FORMAT (1H1,' BAD INPUT CARD-M.A.=',I2,'  CODE=',I2,'  IOX=',F7.0)
000097              STOP.
000098            7 IF (MIC .NE. 0 .OR. TIOX .NE. 0.) GO TO 11
000099        C *** PRINT HEADING FOR ASSEMBLY
000100              NLINE=NLINE+1
000101              IF (NLINE .GT. 44) CALL HEADER(NLINE)
000102              WRITE(6,12)IAM,IA,TPRT1,TPRT2,TPRT3,TPRT4,TPRTN1,TPRTN2,TPRTN3       MAR72*NEW
000103           12 FORMAT(2I3,12X,4A4,6X,2A4,A1)                                       MAR72*NEW
000104        C *** MOVE INPUT DATA TO TEMP1 FOR LATER PRINTING AS ASSEMBLY WITH TOTALS      **-3
000105              IAM1=IAM
000106              IA1=IA
000107              T11=TPRT1
000108              T12=TPRT2
000109              T13=TPRT3
000110              T14=TPRT4
000111              T15=TPRT5
000112              MJ=1
000113              GO TO 1
000114            5 IF (MIC .NE. 0 .OR. TIOY .NE. 0.) GO TO 13
000115        C *** PRINT HEADING FOR SUB-ASSEMBLY.
000116              NLINE=NLINE+1
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000117                IF (NLINE .GT. 44) CALL HEADER(NLINE)
000118                WRITE(6,14)IAM,IA,IASUB,TPRT1,TPRT2,TPRT3,TPRT4,TPRTN1,          MAR72*NEW
000119               1TPRTN2,TPRTN3                                                      **-1
000120             14 FORMAT(3I3,11X,4A4,4X,2A4,A1)                                    MAR72*NEW
000121          C *** MOVE INPUT DATA TO TEMP2 FOR LATER PRINTING AS SUBASSEMBLY WITH TOTALS.   **-1
000122                IAM2=IAM
000123                IA2=IA
000124                IASUB2=IASUB
000125                T21=TPRT1
000126                T22=TPRT2
000127                T23=TPRT3
000128                T24=TPRT4
000129                T25=TPRT5
000130                NK=1
000131                GO TO 1
000132              6 IF (MIC .NE. 0 .OR. TIOX .NE. 0.) GO TO 15
000133          C *** BAD DATA CARD AT PART LEVEL- NEITHER MIC NOR TIOX INPUT.
000134                WRITE (6,16)IAM,MIC,TIOX
000135             16 FORMAT ( 1H1,' BAD DATA CARD AT PART LEVEL,M.A.=',I2,'  CODE=',I2,
000136               1'  IOX=',F7.0)
000137             15 SWX=TW*TX
000138          C *** CALCULATE ALL DATA FOR PART LEVEL-MOMENTS.
000139                SWXX=SWX*TX
000140                SWY=TW*TY
000141                SWYY=SWY*TY
000142                SWZ=TW*TZ
000143                SWZZ=SWZ*TZ
000144                SWXZ=SWX*TZ
000145                SWXY=SWX*TY
000146                SWYZ=SWY*TZ
000147                IF(TWC .EQ. AA) PW(1,M)=PW(1,M)+TW
000148                IF(TWC .EQ. AC) PW(2,M)=PW(2,M)+TW
000149                IF(TWC .EQ. AE) PW(3,M)=PW(3,M)+TW
000150                IF (MIC .NE. 0)
000151          C *** PART MOMENTS OF INERTIA ARE NOT INPUT AND MUST BE CALCULATED.
000152               1CALL CALC(TIOX,TIOY,TIOZ,MIC,TX1,TY1,TZ1,TRL,TRS,TW)
000153          C *** PART MOMENTS OF INERTIA ARE INPUT.
000154          C *** PRINT OF ITEMS AT THE PART LEVEL.
000155                NLINE=NLINE+1
000156                IF (NLINE .GT. 44) CALL HEADER(NLINE)
000157                WRITE(6,17)IAM,IA,IASUB,IP,TGC,TPRT1,TPRT2,TPRT3,TPRT4,           MAR72*NEW
000158               1TPRTN1,TPRTN2,TPRTN3,TW,TX,TY,TZ,SWXX,SWYY,SWZZ,TIOX,TIOY,TIOZ     **-1
000159             17 FORMAT(4I3,1X,A1,8X,4A4,2X,2A4,A1,F10.1,3F7.1,6E8.2)             MAR72*NEW
000160          C *** ADD TOTALS FROM PARTS TO TEMP2 (SUB-ASSEMBLY).                    **-1
000161                BSW=BSW+TW
000162                BSWX=BSWX+SWX
000163                BSWXX=BSWXX+SWXX
000164                BSWY=BSWY+SWY
000165                BSWYY=BSWYY+SWYY
000166                BSWZ=BSWZ+SWZ
000167                BSWZZ=BSWZZ+SWZZ
000168                BWXZ=BWXZ+SWXZ
000169                BWXY=BWXY+SWXY
000170                BWYZ=BWYZ+SWYZ
000171                BTIOX=TIOX+BTIOX
000172                BTIOY=TIOY+BTIOY
000173                BTIOZ=TIOZ+BTIOZ
000174                IF (TGC .NE. G) GO TO 18
000175          C *** INCLUDE ITEMS FOR GIMBALED SUMMARY.
000176                BGSW=BGSW+TW
```

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000177              BGSWX=BGSWX+SWX
000178              BGSWXX=BGSWXX+SWXX
000179              BGSWY=BGSWY+SWY
000180              BGSWYY=BGSWYY+SWYY
000181              BGSWZ=BGSWZ+SWZ
000182              BGSWZZ=BGSWZZ+SWZZ
000183              BGWXZ=BGWXZ+SWXZ
000184              BGWXY=BGWXY+SWX*TY
000185              BGWYZ=BGWYZ+SWY*TZ
000186              BGTIOX=BGTIOX+TIOX
000187              BGTIOY=BGTIOY+TIOY
000188              BGTIOZ=BGTIOZ+TIOZ
000189           18 K=K+1
000190              GO TO 1
000191           13 SWX=TW*TX
000192        C *** CALCULATE MOMENT AND INERTIA DATA FROM INPUTS-NO PART LEVELS FOR THIS
000193        C *** SUB-ASSEMBLY.
000194              SWXX=SWX*TX
000195              SWY=TW*TY
000196              SWYY=SWY*TY
000197              SWZ=TW*TZ
000198              SWZZ=SWZ*TZ
000199              SWXZ=SWX*TZ
000200              SWXY=SWX*TY
000201              SWYZ=SWY*TZ
000202              IF(TWC .EQ. AA) PW(1,M)=PW(1,M)+TW
000203              IF(TWC .EQ. AC) PW(2,M)=PW(2,M)+TW
000204              IF(TWC .EQ. AE) PW(3,M)=PW(3,M)+TW
000205              IF (MIC .NE. 0)
000206        C *** SUB-ASSEMBLY MOMENTS OF INERTIA ARE NOT INPUT AND MUST BE CALCULATED.
000207             1CALL CALC(TIOX,TIOY,TIOZ,MIC,TX1,TY1,TZ1,TRL,TRS,TW)
000208        C *** SUB-ASSY. MOMENTS OF INERTIA ARE INPUT.
000209        C *** PRINT OF ITEMS AT THE SUB-ASSEMBLY LEVEL.
000210              NLINE=NLINE+1
000211              IF (NLINE .GT. 44) CALL HEADER(NLINE)
000212              WRITE(6,21)IAM,IA,IASUB,TGC,TPRT1,TPRT2,TPRT3,TPRT4,TPRTN1          MAR72*NEW
000213             1,TPRTN2,TPRTN3,TW,TX,TY,TZ,SWXX,SWYY,SWZZ,TIOX,TIOY,TIOZ            **-1
000214           21 FORMAT(3I3,4X,A1,6X,4A4,4X,2A4,A1,F10.1,3F7.1,6E8.2)              MAR72*NEW
000215        C *** ADD TOTALS FROM SUB-ASSEMBLIES TO TEMP1 (ASSEMBLIES).               **-1
000216              ZSW=ZSW+TW
000217              ZSWX=ZSWX+SWX
000218              ZSWXX=ZSWXX+SWXX
000219              ZSWY=ZSWY+SWY
000220              ZSWYY=ZSWYY+SWYY
000221              ZSWZ=ZSWZ+SWZ
000222              ZSWZZ=ZSWZZ+SWZZ
000223              ZTIOX=ZTIOX+TIOX
000224              ZTIOY=ZTIOY+TIOY
000225              ZTIOZ=TIOZ+ZTIOZ
000226              ZWXZ=ZWXZ+SWXZ
000227              ZWXY=ZWXY+SWXY
000228              ZWYZ=ZWYZ+SWYZ
000229              IF (TGC .NE. G) GO TO 22
000230        C *** INCLUDE ITEMS FOR GIMBALED SUMMARY.
000231              ZGSW=ZGSW+TW
000232              ZGSWX=ZGSWX+SWX
000233              ZGSWXX=ZGSWXX+SWXX
000234              ZGSWY=ZGSWY+SWY
000235              ZGSWYY=ZGSWYY+SWYY
000236              ZGSWZ=ZGSWZ+SWZ
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000237                ZGSWZZ=ZGSWZZ+SWZZ
000238                ZGTIOX=ZGTIOX+TIOX
000239                ZGTIOY=ZGTIOY+TIOY
000240                ZGTIOZ=ZGTIOZ+TIOZ
000241                ZGWXZ=ZGWXZ+SWXZ
000242                ZGWXY=ZGWXY+SWX*TY
000243                ZGWYZ=ZGWYZ+SWY*TZ
000244             22 J=J+1
000245                GO TO 1
000246             11 SWX=TX*TW
000247          C *** CALCULATE MOMENT OF INERTIA DATA FROM INPUTS-NO PART OR SUB-ASSEMBLY
000248          C *** LEVELS FOR THIS ASSEMBLY.
000249                SWXX=SWX*TX
000250                SWY=TW*TY
000251                SWYY=SWY*TY
000252                SWZ=TW*TZ
000253                SWZZ=SWZ*TZ
000254                SWXZ=SWX*TZ
000255                SWXY=SWX*TY
000256                SWYZ=SWY*TZ
000257                IF(TWC .EQ. AA) PW(1,M)=PW(1,M)+TW
000258                IF(TWC .EQ. AC) PW(2,M)=PW(2,M)+TW
000259                IF(TWC .EQ. AE) PW(3,M)=PW(3,M)+TW
000260                IF (MIC .NE. 0)
000261          C *** ASSEMBLY MOMENTS OF INERTIA ARE NOT INPUT AND MUST BE CALCULATED.
000262               1CALL CALC(TIOX,TIOY,TIOZ,MIC,TX1,TY1,TZ1,RL,TRS,TW)
000263          C *** ASSEMBLY MOMENTS OF INERTIA ARE INPUT
000264          C *** PRINT OF ITEMS AT THE ASSEMBLY LEVEL.
000265                NLINE=NLINE+1
000266                IF (NLINE .GT. 44) CALL HEADER(NLINE)
000267                WRITE(6,23)IAM,IA,TGC,TPRT1,TPRT2,TPRT3,TPRT4,TPRTN1,TPRTN2          MAR72*NEW
000268               1,TPRTN3,TW,TX,TY,TZ,SWXX,SWYY,SWZZ,TIOX,TIOY,TIOZ                    **-1
000269             23 FORMAT(2I3,7X,A1,4X,4A4,6X,2A4,A1,F10.1,3F7.1,6E8.2)                MAR72*NEW
000270          C *** ADD TOTALS FROM ASSEMBLIES TO MAJOR ASSEMBLIES                       **-1
000271                W(M)=W(M)+TW
000272                WX(M)=WX(M)+SWX
000273                WXX(M)=WXX(M)+SWXX
000274                WY(M)=WY(M)+SWY
000275                WYY(M)=WYY(M)+SWYY
000276                WZ(M)=WZ(M)+SWZ
000277                WZZ(M)=WZZ(M)+SWZZ
000278                WXZ(M)=WXZ(M)+SWXZ
000279                WXY(M)=WXY(M)+SWXY
000280                WYZ(M)=WYZ(M)+SWYZ
000281                TIX(M)=TIX(M)+TIOX
000282                TIY(M)=TIY(M)+TIOY
000283                TIZ(M)=TIZ(M)+TIOZ
000284                IF (TGC .NE. G) GO TO 24
000285          C *** INCLUDE ITEMS FOR GIMBALED SUMMARY
000286                WG(M)=WG(M)+TW
000287                WGX(M)=WGX(M)+SWX
000288                WGXX(M)=WGXX(M)+SWXX
000289                WGY(M)=WGY(M)+SWY
000290                WGYY(M)=WGYY(M)+SWYY
000291                WGZ(M)=WGZ(M)+SWZ
000292                WGZZ(M)=WGZZ(M)+SWZZ
000293                WGXZ(M)=WGXZ(M)+SWXZ
000294                WGXY(M)=WGXY(M)+SWX*TY
000295                WGYZ(M)=WGYZ(M)+SWY*TZ
000296                TGIX(M)=TGIX(M)+TIOX
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000297                TGIY(M)=TGIY(M)+TIOY
000298                TGIZ(M)=TGIZ(M)+TIOZ
000299             24 I=I+1
000300                GO TO 1
000301              2 BX=BSWX/BSW
000302          C *** CALCULATE ITEMS FOR TEMP2 (SUB-ASSEMBLY) FROM SUMMED DATA OF PARTS.
000303                BY=BSWY/BSW
000304                BZ=BSWZ/BSW
000305                BIOX=BSWZZ+BSWYY+BTIOX-BSW*(BY*BY+BZ*BZ)
000306                BIOY=BSWXX+BSWZZ+BTIOY-BSW*(BX*BX+BZ*BZ)
000307                BIOZ=BSWYY+BSWXX+BTIOZ-BSW*(BY*BY+BX*BX)
000308                IF (BGSW .EQ. 0.) GO TO 25
000309                BGX=BGSWX/BGSW
000310                BGY=BGSWY/BGSW
000311                BGZ=BGSWZ/BGSW
000312                BGIOX=BGSWZZ+BGSWYY+BGTIOX-BGSW*(BGY*BGY+BGZ*BGZ)
000313               1+BGSW*((BGY-GIMY)**2+(BGZ-GIMZ)**2)
000314                BGIOY=BGSWXX+BGSWZZ+BGTIOY-BGSW*(BGX*BGX+BGZ*BGZ)
000315               1+BGSW*((BGX-GIMX)**2+(BGZ-GIMZ)**2)
000316                BGIOZ=BGSWYY+BGSWXX+BGTIOZ-BGSW*(BGY*BGY+BGX*BGX)
000317               1+BGSW*((BGX-GIMX)**2+(BGY-GIMY)**2)
000318             25 NLINE=NLINE+1
000319                IF (NLINE .GT. 44) CALL HEADER(NLINE)
000320          C *** PRINT OF ITEMS (TOTALS) AT THE SUB-ASSEMBLY LEVEL-COMPRISED OF SUMMED PART
000321                WRITE(6,26)IAM2,IA2,IASUB2,T21,T22,T23,T24,BSW,BX,BY,BZ,          MAR72*NEW
000322               1BSWXX,BSWYY,BSWZZ,BIOX,BIOY,BIOZ                                 **-1
000323             26 FORMAT(3I3,11X,4A4,'*** TOTAL *' ,F12.1,3F7.1,6E8.2)             MAR72*NEW
000324          C *** ADD ITEMS FROM TEMP2 (SUB-ASSY.) TO TEMP1 (ASSEMBLIES).          **-2
000325                ZSW=ZSW+BSW
000326                ZSWX=ZSWX+BSWX
000327                ZSWXX=ZSWXX+BSWXX
000328                ZSWY=ZSWY+BSWY
000329                ZSWYY=ZSWYY+BSWYY
000330                ZSWZ=ZSWZ+BSWZ
000331                ZSWZZ=ZSWZZ+BSWZZ
000332                ZWXZ=ZWXZ+BWXZ
000333                ZWXY=ZWXY+BWXY
000334                ZWYZ=ZWYZ+BWYZ
000335                ZTIOX=ZTIOX+BTIOX
000336                ZTIOY=ZTIOY+BTIOY
000337                ZTIOZ=ZTIOZ+BTIOZ
000338                IF (SGSW .EQ. 0.) GO TO 27
000339          C *** INCLUDE ITEMS FOR GIMBALED SUMMARY.
000340                ZGSW=ZGSW+BGSW
000341                ZGSWX=ZGSWX+BGSWX
000342                ZGSWXX=ZGSWXX+BGSWXX
000343                ZGSWY=ZGSWY+BGSWY
000344                ZGSWYY=ZGSWYY+BGSWYY
000345                ZGSWZ=ZGSWZ+BGSWZ
000346                ZGSWZZ=ZGSWZZ+BGSWZZ
000347                ZGWXZ=ZGWXZ+BGWXZ
000348                ZGWXY=ZGWXY+BGWXY
000349                ZGWYZ=ZGWYZ+BGWYZ
000350                ZGTIOX=ZGTIOX+BGTIOX
000351                ZGTIOY=ZGTIOY+BGTIOY
000352                ZGTIOZ=ZGTIOZ+BGTIOZ
000353             27 BSW=0.
000354          C *** ZERO OUT DATA FOR TEMP2 (SUB-ASSEMBLY).
000355                BSWX=0.
000356                BSWXX=0.
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000357              BSWY=0.
000358              BSWYY=0.
000359              BSWZ=0.
000360              BSWZZ=0.
000361              BWXZ=0.
000362              BWXY=0.
000363              BWYZ=0.
000364              BTIOX=0.
000365              BTIOY=0.
000366              BTIOZ=0.
000367              IF (BGSW .EQ. 0.) GO TO 28
000368              BGSW=0.
000369              BGSWX=0.
000370              BGSWXX=0.
000371              BGSWY=0.
000372              BGSWYY=0.
000373              BGSWZ=0.
000374              BGSWZZ=0.
000375              BGWXZ=0.
000376              BGWXY=0.
000377              BGWYZ=0.
000378              BGTIOX=0.
000379              BGTIOY=0.
000380              BGTIOZ=0.
000381           28 NK=0
000382              K=1
000383              J=J+1
000384              GO TO 20
000385            4 ZX=ZSWX/ZSW
000386        C *** CALCULATE ITEMS FOR TEMP1 (ASSEMBLY) FROM SUMMED DATA OF SUB-ASSEMBLIES.
000387              ZY=ZSWY/ZSW
000388              ZZ=ZSWZ/ZSW
000389              ZIOX=ZSWZZ+ZSWYY+ZTIOX-ZSW*(ZY*ZY+ZZ*ZZ)
000390              ZIOY=ZSWXX+ZSWZZ+ZTIOY-ZSW*(ZX*ZX+ZZ*ZZ)
000391              ZIOZ=ZSWYY+ZSWXX+ZTIOZ-ZSW*(ZY*ZY+ZX*ZX)
000392              IF (ZGSW .EQ. 0.) GO TO 31
000393        C *** INCLUDE ITEMS FOR GIMBALED SUMMAPY.
000394              ZGX=ZGSWX/ZGSW
000395              ZGY=ZGSWY/ZGSW
000396              ZGZ=ZGSWZ/ZGSW
000397              ZGIOX=ZGSWZZ+ZGSWYY+ZGTIOX-ZGSW*(ZGY*ZGY+ZGZ*ZGZ)
000398             1+ZGSW*((ZGY-GIMY)**2+(ZGZ-GIMZ)**2)
000399              ZGIOY=ZGSWXX+ZGSWZZ+ZGTIOY-ZGSW*(ZGX*ZGX+ZGZ*ZGZ)
000400             1+ZGSW*((ZGX-GIMX)**2+(ZGZ-GIMZ)**2)
000401              ZGIOZ=ZGSWYY+ZGSWXX+ZGTIOZ-ZGSW*(ZGY*ZGY+ZGX*ZGX)
000402             1+ZGSW*((ZGX-GIMX)**2+(ZGY-GIMY)**2)
000403           31 NLINE=NLINE+1
000404              IF (NLINE .GT. 44) CALL HEADER(NLINE)
000405        C *** PRINT OF ITEMS (TOTALS) AT THE ASSEMBLY LEVEL-COMPRISED OF SUB-ASSY. TOTAL
000406              WRITE(6,32)IAM1,IAI,T11,T12,T13,T14,ZSW,ZX,ZY,ZZ,ZSWXX,ZSWYY.        MAR72*NEW
000407             1,ZSWZZ,ZIOX,ZIOY,ZIOZ                                                **-1
000408           32 FORMAT(2I3,12X,4A4,2X,'*** TOTAL *',F12.1,3F7.1,6E8.2)               MAR72*NEW
000409        C *** ADD ITEMS FROM TEMP1 (ASSEMBLY) TO MAJOR ASSEMBLY.                   **-2
000410              W(M)=W(M)+ZSW
000411              WX(M)=WX(M)+ZSWX
000412              WXX(M)=WXX(M)+ZSWXX
000413              WY(M)=WY(M)+ZSWY
000414              WYY(M)=WYY(M)+ZSWYY
000415              WZ(M)=WZ(M)+ZSWZ
000416              WZZ(M)=WZZ(M)+ZSWZZ
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000417              WXZ(M)=WXZ(M)+ZWXZ
000418              WXY(M)=WXY(M)+ZWXY
000419              WYZ(M)=WYZ(M)+ZWYZ
000420               TIX(M)= TIX(M)+ZTIOX
000421               TIY(M)= TIY(M)+ZTIOY
000422               TIZ(M)= TIZ(M)+ZTIOZ
000423              IF (ZGSW .EQ. 0.) GO TO 33
000424              WG(M)=WG(M)+ZGSW
000425              WGX(M)=WGX(M)+ZGSWX
000426              WGXX(M)=WGXX(M)+ZGSWXX
000427              WGY(M)=WGY(M)+ZGSWY
000428              WGYY(M)=WGYY(M)+ZGSWYY
000429              WGZ(M)=WGZ(M)+ZGSWZ
000430              WGZZ(M)=WGZZ(M)+ZGSWZZ
000431              WGXZ(M)=WGXZ(M)+ZGSWXZ
000432              WGXY(M)=WGXY(M)+ZGWXY
000433              WGYZ(M)=WGYZ(M)+ZGWYZ
000434              TGIX(M)=TGIX(M)+ZGTIOX
000435              TGIY(M)=TGIY(M)+ZGTIOY
000436              TGIZ(M)=TGIZ(M)+ZGTIOZ
000437           33 ZSW=0.
000438              ZSWX=0.
000439              ZSWXX=0.
000440              ZSWY=0.
000441              ZSWYY=0.
000442              ZSWZ=0.
000443              ZSWZZ=0.
000444              ZWXZ=0.
000445              ZWXY=0.
000446              ZWYZ=0.
000447              ZTIOX=0.
000448              ZTIOY=0.
000449              ZTIOZ=0.
000450              IF (ZGSW .EQ. 0.) GO TO 34
000451              ZGSW=0.
000452              ZGSWX=0.
000453              ZGSWXX=0.
000454              ZGSWY=0.
000455              ZGSWYY=0.
000456              ZGSWZ=0.
000457              ZGSWZZ=0.
000458              ZGWXZ=0.
000459              ZGWXY=0.
000460              ZGWYZ=0.
000461              ZGTIOX=0.
000462              ZGTIOY=0.
000463              ZGTIOZ=0.
000464           34 NJ=0
000465              J=1
000466              I=I+1
000467              IF (IAM .NE. 88 ) GO TO 30
000468        C *** CALCULATE ITEMS FOR MAJOR ASSEMBLY TOTALS FROM ASSY. SUMMATIONS.
000469           68 X(M)=WX(M)/W(M)
000470              Y(M)=WY(M)/W(M)
000471              Z(M)=WZ(M)/W(M)
000472              XIO(M)=WZZ(M)+WYY(M)+ TIX(M)-W(M)*(Y(M)*Y(M)+Z(M)*Z(M))
000473              YIO(M)=WXX(M)+WZZ(M)+ TIY(M)-W(M)*(X(M)*X(M)+Z(M)*Z(M))
000474              ZIO(M)=WYY(M)+WXX(M)+ TIZ(M)-W(M)*(Y(M)*Y(M)+X(M)*X(M))
000475              IF (WG(M) .EQ. 0.) GO TO 35
000476        C *** INCLUDE ITEMS FOR GIMBALED SUMMARY.
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000477                XG(M)=WGX(M)/WG(M)
000478                YG(M)=WGY(M)/WG(M)
000479                ZG(M)=WGZ(M)/WG(M)
000480                XGIO(M)=WGZZ(M)+WGYY(M)+ TGIX(M)-WG(M)*(YG(M)*YG(M)+ZG(M)*ZG(M))
000481               1    +WG(M)*((YG(M)-GIMY)**2+(ZG(M)-GIMZ)**2)
000482                YGIO(M)=WGXX(M)+WGZZ(M)+ TGIY(M)-WG(M)*(XG(M)*XG(M)+ZG(M)*ZG(M))
000483               1    +WG(M)*((XG(M)-GIMX)**2+(ZG(M)-GIMZ)**2)
000484                ZGIO(M)=WGYY(M)+WGXX(M)+ TGIZ(M)-WG(M)*(YG(M)*YG(M)+XG(M)*XG(M))
000485               1    +WG(M)*((XG(M)-GIMX)**2+(YG(M)-GIMY)**2)
000486              35 NLINE=NLINE+1
000487                IF (NLINE .GT. 44) CALL HEADER(NLINE)
000488            C *** PRINT OF ITEMS (TOTALS) AT THE MAJOR-ASSEMBLY LEVEL-COMPRISED OF ASSY. TOT
000489                WRITE(6,36)IMA(M),PRT1(M),PRT2(M),PRT3(M),PRT4(M),                  MAR72*NEW
000490               1M(M),X(M),Y(M),Z(M),WXX(M),WYY(M),WZZ(M),YIO(M),YIO(M),ZIO(M)          **-1
000491              36 FORMAT(1I3,13X,4A4,4X,'*** TOTAL *',F12.1,3F7.1,6E8.2)             MAR72*NEW
000492                NI=0                                                                  **-2
000493                RETURN
000494                END
```

D ELT DATA,1,720224, 40293

000001				012021			986020002000				
000002	1	0	0	0	CASE	1193246-9					
000003	1	1	0	0	FWD CASE	1193245-1	55000	5502000200052		900	
000004	1	2	0	0	FWD CYLINDER		300000	23702000200062	2740	900	
000005	1	3	0	0	FWD JOINT		100000	33002000200063	120	920890	
000006	1	4	0	0	CENTER SECTION		500000	52002000200062	2680	900	
000007	1	5	0	0	AFT JOINT		100000	63002000200063	120	920890	
000008	1	6	0	0	AFT CYLINDER		350000	80302000200062	2740	900	
000009	1	7	0	0	AFT DOME	1193276-7	63000	9?502000200052		900	
000010	1	8	0	0	AFT SKIRT	1193427-9	750001	03002000200062	126	900	
000011	88										
000012	2	0	0	0	IGNITER						
000013	2	1	0	0	IGN ADAPTOR	1195729-3	4300	3152000200061	90	150	
000014	2	2	0	0	GRAIN HSG		350	4002000200061	200	60	
000015	88										
000016	3	0	0	0	NOZZLE	1196372-1					
000017	3	1	0	0	G ENT CAP		9300	98002000200063	120	280240	
000018	3	2	0	0	NOZZLE SUPPORT		100000	102002000200022	400	400280	
000019	3	3	0	0	G EXIT CONE		150000	118602000200022	2300	700260	
000020	88										
000021	20	0	0	0	PROPELLANT						
000022	20	1	0	0	CYL GRAIN		1129243	752002000200063	9990	890120	
000023	20	2	0	0	IGNITER GRAIN		750	4502000200061	240	60	
000024	88										
000025	23	0	0	0	GUIDANCE SYSTEM GFE		930010	6001970212063	250	750700	
000026	88										
000027	40	0	0	0	GFE DESTRUCT FL		750105	501950207363	100	760750	
000028	88										
000029	99										

```
@ ELT HEADER,1,720220,  6286

                SUBROUTINE HEADER(NLINE)
         C *** THIS SUBROUTINE PRINTS THE HEADER FOR THE DETAILED WEIGHT STATEMENT.
                WRITE(6,1)
              1 FORMAT (1H1,/////    )
                WRITE (6,2)
              2 FORMAT     (31X,'DETAILED WEIGHT STATEMENT',//,' MA A SUB P',
               113X,'PART NAME',19X,'PART NO.   WEIGHT  CENTER OF GRAVITY',4X,
               2'MOMENT',12X,'OF',15X,'INERTIA',/,54X,'LB.',11X,'INCHES',20X,
               3'LB-INCHES SQUARED',/,65X,'X     Y     Z',9X,'WXX        WYY',7X,
               4'WZZ     IO      IO      IO',/,114X,'X        Y        Z',/ )
                NLINE=1
                RETURN
                END
```

```
@ ELT MAIN,1,720306, 35199

000001          C *** THIS PROGRAM (SD003A) REPLACES IBM 7094 PROGRAMS 942, 942A, AND 12001.
000002          C *** THIS PROGRAM CALCULATES TOTAL WEIGHT, CENTER OF GRAVITY, AND MOMENTS
000003          C ***     OF INERTIA OF A LIQUID ROCKET ENGINE. INPUTS INCLUDE PART WEIGHTS,
000004          C ***     CENTER OF GRAVITY, AND PART DIMENSION (OR MOMENT OF INERTIA).
000005                COMMON  DX,DY,DZ,G,GIMX,GIMY,GIMZ,IA,IAFLG,IAM,IASUB,IP,IPFL1,
000006               1IPFL2,IPSF,MIC,NI,NLINE,TGC,TIOX,TIOY,TIOZ,TMC,TPSC,TPRT1,TPRT2,
000007               2TPRT3,TPRT4,TPRT5,TPRTN1,TPRTN2,TPRTN3,TRL,TRS,TW,TWC,TX,TX1,
000008               3TY,TY1,TZ,TZ1,WTHE,M,
000009               4NPF(10),IMA(40),PSC(40),WC(40),GC(40),CM(40),PRT1(40),PRT2(40),
000010               5PRT3(40),PRT4(40),PRT5(40),WX(40),WGX(40),WXX(40),WGXX(40),WY(40),
000011               6WYY(40),WGY(40),WGYY(40),WZ(40),WGZ(40),WZZ(40),WGZZ(40),W(40),
000012               7WG(40),XIO(40),XGIO(40),YIO(40),YGIO(40),ZIO(40),ZGIO(40),X(40),
000013               8XG(40),Y(40),YG(40),Z(40),ZG(40),WXZ(40),WGXZ(40),TIX(40),TGIX(40)
000014               9,TIY(40),TGIY(40),TIZ(40),TGIZ(40),PW(3,40),TPW(3,9),
000015               AWXM(9),WGXM(9),WXXM(9),WGXXM(9),WYM(9),WGYM(9),WYYM(9),WGYYM(9),
000016               BWZM(9),WGZM(9),WZZM(9),WGZZM(9),WM(9),WGM(9),XIOM(9),XGIOM(9),
000017               CYIOM(9),YGIOM(9),ZIOM(9),ZGIOM(9),XM(9),XGM(9),YM(9),YGM(9),ZM(9),
000018               DZGM(9),WXZM(9),WGXZM(9),TIXM(9),TGIXM(9),TIYM(9),TGIYM(9),TIZM(9),
000019               ETGIZM(9),WXY(40),WYZ(40),WGXY(40),WGYZ(40),WXYM(9) ,WYZM(9),
000020               FAA,AB,AC,AD,AE,AF,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,
000021               GAW,AX,AY,AZ,WGXYM(9),WGYZM(9),WTMTL(26)
000022             4 DO 3 M=1,10
000023             3 NPF(M)=0
000024               READ(5,1, END=8)
000025               A          NPF,IPSF,DX,DY,DZ,GIMX,GIMY,GIMZ,WTHE,IPFL1,IPFL2,IAFLG
000026             1 FORMAT(7X,10I2,I1,2F5.3, F4.1, F5.1,3F4.1,3I1)                    MAR72*NEW
000027               DO 2 M=1,40                                                        **-1
000028               IMA(M)=0
000029               W(M)=0.
000030               WG(M)=0.
000031               WX(M)=0.
000032               WGX(M)=0.
000033               WXX(M)=0.
000034               WGXX(M)=0.
000035               WY(M)=0.
000036               WGY(M)=0.
000037               WYY(M)=0.
000038               WGYY(M)=0.
000039               WZ(M)=0.
000040               WGZ(M)=0.
000041               WZZ(M)=0.
000042               WGZZ(M)=0.
000043               WXZ(M)=0.
000044               WGXZ(M)=0.
000045               X(M)=0.
000046               XG(M)=0.
000047               Y(M)=0.
000048               YG(M)=0.
000049               Z(M)=0.
000050               ZG(M)=0.
000051               YIO(M)=0.
000052               XGIO(M)=0.
000053               YIO(M)=0.
000054               YGIO(M)=0.
000055               ZIO(M)=0.
000056               ZGIO(M)=0.
```

```
000057                TIX(M)=0.
000058                TGIX(M)=0.
000059                TIY(M)=0.
000060                TGIY(M)=0.
000061                TIZ(M)=0.
000062              2 TGIZ(M)=0.
000063                CALL ASPCID
000064                CALL HEADER(NLINE)
000065                CALL MASIN
000066                CALL MISSUM
000067                CALL PRINT
000068                GO TO 4
000069              8 WRITE(6,9)
000070              9 FORMAT(1H1,/////,50X,'END OF JOB - NO MORE CARDS')
000071                STOP
000072                END
```

```
C ELT MASIN,1,720224, 31492

000001              SUBROUTINE MASIN
000002          C *** THIS SUB PROCESSES THE FIRST CART IN EACH MAJOR ASSEMBLY
000003              COMMON  DX,DY,DZ,G,GIMX,GIMY,GIMZ,IA,IAFLG,IAM,IASUB,IP,IPFL1,
000004             1IPFL2,IPSF,MIC,NI,NLINE,TGC,TIOX,TIOY,TIOZ,TMC,TPSC,TPRT1,TPRT2,
000005             2TPRT3,TPRT4,TPRT5,TPRTN1,TPRTN2,TPRTN3,TR ,TRS,TW,TWC,TX,TX1,
000006             3TY,TY1,TZ,TZ1,WTHE,M,
000007             4NPF(10),IAA(40),PSC(40),WC(40),GC(40),CM(40),PRT1(40),PRT2(40),
000008             5PRT3(40),PRT4(40),PRT5(40),WX(40),WGX(40),WXX(40),WGXX(40),WY(40),
000009             6WYY(40),WGY(40),WGYY(40),WZ(40),WGZ(40),WZZ(40),WGZZ(40),W(40),
000010             7XG(40),XIO(40),XGIO(40),YIO(40),YGIO(40),ZIO(40),ZGIO(40),X(40),
000011             8XG(40),Y(40),YG(40),Z(40),ZG(40),WXZ(40),WGXZ(40),TIX(40),TGIX(40)
000012             9,TIY(40),TGIY(40),TIZ(40),TGIZ(40),PW(3,40),TPW(3,9),
000013             AWXM(9),WGXM(9),WXXM(9),WGXXM(9),WYM(9),WGYM(9),WYYM(9),WGYYM(9),
000014             BWZM(9),WGZM(9),WZZM(9),WGZZM(9),WM(9),WGM(9),XIOM(9),XGIOM(9),
000015             CYIOM(9),YGIOM(9),ZIOM(9),ZGIOM(9),XM(9),XGM(9),YM(9),YGM(9),ZM(9),
000016             DIGM(9),WXZM(9),WGXZM(9),TIXM(9),TGIXM(9),TIYM(9),TGIYM(9),TIZM(9),
000017             ETGIZM(9),WXY(40),WYZ(40),WGXY(40),WGYZ(40),WXYM(9) ,WYZM(9),
000018             FAA,AB,AC,AD,AE,AF,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,
000019             GAW,AX,AY,AZ,WGXYM(9),WGYZM(9),WTMTL(26)
000020              DATA G /'G'/
000021              DATA AA/'A'/,AB/'B'/,AC/'C'/,AD/'D'/,AE/'E'/,AF/'F'/,AH/'H'/
000022              DATA AI/'I'/,AJ/'J'/,AK/'K'/,AL/'L'/,AM/'M'/,AN/'N'/,AO/'O'/
000023              DATA AP/'P'/,AQ/'Q'/,AR/'R'/,AS/'S'/,AT/'T'/,AU/'U'/,AV/'V'/
000024              DATA AW/'W'/,AX/'X'/,AY/'Y'/,AZ/'Z'/
000025              NI=0
000026              DO 20 I=1,26
000027           20 WTMTL(I)=0.
000028              LL=0
000029              DO 200 L=1,10
000030          200 IF (NPF(L) .NE. 0) LL=LL+1
000031            4 READ(5,5)
000032             1       IAM,IA,IASUB,IP,     TWC,TGC,TMC,TPRT1,TPRT2,TPRT3,
000033             1TPRT4,    ,TPRTN1,TPRTN2,TPRTN3,TW,TX,TY,TZ,MIC,TX1,TY1,TZ1,TRL,      MAR72
000034             3TRS,TIOX,TIOY,TIOZ
000035            5 FORMAT(4I2,3A1,4A4,2A4,A1,F8.1,F5.1,2F4.1,I2,3X,2F4.1,F3.1,          MAR72
000036             1F4.1,F3.1,T60,3F7.0)
000037              TPRT5=6H                                                            MAR72
000038              M=IAM
000039              IF (IAM .EQ. 88) GO TO 4
000040              IF (IAM .EQ. 99) RETURN
000041              IF (IAM .GT. 0 .AND. IAM .LT. 41) GO TO 2
000042              WRITE (6,3) IAM
000043            3 FORMAT (1H1,' ERROR ON INPUT CARD, MAJ. ASSY. CODE=',I2)
000044            2 IF (LL .EQ. 0) GO TO 203
000045              IF (M .EQ. 1) GO TO 203
000046              DO 202 L=1,LL
000047          202 IF (NPF(L) .EQ. M) CALL HEADER(NLINE)
000048          203 CONTINUE
000049              CALL MATL
000050              WX(M)=0.
000051              WXX(M)=0.
000052              WY(M)=0.
000053              WYY(M)=0.
000054              WZ(M)=0.
000055              WZZ(M)=0.
000056              WXZ(M)=0.
```

```
000057                WXY(M)=0.
000058                WYZ(M)=0.
000059                TIX(M)=0.
000060                TIY(M)=0.
000061                TIZ(M)=0.
000062                WG(M)=0.
000063                WGX(M)=0.
000064                WGXX(M)=0.
000065                WGY(M)=0.
000066                WGYY(M)=0.
000067                WGZ(M)=0.
000068                WGZZ(M)=0.
000069                WGXZ(M)=0.
000070                WGXY(M)=0.
000071                WGYZ(M)=0.
000072                TGIX(M)=0.
000073                TGIY(M)=0.
000074                TGIZ(M)=0.
000075                PW(1,M)=0.
000076                PW(2,M)=0.
000077                PW(3,M)=0.
000078                IMA(M)=IAM
000079                PSC(M)=TPSC
000080                WC(M)=TWC
000081                GC(M)=TGC
000082                CM(M)=TMC
000083                PRT1(M)=TPRT1
000084                PRT2(M)=TPRT2
000085                PRT3(M)=TPRT3
000086                PRT4(M)=TPRT4
000087                PRT5(M)=TPRT5
000088                W(M)=TW
000089                X(M)=TX
000090                Y(M)=TY
000091                Z(M)=TZ
000092                IF (MIC .NE. 0) GO TO 6
000093          C *** INERTIA DATA INPUT
000094                XIO(M)=TIOX
000095                YIO(M)=TIOY
000096                ZIO(M)=TIOZ
000097              6 IF (MIC .NE. 0 .OR. TIOX .NE. 0.) GO TO 8
000098          C *** MAJOR ASSY. COMPRISED OF COMPONENTS
000099                NLINE=NLINE+2
000100                IF (NLINE .GT. 41) CALL HEADER(NLINE)
000101                WRITE(6,9) IAM,TPRT1,TPRT2,TPRT3,TPRT4,TPRTN1,TPRTN2,TPRTN3          MAR72*NEW
000102              9 FORMAT(/,I3,15X,4A4,8X,2A4,A1)                                      MAR72*NEW
000103                NI=1                                                                  **-2
000104                CALL CROIN
000105                GO TO 4
000106              8 WX(M)=TW*TX
000107          C *** MAJOR ASSY. HAS NO COMPONENTS, CALCULATE ITEMS
000108                WXX(M)=WX(M)*TX
000109                WY(M)=TW*TY
000110                WYY(M)=WY(M)*TY
000111                WZ(M)=TW*TZ
000112                WZZ(M)=WZ(M)*TZ
000113                WXZ(M)=TW*TX*TZ
000114                WXY(M)=TW*TX*TY
000115                WYZ(M)=TW*TY*TZ
000116                IF(TWC .EQ. AA) PW(1,M)=TW
```

```
000117                IF(TWC .EQ. AC) PW(2,M)=TW
000118                IF(TWC .EQ. AE) PW(3,M)=TW
000119                IF (TGC .NE. G) GO TO 10
000120                WG(M)=W(M)
000121                WGX(M)=WX(M)
000122                WGXX(M)=WXX(M)
000123                WGY(M)=WY(M)
000124                WGYY(M)=WYY(M)
000125                WGZ(M)=WZ(M)
000126                WGZZ(M)=WZZ(M)
000127                WGXZ(M)=WXZ(M)
000128                WGXY(M)=WXY(M)
000129                WGYZ(M)=WYZ(M)
000130                XG(M)=X(M)
000131                YG(M)=Y(M)
000132                ZG(M)=Z(M)
000133             10 IF (MIC .EQ. 0) GO TO 41
000134          C *** MOMENTS OF INERTIA NOT INPUT DATA
000135                CALL CALC(XIO(M),YIO(M),ZIO(M),MIC, TX1, TY1, TZ1,TRL,TRS,W(M))
000136             41 TIX(M)=XIO(M)
000137                TIY(M)=YIO(M)
000138                TIZ(M)=ZIO(M)
000139                IF(TGC .NE. G) GO TO 11
000140                TGIX(M)=XIO(M)
000141                TGIY(M)=YIO(M)
000142                TGIZ(M)=ZIO(M)
000143                XGIO(M)=XIO(M)+WG(M)*((TY-GIMY)**2+(TZ-GIMZ)**2)
000144                YGIO(M)=YIO(M)+WG(M)*((TX-GIMX)**2+(TZ-GIMZ)**2)
000145                ZGIO(M)=ZIO(M)+WG(M)*((TX-GIMX)**2+(TY-GIMY)**2)
000146             11 NLINE=NLINE+2
000147                IF (NLINE .GT. 41) CALL HEADER(NLINE)
000148                WRITE(6,12) IAM,GC(M),TPRT1,TPRT2,TPRT3,TPRT4,TPRTN1,TPRTN2          MAR72*NEW
000149               1,TPRTN3,W(M),X(M),Y(M),Z(M),WXX(M),WYY(M),WZZ(M),XIO(M),YIO(M),          **-1
000150               2ZIO(M)
000151             12 FORMAT(/,I3,10X,A1,2X,4A4,8X,2A4,A1,F10.1,3F7.1,6E8.2)             MAR72*NEW
000152                GO TO 4                                                               **-2
000153                END
```

221

```
@ ELT MATL,1,720220,  6293

000001                SUBROUTINE MATL
000002          C *** THIS SUBROUTINE SUMS WEIGHTS BY MATERIAL CODE
000003                COMMON  DX,DY,DZ,G,GIMX,GIMY,GIMZ,IA,IAFLG,IAM,IASUB,IP,IPFL1,
000004               1IPFL2,IPSF,MIC,NI,NLINE,TGC,TIOX,TIOY,TIOZ,TMC,TPSC,TPRT1,TPRT2,
000005               2TPRT3,TPRT4,TPRT5,TPRTN1,TPRTN2,TPRTN3,TRL,TRS,TW,TWC,TX,TX1,
000006               3TY,TY1,TZ,TZ1,WTHE,M,
000007               4NPF(10),IMA(40),PSC(40),WC(40),GC(40),CM(40),PRT1(40),PRT2(40),
000008               5PRT3(40),PRT4(40),PRT5(40),WX(40),WGX(40),WXX(40),WGXX(40),WY(40),
000009               6WYY(40),WGY(40),WGYY(40),WZ(40),WGZ(40),WZZ(40),WGZZ(40),W(40),
000010               7WG(40),XIO(40),XGIO(40),YIO(40),YGIO(40),ZIO(40),ZGIO(40),X(40),
000011               8XG(40),Y(40),YG(40),Z(40),ZG(40),WXZ(40),WGXZ(40),TIX(40),TGIX(40)
000012               9,TIY(40),TGIY(40),TIZ(40),TGIZ(40),PW(3,40),TPW(3,9),
000013               AWXM(9),WGXM(9),WXXM(9),WGXXM(9),WYM(9),WGYM(9),WYYM(9),WGYYM(9),
000014               BWZM(9),WGZM(9),WZZM(9),WGZZM(9),WM(9),WGM(9),XIOM(9),XGIOM(9),
000015               CYIOM(9),YGIOM(9),ZIOM(9),ZGIOM(9),XM(9),XGM(9),YM(9),YGM(9),ZM(9),
000016               DZGM(9),WXZM(9),WGXZM(9),TIXM(9),TGIXM(9),TIYM(9),TGIYM(9),TIZM(9),
000017               ETGIZM(9),WXY(40),WYZ(40),WGXY(40),WGYZ(40),WXYM(9) ,WYZM(9),
000018               FAA,AB,AC,AD,AE,AF,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,
000019               GAW,AX,AY,AZ,WGXYM(9),WGYZM(9),WTMTL(26)
000020                I=1
000021                IF(TMC   .EQ. AA)GO TO 1
000022                I=2
000023                IF(TMC   .EQ. AB) GO TO 1
000024                I=3
000025                IF(TMC   .EQ. AC) GO TO 1
000026                I=4
000027                IF(TMC   .EQ. AD) GO TO 1
000028                I=5
000029                IF(TMC   .EQ. AE) GO TO 1
000030                I=6
000031                IF(TMC   .EQ. AF) GO TO 1
000032                I=7
000033                IF(TMC   .EQ. G ) GO TO 1
000034                I=8
000035                IF(TMC   .EQ. AH) GO TO 1
000036                I=9
000037                IF(TMC   .EQ. AI) GO TO 1
000038                I=10
000039                IF(TMC   .EQ. AJ) GO TO 1
000040                I=11
000041                IF(TMC   .EQ. AK) GO TO 1
000042                I=12
000043                IF(TMC   .EQ. AL) GO TO 1
000044                I=13
000045                IF(TMC   .EQ. AM) GO TO 1
000046                I=14
000047                IF(TMC   .EQ. AN) GO TO 1
000048                I=15
000049                IF(TMC   .EQ. AO) GO TO 1
000050                I=16
000051                IF(TMC   .EQ. AP) GO TO 1
000052                I=17
000053                IF(TMC   .EQ. AQ) GO TO 1
000054                I=18
000055                IF(TMC   .EQ. AR) GO TO 1
000056                I=19
```

```
000057                IF(TMC    .EQ. AS) GO TO 1
000058                I=20
000059                IF(TMC    .EQ. AT) GO TO 1
000060                I=21
000061                IF(TMC    .EQ. AU) GO TO 1
000062                I=22
000063                IF(TMC    .EQ. AV) GO TO 1
000064                I=23
000065                IF(TMC    .EQ. AW) GO TO 1
000066                I=24
000067                IF(TMC    .EQ. AX) GO TO 1
000068                I=25
000069                IF(TMC    .EQ. AY) GO TO 1
000070                I=26
000071                IF(TMC    .NE. AZ) GO TO 2
000072              1 WTMTL(I)=WTMTL(I)+TW
000073              2 CONTINUE
000074                RETURN
000075                END
```

```
D ELT MISSUM,1,720220,  6297

000001                SUBROUTINE MISSUM
000002          C *** CALCULATION OF MOMENT AND INERTIA ITEMS FOR ENGINE, VEHICLE INTEGRATION,
000003          C *** AND TOTAL ENGINE.
000004                COMMON  DX,DY,DZ,G,GIMX,GIMY,GIMZ,IA,IAFLG,IAM,IASUB,IP,IPFL1,
000005               1IPFL2,IPSF,MIC,NI,NLINE,TGC,TIOX,TIOY,TIOZ,TMC,TPSC,TPRT1,TPRT2,
000006               2TPRT3,TPRT4,TPRT5,TPRTN1,TPRTN2,TPRTN3,TRL,TRS,TW,TWC,TX,TX1,
000007               3TY,TY1,TZ,TZ1,WTHE,M,
000008               4NSF(10),IMA(40),PSC(40),WC(40),GC(40),CM(4)),PRT1(40),PRT2(40),
000009               5PRT3(40),PRT4(40),PRT5(40),WX(40),WGX(40),WXX(40),WGXX(40),WY(40),
000010               6WYY(40),WGY(40),WGYY(40),WZ(40),WGZ(40),WZZ(40),WGZZ(40),W(40),
000011               7WG(40),XIO(40),XGIO(40),YIO(40),YGIO(40),ZIO(40),ZGIO(40),X(40),
000012               8XG(40),Y(40),YG(40),Z(40),ZG(40),WXZ(40),WGXZ(40),TIX(40),TGIX(40)
000013               9,TIY(40),TGIY(40),TIZ(40),TGIZ(40),PW(3,40),TPW(3,9),
000014               AWXM(9),WGXM(9),WXXM(9),WGXXM(9),WYM(9),WGYM(9),WYYM(9),WGYYM(9),
000015               BWZM(9),WGZM(9),WZZM(9),WGZZM(9),WM(9),WGM(9),XIOM(9),XGIOM(9),
000016               CYIOM(9),YGIOM(9),ZIOM(9),ZGIOM(9),XM(9),XGM(9),YM(9),YGM(9),ZM(9),
000017               DZGM(9),WXZM(9),WGXZM(9),TIXM(9),TGIXM(9),TIYM(9),TGIYM(9),TIZM(9),
000018               ETGIZM(9),WXY(40),WYZ(40),WGXY(40),WGYZ(40),WXYM(9) ,WYZM(9),
000019               FAA,AB,AC,AD,AE,AF,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,
000020               GAW,AX,AY,AZ,WGXYM(9),WGYZM(9),WTMTL(26)
000021          C *** ZERO OUT ENGINE VEHICLE INTEGRATION,AND TOTAL ENGINE DATA
000022                DO 1 N=1,9
000023                WXM(N)=0.
000024                WGXM(N)=0.
000025                WXXM(N)=0.
000026                WGXXM(N)=0.
000027                WYM(N)=0.
000028                WGYM(N)=0.
000029                WYYM(N)=0.
000030                WGYYM(N)=0.
000031                WZM(N)=0.
000032                WGZM(N)=0.
000033                WZZM(N)=0.
000034                WGZZM(N)=0.
000035                WM(N)=0.
000036                WGM(N)=0.
000037                TIXM(N)=0.
000038                TIYM(N)=0.
000039                TIZM(N)=0.
000040                TGIXM(N)=0.
000041                TGIYM(N)=0.
000042                TGIZM(N)=0.
000043                WXZM(N)=0.
000044                WXYM(N)=0.
000045              1 WYZM(N)=0.
000046                NN=0
000047                N=1
000048                MI=1
000049                MF=18
000050              4 M=MI
000051          C *** CALCULATION FOR BASIC ENGINE DRY, PARTS 1-19.
000052             19 IF (W(M) .EQ. 0.) GO TO 2
000053                WM(N)=WM(N)+W(M)
000054                WXM(N)=WXM(N)+WX(M)
000055                WXXM(N)=WXXM(N)+WXX(M)
000056                WYM(N)=WYM(N)+WY(M)
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000057            WYYM(N)=WYYM(N)+WYY(M)
000058            WZM(N)=WZM(N)+WZ(M)
000059            WZZM(N)=WZZM(N)+WZZ(M)
000060            WXZM(N)=WXZM(N)+WXZ(M)
000061            WXYM(N)=WXYM(N)+WXY(M)
000062            WYZM(N)=WYZM(N)+WYZ(M)
000063            TIXM(N)=TIXM(N)+TIX(M)
000064            TIYM(N)=TIYM(N)+TIY(M)
000065            TIZM(N)=TIZM(N)+TIZ(M)
000066            IF (WG(M) .EQ. 0.) GO TO 2
000067            WGM(N)=WGM(N)+WG(M)
000068            WGXM(N)=WGXM(N)+WGX(M)
000069            WGXXM(N)=WGXXM(N)+WGXX(M)
000070            WGYM(N)=WGYM(N)+WGY(M)
000071            WGYYM(N)=WGYYM(N)+WGYY(M)
000072            WGZM(N)=WGZM(N)+WGZ(M)
000073            WGZZM(N)=WGZZM(N)+WGZZ(M)
000074            TGIXM(N)=TGIXM(N)+TGIX(M)
000075            TGIYM(N)=TGIYM(N)+TGIY(M)
000076            TGIZM(N)=TGIZM(N)+TGIZ(M)
000077          2 CONTINUE
000078            M=M+1
000079            IF (M .GT. MF ) GO TO 3
000080            IF (N .EQ. 9 .AND. M .EQ. 21) M=40
000081            IF (N .EQ. 8 .AND. M .EQ. 21) M=40
000082            GO TO 19
000083          3 IF (WM(N) .EQ. 0.) GO TO 150
000084            XM(N)=WXM(N)/WM(N)
000085            YM(N)=WYM(N)/WM(N)
000086            ZM(N)=WZM(N)/WM(N)
000087            XIOM(N)=WYYM(N)+WZZM(N)+ TIXM(N)-WM(N)*(YM(N)*YM(N)+ZM(N)*ZM(N))
000088            YIOM(N)=WXXM(N)+WZZM(N)+ TIYM(N)-WM(N)*(XM(N)*XM(N)+ZM(N)*ZM(N))
000089            ZIOM(N)=WYYM(N)+WXXM(N)+ TIZM(N)-WM(N)*(YM(N)*YM(N)+XM(N)*XM(N))
000090        150 CONTINUE
000091            IF (WGM(N) .EQ. 0.) GO TO 5
000092          C *** INCLUDE GIMBALED ITEMS
000093            XGM(N)=WGXM(N)/WGM(N)
000094            YGM(N)=WGYM(N)/WGM(N)
000095            ZGM(N)=WGZM(N)/WGM(N)
000096            XGIOM(N)=WGYYM(N)+WGZZM(N)+TGIXM(N)-WGM(N)*(YGM(N)*YGM(N)+ZGM(N)*
000097           1     ZGM(N))+WGM(N)*((YGM(N)-GIMY)**2+(ZGM(N)-GIMZ)**2)
000098            YGIOM(N)=WGXXM(N)+WGZZM(N)+TGIYM(N)-WGM(N)*(XGM(N)*XGM(N)+ZGM(N)*
000099           1     ZGM(N))+WGM(N)*((XGM(N)-GIMX)**2+(ZGM(N)-GIMZ)**2)
000100            ZGIOM(N)=WGYYM(N)+WGXXM(N)+TGIZM(N)-WGM(N)*(YGM(N)*YGM(N)+XGM(N)*
000101           1     XGM(N))+WGM(N)*((XGM(N)-GIMX)**2+(YGM(N)-GIMY)**2)
000102            5 N=N+1
000103            GO TO (20,20,40,50,60,70,80,90,100,101), N
000104           20 MI=20
000105          C *** CALCULATION FOR BASIC ENGINE PROPELLANTS, P/RT 20.
000106            MF=20
000107            GO TO 4
000108           40 J=1
000109          C *** CALCULATION FOR BASIC ENGINE WET, PARTS 1-20.
000110           11 WM(N)=WM(J)
000111            WXM(N)=WXM(J)
000112            WXXM(N)=WXXM(J)
000113            WYM(N)=WYM(J)
000114            WYYM(N)=WYYM(J)
000115            WZM(N)=WZM(J)
000116            WZZM(N)=WZZM(J)
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      WXZM(N)=WXZM(J)
      WXYM(N)=WXYM(J)
      WYZM(N)=WYZM(J)
      TIXM(N)=TIXM(J)
      TIYM(N)=TIYM(J)
      TIZM(N)=TIZM(J)
      IF (WGM(J) .EQ. 0.) GO TO 12
      WGM(N)=WGM(J)
      WGXM(N)=WGXM(J)
      WGXXM(N)=WGXXM(J)
      WGYM(N)=WGYM(J)
      WGYYM(N)=WGYYM(J)
      WGZM(N)=WGZM(J)
      WGZZM(N)=WGZZM(J)
      TGIXM(N)=TGIXM(J)
      TGIYM(N)=TGIYM(J)
      TGIZM(N)=TGIZM(J)
   12 IF (J .EQ. 4 .AND. N .EQ. 6) GO TO 13
      IF (J .EQ. 1 .AND. N .EQ. 7) GO TO 14
      IF (J .EQ. 7 .AND. N .EQ. 9) GO TO 15
      MI=20
      MF=20
      GO TO 4
   50 IF (IAFLG .EQ. 1 ) RETURN
C *** CALCULATION FOR VEHICLE INTEGRATION DRY. PARTS 21-28.
C *** IF IAFLG=1, OPTION IS 'A'.
      MI=21
      MF=27
      GO TO 4
   60 MI=40
C *** CALCULATION FOR VEHICLE INTEGRATION PROPELLANTS. PART 40.
      MF=40
      GO TO 4
   70 J=4
C *** CALCULATION FOR VEHICLE INTEGRATION WET. PARTS 21-28,40.
      GO TO 11
   13 MI=40
      MF=40
      GO TO 4
   80 J=1
C *** CALCULATION FOR TOTAL ENGINE DRY. PARTS 1-19,21-28.
      GO TO 11
   14 MI=21
      MF=27
      GO TO 4
   90 MI=20
C *** CALCULATION FOR TOTAL ENGINE PROPELLANTS. PARTS 20,40.
      MF=40
      GO TO 4
  100 J=7
C *** CALCULATION FOR TOTAL ENGINE WET. PARTS 1-19,20,21-28,40.
      GO TO 11
   15 MI=20
      MF=40
      GO TO 4
  101 CONTINUE
      RETURN
      END
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@ ELT PRINT,1,720506, 33330

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000001                SUBROUTINE PRINT
000002          C *** THIS SUBROUTINE CONTROLLS ALL PRINTING EXCEPT DETAIL  WEIGHT STATEMENT.
000003          C *** PRINT OF SUMMARY WEIGHT STATEMENT.
000004                DIMENSION GCXIOM(3),GCYIOM(3),GCZIOM(3)
000005                DIMENSION H(21),CD(3),PN(4),R(12),PP(2)
000006                COMMON  DX,DY,DZ,G,GIMX,GIMY,GIMZ,IA,IAFLG,IAM,IASUB,IP,IPFL1,
000007               1IPFL2,IPSF,MIC,NI,NLINE,TGC,TIOX,TIOY,TIOZ,TMC,TPSC,TPRT1,TPRT2,
000008               2TPRT3,TPRT4,TPRT5,TPRTN1,TPRTN2,TPRTN3,TRL,TRS,TW,TWC,TX,TX1,
000009               3TY,TY1,TZ,TZ1,WTHE,M,
000010               4NPF(10),IMA(40),PSC(40),WC(40),GC(40),CM(40),PRT1(40),PRT2(40),
000011               5PRT3(40),PRT4(40),PRT5(40),WX(40),WGX(40),WXX(40),WGXX(40),WY(40),
000012               6WYY(40),WGY(40),WGYY(40),WZ(40),WGZ(40),WZZ(40),WGZZ(40),W(40),
000013               7WG(40),XIO(40),XGIO(40),YIO(40),YGIO(40),ZIO(40),ZGIO(40),X(40),
000014               8XG(40),Y(40),YG(40),Z(40),ZG(40),WXZ(40),WGXZ(40),TIX(40),TGIX(40)
000015               9,TIY(40),TGIY(40),TIZ(40),TGIZ(40),PW(3,40),TPW(3,9),
000016               AWXM(9),WGXM(9),WXXM(9),WGXXM(9),WYM(9),WGYM(9),WYYM(9),WGYYM(9),
000017               BWZM(9),WGZM(9),WZZM(9),WGZZM(9),WM(9),WGM(9),XIOM(9),XGIOM(9),
000018               CYIOM(9),YGIOM(9),ZIOM(9),ZGIOM(9),XM(9),XGM(9),YM(9),YGM(9),ZM(9),
000019               DZGM(9),WXZM(9),WGXZM(9),TIXM(9),TGIXM(9),TIYM(9),TGIYM(9),TIZM(9),
000020               ETGIZM(9),WXY(40),WYZ(40),WGXY(40),WGYZ(40),WXYM(9) ,WYZM(9),
000021               FAA,AB,AC,AD,AE,AF,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,
000022               GAW,AX,AY,AZ,WGXYM(9),WGYZM(9),WTMTL(26)
000023                DATA STAR/'*'/,DOL/'$'/
000024                WRITE (6,1)
000025              1 FORMAT(1H1,////////,50X,'SUMMARY WEIGHT STATEMENT',//,
000026               1 ' MA',52X,
000027               2 'WEIGHT   CENTER OF GRAVITY       GIMBALED INERTIA',
000028               317X,'PERCENT',/,56X,
000029               4 'LB.          INCHES              SLUG-FT. SQUARED',/,63X,
000030               5 'X     Y     Z', 6X, '  X-X       Y-Y       Z-Z'
000031               6,8X,'EST.    CAL.    ACT.')
000032                XGIO(20)=XGIO(20)/4637.
000033                YGIO(20)=YGIO(20)/4637.
000034                ZGIO(20)=ZGIO(20)/4637.
000035                XGIO(40)=XGIO(40)/4637.
000036                YGIO(40)=YGIO(40)/4637.
000037                ZGIO(40)=ZGIO(40)/4637.
000038                DO 41 I=1,3
000039                DO 41 N=1,9
000040             41 TPW(I,N)=0.
000041                N=1
000042                M=19
000043                K=1
000044                DO 5 I=1,9
000045                XIOM(I)=XIOM(I)/4637.
000046                YIOM(I)=YIOM(I)/4637.
000047                ZIOM(I)=ZIOM(I)/4637.
000048                XGIOM(I)=XGIOM(I)/4637.
000049                YGIOM(I)=YGIOM(I)/4637.
000050              5 ZGIOM(I)=ZGIOM(I)/4637.
000051             10 DO 2 I=N,M
000052                IF (W(I) .EQ. 0.) GO TO 2
000053                XGIO(I)=XGIO(I)/4637.
000054                YGIO(I)=YGIO(I)/4637.
000055                ZGIO(I)=ZGIO(I)/4637.
000056                DO 42 J=1,3
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000057            TPW(J,K)=TPW(J,K)+PW(J,I)
000058          42 PW(J,I)=PW(J,I)*100./W(I)
000059             WRITE (6,3) IMA(I),PRT1(I),PRT2(I),PRT3(I),PRT4(I),PRT5(I),W(I),
000060            1X(I),Y(I), Z(I),XGIO(I),YGIO(I),ZGIO(I),PW(3,I),PW(2,I),PW(1,I)
000061             3 FORMAT(I3,7X,4A4,A3,20X,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)          MAR72
000062             2 CONTINUE
000063               IF (M .EQ. 28) GO TO 11
000064               TPW(1,1)=TPW(1,1)*100./WM(1)
000065               TPW(2,1)=TPW(2,1)*100./WM(1)
000066               TPW(3,1)=TPW(3,1)*100./WM(1)
000067               IF (IMA(19) .EQ. 0) GO TO 43
000068               WRITE(6,44) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),
000069            1          WM(1),XM(1),YM(1),ZM(1),XGIOM(1),YGIOM(1),ZGIOM(1),
000070            2TPW(3,1),TPW(2,1),TPW(1,1)
000071          44 FORMAT(/,13X,'* NAME * ',4A4,A3,'TOTAL',3X                        MAR72
000072            X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                 MAR72
000073               GO TO 45
000074          43 WRITE (6,46) WM(1),XM(1),YM(1),ZM(1),XGIOM(1),YGIOM(1),ZGIOM(1),
000075            1TPW(3,1),TPW(2,1),TPW(1,1)
000076          46 FORMAT(/ 13X,'BASIC MOTOR INERTS',18X                             MAR72
000077            X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                 MAR72
000078          45 IF (WM(2) .EQ. 0.) GO TO 47
000079               TPW(1,2)=PW(1,20)*100./WM(2)
000080               TPW(2,2)=PW(2,20)*100./WM(2)
000081               TPW(3,2)=PW(3,20)*100./WM(2)
000082               TPW(1,3)=(TPW(1,1)/100.*WM(1)+PW(1,20))*100./ WM(3)
000083               TPW(2,3)=(TPW(2,1)/100.*WM(1)+PW(2,20))*100./WM(3)
000084               TPW(3,3)=(TPW(3,1)/100.*WM(1)+PW(3,20))*100./WM(3)
000085               IF (IMA(19) .EQ. 0) GO TO 48
000086               WRITE (6,49) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),WM(2),
000087            1XM(2),YM(2),ZM(2),XGIOM(2),YGIOM(2),ZGIOM(2),TPW(3,2),TPW(2,2),
000088            2TPW(1,2)
000089          49 FORMAT(13X,'* NAME * ',4A4,A3,'PROP.',3X                          MAR72
000090            X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                 MAR72
000091               WRITE(6,50) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),WM(3),
000092            1XM(3),YM(3),ZM(3),XGIOM(3),YGIOM(3),ZGIOM(3),TPW(3,3),TPW(2,3),
000093            2TPW(1,3)
000094          50 FORMAT( 13X,'* NAME * ',4A4,A3,'TOTAL',3X                         MAR72
000095            X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                 MAR72
000096               GO TO 47
000097          48 WRITE(6,51) WM(2),XM(2),YM(2),ZM(2),XGIOM(2),YGIOM(2),ZGIOM(2),
000098            1TPW(3,2),TPW(2,2),TPW(1,2),WM(3),XM(3),YM(3),ZM(3),XGIOM(3),
000099            2YGIOM(3),ZGIOM(3),TPW(3,3),TPW(2,3),TPW(1,3)
000100          51 FORMAT(13X,'BASIC MOTOR PROPELLANTS ',12X                         MAR72
000101            X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1                                  MAR72
000102            1         /,13X,'BASIC MOTOR',25X                                  MAR72
000103            X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                 MAR72
000104               GO TO 52
000105          47 WRITE(6,53)
000106          53 FORMAT(/)
000107          52 CONTINUE
000108               IF (IAFLG .EQ. 1) GO TO 20
000109                  N=21
000110                  M=28
000111               K=4
000112                  GO TO 10
000113          11 CONTINUE
000114               TPW(1,4)=TPW(1,4)*100./WM(4)
000115               TPW(2,4)=TPW(2,4)*100./WM(4)
000116               TPW(3,4)=TPW(3,4)*100./WM(4)
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000117            IF (IMA(28) .EQ. 0) GO TO 54
000118            WRITE (6,44) PRT1(28),PRT2(23),PRT3(28),PRT4(28),PRT5(28),WM(4),
000119           1XM(4),YM(4),ZM(4),XGIOM(4),YGIOM(4),ZGIOM(4),TPW(3,4),TPW(2,4),
000120           2TPW(1,4)
000121            GO TO 55
000122         54 WRITE(6,56) WM(4),XM(4),YM(4),ZM(4),XGIOM(4),YGIOM(4),ZGIOM(4),
000123           1TPW(3,4),TPW(2,4),TPW(1,4)
000124         56 FORMAT(/ ,13X,'NON-CONTRACTUAL INERT',15X                          MAR72
000125           X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                  MAR72
000126         55 IF (WM(5) .EQ. 0.) GO TO 57
000127            TPW(1,5)=PW(1,40)*100./WM(5)
000128            TPW(2,5)=PW(2,40)*100./WM(5)
000129            TPW(3,5)=PW(3,40)*100./WM(5)
000130            TPW(1,6)=(TPW(1,4)/100.*WM(4)+PW(1,40))*100./WM(6)
000131            TPW(2,6)=(TPW(2,6)/100.*WM(4)+PW(2,40))*100./WM(6)
000132            TPW(3,6)=(TPW(3,6)/100.*WM(4)+PW(3,40))*100./WM(6)
000133            IF (IMA(28) .EQ. 0) GO TO 758
000134            WRITE (6,49) PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),WM(5),
000135           1XM(5),YM(5),ZM(5),XGIOM(5),YGIOM(5),ZGIOM(5),TPW(3,5),TPW(2,5),
000136           2TPW(1,5)
000137            WRITE (6,50) PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),WM(6),
000138           1XM(6),YM(6),ZM(6),XGIOM(6),YGIOM(6),ZGIOM(6),TPW(3,6),TPW(2,6),
000139           2TPW(1,6)
000140            GO TO 57
000141        758 WRITE (6,58) WM(5),XM(5),YM(5),ZM(5),XGIOM(5),YGIOM(5),ZGIOM(5),
000142           1TPW(3,5),TPW(2,5),TPW(1,5),WM(6),XM(6),YM(6),ZM(6),XGIOM(6),
000143           2YGIOM(6),ZGIOM(6),TPW(3,6),TPW(2,6),TPW(1,6)
000144         58 FORMAT(
000145           1 13X,'NON-CONTRACTUAL PROPELLANT',10X                              MAR72
000146           X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1                                   MAR72
000147           2                /,13X,'NON-CONTRACTUAL TOTAL',15X                  MAR72
000148           X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                  MAR72
000149         57 WRITE(6,53)
000150            WRITE(6,8) WGM(7),XGM(7),YGM(7),ZGM(7),XGIOM(7),YGIOM(7),ZGIOM(7)
000151          8 FORMAT(/,13X,'GIMBALED INERTS',21X                                MAR72
000152           Y ,F10.1,3F6.1,2X,3F11.1)                                           MAR72
000153             IF (WGM(8) .EQ. 0.) GO TO 802
000154            WRITE(6,801)
000155           1          WGM(8),XGM(8),YGM(8),ZGM(8),XGIOM(8),YGIOM(8),ZGIOM(8),
000156           2          WGM(9),XGM(9),YGM(9),ZGM(9),XGIOM(9),YGIOM(9),ZGIOM(9)
000157        801 FORMAT(13X,'GIMBALED PROPELLANTS',16X,F10.1,3F6.1,2X,3F11.1,       MAR72
000158           1  /,13X,'TOTAL GIMBALED       ',15X                               MAR72
000159           Y ,F10.1,3F6.1,2X,3F11.1)                                           MAR72
000160        802 WRITE (6,12)
000161         12 FORMAT(/,55X,'WEIGHT   CENTER OF GRAVITY          INERTIA',
000162           121X,'PERCENT' ,/56X,
000163           2'LB.          INCHES            ABOUT MOTOR C. G.',/,88X           MAR72
000164           3'SLUG-FT. SQUARED',/,63X,'X      Y      Z',8X,' X-X      Y-Y      Z-Z'
000165           4,8X,'EST.    CAL.    ACT.')
000166            TPW(1,7)= (TPW(1,1)/100.*WM(1)+TPW(1,4)/100.*WM(4))*100./WM(7)
000167            TPW(2,7)= (TPW(2,1)/100.*WM(1)+TPW(2,4)/100.*WM(4))*100./WM(7)
000168            TPW(3,7)= (TPW(3,1)/100.*WM(1)+TPW(3,4)/100.*WM(4))*100./WM(7)
000169            WRITE(6,59)WM(7),XM(7),YM(7),ZM(7),XIOM(7),YIOM(7),ZIOM(7),
000170           1TPW(3,7),TPW(2,7),TPW(1,7)
000171         59 FORMAT(13X,'TOTAL MOTOR INERTS',18X                               MAR72
000172           X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                  MAR72
000173            IF (WM(8) .EQ. 0.) GO TO 20
000174            TPW(1,8)= (PW(1,20)+PW(1,40))*100./WM(8)
000175            TPW(2,8)= (PW(2,20)+PW(2,40))*100./WM(8)
000176            TPW(3,8)= (PW(3,20)+PW(3,40))*100./WM(8)
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000177            TPW(1,9)= (TPW(1,7)/100.*WM(7)+TPW(1,8)/100.*WM(8))*100./WM(9)
000178            TPW(2,9)= (TPW(2,7)/100.*WM(7)+TPW(2,8)/100.*WM(8))*100./WM(9)
000179            TPW(3,9)= (TPW(3,7)/100.*WM(7)+TPW(3,8)/100.*WM(8))*100./WM(9)
000180            WRITE (6,61) WM(8),XM(8),YM(8),ZM(8),XIOM(8),YIOM(8),ZIOM(8),
000181           1TPW(3,8),TPW(2,8),TPW(1,8),WM(9),XM(9),YM(9),ZM(9),XIOM(9),YIOM(9)
000182           2,ZIOM(9),TPW(3,9),TPW(2,9),TPW(1,9)
000183         61 FORMAT(13X,'TOTAL MOTOR PROPELLANTS',13X                          MAR72
000184           X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1                                  MAR72
000185           1      /,13X,'TOTAL MOTOR',25X                                     MAR72
000186           X ,F10.1,3F6.1,2X,3F11.1,2X,3F5.1)                                 MAR72
000187         20 CONTINUE
000188       C *** WEIGHT AND BALANCE DATA-ENGINE.
000189            WRITE(6,17)
000190         17 FORMAT (1H1,////////////,24X,'WEIGHT AND BALANCE DATA',/)
000191            IF (IMA(19).EQ. 0 ) GO TO 62
000192            WRITE (6,63) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19)
000193         63 FORMAT ( 24X,'* NAME * ',4A4,A3,//)
000194            GO TO 64
000195         62 WRITE (6,65)
000196         65 FORMAT(27X,'BASIC MOTOR',//)                                      MAR72
000197         64 WRITE (6,86)
000198         86 FORMAT(45X,'WEIGHT   CENTER OF GRAVITY',/,46X,
000199           1'LB.        INCHES',//,54X,'X      Y      Z')
000200            IF (IMA(19) .EQ. 0) GO TO 87
000201            WRITE(6,88) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),WM(1),
000202           1XM(1),YM(1),ZM(1)
000203         88 FORMAT(/,'      * NAME * ',4A4,A3,'INERT',3X,F10.1,1X,3F6.1)      MAR72
000204            IF (WM(2) .EQ. 0.) GO TO 89
000205            WRITE (6,90) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),WM(2),
000206           1XM(2),YM(2),ZM(2),PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),
000207           2WM(3),XM(3),YM(3),ZM(3)
000208         90 FORMAT(/'      * NAME * ',4A4,A3,'PROP.',3(,F10.1,1X,3F6.1,//,
000209           1        '      * NAME * ',4A4,A3,'TOTAL',3(,F10.1,1X,3F6.1)      MAR72
000210            GO TO 89
000211         87 WRITE(6,91)WM(1),XM(1),YM(1),ZM(1)
000212         91 FORMAT(//,'      MOTOR INERT',25X,F10.1,1X,3F6.1)                 MAR72
000213            IF (WM(2) .EQ. 0.) GO TO 89
000214            WRITE(6,92) WM(2),XM(2),YM(2),ZM(2),WM(3),XM(3),YM(3),ZM(3)
000215         92 FORMAT(/,'      MOTOR PROPELLANTS',19X,F10.1,1X,3F6.1,//,        MAR72
000216           1          '      MOTOR ',30X,F10.1,1X,3F6.1)                     MAR72
000217         89 IF (IMA(19) .EQ. 0) GO TO 93
000218            WRITE (6,94) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),XIOM(1),
000219           1YIOM(1),ZIOM(1)
000220         94 FORMAT(///,7X'THE INERTIA OF * NAME * ',4A4,A3,/,7X,
000221           1 'INERT ABOUT ITS CENTER OF GRAVITY IS',//,16X,'IX =',           MAR72
000222           2F13.2,'SLUG-FT. SQUARED',//,16X,'IY =',F13.2,' SLUG-FT. SQUARED',
000223           3//,16X,'IZ =',F13.2,'SLUG-FT. SQUARED')
000224            GO TO 95
000225         93 WRITE(6,96) XIOM(1),YIOM(1),ZIOM(1)
000226         96 FORMAT(///,7X,'THE INERTIA OF THE MOTOR INERTS ABOUT ITS CENTER OF  MAR72*NEW
000227           1 GRAVITY IS'                                                      MAR72*NEW
000228           2          ,//,16X,'IX =',F13.2,' SLUG-FT. SQUARED',//,16X,'IY =', MAR72*NEW
000229           2F13.2,' SLUG-FT. SQUARED',//,16X,'IZ =',F13.2,' SLUG-FT. SQUARED')    **-2
000230         95 IF (WM(2) .EQ. 0.) GO TO 97
000231            IF (IMA(19) .EQ. 0) GO TO 98
000232            WRITE (6,101) PRT1(19),PRT2(19),PRT3(19),PRT4(19),PRT5(19),XIOM(3)
000233           1,YIOM(3),ZIOM(3)
000234        101 FORMAT(// ,7X,'THE INERTIA OF * NAME * ',4A4,A3,/,7X,
000235           1 'ABOUT ITS CENTER OF GRAVITY IS',//,16X,'IX =',                 MAR72
000236           2F13.2,' SLUG-FT. SQUARED',//,16X,'IY =',F13.2,' SLUG-FT. SQUARED',
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000237            3//,16X,'IZ =',F13.2,' SLUG-FT. SQUARED')
000238             GO TO 97
000239           98 WRITE(6,103) XIOM(3),YIOM(3),ZIOM(3)
000240          103 FORMAT(//,7X,'THE INERTIA OF THE BASIC MOTOR ABOUT ITS CENTER OF G    MAR72*NEW
000241            1RAVITY IS',//,16X,'IX =',F13.2,' SLUG-FT. SQUARED',//,16X,'IY =',     MAR72**-1
000242            2F13.2,' SLUG-FT. SQUARED',//,16X,'IZ =',F13.2,' SLUG-FT. SQUARED')
000243           97 CONTINUE
000244             IF (IAFLG .EQ. 1) GO TO 99
000245         C *** SUMMARY WEIGHT STATEMENT-VEHICLE INTEGRATION.
000246             WRITE(6,19)
000247           19 FORMAT(1H1,////////////,26X,'SUMMARY WEIGHT STATEMENT ',/)
000248             IF (IMA(28) .EQ. 0) GO TO 104
000249             WRITE (6,105) PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28)
000250          105 FORMAT (26X,'* NAME * ',4A4,A3,/ )
000251             GO TO 106
000252          104 WRITE(6,133)                                                      MAR72
000253          106 WRITE (6,108)
000254          108 FORMAT( / ,' MA',42X,'WEIGHT   CENTER OF GRAVITY',/,46X,
000255            1'LB.',10X,'INCHES',/,57X,'X      Y      Z')
000256             DO 21 I=21,27
000257             IF (W(I) .EQ. 0.) GO TO 21
000258             WRITE (6,109)IMA(I),PRT1(I),PRT2(I),PRT3(I),PRT4(I),PRT5(I),W(I),
000259            1X(I),Y(I),Z(I)
000260          109 FORMAT(/,I3,3X,4A4,A3,17X,F10.1,1X,3F6.1)
000261           21 CONTINUE
000262             IF (IMA(28) .EQ. 0) GO TO 110
000263             WRITE (6,111) PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),WM(4),
000264            1XM(4),YM(4),ZM(4)
000265          111 FORMAT (//,'      * NAME * ',4A4,A3,'DRY',7X,F10.1,1X,3F6.1)
000266             IF (WM(5) .EQ. 0.) GO TO 112
000267             WRITE (6,113) PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),WM(5),
000268            1XM(5),YM(5),ZM(5),PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),
000269            1WM(6),XM(6),YM(6),ZM(6)
000270          113 FORMAT ( /, '      * NAME * ',4A4,A3,'PROP.',5X,F10.1,1X,3F6.1,//,
000271            1'      * NAME * ',4A4,A3,'WET',7X,F10.1,1X,3F6.1)
000272             GO TO 112
000273          110 WRITE (6,114) WM(4),XM(4),YM(4),ZM(4)
000274          114 FORMAT( //,'      NON-CONTRACTUAL INERTS',15X,F10.1,1X,3F6.1)       MAR72
000275             IF (WM(5) .EQ. 0.) GO TO 112
000276             WRITE (6,115) WM(5),XM(5),YM(5),ZM(5),WM(6),XM(6),YM(6),ZM(6)
000277          115 FORMAT( /,'      NON-CONTRACTUAL PROPELLANTS',10X,F10.1,1X,        MAR72
000278            13F6.1,//,'      NON-CONTRACTUAL TOTAL'16X,F10.1,1X,3F6.1)         MAR72
000279          112 CONTINUE
000280         C *** WEIGHT AND BALANCE DATA-VEHICLE INTEGRATION.
000281             WRITE(6,17)
000282             IF (IMA(28) .EQ. 0)GO TO 122
000283             WRITE(6,63)PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28)
000284             GO TO 124
000285          122 WRITE(6,123)
000286          123 FORMAT(27X,'NON-CONTRACTUAL',//)                                  MAR72
000287          124 WRITE(6,86)
000288             IF (IMA(28).EQ. 0) GO TO 125
000289             WRITE(6,88)PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),WM(4),
000290            1XM(4),YM(4),ZM(4)
000291             IF(WM(5).EQ. 0.) GO TO 126
000292             WRITE(6,90)PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),WM(5),
000293            1XM(5),YM(5),ZM(5),PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),
000294            2WM(6),XM(6),YM(6),ZM(6)
000295             GO TO 125
000296          125 WRITE(6,127)WM(4),XM(4),YM(4),ZM(4)
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000297          127 FORMAT(//,'     NON-CONTRACTUAL INERTS',11X,F10.1,1X,3F6.1)          MAR72
000298              IF (WM(5) .EQ. 0.)GO TO 126
000299              WRITE (6,128)WM(5),XM(5),YM(5),ZM(5),WM(6),XM(6),YM(6),ZM(6)
000300          128 FORMAT(/,'      NON-CONTRACTUAL PROPELLANTS',6X,F10.1,1X,           MAR72
000301             13F6.1,//,'      NON-CONTRACTUAL TOTAL',12X,F10.1,1X,3F6.1)          MAR72
000302          126 IF (IMA(28) .EQ. 0) GO TO 129
000303              WRITE (6,94)PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),XIOM(4),
000304             1YIOM(4),ZIOM(4)
000305              GO TO 130
000306          129 WRITE(6,131) XIOM(4),YIOM(4),ZIOM(4)
000307          131 FORMAT(///,7X,'THE INERTIA OF THE NON-CONTRACTUAL INTERS  ABOUT IT   MAR72
000308             1S CENTER OF GRAVITY IS',//,16X,'IX =',F13.2,' SLUG-FT. SQUARED',
000309             2//,16X,'IY =',F13.2,' SLUG-FT. SQUARED',//,16X,'IZ =',F13.2,
000310             3' SLUG-FT. SQUARED' )
000311          130 IF(WM(5) .EQ. 0.) GO TO 99
000312              IF(IMA(28) .EQ. 0) GO TO 133
000313              WRITE (6,101) PRT1(28),PRT2(28),PRT3(28),PRT4(28),PRT5(28),XIOM(6)
000314             1,YIOM(6),ZIOM(6)
000315              GO TO 99
000316          133 WRITE(6,134)XIOM(6),YIOM(6),ZIOM(6)
000317          134 FORMAT( //,7X,'THE INERTIA OF THE NON-CONTRACTUAL TOTAL   ABOUT IT   MAR72
000318             1S CENTER OF GRAVITY IS',//,16X,'IX =',F13.2,' SLUG-FT. SQUARED',
000319             2//,16X,'IY =',F13.2,' SLUG-FT. SQUARED',//,16X,'IZ =',F13.2,
000320             3' SLUG-FT. SQUARED' )
000321           99 CONTINUE
000322          C *** WEIGHT AND BALANCE DATA
000323              WRITE(6,28)
000324           28 FORMAT(1H1,///////,24X,'WEIGHT AND BALANCE DATA',//,47X,
000325             1'GIMBALED COMPONENTS'/' MA',8X,'ITEM',31X,'WEIGHT   CENTER OF GRAV
000326             2ITY',12X,'GIMBALED INERTIA*',/,48X,'LB.',10X,'INCHES',18X,
000327             3'SLUG-FT. SQUARED',/,56X,'X      Y      Z',16X,'X-X     Y-Y     Z-Z'
000328             4,)
000329              DO 29 I=1,40
000330              IF (WG(I) .EQ. 0.) GO TO 29
000331              WRITE(6,31) IMA(I),
000332             1          PRT1(I),PRT2(I),PRT3(I),PRT4(I),PRT5(I),WG(I),XG(I),
000333             2YG(I),ZG(I),XGIO(I),YGIO(I),ZGIO(I)
000334           31 FORMAT(/,I3,5X,4A4,A3,14X,F10.1,1X,3F6.1,8X,3F9.2)
000335           29 CONTINUE
000336              IF(IAFLG .NE. 1) GO TO 666
000337              DO 667 I=1,3
000338              J=I+6
000339              WGM(J)=WGM(I)
000340              XGM(J)=XGM(I)
000341              YGM(J)=YGM(I)
000342              ZGM(J)=ZGM(I)
000343              WGXXM(J)=WGXXM(I)
000344              WGYYM(J)=WGYYM(I)
000345              WGZZM(J)=WGZZM(I)
000346              TGIXM(J)=TGIXM(I)
000347              TGIYM(J)=TGIYM(I)
000348              TGIZM(J)=TGIZM(I)
000349              XGIOM(J)=XGIOM(I)
000350              YGIOM(J)=YGIOM(I)
000351          667 ZGIOM(J)=ZGIOM(I)
000352          666 CONTINUE
000353              WRITE(6,136)WGM(7),XGM(7),YGM(7),ZGM(7),XGIOM(7),YGIOM(7),ZGIOM(7)
000354          136 FORMAT( /,11X,'GIMBALED INERTS',15X,F10.1,1X,3F6.1,8X,3F9.2)          MAR72
000355              IF (WGM(8) .EQ. 0.) GO TO 137
000356              WRITE (6,138)WGM(8),XGM(8),YGM(8),ZGM(8),XGIOM(8),YGIOM(8),
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000357          1ZGIOM(8),WGM(9),XGM(9),YGM(9),ZGM(9),XGIOM(9),YGIOM(9),ZGIOM(9)
000358        138 FORMAT(/,11X,'GIMBALED PROPELLANTS   ',7X,F10.1,1X,3F6.1,8X,3F9.2,
000359          1//,11X,'TOTAL GIMBALED',16X,F10.1,1X,3F6.1,8X,3F9.2)                MAR72
000360        137 WRITE(6,139)GIMX,GIMY,GIMZ
000361        139 FORMAT( /,' *INERTIA ABOUT THE GIMBAL POINT (LOCATED AT X=',F6.1,
000362          1'  Y=',F6.1,'  Z=',F6.1,' INCHES.)')
000363      C *** GIMBALED COMPONENTS.
000364            WRITE (6,33) WGM(7),XGM(7),YGM(7),ZGM(7)
000365         33 FORMAT(1H1,////////////,24X,'GIMBALED COMPONENTS',///,46X,
000366          1'WEIGHT   CENTER OF GRAVITY',/,47X,'LB.',10X,'INCHES',//,56X,
000367          2'X      Y      Z',//,'   GIMBALED INERTS',23(,F10.1,1X,3F6.1)        MAR72
000368            IF (WGM(8) .EQ. 0.)GO TO 140
000369            WRITE(6,141)WGM(8),XGM(8),YGM(8),ZGM(8),WGM(9),XGM(9),YGM(9),
000370          1ZGM(9)
000371        141 FORMAT(
000372          1                 /,'   GIMBALED PROPELLANTS   '15X,F10.1,1X,3F6.1,
000373          2  //,'   TOTAL GIMBALED',24X,F10.1,1X,3F6.1)                       MAR72
000374        140 WRITE(6,142) WGM(7),XGIOM(7),YGIOM(7),ZGIOM(7)
000375        142 FORMAT (
000376          1////,22X'INERTIA ABOUT GIMBAL POINT',//,46(,'WEIGHT',10X,
000377          2'INERTIA',/,47X,'LB.      SLUG-FT. SQUARED',//,56X,'X-X      Y-Y
000378          3  Z-Z',//,'   GIMBALED INERTS',23X,F10.1,3F10.1)                    MAR72
000379            IF (WGM(8) .EQ. 0.) GO TO 143
000380            WRITE(6,144) WGM(8),XGIOM(8),YGIOM(8),ZGIOM(8),WGM(9),XGIOM(9),
000381          1YGIOM(9),ZGIOM(9)
000382        144 FORMAT(
000383          1         /,'   GIMBALED PROPELLANTS   ',15X,F10.1,3F8.2,
000384          2  //,'   TOTAL GIMBALED',24X,F10.1,3F8.2)                          MAR72
000385      C     CALCULATION OF GIMBALED COMPONENTS INERTIA ABOUT CENTER OF GRAVITY
000386        143 CONTINUE
000387            WRITE(6,67)
000388         67 FORMAT(///,20X,'INERTIA ABOUT CENTER OF GRAVITY')
000389            DO 66 I=1,3
000390            N=I+6
000391            IF(WGM(N) .EQ. 0.) GO TO 66
000392            GCXIOM(I)=WGYYM(N)+WGZZM(N)+TGIXM(N)-WGM(N)*(YGM(N)*YGM(N)
000393          1+ZGM(N)*ZGM(N))
000394            GCYIOM(I)=WGXXM(N)+WGZZM(N)+TGIYM(N)-WGM(N)*(XGM(N)*XGM(N)
000395          1+ZGM(N)*ZGM(N))
000396         66 GCZIOM(I)=WGYYM(N)+WGXXM(N)+TGIZM(N)-WGM(N)*(YGM(N)*YGM(N)
000397          1+XGM(N)*XGM(N))
000398            DO 77 I=1,3
000399            GCXIOM(I)=GCXIOM(I)/4637.
000400            GCYIOM(I)=GCYIOM(I)/4637.
000401         77 GCZIOM(I)=GCZIOM(I)/4637.
000402            WRITE (6,68) WGM(7),GCXIOM(1),GCYIOM(1),GCZIOM(1)
000403         68 FORMAT(/,'   GIMBALED INERTS',23X,F10.1,3F8.2)                     MAR72
000404            IF (WGM(8) .EQ. 0.) GO TO 145
000405            WRITE(6,144)                                                      MAR72
000406          1WGM(8),GCXIOM(2),GCYIOM(2),GCZIOM(2),
000407          2WGM(9),GCXIOM(3),GCYIOM(3),GCZIOM(3)
000408        145 WRITE(6,164)
000409            WRITE(6,147)
000410        147 FORMAT(////////,25X,'MATERIAL WEIGHT BREAKDOWN',//,15X,'MATERIAL',
000411          11CX,'CODE',15X,'WEIGHT (LB.)')
000412            IF(WTMTL(1) .NE. 0.) WRITE(6,148) WTMTL(1)
000413        148 FORMAT(12X,'ALUM',19X,'A',15X,F10.1)
000414            IF(WTMTL(2) .NE. 0.) WRITE(6,149) WTMTL(2)
000415        149 FORMAT(12X,'BORAL',18X,'B',15X,F10.1)
000416            IF(WTMTL(3) .NE. 0.) WRITE(6,150) WTMTL(3)
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000417          150 FORMAT(12X,'CRES-300',15X,'C',15X,F10.1)
000418              IF(WTMTL(4) .NE. 0.) WRITE(6,151) WTMTL(4)
000419          151 FORMAT(12X,'CRES-400-664',11X,'D',15X,F10.1)
000420              IF(WTMTL(5) .NE. 0.) WRITE(6,152) WTMTL(5)
000421          152 FORMAT(12X,'ELECTRICAL',13X,'E',15X,F10.1)
000422              IF(WTMTL(6) .NE. 0.) WRITE(6,153) WTMTL(6)
000423          153 FORMAT(12X,'COPPER',17X,'F',15X,F10.1)
000424              IF(WTMTL(7) .NE. 0.) WRITE(6,154) WTMTL(7)
000425          154 FORMAT(12X,'GRAPHITE',15X,'G',15X,F10.1)
000426              IF(WTMTL(8) .NE. 0.) WRITE(6,155) WTMTL(8)
000427          155 FORMAT(12X,'HASTELLOY',14X,'H',15X,F10.1)
000428              IF(WTMTL(9) .NE. 0.) WRITE(6,156) WTMTL(9)
000429          156 FORMAT(12X,'INCONEL',16X,'I',15X,F10.1)
000430              IF(WTMTL(10) .NE. 0.) WRITE(6,157) WTMTL(10)
000431          157 FORMAT(12X,'A-286',18X,'J',15X,F10.1)
000432              IF (WTMTL(12) .NE. 0.) WRITE(6,158) WTMTL(12)
000433          158 FORMAT(12X,'LEAD',19X,'L',15X,F10.1)
000434              IF(WTMTL(13) .NE. 0.) WRITE(6,159) WTMTL(13)
000435          159 FORMAT(12X,'MOLYBDENUM',13X,'M',15X,F10.1)
000436              IF(WTMTL(14) .NE. 0.) WRITE(6,160) WTMTL(14)
000437          160 FORMAT(12X,'NITROGEN-LIQUID',8X,'N',15X,F10.1)
000438              IF(WTMTL(19) .NE. 0.) WRITE(6,161) WTMTL(19)
000439          161 FORMAT(12X,'STEEL CARBON',11X,'S',15X,F10.1)
000440              IF(WTMTL(20) .NE. 0.) WRITE(6,162) WTMTL(20)
000441          162 FORMAT(12X,'TITANIUM',15X,'T',15X,F10.1)
000442              IF(WTMTL(23) .NE. 0.) WRITE(6,163) WTMTL(23)
000443          163 FORMAT(12X,'WESTINGHOUSE SUPPLIED'2X,'W',15X,F10.1)
000444              WRITE(6,164)
000445          164 FORMAT(1H1)
000446        C *** CALCULATION AND PRINTING OF PRODUCTS OF INERTIA
000447              WRITE(6,165)
000448          165 FORMAT(////////////////,20X,'TOTAL MOTOR PRODUCTS OF INERTIA',///,      MAR72
000449             110X,'MOTOR INERT IOXZ   MOTOR INERT IOXY   MOTOR INERT IOYZ')         MAR72
000450              I=1
000451              IF(IAFLG .NE. 1) I=7
000452              J=I+2
000453              PIOXZ=WXZM(I)-WM(I)* XM(I)*ZM(I)
000454              PIOXY=WXYM(I)-WM(I)* XM(I)*YM(I)
000455              PIOYZ=WYZM(I)-WM(I)* YM(I)*ZM(I)
000456              WRITE(6,166) PIOXZ,PIOXY,PIOYZ
000457          166 FORMAT(10X,F10.0, 9X,F10.0, 9X,F10.0)
000458              K=I+1
000459              IF(WM(K) .EQ. 0.) GO TO 170
000460              PIOXZ=WXZM(J)-WM(J)* XM(J)*ZM(J)
000461              PIOXY=WXYM(J)-WM(J)* XM(J)*YM(J)
000462              PIOYZ=WYZM(J)-WM(J)* YM(J)*ZM(J)
000463              WRITE(6,167)PIOXZ,PIOXY,PIOYZ
000464          167 FORMAT( /,10X'MOTOR TOT. IOXZ    MOTOR TOT. IOXY    MOTOR TOT. IOY   MAR72
000465             1Z',/ ,10X,F10.0, 9X,F10.0, 9X,F10.0)
000466          170 WRITE(6,164)
000467        C *** READ AND WRITE HISTORY OF CHANGES
000468              READ (    5,200,END=201) H(1)
000469          200 FORMAT(A1)
000470              IF (H(1) .NE. AH) RETURN
000471              L=1
000472          202 READ(5,203, END=201) H,CC,CD,PN,PP,P
000473          203 FORMAT (A1,A3,19A4,T1,A3,A1,2A4,A2,3A4,2A4 ,A2,11A4)
000474              IF(H(1) .EQ. AF) GO TO 201
000475              IF (H(1) .NE. STAR) GO TO 204
000476              NLINE=10
```

```
000477            WRITE(6,164)
000478        211 CONTINUE
000479            WRITE(6,205) H
000480        205 FORMAT(////,20X,'CHANGE ANALYSIS HISTORY' //,10XA1,A3,19A4,//)
000481            WRITE(6,212)
000482        212 FORMAT(
000483           1' CHG',5X,'DATE',8X,'PART NO.',5X,'WEIGHT DIFF.', 5X,'REMARKS',/)
000484            GO TO 202
000485        204 IF (H(1) .EQ. DOL) GO TO 206
000486            NLINE=NLINE+1
000487            IF( NLINE .LT. 55) GO TO 213
000488            WRITE(6,164)
000489            WRITE(6,212)
000490            NLINE=0
000491        213 CONTINUE
000492            IF (L .GT. 1 ) GO TO 207
000493            WRITE (6,208) CC,CD,PN,PP,R
000494        208 FORMAT(  1X,A3,3X,A1,2A4,3X,A2,3A4,3X,2A4,3X,A2,11A4)
000495            L=2
000496            GO TO 202
000497        207 WRITE (6,209) H
000498        209 FORMAT ( 46X,A1,A3,19A4)
000499            GO TO 202
000500        206 L=1
000501            GO TO 202
000502        201 WRITE (6,210)
000503        210 FORMAT (1H1,/////,50X,'END OF JOB - NO MORE CARDS')
000504            RETURN
000505            END
```

7. 14:00:55

END CUR

```
<****∆****1****∆****2****∆****3****∆****4****∆****5****∆****6****∆****7****∆****8****∆****9****∆****0****∆****1****∆****2****∆****3*>
*****************************************ISD-28.08:INFORMATION-SYSTEMS-DESIGN:15-MAY-1972*****************************************
***∆***1***∆***2***∆***3***∆***4***∆***5***∆***6***∆***7***∆***0***∆***1***∆***2***∆***3***∆***4***∆***5***∆***6***∆***7***∆***0***∆
[]#∆_ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[]#∆ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[]#∆
```


16 MAY 72 P 14:00:55 IDENT=VRONAY ACCOUNT=428218 CARDS IN= 10, OUT= 0

PAGES= 37, LINES= 1830. TIME=00:00:08 (HMS)

*** USER NOTICES - MAY 16, 1972 ***

****

ISD'S 1108 WILL BE UNAVAILABLE FOR TERMINAL SERVICE FROM 7:00 - 7:30 TOMORROW MORNING (5/17/72) IN ADDITION TO THE NORMALLY SCHEDULED DOWN TIME, TO MAKE EQUIPTMENT REPAIRS.

****

(1) ISD 1108 TERMINAL SERVICE WILL BE AVAILABLE AS SCHEDULED BELOW UNLESS OTHERWISE SPECIFIED IN A USER NOTICE.

MON :	07:00 - 24:00
TUE - FRI :	00:00 - 03:00 ; 07:00 - 24:00
SAT :	00:00 - 22:00
SUN :	04:00 - 22:00

(2) RON/I TELEPHONE NUMBERS

10 CHAR/SEC 415-635-1051 (4 PORTS)

**** 415-635-9559 IS NOW AVAILABLE FOR USE AS A 30 CHAR/SEC LOW SPEED PORT.
**** ON 5/17/72, 415-562-4294 WILL BE TAKEN OUT OF SERVICE AS A LOW SPEED PORT.

(3) EFFECTIVE MONDAY - FRIDAY TURNAROUND TIME SHOULD BE REDUCED BETWEEN THE HOURS OF 10:30 - 11:30 AND 14:00 - 17:00 FOR USERS SUBMITTING NON-TAPE JOBS WITH RUN TIMES ESTIMATED AT LESS THAN 6 MINUTES.

(4) THE 1004 DIAL-UP PHONE NUMBERS ARE LISTED BELOW.

415-562-0809 AND 415-562-0810

(5) ATTENTION RON/I USERS:

BEGINNING MAY 15, A MAJOR REVISION TO THE RON/I SYSTEM WILL TAKE PLACE. ALL COMMANDS WILL REQUIRE AT LEAST 2 CHARACTERS. THE SIGN-ON REQUIRES YOUR 6 CHARACTER ACCOUNT NUMBER IN ADDITION TO YOUR SITE CODE (@@SITEA0,123456). THE RON/I MANUAL IS AVAILABLE FROM THE ISD DOCUMENT LIBRARY.

```
<***Δ****1****Δ****2****Δ****3****Δ****4****Δ****5****Δ****6****Δ****7****Δ****8****Δ****9****Δ****0****Δ****1****Δ****2****Δ****3*>
*** *********************************ISD-28.08:INFORMATION-SYSTEMS-DESIGN:15-MAY-1972**********************************
 *Δ***1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***0***Δ***1***Δ***2***Δ***3***Δ***4***Δ***5***Δ***6***Δ***7***Δ***0***Δ
[ ]HΔ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[ ]HΔ ABCDEFGHIJKLMNOPQRSTUVWXYZ)-+<=>&$*(%:?!,\0123456789';/.\ @[ ]HΔ
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16 MAY 72 P 14:00:55 IDENT=VRONAY ACCOUNT=428218 CARDS IN= 10, OUT= 0

PAGES= 37, LINES= 1830, TIME=00:00:08 (HMS)

27

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APPENDIX F

PROGRAM 12001B

USERS' MANUAL

WEIGHT, BALANCE, INERTIA

Program SD003A

Aerojet Solid Propulsion Company

Mission Analysis and Computer Programming

June 1970

R. V. Alexander

I. DEFINITION OF PROBLEM

Program SD003A was written to sum weights, and calculate centers of gravity and moments of inertia for systems comprised of Major Assemblies, Assemblies, Sub-assemblies, and Parts. Moments of inertia can be input for the lowest level items used, or dimensional items and moment of inertia equations can be used to calculate these items. Program SD003A was written in Fortran for the Univac 1108 and replaces Kismet (IBM 7094) programs 942, 942A, 12001, and 12001A.

II. TECHNICAL DISCUSSION

Each Major Assembly can be comprised of Assemblies, which can be comprised of Sub-assemblies, which in turn can be comprised of Parts. It is not necessary that each of these "layers" be present. The Major Assemblies are collected in the following way:

Item	Major Assembly Nos.
Basic Engine Dry	1-19
Basic Engine Propellants	20
Basic Engine Wet	1-20
Vehicle Integration Dry	21-28
Vehicle Integration Propellants	40
Vehicle Integration Wet	21-28, 40
Total Engine Dry	1-19, 21-28
Total Engine Propellants	20, 40
Total Engine Wet	1-20, 21-28, 40

Input items may be designated as Gimbaled (G) for additional calculations. In addition, parts may be specified as to material of manufacture, and if it is a calculated, estimated or actual weight.

A. WEIGHT SUMMATIONS AND MOMENT CALCULATIONS

1. Single Level Items

A single level item is defined as a Major Assembly or Sub-assembly in which only one item is used. Parts are always Single Level Items. The following calculations are always made for Single Level Items.

$$W*X \tag{1}$$

$$W*X*X \tag{2}$$

$$W*Y \tag{3}$$

$$W*Y*Y \tag{4}$$

$$W*Z \tag{5}$$

$$W*Z*Z \tag{6}$$

$$W*X*Z \tag{7}$$

$$W*X*Y \tag{8}$$

$$W*Y*Z \tag{9}$$

where W = weight (mass), lbm

X = X-distance to reference point, in.

Y = Y-distance to reference point, in.

Z = Z-distance to reference point, in.

If the Single Level Item moments of inertia are input (ΔI_{XO}, ΔI_{YO}, ΔI_{ZO}), then the following is not computed:

$$\Delta I_{XO} = f^{*}(W, X1, Y1, Z1, R, r) \tag{10}$$

$$\Delta I_{YO} = g^{*}(W, X1, Y1, Z1, R, r) \tag{11}$$

$$\Delta I_{ZO} = h^{*}(W, X1, Y1, Z1, R, r) \tag{12}$$

---

* See Table 1 for list of available equations.

where ΔI_{XO}, ΔI_{YO}, ΔI_{ZO} = moment of inertia about own c.g., lbm-in.^{2}

X1, Y1, Z1, R, r = part dimensions used in inertia calculations, in.

2. Assemblies of More than One Single Level Item

The following summations are made for Major Assemblies, Assemblies, or Sub-assemblies which contain more than one Single Level Item.

$$\sum_{i=1}^{n} W = W_1 + W_2 + \ldots W_n \tag{13}$$

$$\sum_{i=1}^{n} WX = W_1X_1 + W_2X_2 + \ldots W_nX_n \tag{14}$$

$$\sum_{i=1}^{n} WXX = W_1X_1^2 + W_2X_2^2 + \ldots W_nX_n^2 \tag{15}$$

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.

$$\sum_{i=1}^{n} WYZ = W_1Y_1Z_1 + W_2Y_2Z_2 + \ldots W_nY_nZ_n \tag{22}$$

$$\sum_{i=1}^{n} \Delta I_{XO} = \Delta I_{XO_1} + \Delta I_{XO_2} + \ldots \Delta I_{XO_n} \tag{23}$$

$$\sum_{i=1}^{n} \Delta I_{YO} = \Delta I_{YO_1} + \Delta I_{YO_2} + \ldots \Delta I_{YO_n} \tag{24}$$

$$\sum_{i=1}^{n} \Delta I_{ZO} = \Delta I_{ZO_1} + \Delta I_{ZO_2} + \ldots \Delta I_{ZO_n} \tag{25}$$

where n refers to the number of Single Level Items contained in the Engine, Vehicle, Major Assembly, Assembly, or Sub-assembly.

Centers of gravity are then calculated.

$$\bar{X} = \frac{\sum WX}{\sum W} \tag{26}$$

$$\bar{Y} = \frac{\sum WY}{\sum W} \tag{27}$$

$$\bar{Z} = \frac{\sum WZ}{\sum W} \tag{28}$$

where $\bar{X}$ = X coordinate to center of gravity, in.

$\bar{Y}$ = Y coordinate to center of gravity, in.

$\bar{Z}$ = Z coordinate to center of gravity, in.

Total moments of inertia are then calculated.

$$I_{XO} = \sum_{i=1}^{n} W_i Y_i^2 + \sum_{i=1}^{n} W_i Z_i^2 + \sum_{i=1}^{n} \Delta I_{XO_i} - \left(\sum_{i=1}^{n} W_i\right)\left(\bar{Y}^2 + \bar{Z}^2\right) \tag{29}$$

$$I_{YO} = \sum_{i=1}^{n} W_i X_i^2 + \sum_{i=1}^{n} W_i Z_i^2 + \sum_{i=1}^{n} \Delta I_{YO_i} - \left(\sum_{i=1}^{n} W_i\right)\left(\bar{X}^2 + \bar{Z}^2\right) \tag{30}$$

$$I_{ZO} = \sum_{i=1}^{n} W_i Y_i^2 + \sum_{i=1}^{n} W_i X_i^2 + \sum_{i=1}^{n} \Delta I_{ZO_i} - \left(\sum_{i=1}^{n} W_i\right)\left(\bar{Y}^2 + \bar{X}^2\right) \tag{31}$$

where I_{XO}, I_{YO}, I_{ZO} = moments of inertia about the reference, lbm-in.^{2}

(Note: To convert from lbm-in.^{2} to slug-ft^2, divide by 4637.)

The products of inertia are also calculated for the Total Engine Dry and Wet.

$$I_{XZO} = \sum_{i=1}^{n} W_i X_i Z_i - \left(\sum_{i=1}^{n} W_i\right)(\bar{X})(\bar{Z}) \tag{32}$$

$$I_{XYO} = \sum_{i=1}^{n} W_i X_i Y_i - \left(\sum_{i=1}^{n} W_i \right) (\bar{X})(\bar{Y}) \tag{33}$$

$$I_{YZO} = \sum_{i=1}^{n} W_i Y_i Z_i - \left(\sum_{i=1}^{n} W_i \right) (\bar{Y})(\bar{Z})$$

3. Gimabled Components

In addition to the calculations described above, separate computations are made for the Gimbaled components. Equations 1 - 31 are repeated for the parts indicated as Gimbaled on the input card. The moment is then transferred to the Gimbal point.

$$I_{Xg} = I_{gXO} + \left(\sum_{i=1}^{n} W_{gi} \right) \left(\left[\bar{Y}_g - YIG \right]^2 + \left[\bar{Z}_g - ZIG \right]^2 \right) \tag{35}$$

$$I_{Yg} = I_{gYO} + \left(\sum_{i=1}^{n} W_{gi} \right) \left(\left[\bar{X}_g - XIG \right]^2 + \left[\bar{Z}_g - ZIG \right]^2 \right) \tag{36}$$

$$I_{Zg} = I_{gZO} + \left(\sum_{i=1}^{n} W_{gi} \right) \left(\left[\bar{X}_g - XIG \right]^2 + \left[\bar{Y}_g - YIG \right]^2 \right) \tag{37}$$

where I_{Xg}, I_{Yg}, I_{Zg} = moments of inertia about Gimbal point, lbm-in.^{2}

W_g = weight of Gimbaled parts, lbm.

XIG, YIG, ZIG = coordinates of Gimbal point, in.

4. Percent Estimated, Calculated, or Actual Weight

The weight input for a given component can use an E, C, or A for the weight code and each will be summed by Major Assembly to designate the percent of that component weight which is estimated, calculated, or actual.

5. Material Code

The weight input for a given component uses a "flag" to designate the type of material used. The weights are summed by material code and printed out. Codes are shown below.

Flag	Material
A	Alum
B	Boral
C	Cres-300
D	Cres 400-664
E	Electrical
F	Copper
G	Graphite
H	Hastelloy
I	Inconel
J	A-286
K	
L	Lead
M	Molybdenum
N	Nitrogen-Liquid
O	
P	
Q	
R	
S	Steel Carbon
T	Titanium
U	
V	
W	Westinghouse Supplied
X	
Y	
Z	

Unused flags may be used to add future materials.

6. Change History

Data cards can be added (optionally) so as to record the history of part and weight changes. No analyses of these data are performed, they are just printed.

III. PROGRAM INPUTS

A. FIRST CARD - CONTROL CARD

Columns	Symbol	Units	Decimal Places	Definition
1- 7	CONTROL		N/A	Not required
8- 9	NPF(1)		0	Page control for Major Assembly. Up to 10 Major Assembly numbers can be designated and each will appear on a "fresh" page at printout.
10-11	NPF(2)		0	
12-13	NPF(3)		0	
14-15	NPF(4)		0	
16-17	NPF(5)		0	
18-19	NPF(6)		0	
20-21	NPF(7)		0	
22-23	NPF(8)		0	
24-25	NPF(9)		0	
26-27	NPF(10)		0	
28-43			N/A	Not used
44-47	GIMX	in.	1	X location of Gimbal point
48-51	GIMY	in.	1	Y location of Gimbal point
52-55	GIMZ	in.	1	Z location of Gimbal point
56-61			N/A	Not used
62	IAFLG		0	Flag to get "A" options - only Major Assemblies 1-20 will be input and no items will be included for Vehicle Integration.

B. SECOND SET OF CARDS

These cards describe the part names, weight and inertia characteristics. Any number of cards can appear under a given Major Assembly. If a Major Assembly is nonexistent, no cards need be input.

Columns	Symbol	Units	Decimal Places	Definition
1- 2	MA		0	Major Assembly number
3- 4	IA		0	Assembly number
5- 6	IASUB		0	Sub-Assembly number
7- 8	IP		0	Parts number
9	TWC(1)		N/A	Flag for Actual, Estimated, or Calculated weight
10	TGC		N/A	Gimbal flag (G = Gimbal)
11	TMC		N/A	Type material flag (A-Z, see writeup)
12-29	TPRT(I)		N/A	Part name
30-38	TPRTN(I)		N/A	Part number
39-43	W(I)	lbm	1	Part weight
44-49	X	in.	1	X distance to reference point
50-53	Y	in.	1	Y distance to reference point
54-57	Z	in.	1	Z distance to reference point
58-59	MIC		0	Moment of inertia formula code (See Table 1)
60-62(2)				Not used
63-66(2)	X1	in.	1	X value used in moment of inertia formula
67-70(2)	Y1	in.	1	Y value used in moment of inertia formula
71-73(2)	Z1	in.	1	Z value used in moment of inertia formula
74-77(2)	R	in.	1	R value used in moment of inertia formula
78-80(2)	r	in.	1	r value used in moment of inertia formula
58-59(3)				Not used
60-66(3)	ΔI_{OX}	lbm-in.^{2}	0	Moment of inertia about X axix
67-73(3)	ΔI_{OY}	lbm-in.^{2}	0	Moment of inertia about Y axiz
74-80(3)	ΔI_{OZ}	lbm-in.^{2}	0	Moment of inertia about Z axis

(1) TWC : A = actual, E = estimated, C = calculated
(2) Used only when moment of inertia is to be calculated
(3) Used only when moment of inertia is input

NOTES

(1) If Part Name is not input for Major Assembly number 19, then titles of "Basic Engine" will be used on printout. If Part Name is input, it will be used.

(2) If Part Name is not input for Major Assembly number 28, then titles of "Vehicle Integration" will be used on printout. If Part Name is input, it will be used.

(3) If Propellant weights are not input (Major Assembly parts 20 or 40), then "Propellant" and "Wet" summaries will not be printed.

(4) Each Major Assembly must be followed by a card with 88 in Columns 1 and 2.

(5) End of all weight data is followed by a card with 99 in Columns 1 and 2 (immediately follows last "88" card).

(6) If no decimal point is input, the one indicated above is used.

C. THIRD SET OF CARDS - CHANGE HISTORY

If desired, change history cards can follow the second set of cards described above. This third set of cards are not required and can be omitted if no change history is desired.

1. First Card

This card must contain the word HISTORY in Columns 1-7.

2. Second Card

This card is a group header card and contains an "*" in Column 1 and the heading in Columns 2-80. This card will be printed at the beginning of a new page.

3. Third Card

This is a change card and uses the following format:

Columns	Symbol	Item
2- 3	CC(I)	Change code
4-12	CD(I)	Change date
13-26	PN(I)	Part number
27-34	PW(I)	Weight change
35-80	R(I)	Remarks

4. Additional Remarks Cards

Additional remarks can be included on subsequent cards in Columns 2-80. An unlimited number of cards can be used.

5. End of Change Card

A card with "$" in Column 1 designates the end of each change card comments.

6. Additional Change Cards

Steps 3 and 4 may be repeated as many times as there are changes to a given group.

7. Additional Groups

Steps 2 through 6 can be repeated for as many groups as desired.

8. Last Card

A card with "FINISH" in Columns 1-6 terminates the job.

TABLE 1 -- MOMENT OF INERTIA EQUATIONS

CODE	ΔI_X (ROLL)	ΔI_Y (PITCH)	ΔI_Z (YAW)	INPUT REQUIRED	OTHER
1	PARALLELOPIPED	(SOLID ONLY)	CODES 12, 13, 15, 16, 18, 19 ILLEGAL		
1 1	$W(Y^2 + Z^2)/12$	$W(x^2 + Z^2)/12$	$W(x^2 + Y^2)/12$	x,Y,Z	
1 4	"	"	"	"	
1 7	"	"	"	"	
2	FRUSTRUM OF A CONE CODES 23, 26, 29 ARE ILLEGAL $D = R^4 + R^3r + R^2r^2 + Rr^3 + r^4$, $E = R^2 + Rr + r^2$, $F = R^4 + 4R^3r + 10R^2r^2 + 4Rr^3 + r^4$ $G = (W/4)(R^2 + r^2) + \frac{Wh^2}{18}\left(1 + \frac{2Rr}{(R + r)^2}\right)$				
2 1	$3W\left(\frac{R^5 - r^5}{R^3 - r^3}\right)/10$	$3W\left(\frac{D}{E} + \frac{hF}{4E^2}\right)/20$	$3W\left(\frac{D}{E} + \frac{hF}{4E^2}\right)/20$	X,R,r	x = h
2 4	$3W\left(\frac{D}{E} + \frac{hF}{4E^2}\right)/20$	$3W\left(\frac{R^5 - r^5}{R^3 - r^3}\right)/10$	$3W\left(\frac{D}{E} + \frac{hF}{4E^2}\right)/20$	Y,R,r	y = h
2 7	$3W\left(\frac{D}{E} + \frac{hF}{4E^2}\right)/20$	$3W\left(\frac{D}{E} + \frac{hF}{4E^2}\right)/20$	$3W\left(\frac{R^5 - r^5}{R^3 - r^3}\right)/10$	Z,R,r	Z = h
2 2	$W(R^2 + r^2)/2$	G	G	X,R,r	x = h
2 5	G	$W(R^2 + r^2)/2$	G	Y,R,r	y = h
2 8	G	G	$W(R^2 + r^2)/2$	Z,R,r	Z = h

CODE	ΔI_X (ROLL)	ΔI_Y (PITCH)	ΔI_Z (YAW)	INPUT REQUIRED	OTHER
3	SPHERE CODES 34, 35, 36, 37, 38, 39 ARE ILLEGAL $J = \left(\frac{R^5 - r^5}{R^3 - r^3}\right)$				
3 1	$2WR^2/5$	$2WR^2/5$	$2WR^2/5$	x or r	IF R = 0
3 2	$2WR^2/3$	$2WR^2/3$	$2WR^2/3$	x or R	Set R = x/2
3 3	$2WJ/5$	$2WJ/5$	$2WJ/5$	R,r	
4	TORUS CODES 43, 46, 49 ARE ILLEGAL				
4 1	$W\ (4R^2 + 3r^2)/4$	$W\ (4R^2 + 5r^2)/8$	$W\ (4R^2 + 5r^2)/8$	R,r or x	IF r = 0 r = x/2
4 4	$W\ (4R^2 + 5r^2)/8$	$W\ (4R^2 + 3r^2)/4$	$W\ (4R^2 + 5r^2)/8$	R,r or y	IF r = 0 r = y/2
4 7	$W\ (4R^2 + 5r^2/8$	$W\ (4R^2 + 5r^2)/8$	$W\ (4R^2 + 3r^2)/4$	R,r or z	IF r = 0 r = z/2
4 2	$W\ (R^2 + 3r^2/2)$	$W\ (R^2/2 + 5r^2/4)$	$W\ (R^2/2 + 5r^2/4)$	R,r or x	IF r = 0 r = x/2
4 5	$W\ (R^2/2 + 5r^2/4)$	$W\ (R^2 + 3r^2/2)$	$W\ (R^2/2 + 5r^2/4)$	R,r or y	IF r = 0 r = y/2
4 8	$W\ (R^2/2 + 5r^2/4)$	$W\ (R^2/2 + 5r^2/4)$	$W\ (R^2 + 3r^2/2)$	R,r or z	IF r = 0 r = z/2

CODE	ΔI_X (ROLL)	ΔI_Y (PITCH)	ΔI_Z (YAW)	INPUT REQUIRED	OTHER
5	HEMISPHERE CODES 53, 56, 59 ARE ILLEGAL				
5 1	$2WR^2/5$	$.26WR^2$	$.26WR^2$	R	R ⊥ x
5 4	$.26WR^2$	$2WR^2/5$	$.26WR^2$	R	R ⊥ Y
5 7	$.26WR^2$	$.26WR^2$	$2WR^2/5$	R	R ⊥ Z
5 2	$2WR^2/3$	$5WR^2/12$	$5WR^2/12$	R	R ⊥ x
5 5	$5WR^2/12$	$2WR^2/3$	$5WR^2/12$	R	R ⊥ Y
5 8	$5WR^2/12$	$5WR^2/12$	$2WR^2/3$	R	R ⊥ Z
6	CYLINDER	$P = 3R^2 + 3r^2 + H^2$			
6 1	$WR^2/2$	$W (3R^2 + H^2)/12$	$W (3R^2 + H^2)/12$	R,x	H = x
6 4	$W (3R^2 + H^2)/12$	$WR^2/2$	$W (3R^2 + H^2)/12$	R,Y	H = y
6 7	$W (3R^2 + H^2)/12$	$W (3R^2 + H^2)/12$	$WR^2/2$	R,z	H = z
6 2	WR^2	$W (6R^2 + H^2)/12$	$W (6R^2 + H^2)/12$	R,x	H = x
6 5	$W (6R^2 + H^2)/12$	WR^2	$W (6R^2 + H^2)/12$	R,Y	H = y
6 8	$W (6R^2 + H^2)/12$	$W (6R^2 + H^2)/12$	WR^2	R,z	H = z
6 3	$W (R^2 + r^2)/2$	W P/12	W P/12	R,r,X	H = x
6 6	W P/12	$W (R^2 + r^2)/2$	W P/12	R,r,y	H = y
6 9	W P/12	W P/12	$W (R^2 + r^2)/2$	R,r,z	H = z