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Evaluation of Condition Symptoms in Diagnosing Complex Objects

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Abstract- A method is proposed for selecting the most informative diagnostic symptoms in lifetime consumption monitoring of complex objects. Typically in such cases many symptoms are available and their suitability cannot be evaluated even with a detailed knowledge of object layout and operation. The proposed procedure involves two stages. Preliminary symptom selection is based on the Singular Value Decomposition (SVD) method. Second stage is based on the information content assessment and employs the continuous analogue of Shannon entropy. An example is presented for a steam turbine fluid-flow system.

Keywords: *diagnostic symptom, information content, singular value decomposition, shannon entropy.*

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Tomasz Gałka

Abstract- A method is proposed for selecting the most informative diagnostic symptoms in lifetime consumption monitoring of complex objects. Typically in such cases many symptoms are available and their suitability cannot be evaluated even with a detailed knowledge of object layout and operation. The proposed procedure involves two stages. Preliminary symptom selection is based on the Singular Value Decomposition (SVD) method. Second stage is based on the information content assessment and employs the continuous analogue of Shannon entropy. An example is presented for a steam turbine fluid-flow system.

Keywords: diagnostic symptom, information content, singular value decomposition, shannon entropy.

I. Introduction

Technical condition of any object is described by the *condition parameters vector* $\mathbf{X}(\theta)$, where θ denotes 'operational' time, often–but not necessarily–starting at object commissioning. Condition parameters $X_i(\theta)$ are usually non-measurable, so technical condition is typically determined indirectly, on the basis of the *diagnostic symptoms vector* $\mathbf{S}(\theta)$. In the most general case, relation between these two vectors is given by (see e.g. [1] and references therein):

$$\mathbf{S}(\theta) = \mathbf{S}[\mathbf{X}(\theta), \mathbf{R}(\theta), \mathbf{Z}(\theta)], \qquad (1)$$

where $\mathbf{R}$ and $\mathbf{Z}$ denote control parameters and interferences vectors, respectively. In some specific cases the influences of the $\mathbf{R}$ and $\mathbf{Z}$ vectors can be neglected, but usually in practical applications they have to be accounted for; a brief study can be found in [2].

In diagnosing complex objects, a situation is frequently encountered wherein the number of available diagnostic symptoms $S_i \in \mathbf{S}$ is comparatively large. With some exaggeration it may even be said that this number has no upper limit. Even if we focus our attention on vibration-based symptoms, it has to be kept in mind that vibration signal can be recorded in principle at any available point of the object. Number of these points shall be then multiplied by that of measurement directions (usually three mutually perpendicular ones) and that of frequency bands that contain components generated by elementary sources (determined from the vibrodiagnostic model of the object under consideration). For a large rotating machine, a few hundred is typical. A question therefore arises which of them are the 'best' ones from the point of view of condition assessment and which might be qualified as redundant. Unfortunately, this problem usually cannot be solved on the basis of even detailed knowledge of object layout and operation.

Random damages, or hard faults [3], which are equivalent to stepwise changes of condition parameters, often have their specific representations in diagnostic symptom time histories, although reasoning in such cases is by no means simple (see e.g. [4-7]). Natural damage (soft fault), which may be identified with a continuous lifetime consumption process, is even more difficult to trace, especially when this process is slow and masked by fluctuations caused by control and interference. In such cases, the choice of the most representative symptoms is of prime importance for lifetime consumption assessment and prognosis for further operation.

In this paper a new approach to diagnostic symptoms evaluation is proposed. It consists in a two-stage procedure which involves two distinct methods. The first stage employs the Singular Value Decomposition method, known from linear algebra. The second stage is based on the information contents assessment. For clarity, each stage shall be illustrated by a relevant example. These considerations shall be preceded by a brief description of the object.

II. The Object

a) Brief Presentation

A steam turbine, operated by a utility power plant, is a typical example of a critical machine. It is costly and complex. Potential results of a damage are very serious, in terms of both hazard and generation loss. Maintenance has to be planned very carefully, as spare parts are usually not available off the shelf and have to be manufactured. Moreover, turbines are often operated well beyond the timescale stipulated in the original design. Lifetime consumption assessment and prognosis are thus of paramount importance.

K-200 steam turbines and their derivatives, of which over seventy were built, formed the mainstay of the generating capacity in Poland in the 80s and 90s (Fig.1). A few of them still remain in use. The unit under consideration was commissioned in 1969 and modernized in 1991 (entirely new low-pressure turbine with substantially higher thermal efficiency, new control system and numerous minor improvements).

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Measurements, started in 1997, included recording constant-percentage bandwidth (23% CPB) spectra of vibration velocity in points located at bearing caps and low-pressure turbine casing, using portable equipment (accelerometer and data collector). The unit was finally decommissioned in late 2010 and available database covers 4862 days, with measurements performed at time intervals of approximately two months.

Fig.1 : Machine hall interior with ten K-200 units (source: www.elturow.pgegiek.pl). Letters F and R indicate front and rear HP turbine bearing of the foremost unit

In the following attention shall be focused on the high-pressure (HP) turbine. Vibration velocity was recorded on its front and rear bearings, in vertical, horizontal (i.e. radial) and axial directions. 23% CPB (constant-percentage bandwidth) analysis was employed. HP turbine has twelve stages and, according to the turbine vibrodiagnostic model [8], individual components generated by the fluid-flow system are contained in ten bands with mid-frequencies of 500 Hz, 800 Hz, 1600 Hz, 2000 Hz, 2500 Hz, 3150 Hz, 4000 Hz, 5000 Hz, 6300 Hz and 8000 Hz. This gives sixty individual symptoms in all.

It has to be stressed that time histories of vibration components from the blade frequency range are typically very irregular and exhibit strong fluctuations. This refers in particular to the HP turbine, due to the proximity of the control stage. With the nozzle-type control (partial-arc admission), steam thrust is unevenly distributed over the fluid-flow system cross-section, which strongly influences vibration patterns (see e.g. [9]). This distribution changes as control valves open and close, according to the demanded load profile. This effect is particularly evident at low loads [2] and decreases as we move along the steam expansion path. Examples of symptom time histories are shown in Fig.2.

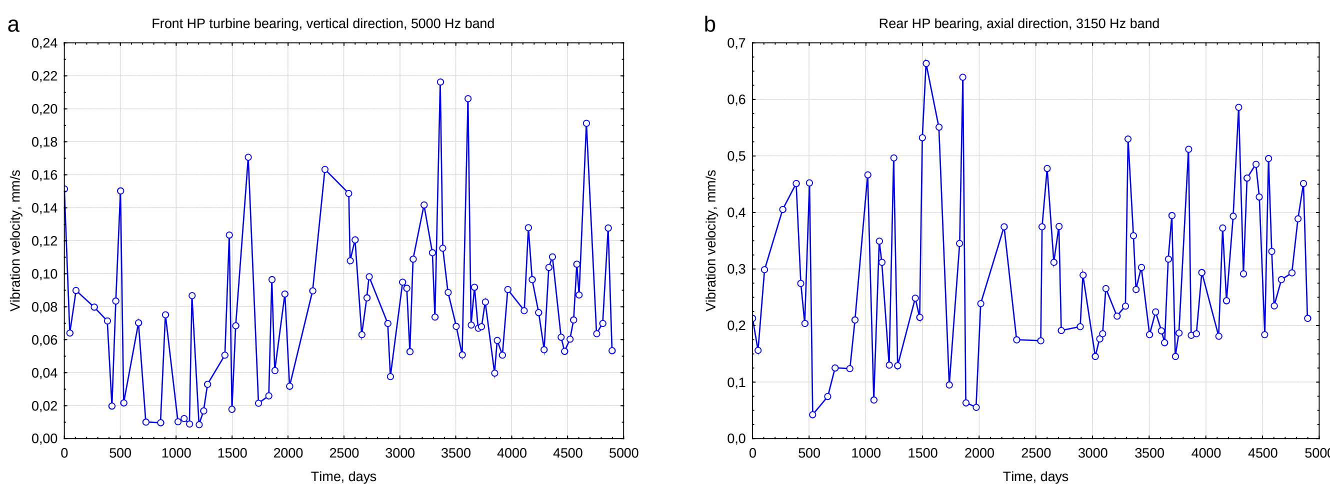

Fig. 2 : Examples of vibration velocity time histories; (a) front HP bearing, vertical direction, 5 kHz band; (b) rear HP turbine bearing, axial direction, 3.15 kHz band

b) Data Smoothing

Examples shown in Fig.2 clearly illustrate that some form of data smoothing should be considered. First attempts were based on the observation that operation at low loads usually causes vibration amplitudes in the blade frequency range to rise dramatically, even by one order of magnitude. Normalization of the load influence therefore seemed a reasonable option [10]; in view of Eq. (1) this implies that interference is not accounted for. Experience has shown that some 'peaks' in vibration time histories could be eliminated in that way, but some – probably caused by temporary steam flow instabilities – remained.

A method known as three-point averaging has been proposed [11], wherein *k*th symptom value reading $S(\theta_k)$ is replaced by the average

$$S'(\theta_k) = \frac{1}{3}[S(\theta_{k-1}) + S(\theta_k) + S(\theta_{k+1})] \qquad (2)$$

In this manner *all* peaks are just 'flattened'. From the statistical point of view, outstandingly high measured symptom values are isolated outliers [12,13]. A procedure of their elimination may consist in excluding peaks supposedly not related to the condition changes, which might be referred to as 'peak trimming' [1]. This approach is based on the assumption that if

$$S(\theta_k)/S(\theta_{k-1}) > c \text{ and } S(\theta_k)/S(\theta_{k+1}) > c, \qquad (3)$$

then the $S(\theta_k)$ value has been strongly influenced by control and/or interference vectors and is therefore suspicious; in such cases, $S(\theta_k)$ is replaced by $S'(\theta_k) = [S(\theta_{k-1}) + S(\theta_{k+1})]/2$. The value of the 'threshold' c should be estimated individually; judging from the author's own experience, $c = 1.5$ is reasonable for steam turbines. It may be noted here that three-point averaging may be considered a limit case of peak trimming, corresponding to $c \to 1$.

III. Stage 1: Svd Method

The idea to employ SVD method in condition monitoring has been first conceived and later developed by Cempel (see e.g. [14,15]). In the following we shall follow the argumentation presented in these references, retaining the original notions. A detailed description of the method itself can be found in specialized reviews and monographs (see e.g. [16]).

In principle, any $m \times n$ matrix $\mathbf{A}$ can be expressed as a product of three matrices $\mathbf{U}$, $\mathbf{\Sigma}$ and $\mathbf{V}^T$:

$$\mathbf{A} = \mathbf{U} * \mathbf{\Sigma} * \mathbf{V}^T, \qquad (4)$$

where $\mathbf{U}$ is a $m \times n$ unitary orthogonal matrix, $\mathbf{\Sigma}$ is a $n \times n$ diagonal matrix and $\mathbf{V}$ is a $n \times n$ unitary orthogonal square matrix (superscript T denotes transpose). The factorization given by the above equation is called a singular value decomposition of the matrix $\mathbf{A}$. The singular values matrix $\mathbf{\Sigma}$ can be written as

$$\mathbf{\Sigma} = \mathrm{diag}(\sigma_1, \sigma_2, \ldots, \sigma_q)\,,\ q = \max(m,n), \qquad (5)$$

σ_i being non-negative real numbers. If non-zero elements σ_i of the matrix $\mathbf{\Sigma}$ are arranged in such manner that

$$\sigma_1 \geq \sigma_2 \geq \ldots \geq \sigma_p\,,\ p = \min(m,n), \qquad (6)$$

then $\mathbf{\Sigma}$ is uniquely determined by $\mathbf{A}$. In general, columns of $\mathbf{V}$ are orthonormal vectors that are sometimes referred to as 'input' basis vector directions of $\mathbf{A}$; similarly, columns of $\mathbf{U}$ can referred to as 'output' basis vector directions. Singular values σ_i within such approach can be thought of as 'gain' scalars that indicate factors by which 'inputs' are multiplied to give corresponding 'outputs'. In other words, matrices $\mathbf{U}$ and $\mathbf{V}$ form the sets of left-singular vectors $\mathbf{u}_i$ and right-singular vectors $\mathbf{v}_i$, respectively, which obey the relation

$$\mathbf{A} * \mathbf{v}_i = \sigma_i \cdot \mathbf{u}_i\,,\ \mathbf{A}^{\mathrm{T}} * \mathbf{u}_i = \sigma_i \cdot \mathbf{v}_i. \qquad (7)$$

Let us consider m distinct symptoms $S_i(\theta)$, $i = 1, 2, \ldots, m$, and n symptom readings:

$$S_i(\theta_k) = S_i(\theta = \theta_0 + k\Delta\theta)\,,\ \Delta\theta << \theta_b\,,\ k = 1, 2, ..., n. \qquad (8)$$

$\Delta\theta$ denotes here the time interval between consecutive readings and θ_b is time to breakdown. It is assumed that condition monitoring was introduced at $\theta = \theta_0$. The method can handle various symptoms of different physical origin, so it is suggested, in order to make all of them comparable, to normalize them with respect to their initial values and then subtract 1, so that all become dimensionless and start from zero. In this manner, the measurement database is transformed into a $m \times n$ matrix $\mathbf{O}$, known as *symptom observation matrix*. In principle, the above approach means that we have p independent sources of information on object condition and therefore we can trace p independently developing generalized faults.

In view of Eq.(7), we may rewrite Eq.(4) in another form:

$$\mathbf{O} = \sum_{t=1}^{p} \sigma_t \cdot (\mathbf{u}_t * \mathbf{v}_t^T)\,, \qquad (9)$$

so that the *t*th generalized fault is characterized by the scalar σ_t and singular vectors $\mathbf{u}_t$ and $\mathbf{v}_t$. From Eqs. (7) and (8) we may conclude that this fault can be described by two independent measures or discriminants:

$$\mathbf{SD}_t = \mathbf{O} * \mathbf{v}_t = \sigma_t \cdot \mathbf{u}_t\,, \qquad (10)$$

$$\|\mathbf{SD}_t\| = \sigma_t\,. \qquad (11)$$

$\mathrm{SD}_t(\theta)$ is a time-dependent vector which represents the *t*th fault profile at a given moment. On the other hand, $\sigma_t(\theta)$ is a time-dependent scalar energy norm of this vector and hence represents fault advancement. Thus, the sum given by

$$F(\theta) = \sum_{i=1}^{p} \sigma_i(\theta) \qquad (12)$$

can be interpreted as a measure of overall lifetime consumption degree and consequently of the overall machine condition. Similarly, the vector given by

$$\mathbf{P}(\theta) = \sum_{i=1}^{p} \mathbf{SD}_i(\theta)\,, \qquad (13)$$

describes the evolution of the total generalized fault profile. In the same manner another discriminant may be defined:

$$\mathbf{AL}_t = \mathbf{u}^T_t \cdot \mathbf{O} = \sigma_t \cdot \mathbf{v}^T_t\,, \qquad (14)$$

which also represents the *t*th fault profile; obviously,

$$\|\mathbf{AL}_t\| = \|\mathbf{SD}_t\| \,. \qquad (15)$$

Elements of both $\mathbf{SD}_t$ and $\mathbf{AL}_t$ vectors represent contributions into the σ_t singular value and hence 'components' of the tth fault profile, which can be expressed in terms of either condition parameters ($\mathbf{SD}_t$) or measurable symptoms ($\mathbf{AL}_t$). Both representations are formally equivalent, but the latter is obviously more useful, as condition parameters are usually 'inaccessible'.

Application of this approach to steam turbines has been described in several earlier publications by the author [1,17]. In general for a unit with short service life no dominant singular value σ_i can be distinguished. As θ_b is approached, however, a dominant failure mechanism appears and with it also a σ_i singular value with the highest contribution into the generalized fault. Symptoms with the highest contributions into this value can then be identified, and these may be viewed most informative from the point of view of lifetime consumption determination.

Let us no return to our example, introduced in Section 2.1. In order to select the most informative symptom for all measuring points and directions, SVD analysis was performed for six sets of symptoms. Following the suggestions given in [14], operational time was included in all sets as the eleventh symptom. Results for one set (front HP turbine bearing, horizontal direction) are presented in Fig.3. It is immediately seen that a dominant fault has already developed, as the contribution of the first singular value is about 54%, while those of the remaining ones do not exceed 15%. The most informative symptom can also be readily identified, namely the 9th one. In this manner the following six symptoms have been specified:

- No.1: front HP turbine bearing, vertical direction, 6300 Hz band;
- No.2: front HP turbine bearing, horizontal direction, 5000 Hz band;
- No.3: front HP turbine bearing, axial direction, 5000 Hz band;
- No.4: rear HP turbine bearing, vertical direction, 8000 Hz band;
- No.5: rear HP turbine bearing, horizontal direction, 5000 Hz band;
- No.6: rear HP turbine bearing, axial direction, 6300 Hz band.

It may be noted here that all frequency bands listed above contain components generated by rotor stages rather than by bladed diaphragms. This indicates that rotor condition deterioration is more pronounced.

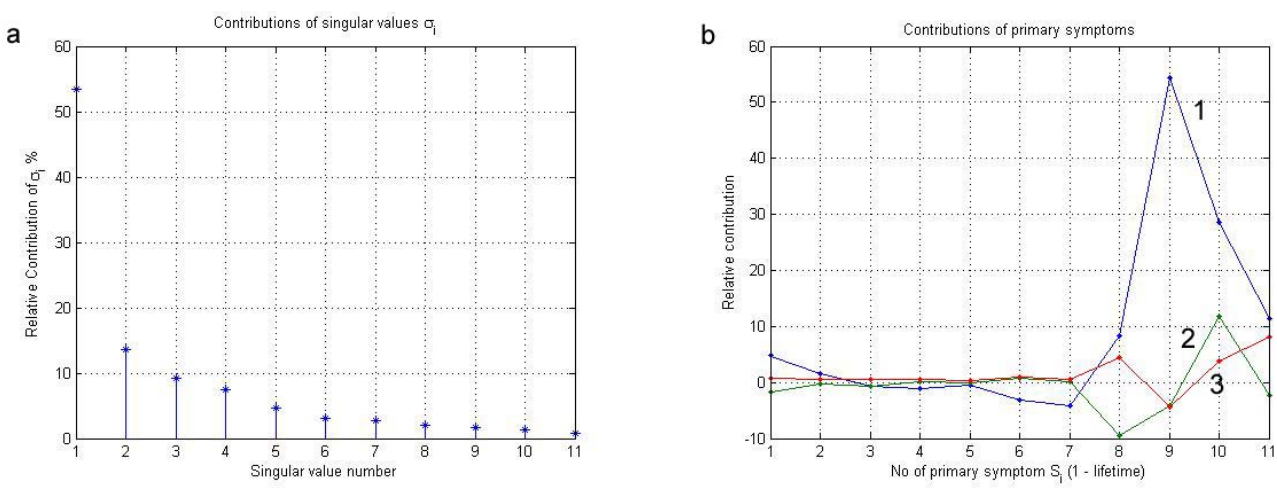

Fig. 3 : Front HP turbine bearing, horizontal direction. (a) Contributions of individual singular values into generalized fault (in descending order). (b) Contri-butions of individual symptoms into first, second and third singular values

Formally the entire SVD procedure may be repeated for six selected symptoms (plus time). Results are shown in Fig.4 and it is easily noticed that they are qualitatively different from those presented in Fig.3. Again, there is a dominant fault (contribution of about 47%), but no dominant symptom can be pointed out. In order to proceed, we shall now evaluate six selected symptoms by applying an information content measure.

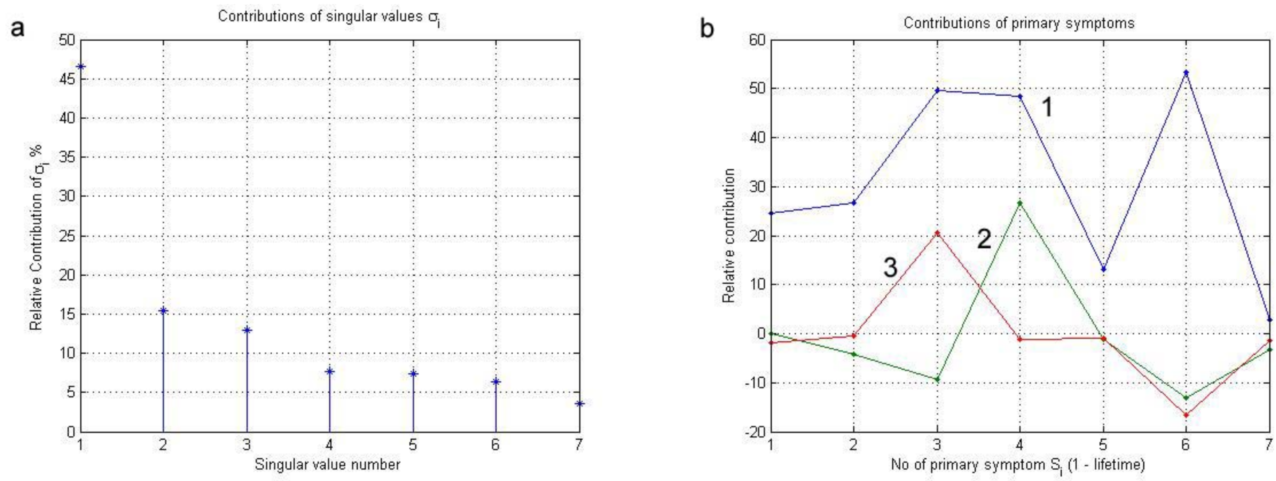

Fig. 4 : SVD evaluation of six selected symptoms (plus time). (a) Contributions of individual singular values into generalized fault (in descending order). (b) Contribution of individual symptoms into first, second and third singular values

IV. Stage 2: Shannon Entropy

Components of the R(θ) and Z(θ) vectors should be considered random variables. The entire symptom time history should thus be treated as a stochastic process rather than a deterministic function of θ. On the other hand, lifetime consumption processes *are* deterministic. It is thus proper to speak in terms of a random variable with time-dependent parameters. With any random variable, a measure of uncertainty can be associated. The most commonly used one is the *Shannon entropy* [18]. For a discrete random variable *Y*, characterized by the probability density function *p*(*y*), Shannon entropy *H*(*Y*) is given by

$$H(Y) = \sum_{i=1}^{n} p(y_i) \log_b \frac{1}{p(y_i)} \tag{16}$$

with the following obvious conditions:

$$p_i \geq 0 \; (i = 1, 2, \ldots, n) \;, \tag{17}$$

$$\sum_{i=1}^{n} p_i = 1 \tag{18}$$

and, by convention [19],

$$0 \log_b 0 = \lim_{t \to 0} t \log_b t = 0 \tag{19}$$

Typical values for *b* are 2, Euler's number *e* and 10; obviously this is a question of multiplication by a constant only. *H* is expressed in bits, nats or bans, respectively. Shannon entropy may be interpreted as the amount of information that is missing when the exact value of a random variable is not known [18]. Equivalently it may be considered a measure of unpredictability of the outcome of an experiment [20]. Zero entropy means that the outcome is entirely predictable. The concept of the Shannon entropy, originally introduced for discrete random variables, can be extended to include continuous random variables (differential entropy, see e.g. [21]).

For a given symptom time history, Shannon entropy as a function of time may be determined in the following way:

- experimental data histogram is determined within a 'time window' of constant length $\delta\theta$ (in practice, for a meaningful estimation, window containing no less than 25 individual data points is necessary);
- statistical parameters are determined by fitting a distribution to this histogram;
- data window is moved to the next point and the procedure is repeated;
- after the entire period under consideration has been covered, statistical parameters are plotted against time and some function (usually exponential) is fitted to them;
- from the data acquired in the previous step, Shannon entropy as a function of time may be easily calculated.

Second step needs some clarification. Basically right-hand skewed distributions are applicable, as there is no upper limit for *S*(θ) while, at the same time, *S*(θ) > 0. In general, symptom value distribution should satisfy the following requirements:

- $S \in (0, \infty)$;
- low probability for values close to zero;
- probability density function maximum at some value (expected or mean);
- $S \to \infty \Rightarrow p(S) \to 0$.

These conditions are met by the gamma distribution, with the probability density function given by

$$p(S)=\frac{1}{\Gamma(k)\lambda^{k}}S^{k-1}e^{-S/\lambda}\ , \tag{20}$$

where Γ denotes gamma function and k and λ are shape and scale parameters, respectively. This distribution is commonly used in probabilistic modeling of lifetimes. Alternatively, Weibull distribution may be used:

$$p(S)=\frac{\lambda}{k}S^{-1}e^{-S^{k}/\lambda} \tag{21}$$

(k and λ as above).

For these two distribution types, Shannon entropy is given by [22]

$$\frac{k-1}{k}\gamma_{E}+\ln\frac{\lambda}{k}+1 \tag{22}$$

for the Weibull distribution and

$$\ln(\lambda\Gamma(k))+(1-k)\psi(k)+k \tag{23}$$

for the gamma distribution, respectively; γ_E is the Euler-Mascheroni constant (≈ 0.5772) and $\psi(k)$ denotes the digamma function.

Fig.5 shows results obtained with the assumption of the Weibull distribution; data pre-processing included peak trimming at c = 1.5 followed by three-point averaging. It is easily seen that five from six symptoms exhibit an increase of Shannon entropy with time. This implies that the uncertainty is increasing, so that the random 'component' (resulting from the influence of control and interference) gradually becomes dominant over the deterministic one (which represents lifetime consumption). Only for the sixth symptom (rear HP turbine bearing, axial direction, 6300 Hz band) there is a slight decrease. This system may thus be pointed out as the most informative one from the point of view of lifetime consumption representation and hence the most suitable for prognosis. Results for the gamma distribution (shown in Fig.6) are qualitatively identical, in that they lead to the same conclusions.

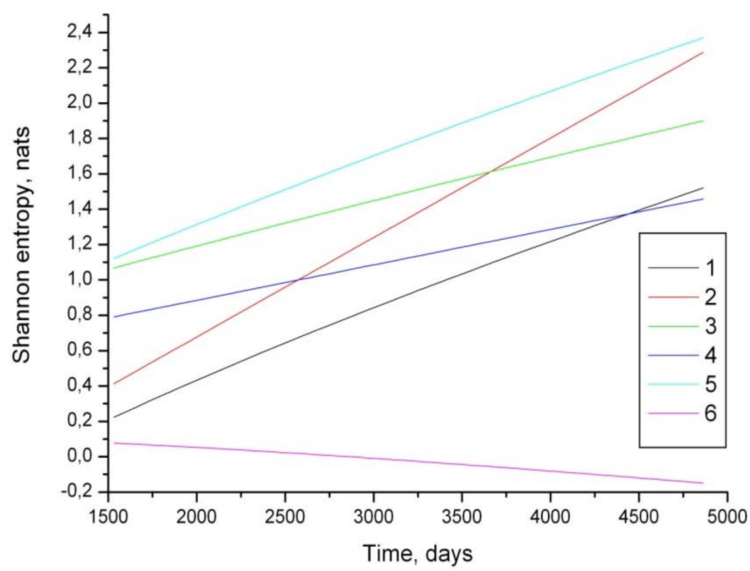

Fig. 5 : Shannon entropy for six symptoms listed in Section 3, plotted against time (Weibull distribution assumption)

V. Discussion And Further Development

The method proposed in this paper has proven capable of selecting the most informative symptom of the turbine fluid-flow system lifetime consumption advancement. Starting from sixty available vibration-based symptoms, one has been selected in a rather unequivocal manner; moreover, this selection is not affected by the assumed distribution type. The procedure may thus be judged suitable for diagnostic symptoms evaluation.

Negative entropy may seem suspicious. It has been pointed out, however, that extension of the Shannon entropy concept onto continuous distributions does not preserve all its properties [21]. In principle $H(Y) \geq 0$ (cf. Eq.(16)), but for certain distribution types differential entropy may be negative.

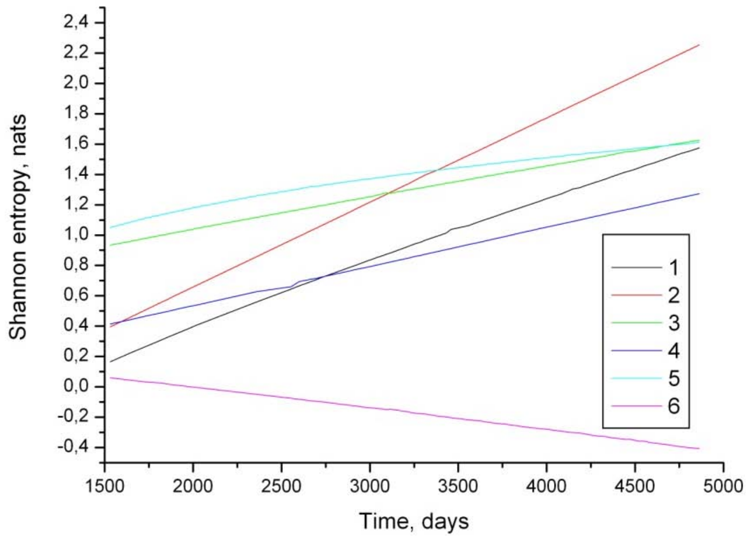

Fig. 6 : Shannon entropy for six symptoms listed in Section 3, plotted against time (gamma distribution assumption)

It has been noted that, even after measurement data pre-processing (smoothing) has been performed, the quality of fitting the shape and scale factors to experimental data was sometimes quite poor, as $\lambda(\theta)$ and $k(\theta)$ tended to be rather irregular. In the author's opinion, time window length is an important and perhaps the key factor. Basically, in order to obtain good fit of Weibull and gamma distributions to experimental histograms, $\delta\theta$ should be as large as possible. On the other hand, when speaking in terms of *fluctuations*, we tacitly assume that they refer to some 'mean' or 'averaged' value, which implies that an increasing trend within the time window is neglected. This may be justified if θ is substantially smaller than θ_b, i.e. for an object with comparatively short operational life. In the case dealt with in this paper, i.e. for large lifetime consumption advancement, this assumption is not valid. It has been suggested (see e.g. [23] and references therein) that, in analyzing time series, it is more appropriate to speak in terms of deviation from a trend than from some 'averaged' value. Such approach has been tested by the author and results have been found promising [1]. Work is currently underway on applying a similar procedure for diagnostic symptoms evaluation and the author hopes to report results in near future.

Finally it has to be noted that the ultimate selection, illustrated graphically in Figs.5 and 6, basically refers to the case when lifetime consumption is assessed directly from the symptom time history. It has been pointed out and proven on the basis of model considerations [1,24]) that information on object condition is also contained in data dispersion measures (standard deviation, median absolute deviation, interquartile range etc.). Moreover, meta-symptoms based on dispersion measures offer certain advantages. Taking this into account, a symptom with the highest increase of Shannon entropy may be considered the most informative one. It is clearly seen in Figs.5 and 6 that also in this case both distribution assumptions yield identical results. Ultimately this choice will thus depend on the very concept of diagnostic information extraction from $S(\theta)$ time histories.

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Errors of the Wheeler School, the Distortions to General Relativity and the Damage to Education in MIT Open Courses in Physics

By C. Y. Lo

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Keywords: einstein's equivalence principle; einstein's covariance principle; einstein's theory of measurement; principle of causality; $E = mc^2$; dynamic solution; repulsive gravitational force; charge-mass interaction; pioneer anomaly. 04.20.-q, 04.20.cv

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Abstract- General relativity is difficult to understand, and recently it is discovered as not yet self-consistent. Einstein's theory of measurement is known as incompatible with the rest of physics, and thus misinterpretations were created. Among them, the dominant misinterpretations of the Wheeler School are due to inadequacy in mathematics and physics. In particular, their distortions of Einstein's equivalence principle maintain initial errors and create their own errors. Moreover, the errors on dynamic solutions have far reaching consequences to other areas of physics. These errors are responsible for the mistakes in the press release of the 1993 Nobel Committee who was unaware of the non-existence of dynamic solutions and the experimental supports to Einstein's equivalence principle. To illustrate the damages of such misinterpretations and errors to education, the MIT Open Course Phys. 8.033 is chosen since it is accessible to the public and the influence of the Wheeler School to MIT is a relatively recent event. Nevertheless, the rectifications of errors in general relativity lead to a discovery of the new charge-mass interaction because $E = mc^2$ is only conditionally valid. And experimental confirmations of such an interaction prove for the necessity of unification between gravitation and electromagnetism, and thus enable other theoretical progresses.

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"Unthinking respect for authority is the greatest enemy of truth." – A. Einstein

I. Introduction

The difficulty to understand general relativity can be illustrated by the dialogue between a Journalist and Eddington: Journalist: Professor Eddington, is it really true that only three people in the world understand Einstein's theory of general relativity?

Eddington: Who is the third?

The response of Eddington would be correct. If one assumes that both Einstein and Eddington understand general relativity, the third person would be Zhou Pei-Yuan [1, 2], who was born in 1902. Zhou is probably the first theorist who correctly understood that there is an inconsistency between Einstein's equivalence principle and his covariance principle [3]. Unfortunately, misunderstandings on general relativity and errors continued as shown in the press release of 1993 Nobel Committee in Physics [4]. General relativity was proposed almost 100 years ago, but still there is no expert in this field so far. In fact, there are at least a dozen of Nobel Laureates who made errors in general relativity (see Appendix).

In this paper, we shall concentrate on the basics such as Einstein's equivalence principle and his covariance principle, the principle of causality, misunderstandings on the Einstein equation, and related consequences. Among sources of misinterpretations, the Wheeler School [5-8] is probably the most influential. This group has members occupying key positions, and the backing of the Princeton University [9]. They made and insisted on errors in physics, mathematics and logic [10, 11]. Moreover, they seem to lose their ability of self-rectification as scientists.[1)] For example, they failed to respond to the challenge of Bondi, Pirani, & Robinson [12, 13]; and were unable to rectify their error on local time shown in their eq. (40. 14); [2)] and made invalid claims on dynamic solutions and physical principles [10].

Wheeler started his career as an accomplished nuclear physicist. After the project of the hydrogen bomb, he picked up the abandoned theory of Oppenheimer; and proposed the formation of the black holes after a test of simulation was passed [14]. Thus, the theory of black holes is based on the unverified implicit assumptions in the simulation.

Wheeler was leading the school at Princeton, while their associates, Sciama and Zel'dovich (another H-bomb maker) developed the subject at Cambridge University and the University of Moscow. However, their speculations remain without conclusive observational supports [10]. Noticeably, Wheeler, Misner, and Thorne wrote the *Gravitation* that collects an exceptionally rich literature on gravitation. However, Einstein's 1916 crucial paper [15] and his comprehensive book [16] on general relativity are not included. Their book distorted general relativity, in particular Einstein's equivalence principle; but also exposes their shortcomings in physics, mathematics, and logic (see Sections 2 - 6).

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Moreover, some theorists would play the role of being the obstacle to other sciences. This has happened towards the NASA's discovery of the pioneer anomaly [17-19]. Some attempted to shut down the Super Collider in Europe. Clearly they need help from the community of sciences [10. 11]. It is for facilitating such assistance that this paper is written.

Since the accurate predictions created a faith on Einstein's theory, a critical analysis was over due [10]. Moreover, as time goes by, misinterpretations from the well known were accepted as part of the faith. Thus, to rectify the errors, a systematic analysis of the whole theory is necessary. This paper would serve essentially as a road map to their errors. Evidences with details that require considerable deliberation are provided in the references.

Einstein [20] once remarked, "If you want to find out anything from the theoretical physicists about the methods they use, I advise you stick to one principle, don't listen to their words, fix your attention on their deeds." In this paper, Einstein's advice is proven to be useful.

Since it is commonly agreed that Einstein's equivalence principle is crucial [15, 16, 21], we would start with discussions on the equivalence principle. It is amazing that while many admire Einstein's intelligence, they were convinced that the 1916 Einstein's equivalence principle that Einstein insists as crucial were the same 1911 assumption of equivalence that has been proven invalid by the light bending experiments. The following sections illustrate the errors related to distortions of Einstein's equivalence principle.

II. The Difference Between Einstein's 1911 Assumption of Equivalence and Einstein's Equivalence Principle

Although many agree with Einstein that his equivalence principle is the foundation of general relativity, there is no book or reference, other than Einstein's own work, that state and explain this principle correctly [22, 23]. In particular, they failed to see the physical contents of Einstein's equivalence principle; and often confused this principle with Einstein's invalid 1911 assumption of equivalence [24]. Thus, it is useful to clarify first what is his 1911 assumption.

In 1911 Einstein assumed the equivalence of a uniformly accelerated system K' and a stationary system of coordinate K with a uniform Newtonian gravitational potential ϕ. Currently many assume the Newtonian metric form,

$$d\tau^2 = (1 + 2\phi)\, dt2 - dx^2 - dy^2 - dz^2, \qquad (1)$$

that later Fock [25] has proved to be impossible. From this metric (1), Einstein derived the correct gravitational redshifts, but an incorrect light velocity that leads to only one half of the observed light bending angle [24].

In 1916, however, Einstein assumed the equivalence of a uniformly accelerated system K' and a stationary system of coordinate K with an *unspecified* metric form that generates a uniform gravitation. In his book, Einstein [16] wrote:

> 'Let now K be an inertial system. Masses which are sufficiently far from each other and from other bodies are then, with respect to K, free from acceleration. We shall also refer these masses to a system of co-ordinates K', uniformly accelerated with respect to K. Relatively to K' all the masses have equal and parallel accelerations; with respect to K' they behave just as if a gravitational field were present and K' were unaccelerated. Overlooking for the present the question as to the "cause" of such a gravitational field, which will occupy us latter, there is nothing to prevent our conceiving this gravitational field as real, that is, the conception that K'; is "at rest" and a gravitational field is present we may consider as equivalent to the conception that only K is an "allowable" system of co-ordinates and no gravitational field is present. The assumption of the complete physical equivalence of the systems of coordinates, K and K', we call the "principle of equivalence;" this principle is evidently intimately connected with the law of the equality between the inert and the gravitational mass, and signifies an extension of the principle of relativity to coordinate systems which are non-uniform motion relatively to each other.'

Later, Einstein made clear that a gravitational field is generated from a space-time metric, but is not a Newtonian potential. (However, the latter was not explicitly stated.) Moreover, concurrent with Einstein's equivalence principle of 1916, Einstein makes the claim of the Einstein-Minkowski condition as a consequence [15].

However, in the press release of the 1993 Nobel Committee [4], the equivalence principle was claimed as the identity between gravitational and inertial mass (due to Galileo and Newton), but not as Einstein's equivalence principle although it has been confirmed by experiments (see eq. [3'd]). [3)] A problem is that since Einstein did not provide an example to illustrate his equivalence principle, a careless reader could mistake the 1911 assumption of equivalence as the 1916 equivalence principle. [4)] It is not until 2007 that a metric for uniform gravity [23] was published as follows:

$$ds^2 = (c^2 - 2U)\, dt'^2 - (1 - 2U/c^2)^{-1} dx'^2 - (dy'^2 + dz'^2), \quad (2)$$

where $c^2/2 > U(x', t') = (at)^2/2$, "a" is the acceleration of system K'(x' y' z') with respect to K(x, y, z, t) in the x-direction. Metric (2) shows the time dilation and space contractions clearly. Here, dt' is defined locally by $cdt' = cdt - (at/c)dx'[1 - (at/c)^2]^{-1}$. Moreover, metric (2) is equivalent to the metric

$$ds^2 = (c^2 - a^2t^2)dt^2 - 2at\, dtdx' - dx'^2 - (dy'^2 + dz'^2) \quad (2')$$

that was derived by Tolman [26]. It was a surprise that U is actually time dependent, and this explains the earlier failed derivation of such a metric [27]. Now, clearly the 1916 principle is different from the 1911 assumption.

To avoid the usual association of an elevator with the gravity of Earth, the equivalence of accelerated frame and uniform gravity is best described, as Einstein did, in terms of a uniformly accelerated chest [29]. Nevertheless, due to the popular "Einstein's elevator" of Bergmann [28], Einstein was often falsely accused of ignoring the tidal force [14]. 5)

To illustrate the equivalence principle further, consider a disk K' uniformly rotating w. r. t. an inertial system (x, y, z, t), a metric for the disk of space K' (x', y', z') is derived [30]. According to Landau & Lifshitz [31], the metric is

$$ds^2 = (c^2 - \Omega^2 r^2)\, dt^2 - 2\Omega r^2\, d\phi' dt - dr^2 - r^2\, d\phi'^2 - dz'^2, \quad (3)$$

where Ω is an angular velocity relative to an inertial system K (x, y, z, t), z and z' coincide with the rotating axis, and $r^2 = x^2 + y^2 = x'^2 + y'^2$. Metric (3) is equivalent to its canonical form,

$$ds^2 = (c^2 - \Omega^2 r'^2)dt'^2 - dr'^2 - (1 - \Omega^2 r'^2/c^2)^{-1} r'^2\, d\phi'^2 - dz^2, \quad (3'a)$$

where

$$cdt' = cdt - (r\Omega/c)rd\phi'[1 - (r\Omega/c)^2]^{-1}. \quad (3'b)$$

Then it is clear that the local light speed cannot be larger than c. However, (3'b) is not integrable [30] because local time dt' is related to different inertial systems at different r or time t. Thus, to obtain the correct space contractions, one must first transform the metric to a canonical form such that the space contractions are clear.

The fact that the local time t'is not a global time was a problem that leads to the rejection by the editorial of the Royal Society [30]. This rejection is incorrect since validity of metric (3') can be derived theoretically with special relativity. Experimentally, the time dilation from metric (3'a) for the local metric, $ds^2 = c^2dT^2 - dX^2 - dY^2 - dz^2$, is

$$dT = [1 - (r\Omega/c)^2]^{1/2}\, dt'. \quad (3'c)$$

From (3'b) the local clock resting at K', if observed from K, would have

$$dt' = dt. \quad \text{and} \quad dT = [1 - (r\Omega/c)^2]^{1/2}\, dt. \quad (3'd)$$

Moreover, as Kundig [32] has shown, the time dilation (3'd) is valid for a local clock fixed at K' 6). Hence, Einstein's equivalence principle has experimental supports although his claim [15] on this dilation was invalid. Therefore, the 1993 Nobel Committee press release should not frivolously reject this principle; especially since it was done implicitly [4].

III. Mathematical Foundation of Einstein's Equivalence Principle and its Misleading Presentations

An earlier source of confusion is that Pauli's invalid version [33] has been mistaken as Einstein's equivalence principle although Einstein has made clear it is a misinterpretation [21]. Since Pauli was an outstanding physicist, and was often critical to theoretical errors, many still rely on his version, instead of the necessary supporting evidences.

For instance, in the book "Gravitation" [5] of Misner, Thorne and Wheeler, there is no reference to Einstein's equivalence principle (i. e. [15] and [16]). Instead, they misleadingly refer to Einstein's invalid 1911 assumption [24] and Pauli's invalid version [33] (see the subsequent theorems). Like Pauli, they also did not refer to the related mathematical theorems [34]. Apparently they failed to understand them - if they are aware of them. 7) In addition, as shown in their Eq. (40.14), they even failed to understand the local time of a particle at free fall [5], a basic of general relativity. Nevertheless, due to their influence, Einstein's equivalence principle was often mistakenly regarded the same as the invalid 1911 assumption. The failure of understanding Einstein's equivalence principle is a major source of current errors. 8)

Note that since the 1911 assumption has been proven invalid by observations in 1919, that Fock [25] misidentified it in 1955 as Einstein's equivalence principle of 1916, *is beyond just incompetence but a deliberate unethical distortion to discredit Einstein*. Unfortunately, many universities, research institutes, as well as the 1993 Nobel Committee are victims of such a distortion.4) This illustrates that a human folly can happen to Sciences, not just politics.

Moreover, many cannot tell the difference between the principle of 1916 and the assumption of 1911 [23, 35-37].4) Although Einstein's equivalence principle is inadequate [38], it is generally valid because a uniform gravity in the equivalence principle is generated by acceleration but not mass. However, experiments on the equivalence of inertial mass and gravitational mass have not been up-dated beyond the case when the mass-charge interaction is absent [39].

The mathematical theorems related to Einstein's equivalence principle are as follows:

Theorem 1. Given any point P in any Lorentz manifold (whose metric signature is the same as a Minkowski space) there always exist coordinate systems (x^μ) in which $\partial g_{\mu\nu}/\partial x^\lambda = 0$ at P.

Theorem 2. Given any time-like geodesic curve Γ there always exists a coordinate system (the so-called

Global Journal of Science Frontier Research (A) Volume XIII Issue VII Version I Year 2013

Fermi coordinates) (x^μ) in which $\partial g_{\mu\nu}/\partial x^\lambda = 0$ along Γ.

In these theorems, the local space of a particle is locally constant, but not necessarily Minkowski.

However, after some algebra, a local Minkowski metric exists at any given point and along any time-like geodesic curve Γ. In a uniformly accelerated frame, the local space in a free fall is a Minkowski space according to special relativity. What Einstein added to these theorems is that physically such a locally constant metric must be Minkowski. Such a condition is needed for the case of special relativity [22, 23]. This is also the theoretical basis of the Einstein-Minkowski condition that Einstein uses to derive the bending of light rays and the gravitational redshifts [15, 16].

Thus, Pauli's version [33] is a simplified but corrupted version of these theorems as follows:

> "For every infinitely small world region (i.e. a world region which is so small that the space- and time-variation of gravity can be neglected in it) there always exists a coordinate system K_0 (X_1, X_2, X_3, X_4) in which gravitation has no influence either in the motion of particles or any physical process."

Pauli regards the equivalence principle as merely the existence of locally constant spaces. Then, Pauli's version is only a corrupted mathematical statement which may not be physically realizable because of the theorems.

A crucial error is that Pauli extended the removal of uniform gravity to the removal of gravity in a small region. This is simply incorrect in mathematics. Because he does not understand mathematical analysis, he did not recognize that the removal of gravity in a small region, no matter how small, would be very different from a removal of gravity at one point. The correct statement should replace "no influence" with "approximately little influence". Then, the removal of gravity would be limited to essentially an isolated point as the mathematical theorems allow.

Moreover, Pauli [33], and Will [6, 39], overlooked Einstein's [15; p.144] remark, "For it is clear that, e.g., the gravitational field generated by a material point in its environment certainly cannot be 'transformed away' by any choice of the system of coordinates…" Apparently, neither Pauli [33] nor the Wheeler School [5-8] understands the mathematics of the above theorems [34]. Misner et al. [5] claimed that Einstein's equivalence principle is as follows: -

> "In any and every local Lorentz frame, anywhere and anytime in the universe, all the (nongravitational) laws of physics must take on their familiar special-relativistic form. Equivalently, there is no way, by experiments confined to infinitesimally small regions of spacetime, to distinguish one local Lorentz frame in one region of spacetime frame from any other local Lorentz frame in the same or any other region."

They claimed this as the Einstein's principle in its strongest form. [8] However, this version makes essentially another form of the misinterpretation of Pauli [33]. They do not seem to understand or to be aware of the related mathematics [34], and their followers probably have similar problems. *This version of the Wheeler School combines errors of Pauli and the 1911 assumption, but ignores the Einstein-Minkowski condition that is the physical essence of Einstein's principle.*

In fact, their phrase, "must take on" should be changed to "must take on approximately". The phrase, "experiments confined to infinitesimally small regions of spacetime" does not make sense since experiments can be conducted only in a finite region. Moreover, in their eq. (40.14) they got an incorrect local time of the earth, in disagreement with Einstein.[2] Thus, clearly these three theorists [5] failed to understand Einstein's equivalence principle [15, 16].

Furthermore, Thorne [14] criticized Einstein's principle with his own distortion as follows:

> *"In deducing his principle of equivalence, Einstein ignored tidal gravitation forces; he pretended they do not exist. Einstein justified ignoring tidal forces by imagining that you (and your reference frame) are very small."*

However, Einstein has already explained these problems in his letter of 12 July 1953 to Rehtz [21] as follows:

> *"The equivalence principle does not assert that every gravitational field (e.g., the one associated with the Earth) can be produced by acceleration of the coordinate system. It only asserts that the qualities of physical space, as they present themselves from an accelerated coordinate system, represent a special case of the gravitational field."*

Perhaps, Thorne did not know that *the term "Einstein elevator" of Bergmann [28] is misleading.*

As Einstein [21] explained to Laue, "What characterizes the existence of a gravitational field, from the empirical standpoint, is the non-vanishing of the Γ^l_{ik} (field strength), not the non-vanishing of the R_{iklm}," and no gravity is a special case of gravity. This allows Einstein to conclude that the geodesic equation is also the equation of motion of a massive particle under gravity, which made it possible to conceive a field equation for the metric.

Although Einstein's equivalence principle was clearly illustrated only recently [10, 22, 23], the Wheeler School should bear the responsibility of their misinformation on this principle [5] by ignoring both crucial work of Einstein, i.e., references [15] and [16], and related theorems [34], and giving an invalid version of such a principle. *A main problem is that the Einstein-Minkowski condition [15, 16], which plays a crucial role in measurement, is eliminated.* As shown by Zhou [1, 2], Einstein's equivalence principle is actually inconsistent with his covariance principle.

Einstein [15, 16] uses the satisfaction of his equivalence principle as an assumption to calculate the bending of light in the harmonic and the Schwarzschild gauges. From the latter, in 1916 Einstein obtains, to the first approximation,

$$\left. \begin{aligned} g_{\rho\sigma} &= -\delta_{\rho\sigma} - \alpha \frac{x_\rho x_\sigma}{r^3} (\rho, \sigma = 1, 2, 3) \\ g_{\rho 4} &= g_{4\rho} = 0) \qquad (\rho = 1, 2, 3) \\ g_{44} &= 1 - \frac{a}{r} \end{aligned} \right\}$$

$$\text{where,} \quad \alpha = \frac{\kappa M}{4\pi}, \quad \kappa = 1.87 \times 10^{-27}, \tag{4}$$

$\delta_{\rho\sigma}$ is 1 or 0, respectively accordingly as $\rho = \sigma$ or $\rho \neq \sigma$, and r is the quantity $(x_1^2 + x_2^2 + x_3^2)^{1/2}$.

Then, based on an assumed validity of his equivalence principle, and the velocity of light to be

$$\sqrt{\left(\frac{dx_1}{dx_4}\right)^2 + \left(\frac{dx_2}{dx_4}\right)^2 + \left(\frac{dx_3}{dx_4}\right)^2} = \gamma, \tag{5}$$

he obtains the deflection angle to be

$$\mathrm{B} = \frac{2\alpha}{\Delta} = \frac{\kappa M}{2\pi\Delta} \tag{6}$$

that has good agreement with observation. Using assumed satisfaction of his equivalence principle again in 1921, Einstein [16] derived the bending of light with harmonic gauge. He obtained the metric, to the first approximation,

$$ds^2 = c^2 \left(1 - \frac{K}{4\pi}\int dV_0 \frac{\sigma}{r'}\right)dt^2 - \left(1 + \frac{K}{4\pi}\int dV_0 \frac{\sigma}{r'}\right)(dx^2 + dy^2 + dz^2), \tag{7}$$

where $r'^2 = x^2 + y^2 + z^2$. Based on an assumed validity of his equivalence principle again, Einstein obtained

$$\left\{ \begin{aligned} &\sqrt{dX^2 + dY^2 + dZ^2} = \left(1 + \frac{\kappa}{8\pi}\int \frac{\sigma dV_0}{r'}\right)\sqrt{dx^2 + dy^2 + dz^2} \\ &dT = \left(1 - \frac{\kappa}{8\pi}\int \frac{\sigma dV_0}{r'}\right)dt \end{aligned} \right. \tag{8}$$

since the local metric is $ds^2 = c^2 dT^2 - dX^2 - dY^2 - dZ^2$. Then the light speed is

$$\frac{\sqrt{dx^2 + dy^2 + dz^2}}{dt} = \left(1 - \frac{\kappa}{8\pi}\int \frac{\sigma dV_0}{r'}\right)c \tag{9}$$

From (9), Einstein obtain

$$\mathrm{B}' = \frac{2\alpha}{\Delta'} = \frac{\kappa M}{2\pi\Delta'}, \tag{10}$$

where $\Delta'$is the shortest distance from the sun center to the light ray. Since Δ' is interpreted as the distance according to the harmonic gauge, Δ' and Δ, which is interpreted according to the Schwarzschild gauge, are actually different. (According to Weinberg [40], we have $r = r' + \kappa M$.) Nevertheless, Einstein [16] incorrectly concluded that the deflection angle is gauge invariant [3]. Thus, Einstein also inadvertently created an error in favor of Pauli's version.

Since time dilation and space contractions should be unique because they can, in principle, be obtained from measurements. Thus, for a given frame of reference, only one gauge can be valid in physics; but the covariance principle implies otherwise. Furthermore, the calculation of the bending of light is also inconsistent with Einstein's theory of measurement that necessitates the covariance principle. In fact, it has been proven that both of them are invalid in physics [10]. Nevertheless, due to inadequate understanding of Einstein's equivalence principle and physics, many theorists make the incorrect choice of accepting the covariance principle.

IV. Invalidity of Einstein's Covariance Principle

Einstein's covariance principle is a source of errors that sustains misinterpretations [1, 2, 10, 41]. Starting from this "principle", Einstein implicitly assigns different physical meaning to coordinates for different gauges [3, 42, 43].

The principle of general relativity states "The law of physics must be of such a nature that they apply to systems of reference in any kind of motion. Einstein extended this principle to unrestricted covariance and called it as the "principle of covariance" [15, 16]. He stated, "The general laws of nature are to be expressed by equations which hold good for all systems of co-ordinates, that is, are co-variant with respect to any substitutions whatever (generally co-variant)."

However, as Einstein [16] pointed out, the time coordinate must be distinct from a space coordinate. Moreover, the gauge conditions are known to be not tensor conditions. Einstein failed to see that different gauges would lead to different physical interpretations of the coordinates, but Zhou did [1, 2]. Based on that both the Schwarzschild and the harmonic solution produced the same first order deflection of a light ray,

Global Journal of Science Frontier Research (A) Volume XIII Issue VII Version I Year 2013

Einstein [16] prematurely remarked, "It should be noted that this result, also, of the theory is not influenced by our arbitrary choice of a system of coordinates."

In Einstein's arguments for this principle, he emphasized that a physical theory is about the coincidences of the space-time points, but the meaning of measurements is crucially omitted [15]. Eddington [44] commented, "space is not a lot of points close together; it is a lot of distances interlocked." To describe events, one must be able to relate events of different locations in a definite manner [45]. Moreover, as pointed out by Morrison, the "covariance principle" is invalid because it disrupts the necessary physical continuity from special relativity to general relativity [30, 45].

Note that Einstein's "principle of covariance" has no theoretical basis or observational support beyond allowed by the principle of general relativity [45]. To start with, the covariance principle was proposed as a remedy for the deficiency of Einstein's adaptation of the notion of distance in a Riemannian space. Such an adaptation has been pointed out by Whitehead [46] as invalid in physics. However, Einstein does not know how to modify the mathematics [15]. Recently, it is found that his justifications are due to invalid applications of special relativity [10].

Moreover, his calculation for the bending of light has actually proved that his theory of measurement is experimentally invalid. If one defines the distance as in the Riemannian space, one would get only half of the observed value of light blending [22]. It turns out, however, that the correct theory of measurement [43] is just what Einstein practiced in his calculation of the bending of light [10].

Nevertheless, many still believe in this invalid "principle", in part, because gauge invariance has a long history starting from electrodynamics. The notion of gauge invariance has been developed to non-Abelian gauge theories such as the Yang-Mills-Shaw theory [47, 48]. [9)] They naively extended the invariance of the Abelian gauge to the cases of the Non-Abelian gauges in terms of mathematics. However, subsequently as shown by Aharonov & Bohm [49], the electromagnetic potentials actually are physically effective; and, as shown by Weinberg [50], all the physical non-Abelian gauge theories are not gauge invariant such that masses can be generated. These facts support the view that gauge invariance of the whole theory would be a manifestation that there are some deficiencies [51, 52].

It has been shown by Bodenner & Will [53] and Gérard & Piereaux [54] that the deflection angle is gauge invariant to the second order. However, upon examining the physical meaning of the impact parameter b of the light ray and the shortest distance r_0 from the light ray to the center of the sun, it is clear that these physical quantities cannot be both gauge invariant. From the Schwarzschild gauge and the harmonic gauge, one has respectively

$$b \approx \kappa M + r_0, \tag{11a}$$

but

$$b \approx 2\kappa M + r_0 . \tag{11b}$$

Thus, Einstein's covariance principle is clearly invalid.

Another counter example for the covariance principle is the formulas for the de Sitter precession. For instance, from the Maxwell-Newton Approximation [55, 56], one would obtain a formula [45] as follows:

$$\frac{d\vec{S}}{d\tau} = -2(\vec{v}\bullet\vec{S})\vec{\nabla}\Phi + v(\vec{S}\bullet\vec{\nabla}\Phi) + \vec{S}(\vec{v}\bullet\vec{\nabla}\Phi) = \vec{v}\times(\vec{S}\times\vec{\nabla}\Phi) + \vec{S}\times(\vec{v}\times\vec{\nabla}\Phi), \text{ where } \phi = -\kappa M/r \tag{12a}$$

v is the velocity of the gyroscope, and **S** is the spin. From the Kerr metric, one has a different formula [3] as follows:

$$\frac{d\vec{S}}{d\tau} = -3(\vec{v}\bullet\vec{S})\vec{\nabla}\Phi + 3\hat{r}(\vec{S}\bullet\hat{r})(\vec{v}\bullet\vec{\nabla}\Phi), \tag{12b}$$

where $\hat{r}$ is the unit vector in the r-direction. For a circular orbit, since $(\vec{v}\bullet\vec{\nabla}\Phi) = 0$, we have

$$\frac{d\vec{S}}{d\tau} = -2(\vec{v}\bullet\vec{S})\vec{\nabla}\Phi + v(\vec{S}\bullet\vec{\nabla}\Phi) \tag{12a'}$$

and

$$\frac{d\vec{S}}{d\tau} = -3(\vec{v}\bullet\vec{S})\vec{\nabla}\Phi, \tag{12b'}$$

that is, formula (12a) and (12b) are reduced to (12a') and (12b') respectively.

One may ask whether the difference between (12'a) and (12'b) can be detected experimentally. In principle, they should be distinguishable. However, they cannot be distinguished by the Stanford experiment, gravity Probe-B because this experiment detects only the time average. The time average of the difference is essentially zero since

$$(\vec{v}\bullet\vec{S})\vec{\nabla}\Phi + \vec{v}(\vec{S}\bullet\vec{\nabla}\Phi) = \frac{\kappa M}{r^2}\left[\hat{y}(-S^y\sin 2\omega t + S^z\cos 2\omega t) + \hat{z}(S^y\cos 2\omega t + S^z\sin 2\omega t)\right] \tag{12c}$$

where ω is the circular frequency of the orbiting gyroscope. Thus, gravity Probe-B is designated to accomplish little beyond the bending of light because of inadequate theoretical understanding. It seems a feasible simple experiment to show the broken down of gauge invariance is still the experiment on local light speeds [43] pioneered by Zhou [2].

Global Journal of Science Frontier Research (A) Volume XIII Issue VII Version I Year 2013

Nevertheless, Misner et al. [5, p. 430] claimed that the covariance principle can be verified experimentally, but provided the opposite evidence. For instance, Will [5; p. 1067] claimed Whitehead's theory is invalid; but the solution of Whitehead is diffeomorphic to Einstein's [57]. Their motivation seems to justify such a "principle" because it is often used in arguments of their theory of black holes. One may wonder why nobody corrected their mistake [5]? The answer would be that that many theorists often failed to distinguish the difference between physics and mathematics.[10)]

Moreover, since the covariance principle is necessary to remedy the shortcomings of Einstein's theory of measurement [16], which was justified with applications of special relativity, many would still believe in the covariance principle even though counter examples have been found [41]. *Thus, to understand the issue of the covariance principle thoroughly, one must examine also Einstein's justification for "measurement" with applications of special relativity.*

In the book of Misner et al., their errors in physics, mathematics and logic are exposed, but were not recognized. This supports the claim of Feynman [58] that many theorists in gravitation are just incompetent. To see all these errors clearly, it is necessary to understand also the principle of causality.

V. The Principle of Causality and the Einstein Equation

The time-tested assumption that phenomena can be explained in terms of identifiable causes is called the principle of causality [55, 56]. This principle is the basis of relevance for all scientific investigations, and thus is always implicitly used [59]. This principle is commonly used in symmetry considerations in electrodynamics.

In general relativity, Einstein and other theorists have used this principle implicitly on symmetry considerations [55] such as for a circle in a uniformly rotating disk and the metric for a spherically symmetric mass distribution. Nevertheless, this principle is often neglected [55, 60] because the confusion on physical coordinates created by the invalid covariance principle that would make it almost impossible to justify the symmetry used. *Applications of the principle of causality become clear after Einstein's equivalence principle is understood* [10, 11].

Because of the "covariance principle", the coordinates were ambiguous, and thus it is often difficult to apply the principle of causality in a logical manner other than implicitly as Einstein did. Since the covariance principle is necessary to remedy the shortcomings of Einstein's theory of measurement [16], many would give up only after it was found recently that the justifications of Einstein's theory of measurement actually were based on invalid applications of special relativity [10, 61],[11)] in addition to being in disagreement with observed bending of light rays.

There are other useful consequences of the principle of causality. For instance, the weak sources would produce weak gravity is the theoretical foundation of Einstein's requirement on weak gravity [59].[12)] The unbounded "weak waves" of Bondi, Pirani, & Robinson [12] are not valid because it cannot be reduced to the flat metric when gravity is absent. Parameters unrelated to any physical cause in a solution are not allowed. For instance, Penrose [62] accepted the metric with an electromagnetic plane-wave as a source, but it actually is not valid in physics because unphysical parameters are involved [13]. Moreover, a dynamic solution must be related to appropriate dynamic sources [63].

One might argue that a gravitational plane-wave would have no source. For the fact that a plane-wave is intrinsically unbounded, there is no valid explanation until the principle of causality is recognized. A plane wave is not real, but a local idealization of a section of the wave. For a cylindrical symmetric wave, however, appropriate sources must be present. The Einstein-Rosen type waves are invalid because it is impossible to have physically appropriate sources [63]. However, due to inadequate understanding in mathematics and physics, the principle of causality can be misunderstood.

For instance, 't Hooft naively claimed [64], "Dynamical solutions means solutions that depend non-trivially on space as well as time. Numerous of such solutions are being generated routinely in research papers ..." Thus, he has different, but invalid understanding of the principle of causality. He [64] claimed, "To me, causality means that the form of the data in the future, $t > t_1$, is completely and unambiguously dictated by their values and, if necessary, time derivatives in the past, $t = t_1$. So, I constructed the complete Green function for this system and showed it to Mr. L. This function gives the solution at all times, once the solution and its first time derivative is given at $t = t_1$, which is a Cauchy surface." However, his data actually are calculated values only [63] and this unequivocally confirms his confusion.

Thus, his causality only means that a Maxwell-type equation, which produces the Green function, is satisfied. This is inadequate because a solution of the Maxwell equation could violate the principle of causality. For instance, the electromagnetic potential $A_0[\exp(t - z)^2]$ (A_0 is a constant), is invalid in physics. Although a plane-wave can be considered as an idealization of a field generated by sources, this function cannot be considered as such an idealization [63].

Many relativists recognize the light speed as the speed limit of physical influence, but failed to understand the principle of causality. Moreover, the covariance principle would confuse applied mathematicians such as 't Hooft, [13)] to fail in distinguishing physics from mathematics [63]. In fact, journals such as the Physical Review also do not understand the principle of causality adequately, and accept unbounded solutions [63]. However, since a bounded dynamic solution is needed for the calculation of radiation, *the non-existence of a bounded dynamic solution remains an unsolved issue.*

VI. The Einstein Equation and its Misinterpretations

Based on his field equation, Einstein [15, 16] made three predictions namely: 1) the gravitational redshifts, 2) the perihelion of Mercury, and 3) the deflection of light. Observations accurately confirm and create a faith in his theory. However, these confirmations are actually inflated and explained as follows:

1) The gravitational redshifts were first derived from the invalid 1911 assumption of the equivalence between acceleration and Newtonian gravity. This shows that the gravitational redshifts can be derived from an invalid theory.
2) The observed bending of light is inconsistent with Einstein's theory of measurement [65], [14)] but is consistent with the measurement based on the Euclidean-like structure if his equivalence principle is valid for the metric [16].
3) As Gullstrand [66] suspected, in 1995 it has been proven impossible to have a bounded dynamic solution.[15)] Thus, the perihelion of Mercury, in principle, is still beyond the reach of the Einstein equation [56]. *This fundamental mistake in calculation, as will be shown, has far reaching influences to other important errors in astrophysics.*

Also, Einstein's controversial notion of gravitational energy-stress being a pseudo-tensor has been proven incorrect [56]. Since Einstein's covariance principle is proven to be invalid [3], and diffeomorphic solutions with the same frame of reference are not equivalent in physics. Therefore, actually none of the predictions had a solid theoretical foundation yet.

An urgent issue is to find a valid physical gauge for a given problem. Fortunately, the Maxwell-Newton approximation has been proven to be an independently valid first order approximation for gravity due to massive sources [59], so that the binary pulsar radiation experiments can be explained satisfactorily [55, 56]. Thus, Einstein's notion of weak gravity (including gravitomagnetism and gravitational radiation [67]) is valid [13, 59]. Moreover, calculations of the Hulse-Taylor experiments of the binary pulsars necessitate that the coupling constants have different signs [56]. Thus, the assumption of a unique coupling sign for the singularity theorems [7] of Penrose and Hawking is proven invalid. [16)]

Moreover, this leads to the investigation that Lo [68] discovered the static charge-mass neutral repulsive force, and thus further confirms the famous formula $E = mc^2$ being only conditionally valid. Nevertheless, as shown in the 1993 press release of the Nobel Committee for the Physics Prize [4], the "experts" failed to see that the Einstein equation does not have a dynamic solution for a two-body problem. The root of this problem is a failure in mathematics to see that the linearization to obtain an approximate solution is not valid for the dynamic case [10, 11, 56]. Physically, this is due to a failure to recognize that, for the dynamic case, the Einstein equation violates the principle of causality because the absence of an energy-stress tensor in vacuum. Such a tensor is necessary, according to Hogarth [69].

Nevertheless, to counter the claims of Gullstrand [66], the Princeton University published a book [9] by Christodoulou & Klainerman. They claimed that bounded dynamic solutions have been constructed, [17)] due to errors in mathematics such as forgotten to prove a set is non-empty [70-72]. [18)] Misner et al. [5] invalidly claimed that their eq. (35.31) has a bounded plane-wave solution [11]; and Wald [7] invalidly claimed that his eq. (4.4.52) has a solution for the second order [55]. Wald [7; p. 183] also incorrectly extended the process of perturbation approximation to the case that the initial metric is not flat. These show that a biased belief can absurdly lead to collective mistakes in mathematics.

Consequently, they also failed to see that the electromagnetic energy is not equivalent to mass [6-8], can be proven even if the electrodynamics of Maxwell were only approximately valid [73, 74]. As a result, not only they incorrectly insisted that the formula $E = mc^2$ is unconditional [60] but also over-looked that, in contrast to the implicit assumption of Wheeler's simulation, the Einstein equation necessitates the existence of a repulsive charge-mass interaction [75, 76].

In 2005 the effect of such a repulsive force was inadvertently detected by Tsipenyuk & Andreev [77]. They discovered that the weight of a metal ball is reduced after it is irradiated with high energy electrons. However, they could not explain this phenomenon because it was believed that gravity would increase as energy increases. The static charge-mass repulsive force was discovered in 1997 because Lo [68] had already known that $E = mc^2$ may be invalid. [19)]

The neutral repulsive force derived by Lo [68, 76] is: *For a charge q and a mass m separated by a distance r, the charge-mass repulsive force is* mq^2/r^3 (in the units, light speed $c = 1$, and Newtonian coupling constant $\kappa = 1$ [5]). Further experimental verifications for the details are important because it is the only confirmation of general relativity with a non-massive source, and thus is beyond the Maxwell-Newton Approximation.

In short, for the dynamic case, the Einstein equation is proven invalid. For the static case, verification of the Einstein equation beyond the Maxwell-Newton Approximation depends on the experimental confirmation of the static charge-mass repulsive force. However, the discovery of such a repulsive force casts a strong doubt on a current belief that gravity is always attractive. The explosion of a super nova is a frequently observed phenomenon, but a black hole remains a conjecture that has never been confirmed by observation.

Einstein believed that he has proved the famous formula $E = mc^2$ for the electromagnetic energy because he has mistaken that the photons have only electromagnetic energy. In 1997, it has been proven that $E= mc^2$ is conditionally valid, and this explains the failure of Einstein's several attempts to prove this formula for other types of energy [78]. This error on $E = mc^2$ is the root that the charge-mass interaction is not only overlooked but denied by other theorists earlier.

VII. MIT Open Course Phy. 8.033, Fall 2006, Lecture 16 -- Max Tegmark [20)]

To illustrate the influence of the Wheeler School, an open course MIT phys. 8.033 is chosen since it is accessible to everybody. If a reader checks MIT 8.962 general relativity, similar errors can be found although its contents were not very clear. These courses were established in 2006 after P. Morrison passed away.

Some course contents are out-dated at least 25 years since the Wheeler School does not read broadly. Notably, the formula $E = mc^2$ is still incorrectly considered as unconditionally valid.

In general relativity, the course addresses three issues:

- Principle of equivalence
- Light bending, gravitational redshift
- Metrics

Since the course was prepared in 2006, the influence of Institute Professor P. Morrison disappeared. In this course, the invalid 1911 assumption of equivalence is mistaken as Einstein's equivalence principle of 1916.

The course proclaimed the "weak equivalence principle" as no local experiment can distinguish between a uniform gravitational field g and a frame of accelerated with a = g. This error is due to the Wheeler School since the ambiguous notion of local experiment is invented by the Wheeler School. First, according to Einstein's equivalence principle, the effect of an accelerated frame is not equivalent to a uniform Newtonian gravitational field [23, 25]. Second, the Einstein-Minkowski condition [15, 16], which is the physics of Einstein's equivalence principle, is ignored. Also, there are local experiments that can distinguish the effect of an accelerated frame from an approximately uniform field [79].

The claim of the "strong equivalence principle" that the laws of physics take on their special relativistic form in any local inertial frame is due to the Wheeler School. The correct statement should be that the laws of physics take on the approximate special relativistic form in any local inertial frame. The claim of considering that a free falling elevator is a locally inertial frame so the strong version says that special relativity applies in all such elevators anywhere and any time in the universe, is copied from the Wheeler School and manifests of ignorance on Einstein's equivalence principle.

The course incorrectly claimed

- EP implication 1: Gravity bends light
- EP implication 2: Gravitational redshift.
- EP implication 3: It is all geometry (learn how to work with metrics!)

First their version of EP, as already known, cannot lead to the correct light bending. Second, although it does lead to gravitational redshift, the argument has been proven invalid in physics since gravity is not generally equivalent to acceleration. The claim, "It is all geometry" has no meaning since the issue of the physical gauge is ignored.

Since the instructor does not understand Einstein's equivalence principle, he is unable to address how the issue of length related to the metric that Whitehead [46] criticized. In particular, he also did not know that the Newtonian metric, $d\tau^2 = (1 + 2\phi)dt^2 - dx^2 - dy^2 - dz^2$, is not valid in general relativity [25] although the Wheeler School knows this well. [21)]

It is also clear that the instructor does not understand Einstein's covariance principle. He considered this naively as only the validity of coordinate transformation in mathematics. However, the essence of the covariance principle leads to conflicts because the physical meaning of the coordinates is related to the gauge [1-3, 40].

Another important issue is the perihelion of Mercury that Einstein claimed to have been fully explained in general relativity. On the other hand, Gullstrand [66] suspected that Einstein's claim is invalid. Since the perihelion is actually calculated in term of the perturbations of other planets, a central issue is whether the perturbation approach is valid for the Einstein equation. In most textbooks, for instance reference [67], it is claimed that linearization would give a valid approximate solution.[22)] However, it has been proven that the Einstein equation does not have a bounded solution for a two-body problem [55, 56]. Many insisted on that the approach of linearization is valid. However, sciences are based on evidences not just the opinion of majority. Nevertheless, many just do not have the mathematical background [63].

Global Journal of Science Frontier Research (A) Volume XIII Issue VII Version I Year 2013

In short, Tegmark also fails to tell the difference between mathematics and physics and in addition has an inadequate background in mathematics and is essentially an applied mathematicians such as 't Hooft [63]. This is further supported by the fact that Tegmark has also formulated the "Ultimate ensemble theory of everything", whose only postulate is that "all structures that exist mathematically exist also physically". This idea is formalized as the "Mathematical universe hypothesis" in his paper *The mathematical universe*, a short version of which was published as *Shut up and calculate* (Wikipedia). A suggestion for him would be "Shut up, think, and then calculate". [23)]

Also, the Wheeler School actually provides a simple evidence for their own down fall. They claim [5] that there is a bounded wave solution for their equation (35.31). However, it is not difficult to show that such a claim is incorrect with mathematics at the undergraduate level [10, 11]. Since everybody would understand mathematics at such a level, the claim of authority would no longer work for them. This is also a problem for the Nobel Committee to consider.

E. Bertschinger and S. A. Hughes of MIT studied the linearized equation of the Einstein equation. However, they do not understand that for the dynamic case, the non-linear Einstein equation and its linearized equation do not have any compatible solutions [55, 56]. In fact, the linearized equation is compatible with a modified Einstein equation with an additional gravitational energy-momentum tensor in the source with an anti-gravity coupling [55, 56]. In other words, in the Physics Department of MIT, nobody understands the basic essence of general relativity.

VIII. Conclusions and Remarks

The Wheeler School continues Einstein's error on the principle of covariance; and made new errors in misinterpreting Einstein's equivalence principle and the principle of causality. Moreover, they maintain even obvious errors by ignoring work of others, including Einstein [15] and Weinberg [40]. Their ambition is manifested in naming their book "Gravitation" instead of general relativity like others. [24)] *However, to justify Einstein's covariance principle as if valid, it is necessary to distort Einstein's equivalence principle for consistence; and thus created more errors.*

Wheeler started by picking up the abandoned work of Oppenheimer [14]. The Wheeler School gained their reputation as the advocate of general relativity [1)] by distorting Einstein's equivalence principle to a combination of the errors of Pauli [33] and also Fock [25], but ignored Einstein's [15, 16] and related mathematics [34]. Nevertheless, they managed to convince the 1993 Nobel Committee to adopt their version [4]. In 1994 they [8] openly rejected Einstein's equivalence principle, which they [5] do not understand as shown by their erroneous eq. (40. 14).[2)] Also the MIT Open Course phys. 8.033 has been changed to their views the next year after MIT Institute Professor P. Morrison passed away.[25)] Thus, in defense of the honor of Morrison, it is necessary to point out their distortions and related errors [30].

The acceptance of the Wheeler School is due to the publicity skills of Wheeler in spite of inadequacy in mathematics and physics [43, 56].[1)] However, there is no conclusive hard evidence to support any of their speculations. They [5] rely essentially on the covariance principle to create confusion to substantiate their claims. The Wheeler School invents the term "standard theory" for their status. However, such a notion was challenged by the editorial of the Royal Society. They failed to meet such a challenge [13] because they do not understand the principle of causality adequately. However, they simply ignore the challenge. Members of the Wheeler School help each other to maintain and re-enforce their errors by ignoring criticisms and/or with invalid arguments.[1)] However, their incompetence illustrates their errors. They claimed that their eq. (35.31) has a bounded solution is due to errors at the undergraduate level [11, 80]; and there are no bounded plane-wave solutions [81]. Another basic problem of the Wheeler School is that they are unable to recognize any new physics from observation; and those in the position of editors would reject a paper according to just their opinion instead of evidence. For instance, the fact that a charged capacitor has reduced weight [82] was ignored as experimental errors without adequate deliberation.

Einstein's equivalence principle has a foundation in mathematics [38] and also experimental supports [32]. Nevertheless, many instead believe in errors related to the covariance principle [10]. They failed to see that the notion of general gauge invariance is actually invalid (see Section 4). *Due to inadequacy in mathematics and physics, the Wheeler School mistakenly chooses the covariance principle; and thus it becomes necessary for them to distort Einstein's equivalence principle.* However, the problem is that both mathematics and physics do not allow such distortions.

Unfortunately, there are prominent theorists who also made similar errors as the Wheeler School.[26)] For instance, Eric J. Weinberg, editor of the "Physical Review D", claimed that the difference between these two versions of Einstein and Pauli is not physical [22], and rejected any paper claimed otherwise. *Thus, he failed to see that eq. (40. 14) in reference [5] is incorrect.* He rejected proofs for the conditionally validity of $E = mc^2$ based on existing theories [68, 83, 84]. [27)] He also won prizes (1992, 1995, 2000) from "Gravity Research Foundation" that always keeps her judges undisclosed.

In general relativity, the fundamental issues are: Einstein's equivalence principle, Einstein's covariance principle, the principle of causality, invalidity of linearization, and measurements of the distance.

However, the Wheeler School and associates manage to make errors in all five issues because of their inadequacy in mathematic and physics.

Moreover, there are three more related issues: 1) the formula $E = mc^2$ is conditionally valid since the electromagnetic energy is not equivalent to mass; 2) the coupling signs have been found not unique, and thus the singularity theorems are irrelevant; and 3) the photons include non-electromagnetic energy because they are equivalent to mass. The errors on these issues are due to inadequacy in mathematics, and earlier immature physical concepts. The photon was proposed as including only electromagnetic energy before general relativity. Moreover, the photons including energy other than the electromagnetic energy imply that current quantum mechanics is not a final theory.

Nevertheless, after general relativity is rectified, the necessity of unification between gravitation and electromagnetism is clear since the charge-mass interaction is discovered. Then the discovery of NASA's pioneer anomaly would be understandable in physics. Einstein actually leaves us a far greater treasure to be explored [73, 74].

Great scientists such as Einstein also made mistakes. (Einstein's justifications for measurement [15, 16] are based on invalid applications of special relativity [10] and lead to difficulties in defining physical quantities [65]. His simple adaption to Riemannian geometry [15, 16] created a problem of incompatibility to the rest of physics.) *However, after his errors are rectified, general relativity is no longer incompatible with other theories in physics; and Einstein emerges as an even better physicist since his conjecture of unification is proven necessary.* Whitehead [46] had remarked, "But the worst homage we can pay to genius is to accept uncritically formulations of truths which we owe to it."

Modern physics has been developed to such a stage that frontier physicists can no longer afford to ignore physical principles, and/or to leave all pure mathematics to mathematicians. Einstein did not understand mathematical analysis, and thus he could not modify the mathematics for the need of physics [43]. Pauli and the Wheeler School do not understand the related mathematics, and thus failed to see that there are restrictions to the equivalence principle that cannot be changed at will. *The distortion of Einstein's equivalence principle is the root that is related to all other errors.* Now, the importance of Einstein's equivalence principle has been firmly re-established [10]. Note also that only when the principle of causality is better understood, can we succeed in proving the non-existence of dynamic solutions.

Nevertheless, because the Field medalists do not understand the restriction in physics,[28)] they also failed to see this. Thus, in 2011 Christodoulou was absurdly awarded a half Shaw Prize for his errors in general relativity [3, 9] against the honorable Gullstrand [66].[29)] Note that, as Whitehead [46] pointed out, *Physics is not just a branch of geometry as the Wheeler School advocated.* Some theorists claim if there are more experiments, the situation in general relativity would be better. However, the realistic situation is, for instance, experiments of the binary pulsar are misinterpreted because of theoretical errors. [30)] Now, it is the time for the US to get rid of the theoretical obstacles [31)] and get the benefits from extensively invested experiments in return. Then, new theoretical research and experiments would start.

It is hoped that this paper, together with the quotation of Weinberg, would be helpful to physicists, including those who used to work on out-dated theories. [32)] Also, one would see errors, if one works out explicit specific examples for the claims and reads the original papers carefully. Moreover, it is time to do some meaningful work related to experiments together with reliable mathematics and logic [3, 10, 79, 85].[33)] An interesting issue would be how to prevent errors of such a magnitude and duration in the future. Many of the current problems are due to irrational confidence because of early widely spread ignorance and error; and thus it would be helpful if the education of mathematics is strengthened.

IX. Acknowledgments

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a) *Appendix: Summary of Misrepresentations and Errors in General Relativity*

For the convenience of the readers, the errors and misinterpretations in general relativity are summarized in this Appendix. The first error, suspected by Gullstrand [66], is the non-existence of dynamic solutions. However, this error lasts for more than 95 years; and in 2011 half of a Shaw Prize for mathematics was awarded to Christodoulou [86] for his errors against Gullstrand. [34)] This error has been firmly well-established because it can also be illustrated with examples understandable at the undergraduate level. The fundamental issues that historically relate to errors are:

1) Einstein's 1911 assumption of equivalence between acceleration and Newtonian gravity [24]: It was used to derive the correct gravitational redshifts, but the so-obtained light bending deflection disagrees with observation.
2) Einstein's equivalence principle [15]: The effects of an accelerated frame are equivalent to a uniform

gravity (generated by a metric). In physics, the local metric of a particle under the influence of gravity is a local Minkowski metric [15]. This principle can be illustrated with explicit examples and is supported by experiments. Since the local metric of the earth is only a locally constant metric at one point, Einstein pointed out that the gravity cannot be transformed away by using an accelerated frame. Thus, gravity and acceleration are not generally equivalent.

a) Pauli's misinterpretation [33]: Pauli claimed that the gravity of an infinitesimal region can be transformed away; but the local metric of a particle need not be locally Minkowski.
b) The misinterpretation of Misner, Thorne & Wheeler [5]: They agree with Pauli and incorrectly claimed that gravity is equivalent to acceleration in a small region of the local metric. What they referred to is the Newtonian gravity (since they agree with Fock [25] and reject the principle). Moreover, they claimed that in such a small region the local metric is necessarily Minkowski (the so-called Lorentz invariance). However, their notion of Lorentz invariance is incorrect in mathematics and is not favored by the 2009 experiment of Chu et al. [87].
c) Fock [25] misinterpreted that Einstein's equivalence principle as the 1911 assumption. He shows that it is impossible to have a metric for the Newtonian gravity in general relativity; and invalidly rejected the principle.

3) Einstein's covariance principle: Einstein extended his principle of general relativity to unrestricted mathematical covariance and called it as the "principle of covariance". The motivation of this principle is a remedy of his theory of measurement [15, 16]. Since different gauges would lead to different physical interpretations of the coordinates [1, 3], this is in conflict with his equivalence principle which implies the local time dilation and space contractions are unique. These are the experimental support of Einstein's equivalence principle.
4) Einstein's measurement of the distance [15]: Einstein's adaptation of the notion of distance in a Riemannian space. Such an adaptation has been pointed out by Whitehead [46] as invalid in physics. Also, it is found that his justifications for his adaptation are due to invalid applications of special relativity [10]. It turns out that the correct theory of measurement [43] is just what Einstein practiced in his calculation of light bending. Then, the measurement of distance is consistent with the observed bending of a light ray [22]. Thus, it becomes clear that to regard the Hubble redshifts as due to the Doppler effects is invalid [88], as Hubble himself also disagrees.
5) The question of a physical gauge: The invalidity of the covariance principle exposed an urgent issue, i.e., to find a valid physical gauge for a given problem. Fortunately, the Maxwell-Newton approximation has been proven to be an independently valid first order approximation for gravity due to massive sources [59], so that the binary pulsar radiation experiments can be explained satisfactorily [55, 56]. Thus, Einstein's notion of weak gravity (including gravitomagnetism and gravitational radiation [67]) is valid [13, 59].
6) The principle of causality is implicitly used in any scientific research. In general relativity, this principle is implicitly used by Einstein in symmetry considerations [15]. However, theorists such as Penrose [62] and 't Hooft [63, 64] do not understand this principle adequately. The Physical Review also failed to understand the principle of causality adequately and thus mistakenly believed that the non-linear Einstein equation has wave solutions [63]. In particular, this journal still falsely considered their editors are better than anybody else in the field of physics.
7) Invalidity of linearization [10]: Currently, to obtain an approximation through linearizing the Einstein equation is incorrectly believed as generally valid because linearization has been successful for the static case of massive source. However, this process of linearization for the dynamic cases is invalid since the Einstein equation actually has no bounded dynamics solutions [55, 56]. The physical reason is that such an Einstein equation has no source tensor in the vacuum and thus, the principle of causality is violated since a wave carries energy in vacuum.
8) Bounded dynamic solutions: The Einstein equation has no bounded dynamic solution. Thus the perihelion of Mercury is beyond the reach of Einstein's theory as Gullstrand [66] suspected; and the calculation for the gravitational radiation of binary pulsars is actually invalid. A conclusion from this result is that all the coupling constants cannot have the same sign, and thus the physical assumption of the space-time singularity theorems [7] is invalid.
9) The sign of coupling constants being unique was accepted since $E = mc^2$ was considered as unconditional. However, the electromagnetic energy cannot be equivalent to mass since the trace of an electromagnetic energy-stress tensor is zero. In fact, for several years, Einstein had tried and failed to prove this formula for other type of energy [78].
10) The photons must have non-electromagnetic energy because the meson π_0 decays into two photons. The immature assumption that the photons have

Global Journal of Science Frontier Research (A) Volume XIII Issue VII Version I Year 2013

only electromagnetic energy was proposed before general relativity.[35)] Since a charged particle is massive, it is not surprising that the photons should also include gravitational energy.

11) The static Einstein equation with the source of a charged particle implies the existence of a static repulsive force between a charge and a massive particle. Moreover, such a repulsive effect has been inadvertently observed by Tsipenyuk & Andreev [77]. Thus, unification of gravitation and electromagnetism is actually necessary.

Note that all the errors are directly or indirectly related to distortions of Einstein's equivalence principle. The invalid speculation of unconditional validity of $E = mc^2$ is the source of many errors in general relativity, and thus Einstein's general relativity is not yet complete. Its completion would be crucial to explain the Hubble redshifts and the pioneer anomaly discovered by NASA [17-19], and may even be needed to explain problem of renormalization.

Endnotes

1) The editorial of General Relativity and Gravitation considers the claims of the Wheeler School as "well-established science", but were unable to provide evidence to support such claims [March 8, 2012]. Note that since there is no bounded dynamic solution for the Einstein equation [56], the thesis of A. Ashtekar (editor-in-chief), "*Asymptotic Structure of the Gravitational Field at Spatial Infinity*", seems to just inherit the errors of Wald [7]. Moreover, in his quantum gravity, he failed to see that the photons must include gravitational energy [10, 83]. C. M. Will, editor-in-chief of Classical and Quantum Gravity, continues to ignore the errors of the Wheeler School [6, 68, 84].
2) Eddington [44], Liu [36], Straumann [89], Wald [7], and Weinberg [40] did not make the same mistake.
3) This experimental fact is ignored by the Wheeler School or they simply were unaware of this.
4) In fact, this author had made the same mistake [90] that was discovered in our discussions with Morrison.
5) It is surprising that "expert" Thorne [14] also made such a factual error.
6) Nevertheless, the 1993 Nobel Committee was unaware of that Einstein's equivalence principle has been verified.
7) Like other theoretical physicists, Pauli [33] and Misner et al. [5] also did not have adequate training in pure mathematics.
8) The misinterpretation of Misner et al. [5] creates the so-called Lorentz invariance, being tested by Chu et al. [87].
9) A footnote of Part II of reference [48] reads: "The work described in this chapter (ch.III) was completed, except for its extension in Section 3, in January 1954, but was not published. In October 1954, Yang and Mills adopted independently the same postulate and derived similar consequences." Yang-Mills-Shaw made only a crude proposal that cannot explain things [50]. Moreover, the underlying idea of total gauge invariance has been proven invalid.
10) Being a student of Oppenheimer, Morrison has a very sharp ability in distinguishing the physics from mathematics.
11) Experimentally, based on Thorne's calculation [91], invalidity of such a measurement can be further proven [92].
12) The Wheeler School failed to defend the requirement for weak gravity to meet the challenge of Bondi et al. [12].
13) In his 1999 Nobel Speech, 't Hooft also showed misunderstandings of the notion of mass and special relativity. 't Hooft [64] claimed that many of his colleagues agree with him, but this only means they make the same error.
14) Such an inconsistency has been discovered, and Einstein's derivation was not repeated in most textbooks.
15) A main error of Einstein, Infeld, & Hoffmann [93], Damour [94], Misner et al, [5], Wald [7], Will [6] and etc. is that they are unaware of that the mathematical existence of a bounded dynamic solution needs to be proved. It should be noted that Wald [7] failed to see that his eq. (4.4.52) cannot be satisfied for the dynamic case [55, 56].
16) The unique sign of couplings was accepted because the formula $E = mc^2$ was believed to be unconditional.
17) Understandably, because of totally unexpected, it was difficult for Princeton graduates such as Frank Wilczek to see such mathematical errors from Princeton University although he has a M. Sc. degree in mathematics.
18) Christodoulou & Klainerman [9] were unaware of that their set of solutions may have only static physical solutions [70-72]. Obviously, Christodoulou was still not aware of this when he received his half Shaw Prize in 2011.
19) This is a case that the static Einstein equation can predict beyond the Maxwell-Newton Approximation [95].
20) The research of Tegmark has focused on cosmology, combining theoretical work with new measurements to place constraints on cosmological models and their free parameters, often in collaboration with experimentalists (from Wikipedia, the free encyclopedia). He has developed data analysis tools based on information theory and applied them to Cosmic Microwave Background

experiments such as COBE, QMAP, and WMAP, and to galaxy redshift surveys such as the Las Campanas Redshift Survey, the 2dF Survey and the Sloan Digital Sky Survey.

21) Fock [25] showed that it is impossible to express a Newtonian uniform gravity with a spacetime metric.
22) Nobel Laureate 't Hooft [63] and Hehl [96] also believe that linearization is unconditionally valid as Bertschinger did [67]. However, the error is probably originated from the book of Christodoulou & Klainerman [9].
23) In cosmology, as C. N. Yang [97] pointed out, it is rather speculative and difficult to be rigorous. This inevitably would make some of them to argue speculatively, and occasionally to use questionable logic without noticing it.
24) Misner et al. [5] combined the 1911 assumption [24] and the errors of Pauli [33] as their version of the equivalence principle. Another problem is that they [5] maintain mistakes that others [15, 40] have clearly shown.
25) Under the leadership of Weisskopf, the tradition of MIT is that general relativity must be understood in terms of physics. However, the Wheeler School started to take over after Morrison past away.
26) Because the 1911 assumption is well-known to be incorrect after the 1919 British expeditions, in a book of 1973, there is no rational reason to take the 1911 assumption of equivalence between acceleration and Newtonian gravity as the reference for Einstein's equivalence principle, instead of his statements in his 1916 paper and his book. Such acts support the suspicion that the Wheeler School had planned to get rid of Einstein's equivalence principle.
27) His demand for experimental supports helps discovering of the charge-mass interaction. However, due to inadequacy in mathematics, Eric J. Weinberg believes that there are dynamic solutions for the Einstein equation [98].
28) Before 1993 mathematicians (including the Field Medalists E. Witten (1990), and S. T. Yau (1982) whose works have been closely related to general relativity) also failed to discover their work is misleading in physics [99]. Note also that there are at least a dozen of Nobel Laureates who had made errors in general relativity.
29) A. Gullstrand won a Nobel Prize in 1911, was a member of the Nobel Physics Committee of the Swedish Academy of Sciences in 1921, and was the Chairman of the committee (1922-1929).
30) Morrison had discussed with Taylor, but he clarified that Damour is responsible for the calculations [30].
31) In spite of the fact that many errors in general relativity were generated in Princeton University, this does not diminish my respect to this institute as a whole. Many of my respected teachers were graduated from Princeton University; such as Prof. A. J. Coleman and Prof. I. Halperin, who was my advisor for my degrees in mathematics.
32) The invalid speculation $E = mc^2$, misinterpreted as mass and energy unification, is prevailing in university courses such as MIT's Phys. 8.033, and Stanford's open lectures on Einstein's Theory of Relativity by Prof. L. Susskind. While giving very clear lectures, he also does not seem to have the background in mathematics to see the errors of Pauli and the Wheeler School on Einstein's equivalence principle and other prevailing errors.
33) Currently MIT has just changed the presidency from the hand of Hockfield to. Reif. While they both are competent administrators, they may have different styles in their leadership, in part, because of differences in background. Hockfield is a scientist and she tends to put more weight to considering evidence instead of a theory; and Rief is an engineer and thus would have an opposite attitude. Both presidents are enthusiastic about basic research extended into new areas. However, in terms of judging a field beyond one's expertise, a person who is more evidence oriented would have a better advantage. Thus, it is expected to be a tough job for Reif, if he wants to go to the bottom of matter for the field of general relativity.
34) Members of the selection committee seem to be very careless. Had the Selection Committee tried to find an example of the dynamic solution that could support the claims of Christodoulou, they would have found his errors.
35) Although the initial proof for the non-equivalence of mass and electromagnetic energy has used general relativity [68], this non-equivalence is independent of general relativity. In fact, this nonequivalence comes from the electromagnetism alone because the electromagnetic energy-stress tensor has a zero trace. Thus, the assumption that the light (or photon) includes only electromagnetic energy is incorrect [10, 85].

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Effect of Power Law Temperature Variation on a Vertical Conical Annular Porous Medium

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Abstract- In this chapter, we concentrate on the study of heat transfer by natural convection in a saturated porous medium with a power law temperature variation on a vertical conical annular porous medium". In this study Finite Element Method (FEM) has been used to solve the governing partial differential equations. There have been considerable interest in studying natural or buoyancy – induced flows in fluid saturated porous media adjacent to surfaces in recent years. This interest stems from numerous possible industrial and technological applications. Example of some applications include geothermal reservoirs, drying of porous solids, heat exchanger design, petroleum production, filtration, chemical catalytic reactor, nuclear waste repositories, and geophysical flows. The prediction and knowledge of heat transfer rate and temperature distribution from a heated horizontal surface to surrounding ground water in a subsurface environment has important applications in the assessment of geothermal resources and the design of a geothermal power plant.

Keywords: nusselt number ($\overline{Nu}$), rayleigh number (Ra), cone angle (C_A), radius ratio (R_r) and power law exponent (λ).

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EFFECT OF POWER LAW TEMPERATURE VARIATION ON A VERTICAL CONICAL ANNULAR POROUS MEDIUM

Strictly as per the compliance and regulations of :

Effect of Power Law Temperature Variation on a Vertical Conical Annular Porous Medium

Dr. D. Prabhakar [α] & Dr. G. Prabhakararao [σ]

Abstract- In this chapter, we concentrate on the study of heat transfer by natural convection in a saturated porous medium with a power law temperature variation on a vertical conical annular porous medium". In this study Finite Element Method (FEM) has been used to solve the governing partial differential equations. There have been considerable interest in studying natural or buoyancy – induced flows in fluid saturated porous media adjacent to surfaces in recent years. This interest stems from numerous possible industrial and technological applications. Example of some applications include geothermal reservoirs, drying of porous solids, heat exchanger design, petroleum production, filtration, chemical catalytic reactor, nuclear waste repositories, and geophysical flows. The prediction and knowledge of heat transfer rate and temperature distribution from a heated horizontal surface to surrounding ground water in a subsurface environment has important applications in the assessment of geothermal resources and the design of a geothermal power plant.

Keywords: nusselt number ($\overline{Nu}$), rayleigh number (Ra), cone angle (C_A), radius ratio (R_r) and power law exponent (λ).

I. Introduction

There have been considerable interest in studying natural or buoyancy – induced flows in fluid saturated porous media adjacent to surfaces in recent years. This interest stems from numerous possible industrial and technological applications. Example of some applications include geothermal reservoirs, drying of porous solids, heat exchanger design, petroleum production, filtration, chemical catalytic reactor, nuclear waste repositories, and geophysical flows. The prediction and knowledge of heat transfer rate and temperature distribution from a heated horizontal surface to surrounding ground water in a subsurface environment has important applications in the assessment of geothermal resources and the design of a geothermal power plant. Ali J. Chamaka [1] have studied, laminar buoyancy – induced flow of a power – law fluid over a semi-infinite horizontal surface embedded in a uniform porous medium. Cheng and Chang [2] have used a similarity transformation in solving free convection flow from a horizontal surfaces in porous media while Nakayama and Koyama [3] have employed the Karman – Pohihavsen approximate integral method. Chamkha [4] have considered free convection from a cone and a wedge in porous media.

Inspite of the frequent occurrence of industrial applications using power-law fluids such as fossil fuels, molten plastics, polymer solutions, dyes, varnishes, suspensions, paints, and multi-grade oil, there have been little work done on power – law flows in porous media. Some of this work can be found in the papers by Chen and Chen [5,6] have obtained solutions for free convection power-law fluid flows over a vertical plate, horizontal circular cylinder, and a sphere embedded in a porous medium. Nakayama and Koyama [7] have generalized the work of Chen and Chen [5,6] to non-isothermal bodies of arbitrary shape. Chamkha [8,9] have considered steady and transient power-law fluid flow in a porous medium channel. Metha and Rao [10] have studied buoyancy-induced flow of power-law fluids over a nonisothermal horizontal plate embedded in a porous medium using a similarity transformation.

Hering and Grosh [11] examined the laminar natural convection flow over a non-isothermal cone. Cheng et al [12] studied the heat transfer of a Darcian fluid by natural convection over a cone. Gorla et al [13] studied the free convection of powerlaw fluid over the vertical frustum of a cone.

Natural convection about an impermeable vertical flat plate, horizontal plate, vertical cylinder, and vertical cone is studied by Cheng and Minkowycz [14], and Minkowycz and Cheng [15] respectively. studies of uniform surface mass transfer effect have been presented by Minkowycz and Cheng [16] for a vertical flat plate, Minkowycz et al. [17] for horizontal plate, Huang and Chen [18] for vertical Cylinder and Yih [19] for a vertical cone. Previous researches [14-19], however, have been only concentrated upon the power-law fluid. A number of industrially important fluids, including fossil fuels which can have saturated underground beds, display the behavior of power-law fluids, exhibit a non-linear relationship between shear strain rate and shear stress.

In this chapter, we concentrate on the study of heat transfer by natural convection in a saturated porous medium with a power law temperature variation on a vertical conical annular porous medium". In this study Finite Element Method (FEM) has been used to solve the governing partial differential equations. Results are presented interms of average Nusselt number ($\overline{Nu}$),

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streamlines and isothermal lines for various values of Rayleigh number (Ra), Cone angle (CA), Radius ratio (Rr) and power law exponent (l).

II. Mathematical Formulation

A vertical annular cone of inner radius ri and outer radius r0 as depicted by schematic diagram as shown in figure (A) is considered to investigate the heat transfer behavior. The co-ordinate system is chosen such that the r-axis points towards the width and z-axis towards the height of the cone respectively. Because of the annular nature, two important parameters emerge which are Cone angle (C_A) and Radius ratio (R_r) of the annulus. They are defined as

$$C_A = \frac{H_t}{r_0 - r_i}, \qquad R_r = \frac{r_0 - r_i}{r_i}$$

where H_t is the height of the cone.

The inner surface of the cone is assumed to be power law functions and it varies in the vertical direction along the height of the inner wall of the vertical annular cone $T_h = T_\infty + B(z)^\lambda$ and the outer surface at an ambient temperature T_∞ respectively. Where λ and B are the constants responsible for temperature variations along the length of the vertical annular cone.

We assume that the flow inside the porous medium is assumed to obey Darcy law and there is no phase change of fluid. The porous medium is saturated with fluid, the convective fluid and the porous medium are every where in local thermal equilibrium in the domain. The properties of the fluid and of the porous medium are homogeneous, isotropic constant except variation of fluid density with temperature. Under these assumptions the equations governing the flow, heat transfer are given by Continuity Equation:

$$\frac{\partial(ru)}{\partial r} + \frac{\partial(rw)}{\partial z} = 0 \qquad (4.2.1)$$

The velocity in r and z directions can be described by Darcy law as

Velocity in horizontal direction

$$u = \frac{-K}{\mu}\frac{\partial p}{\partial r} \qquad (4.2.2)$$

velocity in vertical direction

$$w = \frac{-K}{\mu}\left(\frac{\partial p}{\partial z} + \rho g\right) \qquad (4.2.3)$$

the permeability K of porous medium can be expressed as Bejan [27]

$$K = \frac{D_p^2 \phi^3}{180(1-\phi)^2} \qquad (4.2.4)$$

The variation of density with respect to temperature can be described by Boussinesq approximation as

$$\rho = \rho_\infty [\, 1 - \beta_T (T - T_\infty) \qquad (4.2.5)$$

Momentum Equation :

$$\frac{\partial w}{\partial r} - \frac{\partial u}{\partial z} = \frac{gK\beta}{\nu}\frac{\partial T}{\partial r} \qquad (4.2.6)$$

Every equation:

$$u\frac{\partial T}{\partial r} + w\frac{\partial T}{\partial z} = \alpha\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\partial^2 T}{\partial z^2}\right) \qquad (4.2.7)$$

The continuity equation (4.2.1) can be satisfied by introducing the stream function ψ as

$$u = -\frac{1}{r}\frac{\partial \psi}{\partial z} \qquad (4.2.8)$$

$$w = -\frac{\partial \psi}{r\,\partial r} \qquad (4.2.9)$$

The corresponding dimensional boundary conditions are

$$\text{at} \quad r = r_i, \quad T_w = T_\infty \qquad (4.2.10a)$$

$$r = r_0, \quad T = T_\infty, \quad u = 0 \qquad (4.2.10b)$$

The new parameters arising due to cylindrical co -ordinates system are

Non-dimensional Radius $$\bar{r} = \frac{r}{L} \qquad (4.2.11a)$$

Non-dimensional Height $$\bar{z} = \frac{z}{L} \qquad (4.2.11b)$$

Non-dimensional stream function $$\bar{\psi} = \frac{\psi}{\alpha L} \qquad (4.2.11c)$$

Non-dimensional Temperature $$\bar{T} = \frac{(T - T_\infty)}{(T_w - T_\infty)} \qquad (4.2.11d)$$

Rayleigh number $$Ra = \frac{g\beta_T \Delta TKL}{\nu\alpha} \qquad (4.2.11e)$$

The non-dimensional equations for the heat transfer in vertical cone are

Momentum equation: $$\frac{\partial^2 \bar{\psi}}{\partial \bar{z}^2} + \bar{r}\left(\frac{1}{\bar{r}}\frac{\partial \bar{\psi}}{\partial \bar{r}}\right) = \bar{r}Ra\frac{\partial \bar{T}}{\partial \bar{r}} \qquad (4.2.12)$$

Energy equation : $$\frac{1}{\bar{r}}\left[\frac{\partial \bar{\psi}}{\partial \bar{r}}\frac{\partial \bar{T}}{\partial \bar{z}} - \frac{\partial \bar{\psi}}{\partial \bar{z}}\frac{\partial \bar{T}}{\partial \bar{r}}\right] = \left(\frac{1}{\bar{r}}\frac{\partial}{\partial \bar{r}}\left(\bar{r}\frac{\partial \bar{T}}{\partial \bar{r}}\right) + \frac{\partial^2 \bar{T}}{\partial \bar{z}^2}\right) \qquad (4.2.13)$$

III. Solution of the Governing Equations

Applying Galerkin method to momentum equation (4.2.12) yields:

$$\{R^e\} = -\int_V N^T\left(\frac{\partial^2 \bar{\psi}}{\partial \bar{z}^2} + \bar{r}\frac{\partial}{\partial \bar{r}}\left(\frac{1}{\bar{r}}\frac{\partial \bar{\psi}}{\partial \bar{r}}\right) - \bar{r}Ra\frac{\partial \bar{T}}{\partial \bar{r}}\right)d\nu \qquad (4.3.1)$$

$$\{R^e\} = -\int_A N^T\left(\frac{\partial^2 \bar{\psi}}{\partial \bar{z}^2} + \bar{r}\frac{\partial}{\partial \bar{r}}\left(\frac{1}{\bar{r}}\frac{\partial \bar{\psi}}{\partial \bar{r}}\right) - \bar{r}Ra\frac{\partial \bar{T}}{\partial \bar{r}}\right)2\Pi\bar{r}dA \qquad (4.3.2)$$

Where R^e is the residue. Considering individual terms of equation (4.3.2)
The differentiation of following term results into

$$\frac{\partial}{\partial \bar{r}}\left[[N^T]\frac{\partial \bar{\psi}}{\partial \bar{r}}\right] = [N^T]\frac{\partial^2 \bar{\psi}}{\partial \bar{r}^2} + \frac{\partial [N]^T}{\partial \bar{r}}\frac{\partial \bar{\psi}}{\partial \bar{r}} \qquad (4.3.3)$$

Thus

$$\int_A N^T\frac{\partial^2 \bar{\psi}}{\partial \bar{r}^2}dA = \int_A \frac{\partial}{\partial \bar{r}}\left([N^T]\frac{\partial^2 \bar{\psi}}{\partial \bar{r}^2}\right)2\Pi\bar{r}dA - \int_A \frac{\partial [N]^T}{\partial \bar{r}}\frac{\partial \bar{\psi}}{\partial \bar{r}} \qquad (4.3.4)$$

The first term on right hand side of equation (4.3.4) can be transformed into surface integral by the application of Greens theorem and leads to inter-element requirement at boundaries of an element. The boundary conditions are incorporated in the force vector.

Let us consider that the variable to be determined in the triangular area as "T". The polynomial function for "T" can be expressed as

$$T = \alpha_1 + \alpha_2 r + \alpha_3 \qquad (4.3.5)$$

The variable T has the value T_i, T_j & T_k at the nodal position i, j and k of the element. The r and z co-ordinates at these points are r_i, r_j, r_k and z_i, z_j, z_k respectively.

Since $$T = Ni\,Ti + Nj\,Tj + Nk\,Tk \qquad (4.3.6)$$

Where N_i, N_j & N_k are shape functions given by

$$N_m = \frac{a_m + b_m r + c_m z}{2A} \qquad (4.3.7)$$

Making use of (4.3.7) gives

$$\int_A N^T \frac{\partial^2 \bar{T}}{\partial \bar{z}^2} 2\Pi \bar{r} dA = -\int_A \frac{\partial N^T}{\partial \bar{r}} \frac{\partial N}{\partial \bar{r}} \begin{Bmatrix} \bar{\psi}_1 \\ \bar{\psi}_2 \\ \bar{\psi}_3 \end{Bmatrix} dA \tag{4.3.8}$$

Substitution of (4.3.7) into (4.3.8) gives:

$$= \frac{-1}{(2A)^2} \int_A \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} [b_1 b_2 b_3] \begin{Bmatrix} \bar{\psi}_1 \\ \bar{\psi}_2 \\ \bar{\psi}_3 \end{Bmatrix} 2\Pi \bar{r} dA$$

$$= -\frac{2\Pi \bar{R}}{4A} \begin{bmatrix} b_1^2 & b_1 b_2 & b_1 b_3 \\ b_1 b_2 & b_2^2 & b_2 b_3 \\ b_1 b_3 & b_2 b_3 & b_3^2 \end{bmatrix} \begin{Bmatrix} \bar{\psi}_1 \\ \bar{\psi}_2 \\ \bar{\psi}_3 \end{Bmatrix} \tag{4.3.9}$$

Similarly

$$\int_A N^T \frac{\partial^2 \bar{\psi}}{\partial \bar{z}^2} 2\Pi \bar{r} dA = -\frac{2\Pi \bar{R}}{4A} \begin{bmatrix} c_1^2 & c_1 c_2 & c_1 c_3 \\ c_1 c_2 & c_2^2 & c_2 c_3 \\ c_1 c_3 & c_2 c_3 & c_3^2 \end{bmatrix} \begin{Bmatrix} \bar{\psi}_1 \\ \bar{\psi}_2 \\ \bar{\psi}_3 \end{Bmatrix} \tag{4.3.10}$$

The third term of equation (4.3.2) us

$$\int_A N^T \bar{r} Ra \frac{\partial \bar{T}}{\partial \bar{r}} 2\Pi \bar{r} dA = Ra \int_A N^T \bar{r} \frac{\partial \bar{T}}{\partial \bar{r}} 2\Pi \bar{r} dA \tag{4.3.11}$$

Since $M_1 = N_1, \quad M_2 = N_2, \quad M_2 = N_3$

Where M_1, M_2, and M_3 are the area ratios of the triangle and N_1, N_2 and N_3 are the shape functions. Replacing the shape functions in the above equation (4.3.11) gives

$$\int_A N^T \bar{r} Ra \frac{\partial \bar{T}}{\partial \bar{r}} 2\Pi \bar{r} dA = \bar{r} Ra \int_A \begin{bmatrix} M_1 \\ M_2 \\ M_3 \end{bmatrix} \frac{\partial [N]}{\partial \bar{r}} \begin{bmatrix} \bar{T}_1 \\ \bar{T}_2 \\ \bar{T}_3 \end{bmatrix} 2\Pi \bar{r} dA \tag{4.3.12}$$

$$= Ra \frac{A}{3} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \frac{2\Pi \bar{R}^2}{2A} [b_1 + b_2 + b_3] \begin{bmatrix} \bar{T}_1 \\ \bar{T}_2 \\ \bar{T}_3 \end{bmatrix}$$

$$= \frac{2\Pi \bar{R}^2 Ra}{6} \begin{Bmatrix} b_1 \bar{T}_1 + b_2 \bar{T}_2 + b_3 \bar{T}_3 \\ b_1 \bar{T}_1 + b_2 \bar{T}_2 + b_3 \bar{T}_3 \\ b_1 \bar{T}_1 + b_2 \bar{T}_2 + b_3 \bar{T}_3 \end{Bmatrix} \tag{4.3.13}$$

Now Momentum equation leads to

$$\frac{2\Pi \bar{R}}{4A} \left\{ \begin{bmatrix} b^2 & b_1 b_2 & b_1 b_3 \\ b_1 b_2 & b_2^2 & b_2 b_3 \\ b_1 b_3 & b_2 b_3 & b_3^2 \end{bmatrix} + \begin{bmatrix} c_1^2 & c_1 c_2 & c_1 c_3 \\ c_1 c_2 & c_2^2 & c_2 c_3 \\ c_1 c_3 & c_2 c_3 & c_3^2 \end{bmatrix} \right\} \begin{Bmatrix} \bar{\psi}_1 \\ \bar{\psi}_2 \\ \bar{\psi}_3 \end{Bmatrix} + \frac{2\Pi \bar{R}^2 Ra}{6} \begin{Bmatrix} b_1 \bar{T}_1 + b_2 \bar{T}_2 + b_3 \bar{T}_3 \\ b_1 \bar{T}_1 + b_2 \bar{T}_2 + b_3 \bar{T}_3 \\ b_1 \bar{T}_1 + b_2 \bar{T}_2 + b_3 \bar{T}_3 \end{Bmatrix} = 0 \tag{4.3.14}$$

Which is in the form of the stiffness matrix

$$[K_s]\{\bar{\psi}\}=\{f\} \tag{4.3.15}$$

Similarly application of Galerking method to Energy equation gives

$$\{R^e\}=-\int_A N^T\left[\frac{1}{\bar{r}}\left(\frac{\partial\bar{\psi}}{\partial\bar{r}}\frac{\partial\bar{T}}{\partial\bar{z}}-\frac{\partial\bar{\psi}}{\partial\bar{z}}\frac{\partial\bar{T}}{\partial\bar{r}}\right)\right]-\left[\frac{1}{\bar{r}}\frac{\partial}{\partial\bar{r}}\left(\bar{r}\frac{\partial\bar{T}}{\partial\bar{r}}\right)+\frac{\partial^2\bar{T}}{\partial\bar{z}^2}\right]2\Pi\bar{r}dA \tag{4.3.16}$$

Considering the terms individually of the above equation (4.3.16)

$$\int_A [N]^T\frac{\partial\bar{\psi}}{\partial\bar{z}}\frac{\partial\bar{T}}{\partial\bar{r}}2\Pi dA=\int_A\begin{bmatrix}M_1\\M_2\\M_3\end{bmatrix}\frac{\partial[N]}{\partial\bar{z}}\{\bar{\psi}\}\frac{\partial[N]}{\partial\bar{r}}\{\bar{T}\}2\Pi\bar{r}dA \tag{4.3.17}$$

$$=\frac{2\Pi A}{3}\mathrm{X}\frac{1}{4\mathrm{A}^2}\left[c_1\bar{\psi}_1+c_2\bar{\psi}_2+c_3\bar{\psi}_3\right][b_1,b_2,b_3]\begin{Bmatrix}\bar{T}_1\\\bar{T}_2\\\bar{T}_3\end{Bmatrix}$$

$$=\frac{2\Pi}{12A}\begin{Bmatrix}c_1\bar{\psi}_1+c_2\bar{\psi}_2+c_3\bar{\psi}_3\\c_1\bar{\psi}_1+c_2\bar{\psi}_2+c_3\bar{\psi}_3\\c_1\bar{\psi}_1+c_2\bar{\psi}_2+c_3\bar{\psi}_3\end{Bmatrix}[b_1,b_2,b_3]\begin{Bmatrix}\bar{T}_1\\\bar{T}_2\\\bar{T}_3\end{Bmatrix} \tag{4.3.18}$$

Following the same above steps

$$\int_A [N]^T\frac{\partial\bar{\psi}}{\partial\bar{r}}\frac{\partial\bar{T}}{\partial\bar{z}}2\Pi dA=\int_A\begin{bmatrix}M_1\\M_2\\M_3\end{bmatrix}\frac{\partial[N]}{\partial\bar{r}}\{\bar{\psi}\}\frac{\partial[N]}{\partial\bar{z}}\{\bar{T}\}2\Pi dA \tag{4.3.19}$$

$$\int_A N^T\frac{\partial\bar{\psi}}{\partial\bar{r}}\frac{\partial\bar{T}}{\partial\bar{z}}2\Pi dA=\frac{2\Pi}{12A}\begin{Bmatrix}b_1\bar{\psi}_1+b_2\bar{\psi}_2+b_3\bar{\psi}_3\\b_1\bar{\psi}_1+b_2\bar{\psi}_2+b_3\bar{\psi}_3\\b_1\bar{\psi}_1+b_2\bar{\psi}_2+b_3\bar{\psi}_3\end{Bmatrix}[c_1,c_2,c_3]\begin{Bmatrix}\bar{T}_1\\\bar{T}_2\\\bar{T}_3\end{Bmatrix} \tag{4.3.20}$$

The remaining terms of Energy equation can be evaluated in similar fashion of equation (4.3.16)

$$\int_A N^T\frac{1}{\bar{r}}\frac{\partial}{\partial\bar{r}}\left(\bar{r}\frac{\partial\bar{T}}{\partial\bar{r}}\right)2\Pi\bar{r}dA=-\frac{2\Pi\bar{R}}{4A}\begin{bmatrix}b_1^2&b_1b_2&b_1b_3\\b_1b_2&b_2^2&b_2b_3\\b_1b_3&b_2b_3&b_3^3\end{bmatrix}\begin{Bmatrix}\bar{T}_1\\\bar{T}_2\\\bar{T}_3\end{Bmatrix} \tag{4.3.21}$$

$$\int_A N^T\frac{\partial^2\bar{T}}{\partial\bar{z}^2}2\Pi\bar{r}dA=-\frac{2\Pi\bar{R}}{4A}\begin{bmatrix}c_1^2&c_1c_2&c_1c_3\\c_1c_2&c_2^2&c_2c_3\\c_1c_3&c_2c_3&c_3^2\end{bmatrix}\begin{Bmatrix}\bar{T}_1\\\bar{T}_2\\\bar{T}_3\end{Bmatrix} \tag{4.3.22}$$

Thus the stiffness matrix of Energy equation is given by

$$\left[\frac{2\Pi}{12A}\begin{Bmatrix} c_1\overline{\psi}_1 + c_2\overline{\psi}_2 + c_3\overline{\psi}_3 \\ c_1\overline{\psi}_1 + c_2\overline{\psi}_2 + c_3\overline{\psi}_3 \\ c_1\overline{\psi}_1 + c_2\overline{\psi}_2 + c_3\overline{\psi}_3 \end{Bmatrix}[b_1, b_2, b_3] - \frac{2\Pi}{12A}\begin{Bmatrix} b_1\overline{\psi}_1 + b_2\overline{\psi}_2 + b_3\overline{\psi}_3 \\ b_1\overline{\psi}_1 + b_2\overline{\psi}_2 + b_3\overline{\psi}_3 \\ b_1\overline{\psi}_1 + b_2\overline{\psi}_2 + b_3\overline{\psi}_3 \end{Bmatrix}[c_1, c_2, c_3]\right]\begin{Bmatrix} \overline{T}_1 \\ \overline{T}_2 \\ \overline{T}_3 \end{Bmatrix}$$

$$+\frac{2\Pi\overline{R}}{4A}\left\{\begin{bmatrix} b_1^2 & b_1b_2 & b_1b_2 \\ b_1b_2 & b_2^2 & b_2b_3 \\ b_1b_3 & b_2b_3 & b_3^3 \end{bmatrix}\begin{bmatrix} \overline{T}_1 \\ \overline{T}_2 \\ \overline{T}_3 \end{bmatrix} + \begin{bmatrix} c_1^2 & c_1c_2 & c_1c_3 \\ c_1c_2 & c_2^2 & c_2c_3 \\ c_1c_2 & c_2c_3 & c_3^2 \end{bmatrix}\begin{Bmatrix} \overline{T}_1 \\ \overline{T}_2 \\ \overline{T}_3 \end{Bmatrix}\right\} = 0 \qquad (4.3.23)$$

IV. Results and Discussion

Results are obtained in terms of the average Nusselt number ($\overline{Nu}$) at hot wall for various parameters such as Rayleigh number (Ra), Radius ratio (R_r) Cone angle (C_A) and Power law exponent (λ) when heat supplied to the vertical annular cone.

The average Nusselt number ($\overline{Nu}$), is given by

$$\overline{Nu} = \int_0^{\bar{z}} \left(\frac{\partial \overline{T}}{\partial \overline{r}}\right)$$

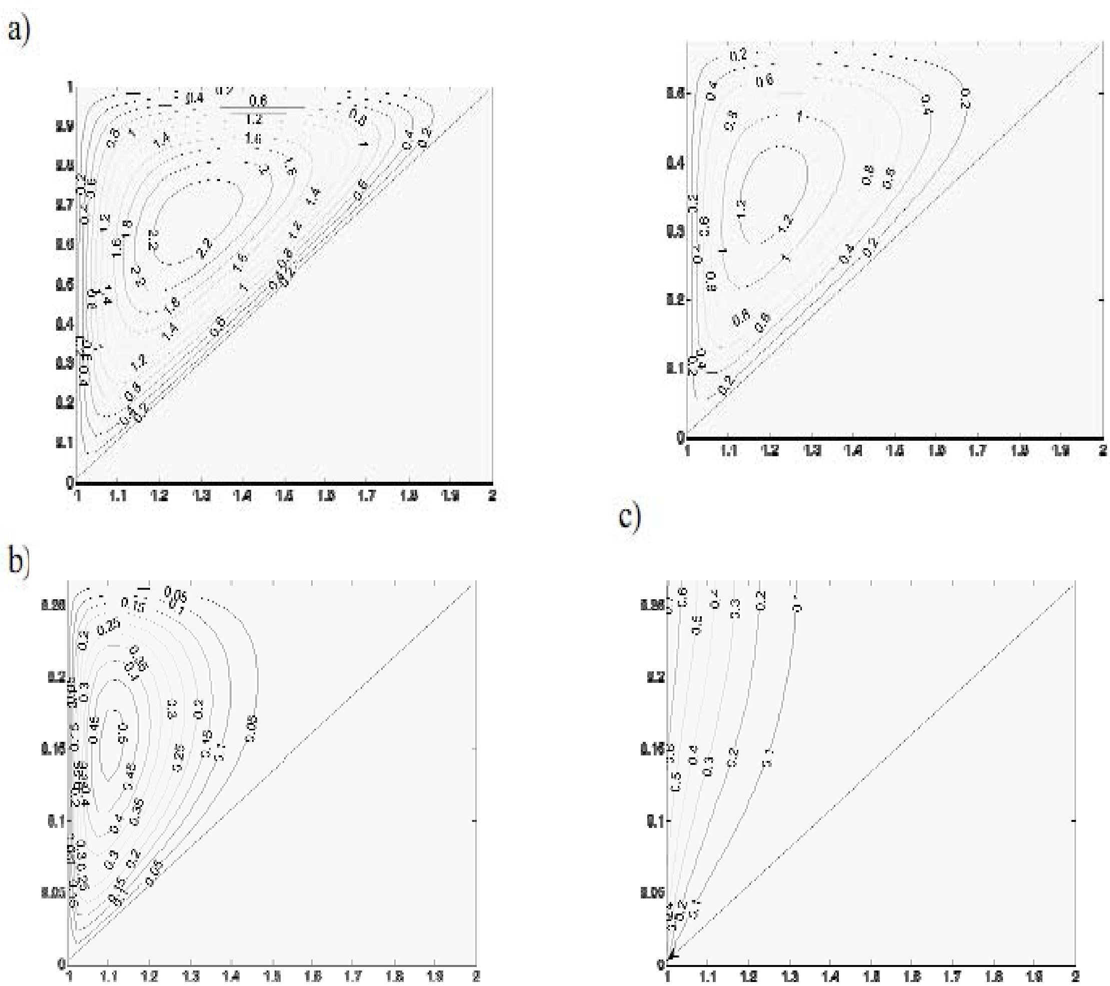


Figure 4.4.1 : Streamlines(left) and Isotherms(Right) for Ra=50, R_r=1, λ=0.25
a) C_A =45 b) C_A =60 c) C_A =75

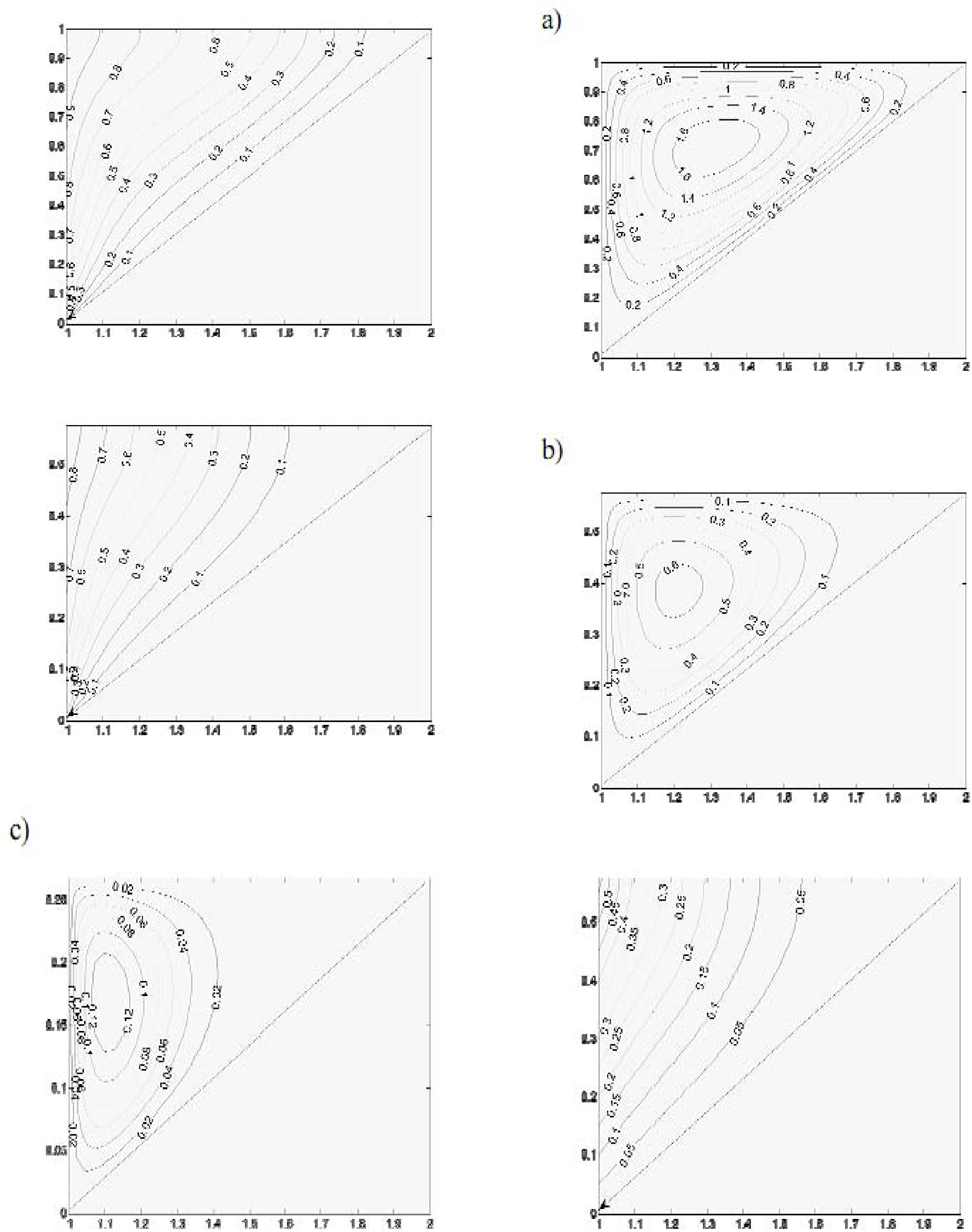
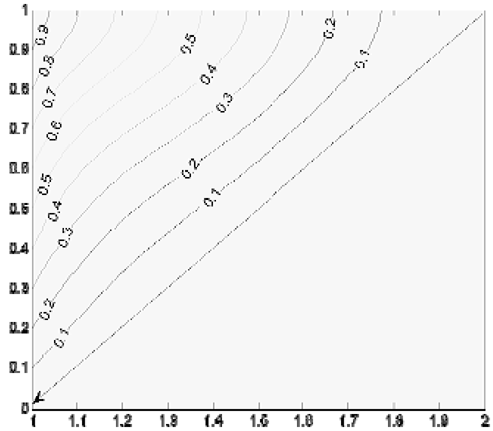


Figure 4.4.2 : Streamlines(left) and Isotherms(Right) for Ra=50, R_r=1, λ=1
a) C_A =45 b) C_A =60 c) C_A =75



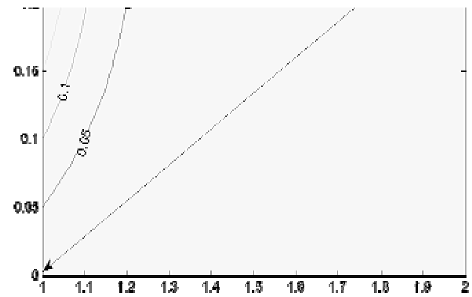


Fig (4.4.1) shows the streamlines and isothermal lines distribution inside the porous medium of the vertical annular cone for various values of Cone angle (C_A) at Ra = 50, R_r = 1, λ= 0.25. The streamlines and isothermal lines move away from the cold wall and reach nearer to hot wall as Cone angle (C_A) increases. It can be seen that the thermal boundary layer thickness decreases as cone angle (C_A) increases. It is obvious from the Fig (4.4.1) that the heat transfer rate is higher at the centre portion of the annular cone at higher values of Cone angle (C_A), which is indicated by crowding of isothermal lines in the vicinity of centre portion of hot wall as shown in figure.

Fig (4.4.2) depicts the streamlines and isothermal lines inside porous medium for various values of Cone angle (C_A) at Ra = 50, Rr = 1 and λ= 1 when compared with Fig (4.4.1) by Fig (4.4.2) formation of streamlines and isothermal lines decreases the occupation of the domain for the increased values of Cone angle (C_A). This is due to reason that the increase of Power law index (λ= 1).

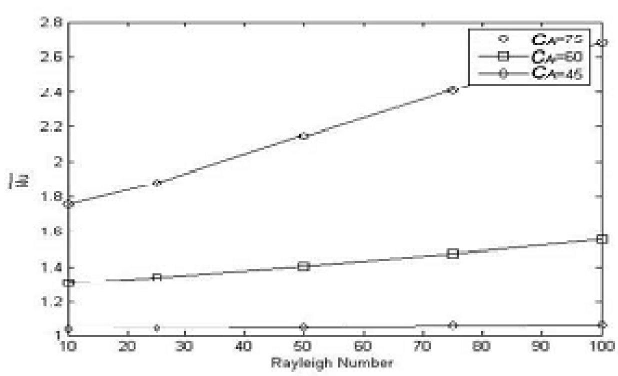


Fig.4.4.3: Nu variations with Ra at hot surface for different values of C_A at R_r=1, λ =1 Fig (4.4.3) illustrates the variation of average Nusselt number ($\overline{Nu}$) at hot wall, with respect to Rayleigh number (Ra) of the vertical annular cone for various values of Cone angle (C_A) at R_r = 1, λ = 1. It is found that the average Nusselt number ($\overline{Nu}$) increases with increase in Rayleigh number (Ra). It can be seen that the average Nusselt number ($\overline{Nu}$) increases with increase in Cone angle (C_A). For a given Rayleigh number (Ra), the difference between two different values of Cone angle (C_A) increase with increase in Cone angle (C_A). For instance, the average Nusselt number ($\overline{Nu}$) increases by 25%, when Cone angle (C_A) is increased from 45 to 60 at Ra = 10. However the average Nusselt number ($\overline{Nu}$) increased by 45%. When Cone angle (C_A) is increased 45 to 60 at Ra = 100. This difference becomes more prominent as the Rayleigh number (Ra) increase.

a)

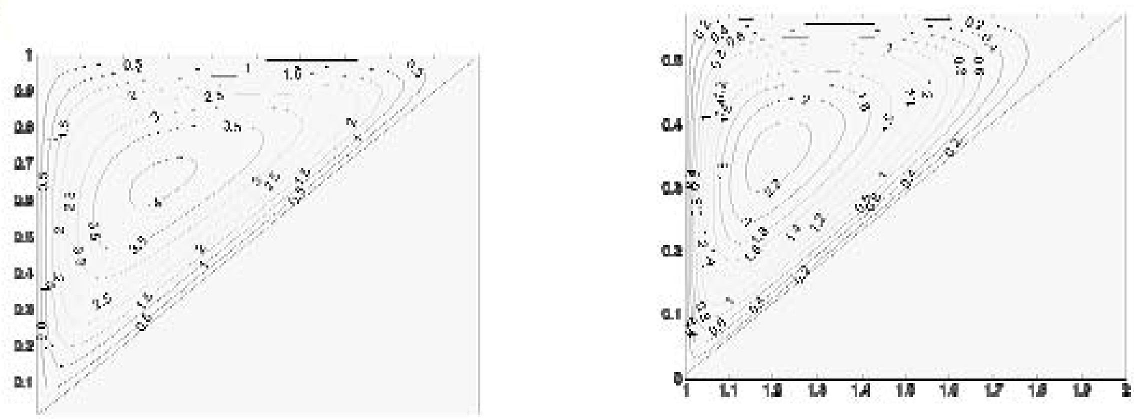


Figure 4.4.4 : Streamlines(left) and Isotherms(Right) for Ra=100, R_r=1, λ=0.25
a) C_A =45 b) C_A =60 c) C_A =75

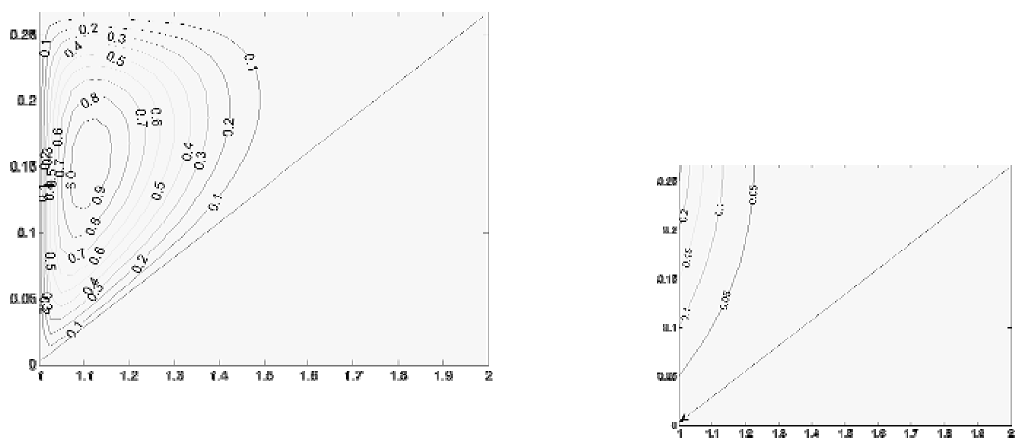
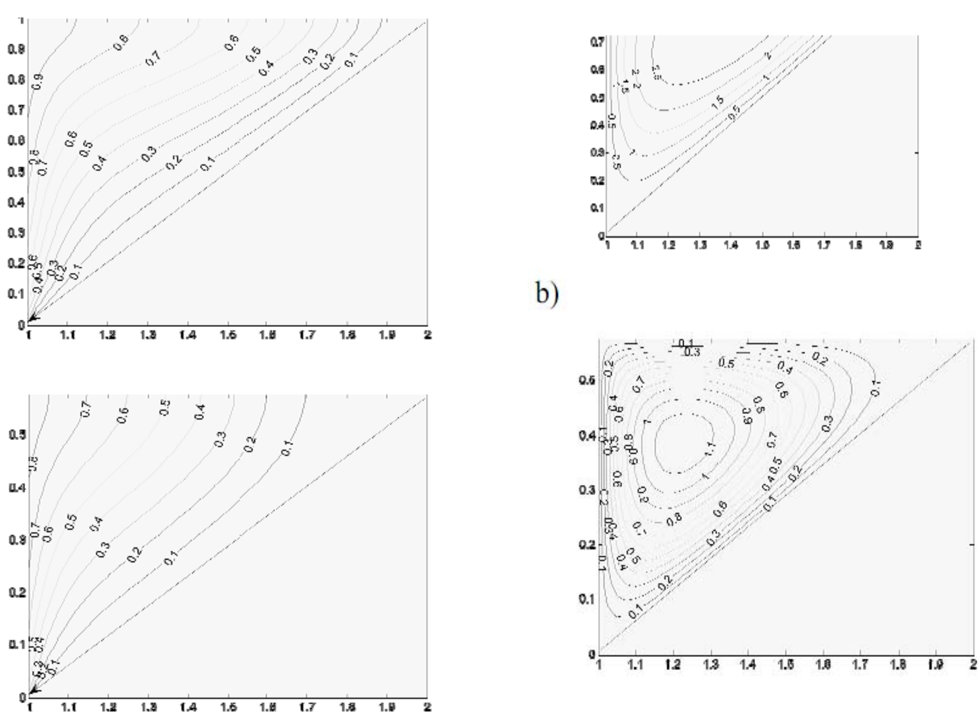


Figure 4.4.5 : Streamlines(left) and Isotherms Isotherms (Right) for Ra=100, R_r=1, λ =1
a) C_A =45 b) C_A =60 c) C_A =75



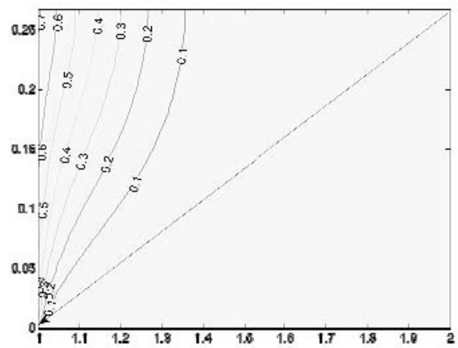


Fig (4.4.4) illustrates the streamlines and isothermal lines distribution inside the porous medium for various values of Cone angle (C_A) at Ra = 100, R_r = 1 and λ = 0.25. The boundary layer thickness moves from colar wall to Hot wall in the occupation of the domain by stream and isothermal lines decreases for the increased values of Cone angles (C_A = 45 , 60, 75), i.e. boundary layer thickness reduces with increase in Cone angle (C_A).

Fig (4.4.5) shows the streamlines and isothermal lines inside the porous medium for various values of Cone angle (C_A) at Ra= 100, R_r = 1 and λ =1. When compared with the Fig (4.4.2) by Fig (4.4.5) the formation of the fluid by the stream and isothermal lines decreased and occupies the domain by stream and isothermal lines decreased. This is due to the increased values of power law index (λ = 1)

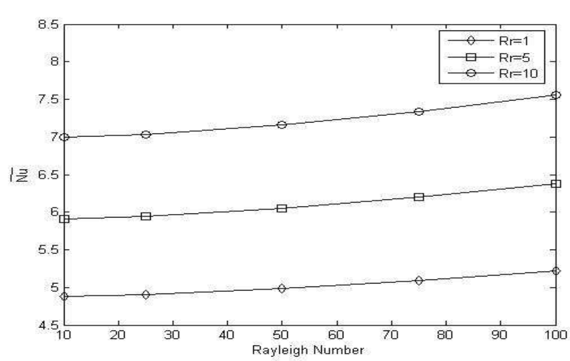
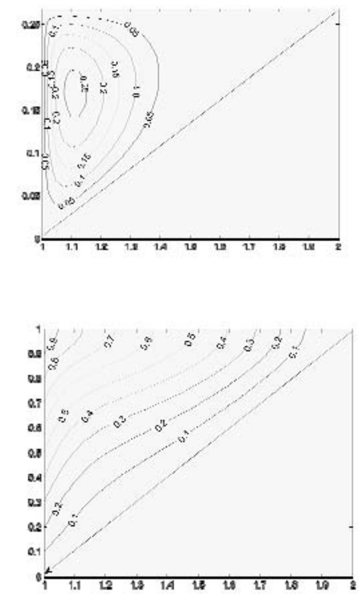
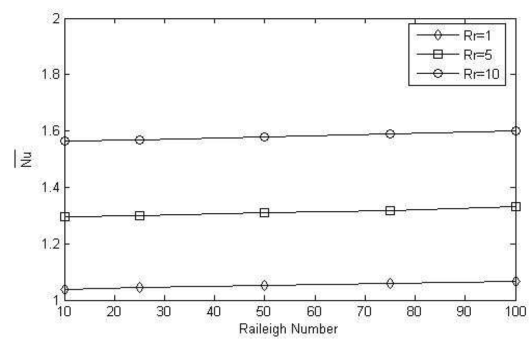


Figure 4.4.6 : $\overline{Nu}$ variations with Ra at hot surface for different values of R_r at C_A=75, λ=0.25

c)





R_r
R_r
R_r

Figure 4.4.7 : $\overline{Nu}$ variations with Ra at hot surface for different values of R_r at C_A=75, λ=1

Fig (4.4.6) illustrates the variation of average Nusselt number ($\overline{Nu}$) at hot wall, with respect to Rayleigh number (Ra) of vertical annular cone for various values of Radius ratio (R_r) at C_A = 75, λ = 0.25. It is found that the average Nusselt number ($\overline{Nu}$) increases with increase in Rayleigh number (Ra). It can be seen that the average Nusselt number ($\overline{Nu}$) increases with increase in Radius ratio (R_r). For a given Rayleigh number (Ra), the difference between the average Radius ratio (R_r) at two different values of Radius ratio (R_r). For instance, the average Nusselt number ($\overline{Nu}$) increased by 22% when Radius ratio (R_r) is increased from 1 to 5, at Ra = 10. However the average Nusselt number ($\overline{Nu}$) increased by 21%, when Radius ratio(R_r) is increased from 1 to 5 at Ra = 100. This shows that the average Nusselt number ($\overline{Nu}$) increases linearly with the increase in Rayleigh number (Ra).

Fig (4.4.7) demonstrates the effect of Rayleigh number (Ra) on the average Nusselt number ($\overline{Nu}$) for various values of Radius ratio (R_r). This figure is obtained for CA=75, λ = 1. It if found that the average Nusselt number (Nu) increases slightly with increase in

Rayleigh number (Ra). It can be seen that the average Nusselt number ($\overline{Nu}$) increase with increase in Radius ratio (R_r). For a given Rayleigh number (Ra), the difference between the average Nusselt number ($\overline{Nu}$) at two different values of Radius ratio (R_r) increases with increase in Radius ratio (R_r). For instance, the average Nusselt number ($\overline{Nu}$) increased by 25% when Radius ratio (R_r) is increased from 1 to 5 at Ra = 10. However the average Nusselt number ($\overline{Nu}$) increased by 23%, when Radius ratio (R_r) is increased from 1 to 5 at Ra = 100. This shows that the average Nusselt number ($\overline{Nu}$) increases linearly with the increase in Rayleigh number (Ra).

a) b)

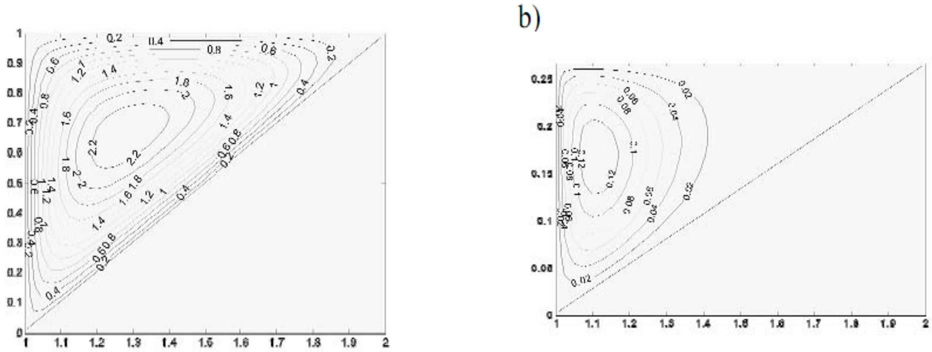
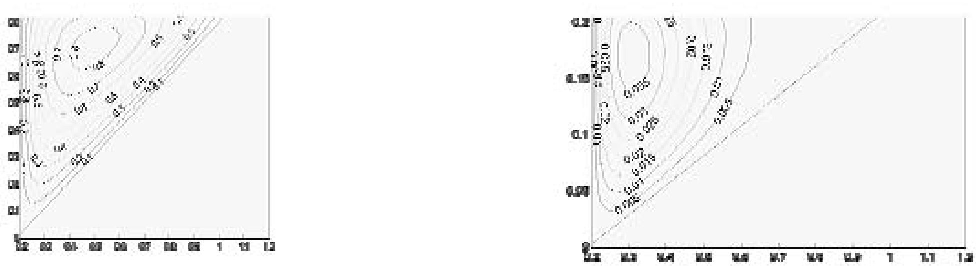
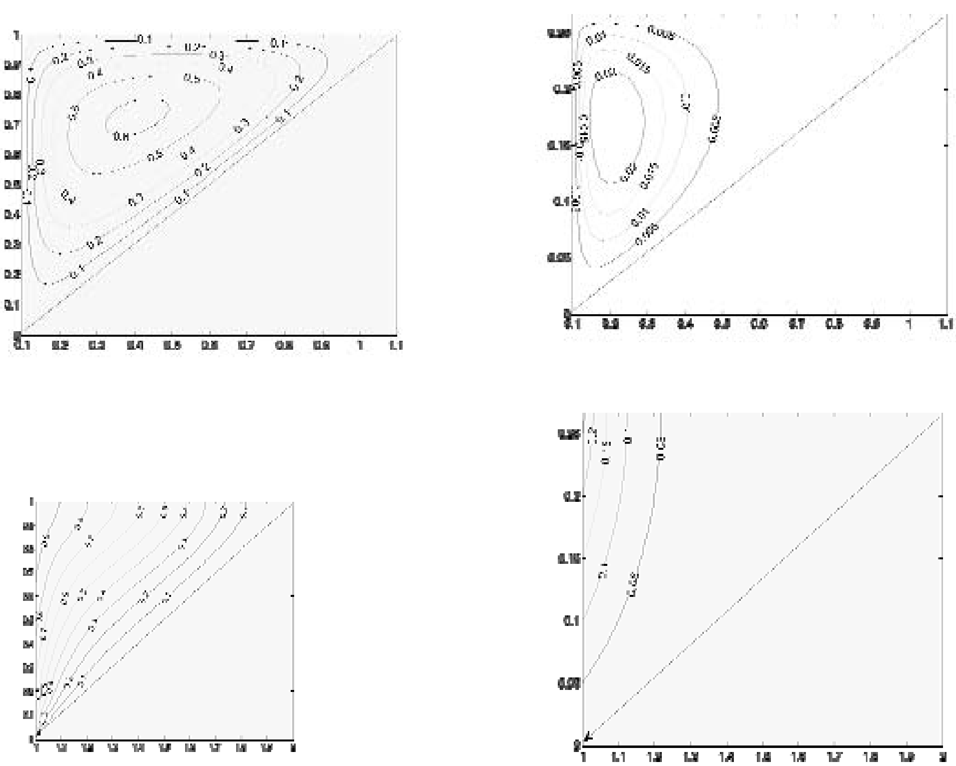
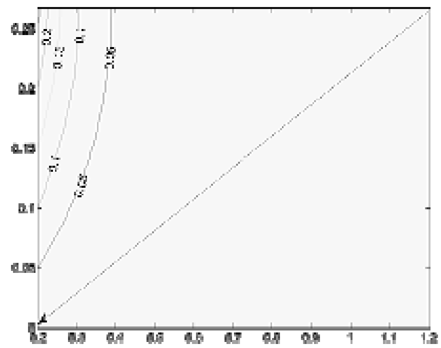


Figure 4.4.8 : Streamlines(left) and Isotherms(Right) C_A =45, λ=0.25
a) R_r=1 b) R_r=5, c) R_r=10



c)





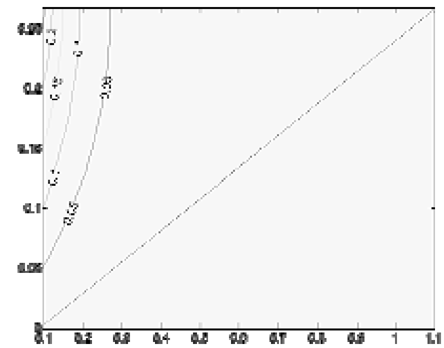
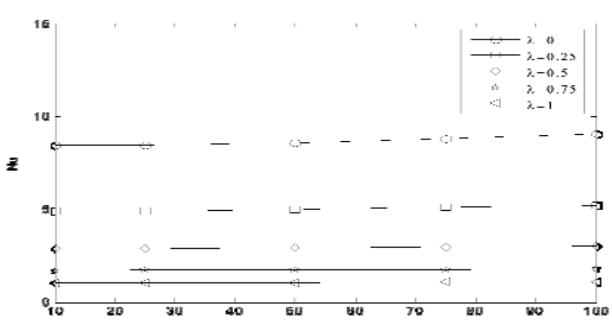


Fig (4.4.8) illustrates the streamlines and isothermal lines distribution inside the porous medium for various values of Radius ratio (R_r) at Ra = 50, C_A = 45 and λ=0.25. The magnitude of streamlines decreases as the Radius ratio (R_r) increases. This is due to the reason the increased Radius ratio (R_r) promotes the fluid movements due to higher buoyancy force, which in term allows the connection heat transfer to take dominant position. The increased Radius ratio (R_r) particularly enhance the heat transfer rate at lower portion of hot and cold walls of vertical annular cone respectively. The fluid circulation moves towards the lower portion of cold wall when Radius ratio (R_r) is increased.

Fig (4.4.9) shows the streamlines and isothermal lines inside the porous medium for various values of Radius ratio (R_r) at Ra = 50, CA = 75, and λ=1. The boundary layer thickness decreases when Radius ratio (R_r) increases and also occupies the half of the domain by stream lines. Where as for the same Radius ratio (R_r) values of isothermal lines remain same.



Rayleigh number

Figure 4.4.10 : Nu variations with Ra at hot surface for different values of λ at C_A=75, R_r=1

Fig (4.4.10) illustrates the variation of average Nusselt number ($\bar{Nu}$) at hot wall, with respect to Rayleigh number (Ra) of the vertical annular cone for various values of power law exponent (λ) at C_A = 75, R_r = 1. It is found that the average Nusselt number ($\bar{Nu}$) increases with the increase in Rayleigh number (Ra). It can be seen that the average Nusselt number ($\bar{Nu}$) decreases with increase in Power law exponent (λ). For a given Rayleigh number (Ra) the difference between the average Nusselt number ($\bar{Nu}$) at different values of power law exponent (λ) decreases with increase in power law exponent (λ). For instance, the average Nusselt number ($\bar{Nu}$) decreased by 70%, when power law exponent (λ) is increased from 0 to 1 at Ra = 10. However the average Nusselt number ($\bar{Nu}$) decreased by 71.2%, when power law exponent (λ) is increased from 0 to 1 at Ra = 100. This shows that the average Nusselt number ($\bar{Nu}$) increases with the increase in Rayleigh number (Ra) for λ = 0 and increases as λ increases.

a)

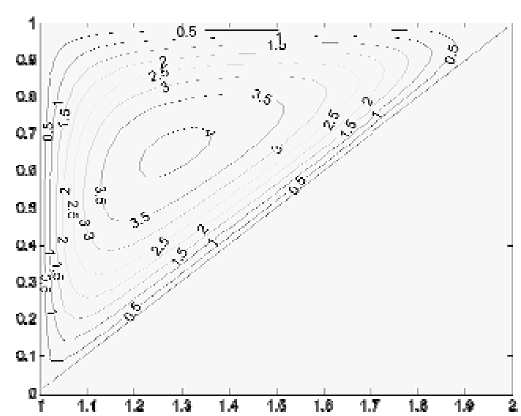
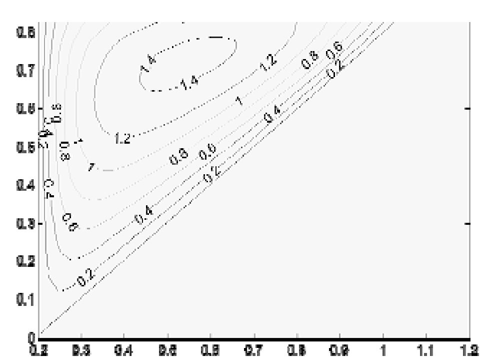


Figure 4.4.11 : Streamlines(left) and Isotherms(Right) for Ra=100, C_A =45, λ=0.25 a) R_r=1 b) R_r=5, c) R_r=10



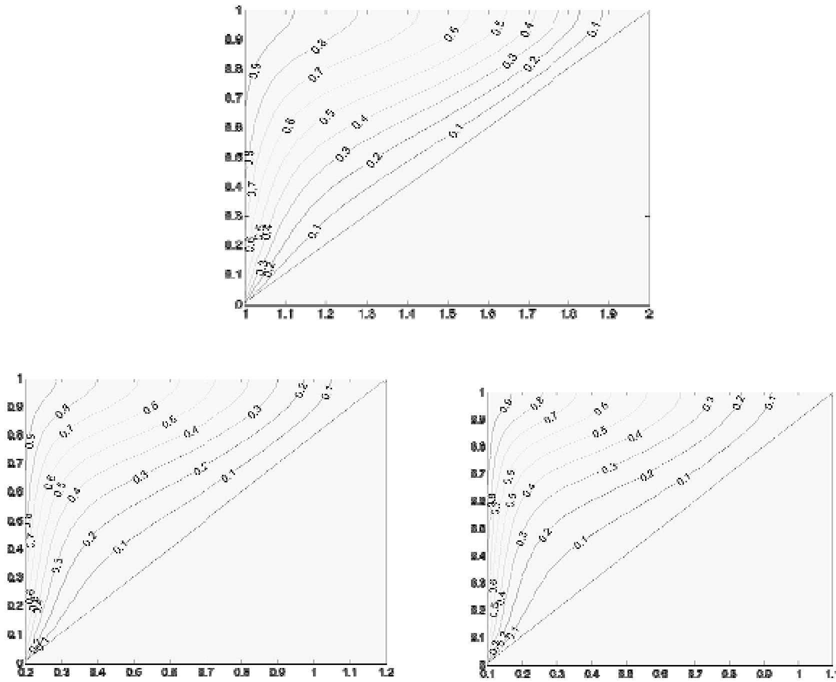


Figure 4.4.12 : Streamlines(left) and Isotherms(Right) for Ra=100, C_A =75, λ=1
a) R_r=1 b) R_r=5 c) R_r=10

Fig (4.4.11) shows the streamlines and isothermal lines distribution inside the porous medium of the vertical annular cone for various values of Radius ratio (R_r) at Ra = 100, C_A = 45 and l = 0.25. The streamlines move away from the cold wall and reach nearer to hot wall as Radius ratio (R_r) increases. It can be seen that the thermal boundary layer thickness decreases as Radius ratio (R_r) increases and occupies the whole domain of cone, where as isothermal lines for the same value of Radius ratio (R_r) remains same.

Fig (4.4.12) depicts the streamlines and isothermal lines inside the porous medium for various values of Radius ratio (R_r) at Ra = 100, C_A = 75 and r = 1. The stream lines move away from the cold wall and reach nearer to hot wall as Radius ratio (R_r) increases. It can be seen that the thermal boundary layer thickness decreases as Radius ratio (R_r) increases and occupying half of the domain of cone, where as isothermal lines for the same value of Radius ratio (R_r) remains same.

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Measurement of Liquid Volume in Stomach Using 6-Elctorde FIM for Saline Water Intake at Periodic Intervals

By Samiron K. Saha & Pretam K. Das
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Abstract- Focused Impedance Measurement (FIM) is a relatively new technique developed in the Biomedical Physics Laboratory of Dhaka University which allows improved localization of a zone without much increase in complexity of the measuring instrumentation when the electrodes are applied on the skin surface with the organs inside contributing the measurement of impedance since the body is a volume conductor. The present work is basically a preliminary study which aims at measuring the absolute volume of food or drinks of known conductivity inside a human stomach. The circuitry of a FIM system was used to study the impedance change in the stomach region of two subjects for the intake of saline (water with a little salt) with a particular conductivity on several days, each day with a different volume of the saline. It was ensured that they had the same history of food intake in the previous day and all physical conditions remain the same during the measurement for reproducibility. The impedance changes for different volumes of the saline in the one subject agreed well, and it appears that provided the correction factors mentioned above are incorporated, FIM may be used to measure the volume of food or saline in the stomach of a person.

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MEASUREMENT OF LIQUID VOLUME IN STOMACH USING 6-ELCTORDE FIM FOR SALINE WATER INTAKE AT PERIODIC INTERVALS

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Abstract- Focused Impedance Measurement (FIM) is a relatively new technique developed in the Biomedical Physics Laboratory of Dhaka University which allows improved localization of a zone without much increase in complexity of the measuring instrumentation when the electrodes are applied on the skin surface with the organs inside contributing the measurement of impedance since the body is a volume conductor. The present work is basically a preliminary study which aims at measuring the absolute volume of food or drinks of known conductivity inside a human stomach. The circuitry of a FIM system was used to study the impedance change in the stomach region of two subjects for the intake of saline (water with a little salt) with a particular conductivity on several days, each day with a different volume of the saline. It was ensured that they had the same history of food intake in the previous day and all physical conditions remain the same during the measurement for reproducibility. The impedance changes for different volumes of the saline in the one subject agreed well, and it appears that provided the correction factors mentioned above are incorporated, FIM may be used to measure the volume of food or saline in the stomach of a person.

I. Introduction

Biomedical physics is a comparatively new branch of physics, which projects the application of physics in the medical science. This helps to understand the normal and diseased condition in the body and design suitable method and instruments for diagnosis and therapy. Bio-impedance techniques were born within the last century. Impedance is a characteristics property of any material, including biological materials. Different body tissues may have different electrical conductivities, and which can again vary between health and disorder. Monitoring of physiological events by impedance has become a subject matter of great interest. These techniques are only applicable for those disorders, which are located on the surface or near the surface of the human body. Images can be formed considering the variation of electrical properties that biological tissue exhibits. Biological tissue exhibits two important passive electrical properties. First, it comprises free charge carriers and may thus be considered as an electrical conductor. Electrical conductivity is a characteristic property of different tissues and images of tissues having different electrical conductivities may resolve structure and even be indicative of pathology. Secondly, tissues also contain bound charges leading to dielectric effect and it might be possible to form an image of relative electrical permittivity. Electrical impedance is a measurement of how electricity travels though a given material. Every tissue has different electrical impedance determined by its molecular composition. Focused impedance measurement (FIM) technique, a new measurement technique with improved zone localization, was proposed and developed in Biomedical Physics laboratory of the University of Dhaka [1, 2]. In FIM technique, the impedance of the region of interest is measured from two mutually perpendicular directions simultaneously. In one method, two independent sets of four-electrode system are placed orthogonally enclosing the region for this purpose. In another, the currents in two perpendicular directions are of the same frequency, phase and amplitude but isolated from each other. By placing two potential measuring electrodes at appropriate points, a single potential measurement gives a combination of the two perpendicular measurements measured in this procedure. In this method, the central region has more contribution than the neighboring region. Therefore, focusing is expected and an experimental study was taken up to analyze this in detail.

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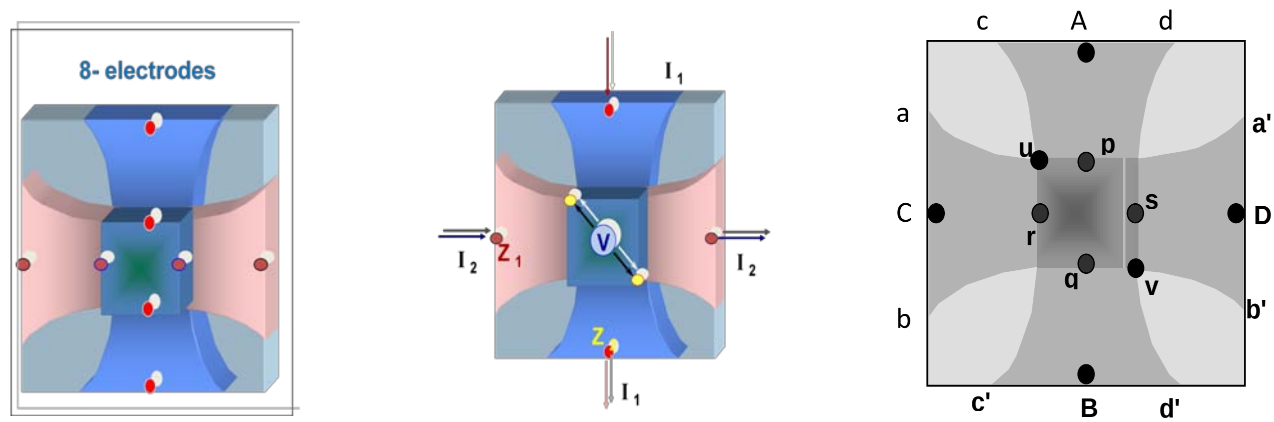
II. Theory

In this method impedance of the region of interest is measured from two mutually perpendicular directions simultaneously is the basis idea of the new technique. For this method two independent sets of four electrode system placed orthogonally to one another surrounding the region. Two current sources of same frequency, phase and amplitude are introduced simultaneously and resulting potentials are recorded. Impedance follows according to the Ohm's law ($Z = V/I$) where V is the combined potential and I is constant current passing through driving electrodes. The impedance of the region of interest contributes more than the neighboring regions as it is counted twice. Thus some degree of focusing on a particular region is expected to be obtained by our new technique. And as the region of interest is more focused compared to the other regions, the name has been offered to the proposed technique is Focused Impedance Method (FIM).

a) Six Electrode Fim System

The focused system basically involves two independent four electrode measurements which need eight electrodes in all. To obtain this combined output the hardware may be simplified through some modified placement of measuring electrodes and by electrically isolating the two current drives so that they do not interact, it was possible to reduce the number of electrodes to six and to obtain the desired combined impedance through a single measurement as described below[3, 4].



(a) (b) (c)

Figure 1 : Reduced six electrode FIM

Figure 1, electrode u can replace electrodes p and r for measurements in either of the perpendicular directions as it falls on the appropriate equipotentials *aa*' and *cc*' respectively. Similarly, electrode v can replace electrodes q and s for similar measurements. Now if the alternating currents through electrodes *AB* and *CD* can be made to have the same frequency, magnitude and phase but electrically isolated, the potential measured across uv will be directly proportional to the sum of the individual four electrode impedances. Thus the number of electrodes is reduced to six from eight and only one potential measurement circuitry is needed instead of the expected two (considering two separate four electrode measurements). The prototype was designed and fabricated following this concept as described below.

b) Instrumentation For Six Electrode Fim

A block diagram of necessary instrumentation developed for the FIM is shown in *Figure 2* [5].

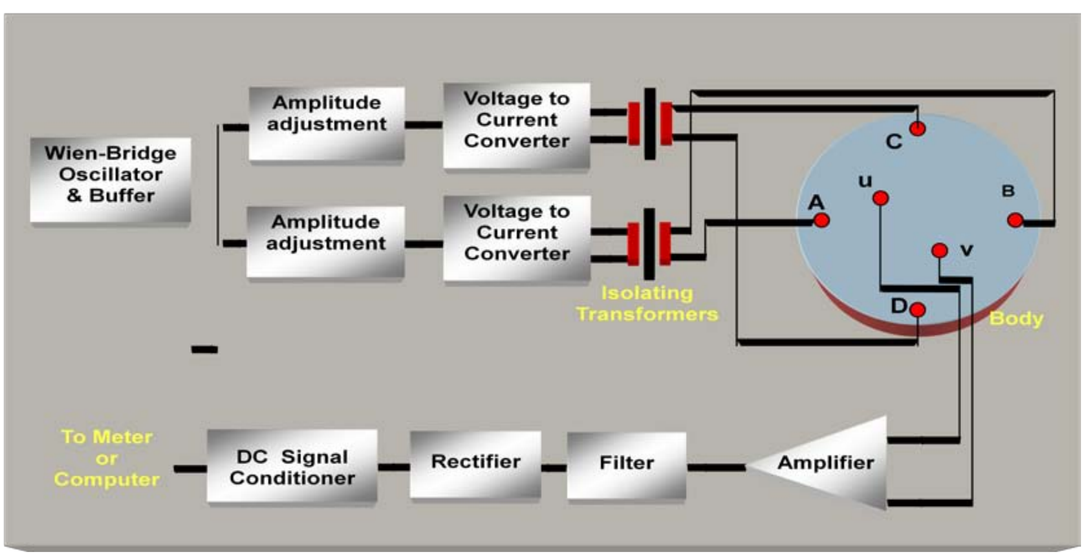


Figure 2 : A block diagram of the 6-electrode FIM

A sinusoidal signal at about 10 kHz is generated using a Wien Bridge oscillator. This is branched out to two isolated current drives (AB and CD) through appropriate voltage to current converters and isolating transformers. The necessary electrode connections are shown on a circular body. The current drives may be set in the same phase or in the opposite phase by simply reversing the electrode connections from one of the two isolating transformers. Since the two isolating transformers may not be exactly equal, two amplitude adjusting circuitry as shown were introduced to make the two perpendicular driving currents the same. The combined impedance measurement (sum) is carried out through measuring the potentials between electrodes u and v. The measured potential is amplified, filtered, rectified and smoothed out to obtain a dc voltage which is proportional to the combined impedance. This dc output voltage may be measured using a digital volt-meter for manual work or may be fed to a computer for automated data acquisition. [Rabbani, 1994].

III. Result and Discussion

For human subjects the depth of the stomach and the resistivity of liquids within them are approximately known (blood, acid, urine respectfully) although the last one may vary depending on the water intake by the subject. If these two parameters are assumed to remain constant then the volume may be measured too.

a) Measurement Made on Human Objects

All collected data are shown graphically in the following figures to have the understanding of measuring liquid volume in stomach by using 6-electrode FIM system and we tried to collect result and discussion from these graphs.

a. Variation of impedance in empty stomach

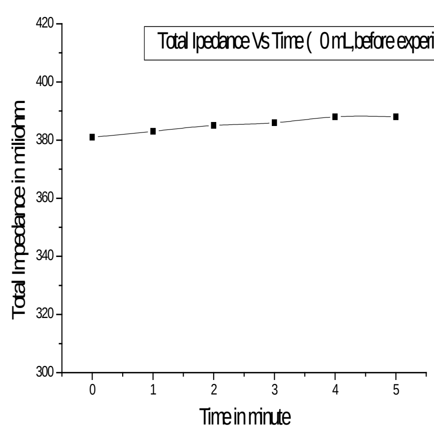


Figure : 3

From the fig.3 we see that in empty stomach the total impedance was approximately, the same i.e. did not change of time. Since the content of the stomach did not change, its impedance also did not, as expected. The slight increase of the impedance may be attributed to the change of position of the stomach and other experimental errors.

b. Variation of impedance with repeated saline intake in the stomach

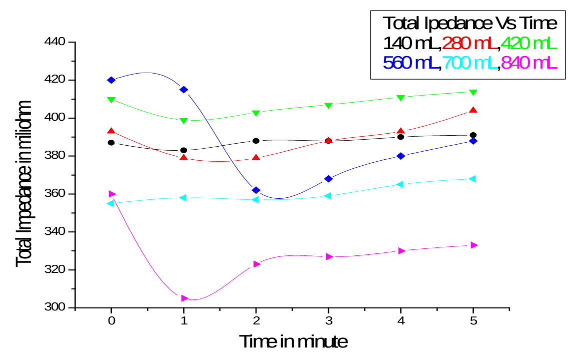


Figure : 4

From the fig.4 above, we see that after the subjects had a drink of water with a little salt the total impedance decreased immediately. Gradually the total impedance increased with the passage of time. When the subjects had a drink of water the position of stomach may have changed. It is also possible that we could not have changed the position of the electrodes correctly to compensate the change of the position of the stomach. The reading of multi-meter fluctuated slightly which resulted in an error in the measurement of the impedance.

b) Repeated Drink by a Human Subject

The following graph shows the variation in impedance-value when a person drank saline water repeatedly maintaining a fixed time interval of 5 minutes.

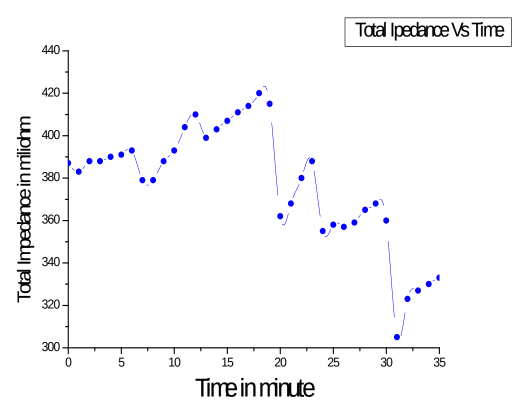


Figure : 5

Fig.5 represents the overall trend of the impedance over the total period of time. It is clear that we got different rates of increase and decrease in the total impedance at different times. There is an overall decreasing trend for the impedance with time. Notice that, the amount of change of impedance with subsequent drinks fluctuated with time, which may be accounted for due to the unequal flow of water from the stomach into the intestine.

IV. Conclusion

We had human subjects drink saline water (to get an increased conductivity as compared to using pure water) and measured the electrical impedance of the region of the body where stomach is situated. The measurement probes were put on the skin and we got interesting variation of the impedance right after the drink was taken. During the measurement, subjects were asked to breathe in fully and to hold the breath so that all the measurements were reproducible. Breathing in also reduces the current through adjacent lungs as they are filled with insulting air. The subjects were kept at sitting position during the measurements, again to obtain reproducibility. The impedance measurement on the stomach showed that intake of saline water reduces the impedance sharply. Current will flow more easily through a stomach, filled partially or fully with saline water, as its impedance is smaller than that of stomach tissue plus the air inside the stomach. Hence, the net impedance will be that of the parallel combination of a saline-filled stomach (having low impedance) and adjacent tissues (having higher impedance). Hence, the saline-filled stomach dominated in the impedance of the region. Using impedance measurement, we can easily identify an intake of water into the stomach in almost real-time. Later measurements showed a gradual increase of impedance of the region of interest where stomach is situated. The obvious reason is that, water flowing into the stomach does not remain confined within it. It continuously, albeit slowly, flows out of the stomach into the intestine. The reduction of water volume inside the stomach results in a subsequent increase of the impedance value. However, depending on the flow into the stomach and out of it, the resultant volume of saline water may increase or decrease. The gradual decreasing trend of the impedance vs. time graph (Figure 36) implies that net volume of water inside the human subject was increasing. Besides water intake, another factor that affects the impedance is acid secreted from the walls of the stomach. Acid acts as a low impedance material and reduces the impedance of the stomach when screted. *FIM is thus a promising technique for the study of acid secretation and has medical uses in identifying stomach deseases.* The results that we obtained for the two subjects for impedance (proportional to the output voltage, since the current is constant) change with volume of water intake appeared to agree well. However, the subjects were both young and had a similar physical frame. We may expect wider variation of the impedance with subjects of different ages and physical build up. We could not perform measurements on more than three subjects due to shortage of time. During the measurements, the stomach did not remain at the same depth in different human bodies. It also does not remain static; rather it moves constantly. If the electrode distance is comparatively less and stomach remains at greater depth than electrode distance, then we will obtain less sensitivity and zone localization becomes arduous. The present work on sensitivity variation and on local impedance measurement of human body have increased the confidence with which the FIM system may be applied for real life measurements on human subjects for physiological studies and for diagnosis of disorders such as cancer cell – identification, post heart attack, kidney, skin disease identification etc.. In this respect, our work has passed the way for future application of FIM for useful medical purposes.

V. Acknowledgement

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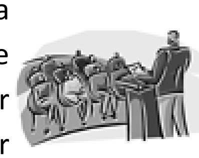

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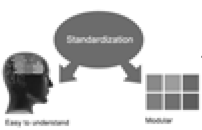

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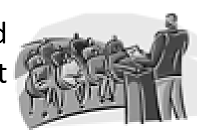

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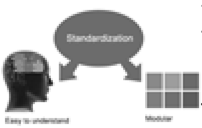

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3. Submission of Manuscripts,

4. Manuscript’s Category,

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- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

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