Department of
Electrical and Computer Engineering

Undergraduate Teaching Labs
Safety Manual*

* *Energy Systems Group, Microwave and Photonics labs either follow their own policy document or complement this document with specific guidelines for their activities.*

Version 1.0 - November 2021

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Emergency & Other Contacts

AMBULANCE, FIRE DEPARTMENT, POLICE	911
U OF T CAMPUS SAFETY (*Formerly Campus Police*)	416-978-2222
ENVIRONMENTAL HEALTH & SAFETY (*For critical / life-threatening injuries and other health & safety emergencies*)	416-208-5141

Other Contacts

UNDERGRADUATE OFFICE	416-978-0488
GRADUATE OFFICE	416-978-5804
HEALTH & WELLNESS CENTRE	416-970-8080
DIRECTOR, TEACHING LABS (**Afshin Poraria**)	416-946-8706
FACILITIES COORDINATOR (**Bianca Britten)**	416-978-7369

Lab Supervisors, Managers and Technicians

COMMUNICATIONS & ADVANCED ELECTRONICS LAB (**Tse Chan)** (*GB347B*)	416-946-5869
COMPUTER LABS (**George Owen**) (*BA3129*)	416-978-2519
DIGITAL & EMBEDDED SYSTEMS LAB (**Hoda Najafi)** (*BA3110*)	416-946-5273
FPGA DROP-IN LABS (**Mike Mehramiz**) (*BA3129*)	416-946-3321
FUNDAMENTALS LAB (**Mihai Zaharia)** (*GB338A*)	416-946-4070
MICROWAVE & PHOTONICS LAB (**Tse Chan**) (*GB347B*)	416-946-5869
SYSTEMS CONTROL LAB (**Mike Mehramiz**) (*BA3129*)	416-946-3321

General Safety Instructions and Precautions

Every person working in a laboratory is responsible for ensuring that:

- All applicable health and safety training has been completed.
- All applicable safety rules and practices are followed.
- All required protective equipment is used as recommended.
- All unsafe equipment and working conditions are reported to the laboratory supervisor, manager or technician.
- All accidents/incidents must be promptly reported (see ***Reporting an Incident*** below)
- All lab staff (supervisors, managers, technicians) are required to be present and accessible in person at the laboratories during experiments, conditioned on the standard working hours of the University. In the event of multiple rooms hosting experiments, staff must make frequent visits to all occupied rooms. This applies to the standard working hours of the university, or pre-arranged modified working hours approved by the Director of Teaching Labs.

General Lab Rules

- **No food or drink allowed in the lab**.
- Use of lab equipment to store or prepare food is prohibited.
- Do not work alone, unless specifically authorized to do so.
- Do not use unauthorized equipment.
- Follow all requirements of safety indicated in the lab manual and posters located on or near the door of the lab.

General Safety

- Be aware of the risks that are present in the particular lab you are working in.
- **Learn the location of emergency exits, fire alarms, fire extinguishers and first-aid kits**.
- All aisles and workspaces must be kept clear of clutter.
- All exits, fire extinguishers and electrical disconnects must remain accessible at all times.
- Know and understand the hazards, safe handling and standard operating procedures of the materials, equipment and methods being used.
- Review equipment manuals, procedures and instructions before attempting to operate any machine or instrument.
- Read labels carefully.
- Any unsafe or dangerous behavior and accidents must be reported to the lab supervisor, manager, technician and TAs.
- Never block access to exits, emergency equipment (e.g., fire extinguishers, fire alarms, electrical panels, first-aid kits).
- Keep your work area clear of all materials except those needed for your work.
- Extra books, bags, coats and other personal items should be kept away from equipment (e.g., place items on the back tables, hang jackets on hooks).

- Equipment must be properly handled. Any damages or technical issues regarding equipment should be reported to the lab supervisor, manager or technician.
- Return all tools to their proper storage places.
- Do not change faulty equipment and instruments without explicit permission of the lab supervisor, manager or technician.

Smoking

Smoking is not permitted inside any University of Toronto building or vehicle or in areas within eight metres of all buildings. This includes any form of e-cigarette or vaping.

Laboratory Security

Keep laboratories locked when unoccupied to avoid unauthorized entry. Individual users are responsible for the security of any space to which they have keys and shall not admit unauthorized or non-registered persons into that space. Safeguarding University of Toronto resources from unauthorized access, misuse or removal is a duty of all faculty, staff, and students. All laboratory users have a responsibility to take reasonable precautions against theft or misuse of materials, particularly those that could cause public harm.

Working Alone

No one is permitted to carry out alone any electrical work over 50V peak. Even for voltages less than 50V peak, it is highly recommended to secure the presence of another student or colleague familiar with the safety procedures in the close vicinity of the area where work is being carried out. The provisions to call for help must always be considered as the primary rule of safety. If solo work on setups limited to below 50V is to be performed at any time, the immediate supervisor and the lab manager must be informed.

Do not work alone in a teaching laboratory.

Always work in the lab with another person. This ensures that in the case of an accident someone is there to assist.

Electrical Safety

At each stage of your experiment, you should be cautious and mindful of safety rules.

- Stay *calm* and *relaxed*; never rush through any experiments.
- At any stage of the experiment, never touch another person's setup.
- If in doubt, always ask questions before you take any actions.
- Make sure that your hands are dry.

Refer to the Appendix D for additional information regarding electrical safety and shocks.

General Instruction and Precautions While Performing Experiments

You MUST familiarize yourself with the physical lab layout, the emergency procedures, AND the operation of all lab equipment.

- **No liquids in the lab.** (Drinks must be either left outside the lab or placed in your bag and kept in one of the designated areas.)
- Do not wear loose clothing (including straps or strings) near electrical equipment.
- If you are wearing metal jewellery (e.g., a watch, long earrings, bracelets, or a necklace), you need to take it off during the lab.
- Long hair must be tied back.
- Make sure you have a proper layout of the power components and instruments on your table. You may need to touch the measurement devices while the circuit is live (e.g., oscilloscope and multimeters). A proper layout of the power components and instruments minimizes the risk of touching the live circuit.
- Select wires with proper length to keep your setup organized and reduce the risk of touching the live nodes. This also makes it easier to troubleshoot your circuit.
- Do not keep any unconnected wires on the experiment table once you have finished wiring up the experiment. This might cause indirect contact. Remove devices and wires that are not connected.
- Make sure all knobs and terminals are fastened firmly.
- Ensure all tools, papers or other personal items are removed from the test table if not required for the experiment.
- **Haste and inattention cause many accidents**. **Work deliberately and carefully**. Plan your activities prior to the experiment, familiarize yourself with equipment prior to actual operation and verify your work as you progress (consult your TA).
- Learn the location of Emergency Exit doors, First Aid Kit, Fire Extinguishers and Fire Alarm. (See Appendix B.)
- **Report potential hazards and suspected faulty equipment to your TA or one of the lab staff immediately.** This includes wires that have poor insulation, set screws that are loose, insecure connections that may come apart, etc.
- If you smell or observe smoke or fire from a circuit or a piece of equipment*, and if you can do so safely,* turn off power to the circuit or the equipment *and inform the lab supervisor, manager, or technician.*
- Do not attempt to perform any diagnosis, maintenance or repairs yourself. Removing or opening the case from any apparatus may expose parts at line voltage.
- **Tampering with or removal of any laboratory equipment is strictly forbidden**.
- **Students should clean and tidy their workstations when they have finished and return all leads before leaving the laboratory.**
- Many drugs, including alcohol and some medications, can impair your thinking (i.e., judgment) and slow your reactions. *Any student displaying such adverse effects, no matter*

what substance, will be excluded from laboratory classes. Similarly, *do not work in the laboratory if you are too tired to think clearly*. Speak to your instructor or lab staff to make alternative arrangements.

Violation of safety standards will not be tolerated. Minor infractions may only incur a verbal warning, but continued failure to follow safe practices may result in removal from the laboratory.

Flagrant violation of safety rules will result in immediate removal from the lab. Any violation occurring within the computer labs will result in the immediate loss of access privileges until further notice.

FOLLOW PROCEDURES - MINIMIZE HAZARDS - AVOID UNSAFE BEHAVIOR.

THINK FIRST, ACT CAREFULLY!

Emergency Procedures

In the event of any emergency, you must think clearly.

Remain calm.

It is your responsibility to read safety posters and follow instructions during an emergency. ***Know the location of the laboratory fire extinguisher, fire alarm, first-aid kit, room and building fire exits and emergency contact numbers.***

General Emergency

1. **Notify emergency personnel.**
   - **Call emergency (911)** and direct them to the location of the accident/incident:

Fundamentals Lab:
35 St. George Street, 3rd Floor, Room 341

Communications Lab:
10 King's College Rd, 2nd Floor, Room 2201

Microwave Lab:
35 St. George Street, 3rd Floor, Room 347

Photonics Lab:
10 King's College Rd, 2nd Floor, Room 2112

Digital & Embedded Systems Lab (DESL):
40 St. George Street, 3rd Floor,
Rooms BA3135 / BA3145 / BA3155 / BA365

Systems Control Lab:
40 St. George Street,, 3rd Floor, Room BA3114

It is critical to **inform the emergency personnel of the nature of the accident** especially if it is an electrical accident, which they need to deal with.

- **Call U of T Campus Safety (416-978-2222)** to inform them of the incident for support and resources.
- **Inform Lab Manager and TA of the incident.**

2. Clear a path to the injured person – move furniture, equipment and unlock doors.
3. Bring in the Automated External Defibrillator (AED) device.
4. Send one individual to the main entrance of the building to help direct emergency response to the incident location.

Fire and Evacuation Procedures

Evacuation

Upon hearing the fire alarm or when an evacuation order is received, remain calm and immediately **WALK** to the nearest exit (see Appendix B for corresponding maps). Remain outside until further instructions are received.

Fire Emergency

When calling to report a fire, notify emergency personnel of the exact location (building and room number) of the incident.

1. In the event of a fire in your work area, shout “Fire!" to alert all in the area.
2. Do not attempt to extinguish a fire unless you are confident it can be done in a prompt and safe manner using a hand-held fire extinguisher. *If safe*, attempt to extinguish the fire with a fire extinguisher:
    - Pull the pin located at the top of the level while you hold the extinguisher in an upright position by the handle.
    - Aim the nozzle of the extinguisher directly at the fire. Try to identify the point of origin, if you can.
    - Squeeze the level of the extinguisher while directing the nozzle at the point of origin.
    - Sweep and cover the area with the extinguishing substance.
3. **If the fire is growing beyond your control**, and you **cannot put the fire out within 30 seconds:**
    - **Pull the fire alarm** (See Appendix B for locations of the nearest alarm).
    - Immediately vacate the building via the safest and closest exit route.
    - **Call 911** and Campus Safety (**416-978-2222**). Be prepared to state the address (see above).
    - **Get out of the building/area immediately, close but do NOT lock the door.** Do NOT use elevators!

Important Reminders:

- Do not attempt to fight a major fire on your own.

- Never throw water on an electrical fire.
- Never enter a room that is smoke-filled or containing a fire.
- Everyone is responsible for knowing the location of the nearest fire extinguisher, the fire alarm and the nearest fire escape.

Calling 911

- **Listen carefully, speak clearly and try to remain calm**.
- **Stay on the line and follow instructions**. Your 911 call taker will stay on the line with you to make sure your call is answered by the appropriate agency.
- Do not hang up until the emergency operator says it's okay to.
- **Be prepared to provide your exact location (building and room number)** when asked. These can be found on the Fire Safety posters near the room entrance (See Appendix B).
  - Location is particularly important if you are calling from a cellphone or an internet/VoIP phone (see below). Cellphones provide only general location information; internet phones provide no location information.
  - Any other information, such as major intersections and street access to your current location, would be helpful indicators for emergency personnel.
- Ensure you know the name of the individual(s) involved in the accident, as this will be critical information needed to fill out an incident report.

Clothing on Fire

Do not use a fire extinguisher on people.

STOP what you are doing, **DROP** to the floor and cover your face, then **ROLL** back and forth on floor and scream for help until the fire is out.

If you cannot stop, drop and roll...

Wrap with a fire blanket to smother the flame (a coat or other non-flammable fibre may be used if the fire blanket is unavailable). Do not wrap a standing person; rather, lay the victim down to extinguish the fire. The blanket should be removed once the fire is out to disperse the heat.

Figure 1. Fire Extinguisher

Refer to Appendix B to familiarize yourself with where the fire extinguisher and first aid kits are located in your lab.

First Aid

First-Aid Kits

First-aid kits are located on the wall by the main doors of most research labs. If there is no first-aid kit present in the lab, there will be a poster near the main lab door that indicates the location of the nearest first-aid kit.

- Lab ***supervisor, manager or technician*** are responsible for ensuring first-aid kits are within the expiration time-period and restocked with all necessary items prior to the start of every semester.

First-Aid Procedures

Minor injuries may be treated by trained ECE Staff.

Major injuries or illness are best handled by phoning **911**. If you encounter someone who is suffering from a medical condition or injury, take the following action:

- If an ambulance is required, contact **911** and Campus Safety at ***416-978-2222*** advising of your location (see Appendix B) and the condition of the individual.
- **Send one individual to the main entrance of the building to help direct the emergency responders to the incident location.**
- If qualified, administer first aid, or seek assistance from someone who is qualified.
- Monitor the individual until the arrival of Fire/Paramedic Service personnel.

Figure 2. First-Aid Kit

Get familiar with items in the first-aid kit. For where kits are located, see Appendix B.

Using an Automated External Defibrillator (AED)

An AED is a small, portable and easy-to-use device that assesses the heart rhythm of a person in cardiac arrest to determine whether it is shockable. If such a rhythm is detected, the provider is instructed to press a button to deliver a shock or series of shocks to the victim's heart, stopping the heart to allow it to return to a normal rhythm. If no shockable rhythm is detected, no shock can be given and the provider must perform CPR until professional help arrives.

Until recently, only medical and paramedical staff used AEDs. However, the advent of safe and easy-to-use AEDs now makes it possible to extend the use of AEDs to people with little or no medical background.

Here at ECE we are using AED Plus / AHA 2010 from ZOLL. The location of the AED device is shown in Figure 3.

See Appendix C for instructions on how to use the AED.

Do NOT use the AED when a victim:

- **Is conscious, or**
- **Is breathing, or**

- **Has a detectable pulse or other signs of circulation.**

The following layout shows the location of the AED device, mounted on a wall next to **Room 132 of Galbraith Building, 1st floor**:

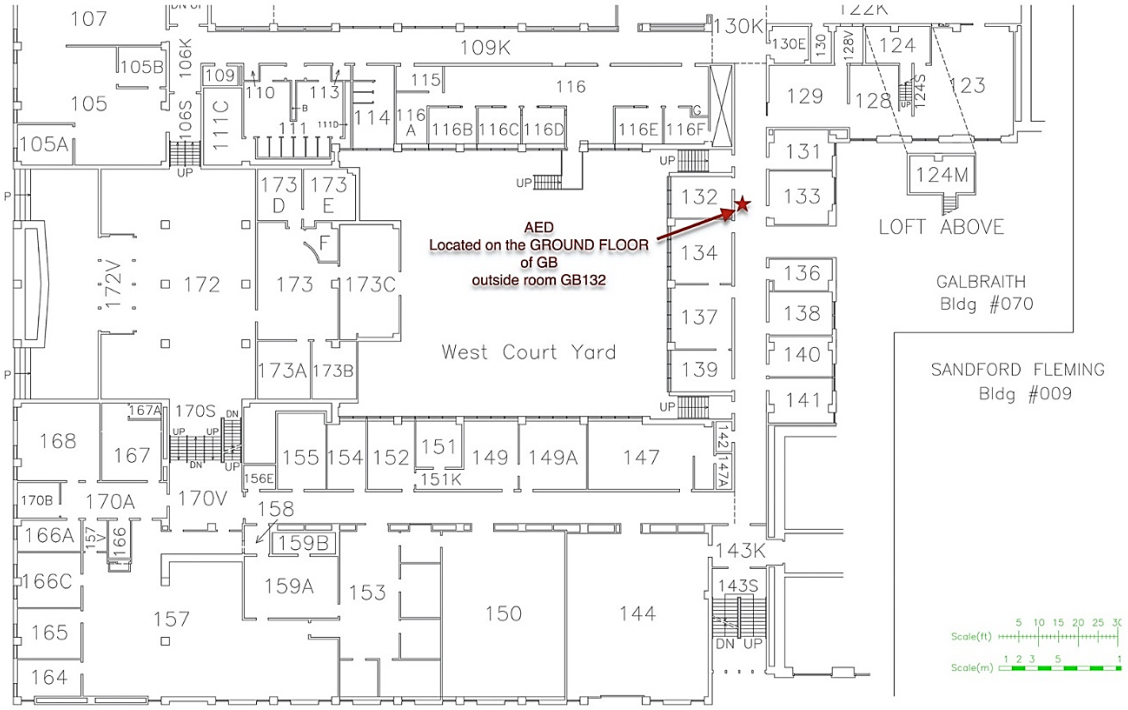


Figure 3. Location of the AED device

Reporting an Incident

Reporting of Accidents, Incidents and Occupational Illnesses

These procedures outline the reporting requirements for accidents, occupational illnesses and incidents which result in or have the potential to result in personal injury or property damage.

Reportable incidents are those which:

- Result in personal injury or lost time from work (including those requiring first aid, and occupational illness).
- Have the potential to result in personal injury or property damage even though no injury or damage was perceived to have occurred.
- Occur to any person on university premises.
- Occur to a university employee(s) during the course of their work either on or off university premises.
- Occur to a student(s) during the course of their classroom, laboratory or field work.
- Occur to a student(s) during the course of a work placement (either paid or unpaid) which forms part of their university curriculum.

The above applies to incidents that occur outside of Ontario. If you will be working outside of Ontario for more than six months, you must contact the Health & Well-being Office at 416-978-2149 to extend your WSIB coverage.

Filling Out Accident/Incident Reports

1. All employees must report the accident/incident to their supervisor or home department immediately.
2. The employer is responsible for providing and paying for immediate transportation to a hospital, health professional office or the worker's home (as necessary).
3. Within 24 hours, the supervisor must complete and submit the "Online Accident/Incident eForm for Employees" found at: https://ehs.utoronto.ca/report-an-incident/
   This form requires UTORid authentication.
4. Please ensure you have all the required information (details of the incident and personal information of the employee) before starting to fill out the form, as it cannot be saved.
   - When the **supervisor, manager or technician** is unable to fully complete the form within 24 hours, it should still be sent, with the missing information to follow later. Use "not available" for missing information.

If you are having difficulty completing the form after 12 hours of the incident, please contact the EHS office at 416 978-4467 or ehs.office@utoronto.ca.

Once submitted, a copy of this report will be sent to the email addresses that you provided on the form. Please also include:

- The ECE Facilities Co-ordinator, **Bianca Britten**: bianca.nagy@utoronto.ca
- Director of Teaching Labs, **Afshin Poraria**: afshin.poraria@utoronto.ca

If you do not immediately receive a copy via email, please contact the EHS office (416-978-4467) as your submission may have failed.

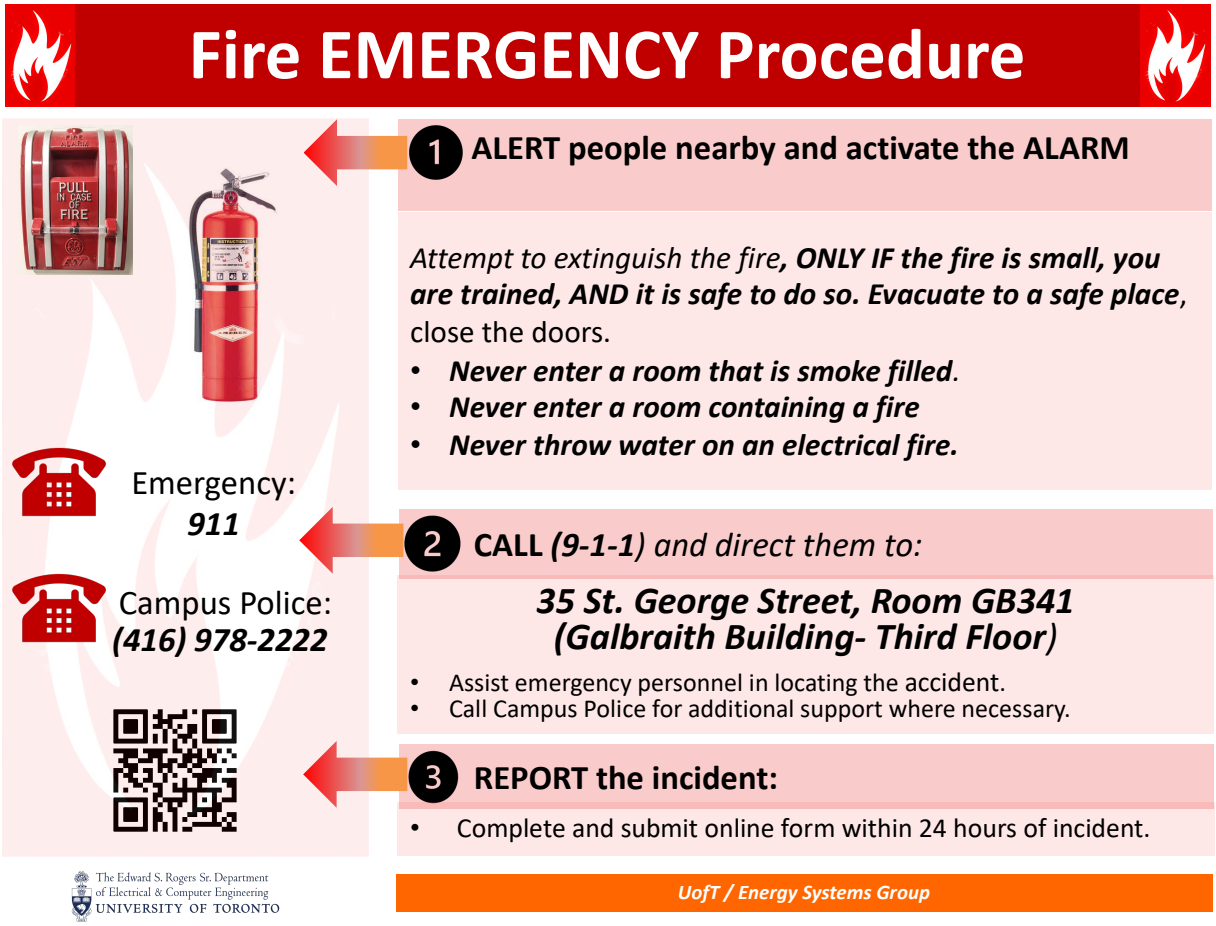
Common Errors/Omissions

- Omission of the name of the injured:
  - Ensure that the name of the person involved in the accident/incident is recorded.
  - If possible, also record the student number of the injured person.
- Incorrect date and time of incident are provided:
  - Ensure the date the time are accurately recorded. (Please note, the form uses a 24-hour drop box.)
- Submission unsuccessful:
  - Ensure all the "Required" fields are filled out.
  - Ensure the green "complete" display appears after submission.
  - Contact the EHS office if your submission is unsuccessful.
- Incorrect classification:
  - Ensure that the accident/incident and the actions taken are appropriately classified.
  - First aid: band-aids and ice packs.
  - Healthcare: family doctor, EMS and Hospital.
- Avoid general statements:
  - Be specific and descriptive when describing the accident/incident and where it occurred.
- Insufficient details of incident:
  - Include in-depth and relevant details surrounding the accident/incident, such as what happened and how it happened.
  - Details of the incident need to be fully understood by outside groups (e.g., WSIB), and they therefore must receive the complete picture.

APPENDIX A

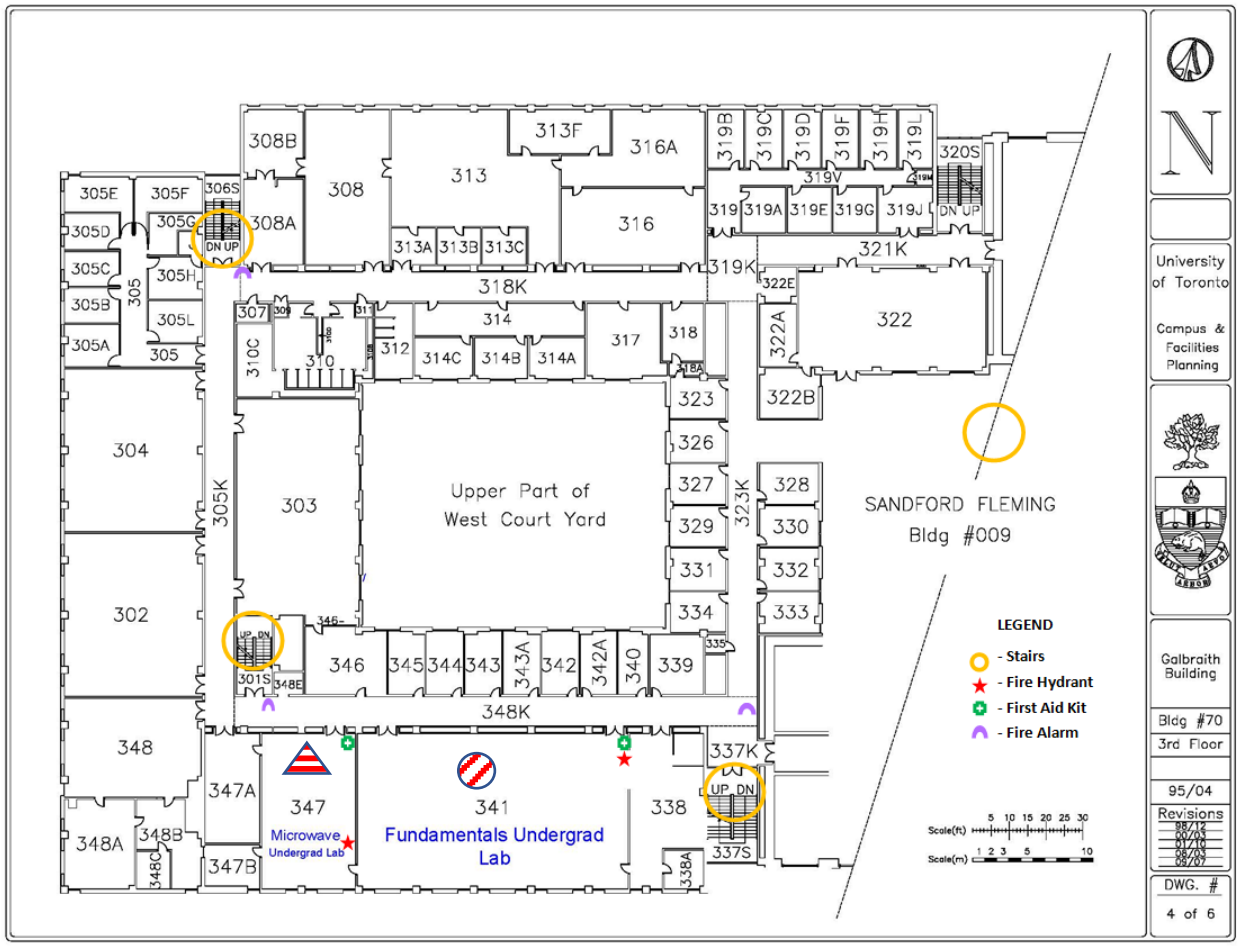
Fire Safety Poster

A fire safety poster will be found near the exit(s) of all laboratories. Posters may vary slightly across different laboratories, depending on if any lab specific safety procedures are necessary.



APPENDIX B: Maps for Laboratories

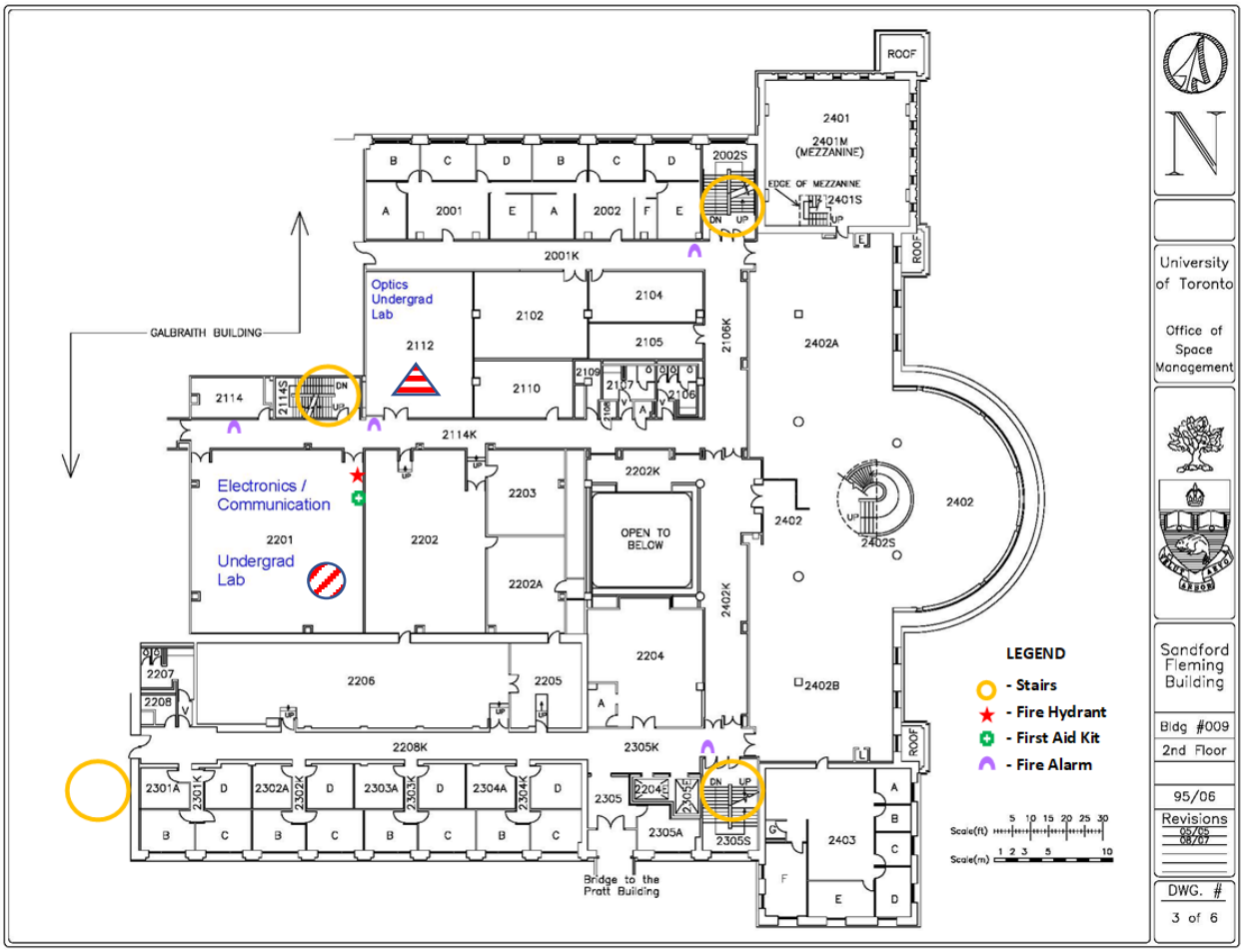
1. Galbraith Building, 3rd Floor



Fundamentals Lab:
3rd Floor, Room 341

Microwave Lab:
35 St. George Street, 3rd Floor, Room 347

2. Sanford Fleming Building, 2nd Floor

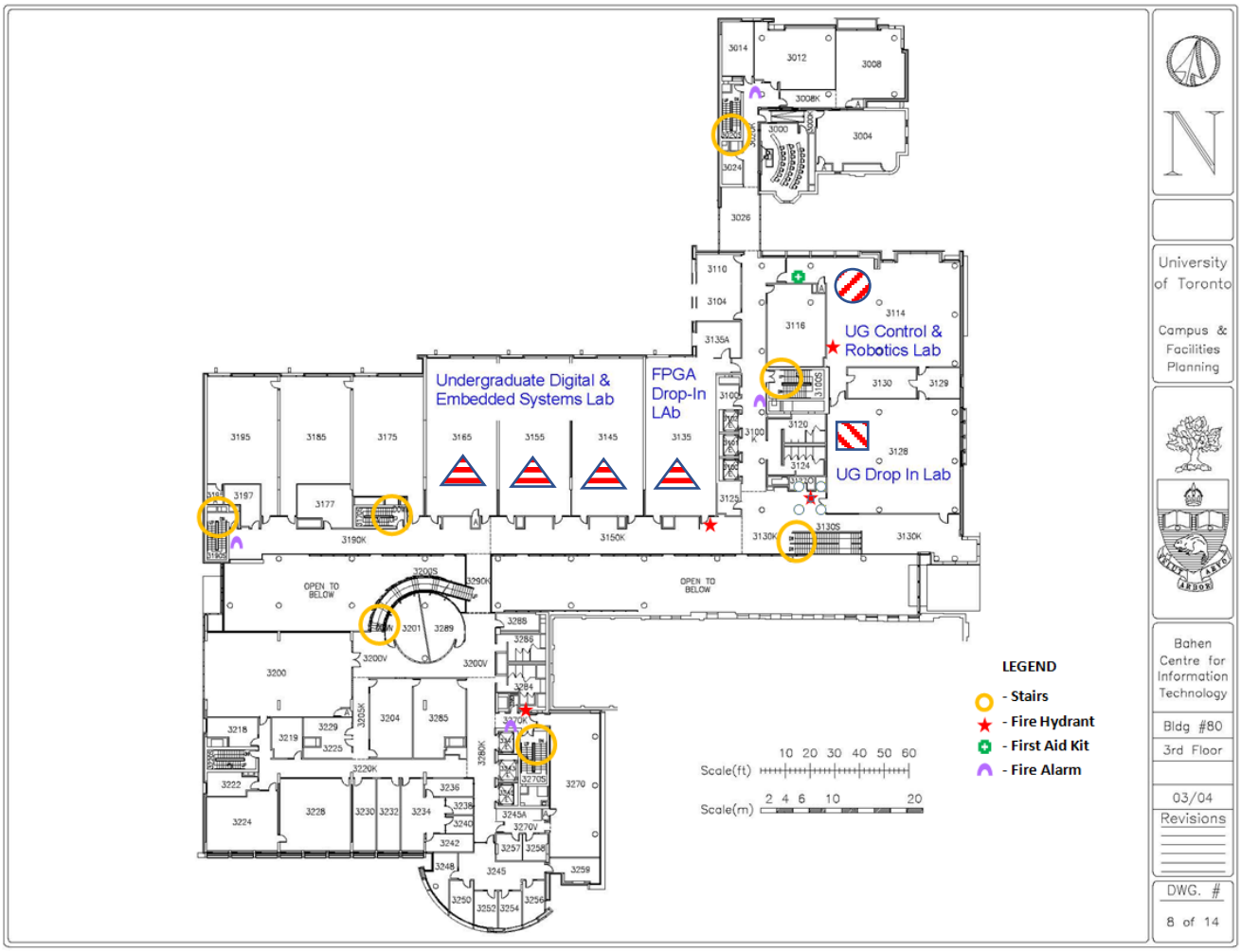


Communications Lab:

2nd Floor, Room 2201

Photonics Lab:

2nd Floor, Room 2112



Digital & Embedded Systems Lab (DESL):

3rd Floor,

Rooms BA3135 / BA3145 / BA3155 / BA365

Systems Control Lab:

3rd Floor, Room BA3114

Computer Drop-In Lab:

3rd Floor, Room BA3128

Warning!

- Use the AED Plus® unit only as described in this manual. Improper use of the device can cause death or injury.
- DO NOT use or place the AED Plus unit in service until you have read the AED Plus Operator's and Administrator's Guides.
- DO NOT use or place the AED Plus unit in service if the unit's status indicator window (located on the left side of the handle) displays a red "X".
- DO NOT use or place the AED Plus unit in service if the unit emits a beeping tone.

- Connect the electrode cable to the AED Plus unit after installing batteries.
- Keep the electrode cable connected to the AED Plus unit at all times.
- This device should only be used by properly trained individuals.
- Only use electrodes labeled "Infant/Child" on children less than 8 years old or weighing less than 55 lbs (25 kg). Use ***CPR-D•padz***® if patient is older than 8 years or weighs more than 55 lbs (25 kg).
- Always stand clear of patient when delivering treatment. Defibrillation energy delivered to the patient may be conducted through the patient's body and cause a lethal shock to those touching the patient.
- DO NOT touch the electrode surfaces, the patient, or any conductive material touching the patient during ECG analysis or defibrillation.
- Move patient away from electrically conductive surfaces prior to use of equipment.
- DO NOT use the unit near or within puddles of water.
- Keep the patient as motionless as possible during ECG analysis.
- DO NOT use the unit near flammable agents, such as gasoline, oxygen-rich atmospheres, or flammable anesthetics.
- Avoid radio frequency interference from high-power sources that might cause the defibrillator to interpret cardiac rhythms incorrectly by turning off cell phones and 2-way radios.
- Disconnect non-defibrillation protected electronic devices or equipment from patient before defibrillation.
- Dry victim's chest, if wet, before attaching electrodes.
- Apply freshly opened and undamaged electrodes, within the electrode expiration date, to clean and dry skin to minimize burning.
- DO NOT place electrodes directly over the patient's implanted pacemaker. Pacemaker stimuli may degrade the accuracy of ECG rhythm analyses or the pacemaker may be damaged by defibrillator discharges.
- Check labeling inside the ZOLL® AED Plus cover before using the cover as a Passive Airway Support System (PASS) device to ensure it is intended for this use.
- DO NOT use the Passive Airway Support System (PASS) if there is a suspected head or neck injury. Place the patient on a firm surface before performing CPR.
- DO NOT recharge, disassemble, or dispose of batteries in fire. Batteries may explode if mistreated.
- DO NOT use or stack the AED Plus unit with other equipment. If the unit is used or stacked with other equipment, verify proper operation prior to use.

Caution!

- DO NOT disassemble the unit. A shock hazard exists. Refer all servicing to qualified personnel.
- Use only commercially available type 123A lithium manganese dioxide batteries. Discard batteries properly after removal from unit. Use only batteries from recommended manufacturers. See the AED Plus Administrator's Guide (P/N 9650-0301-01) for a list of recommended battery manufacturers.
- If the device is stored outside the recommended environmental conditions, the electrode pads and/or batteries may be damaged or their useful life reduced.
- The ***CPR-D•padz*** Electrode can be connected to other ZOLL defibrillators with Multifunction Cables. Defibrillation can be administered when connected to other ZOLL defibrillators.The CPR function does not operate with any device other than the AED Plus defibrillator.

Important!

This symbol indicates that an AED Plus unit is equipped for treating adult and pediatric patients. An AED Plus unit without this symbol is not equipped to treat pediatric patients and will NOT work with ***pedi•padz® II*** pediatric electrodes. To upgrade an AED Plus unit for use with ZOLL ***pedi•padz II*** pediatric electrodes, contact ZOLL Medical Corporation or an authorized ZOLL distributor for information on the ZOLL AED Plus Pediatric Upgrade Kit.

Set-up and Check-out Procedure:

1. Insert 10 new batteries into AED Plus unit.
2. Connect electrode cable to AED Plus unit and pack sealed electrodes inside unit cover. Close cover.
3. Turn unit on and wait for "Unit OK" audio message. Verify that unit issues appropriate "Adult Pads" or "Pediatric Pads" audio message.
4. Turn unit off.
5. Wait 2 minutes. Verify that green check symbol (✓) appears in status indicator window (located on left side of handle) and that unit does not emit a beeping tone.
6. Place AED Plus unit in service.
7. Check AED Plus unit periodically to ensure that green check symbol (✓) appears in status indicator window.

Battery Replacement

For AED Plus units running software version 5.32 or higher, replace batteries every 5 years or if unit prompts. For earlier software versions, replace batteries every 3 years and place a dated AED Plus battery replacement reminder label next to the On/Off button. These labels are available from ZOLL Customer Service. Use only type 123A lithium manganese dioxide batteries from recommended manufacturers.

- Remove all batteries from battery compartment and discard before installing any new batteries.
- Insert 10 new batteries into battery well. Do not use old batteries.
- Press button in battery well only after installation of new batteries.

Cleaning

- Clean and disinfect unit with soft, damp cloth using 90% isopropyl alcohol or soap and water, or chlorine bleach (30 ml/liter water).
- Do not immerse any part of the unit in water.
- Do not use ketones (MEK, acetone, etc.).
- Avoid using abrasives (e.g., paper towels) on the LCD display, if so equipped.
- Do not sterilize the unit.

TROUBLESHOOTING

Problem	Recommended Action
Self-test failed.	Manually test by pressing and holding the ON/OFF button for more than 5 seconds. If unit fails test again, remove from service.
"Change batteries" prompt.	Replace all batteries at the same time.
Red "X" in Status Indicator window OR beeping noise when unit is OFF.	Perform manual test. Check to see if cable is attached properly to unit. Replace batteries. If unit still does not operate correctly, remove from service.
Red "X" in Status Indicator window when unit is ON.	Power cycle the unit. If Red "X" is still present in Status Indicator window, remove unit from service.

Federal (U.S.A.) law restricts this device for sale to or on the order of a physician.

AED Plus®

Automated External Defibrillator

Operator's Guide

AHA 2010

ZOLL®

For Technical support or repair:

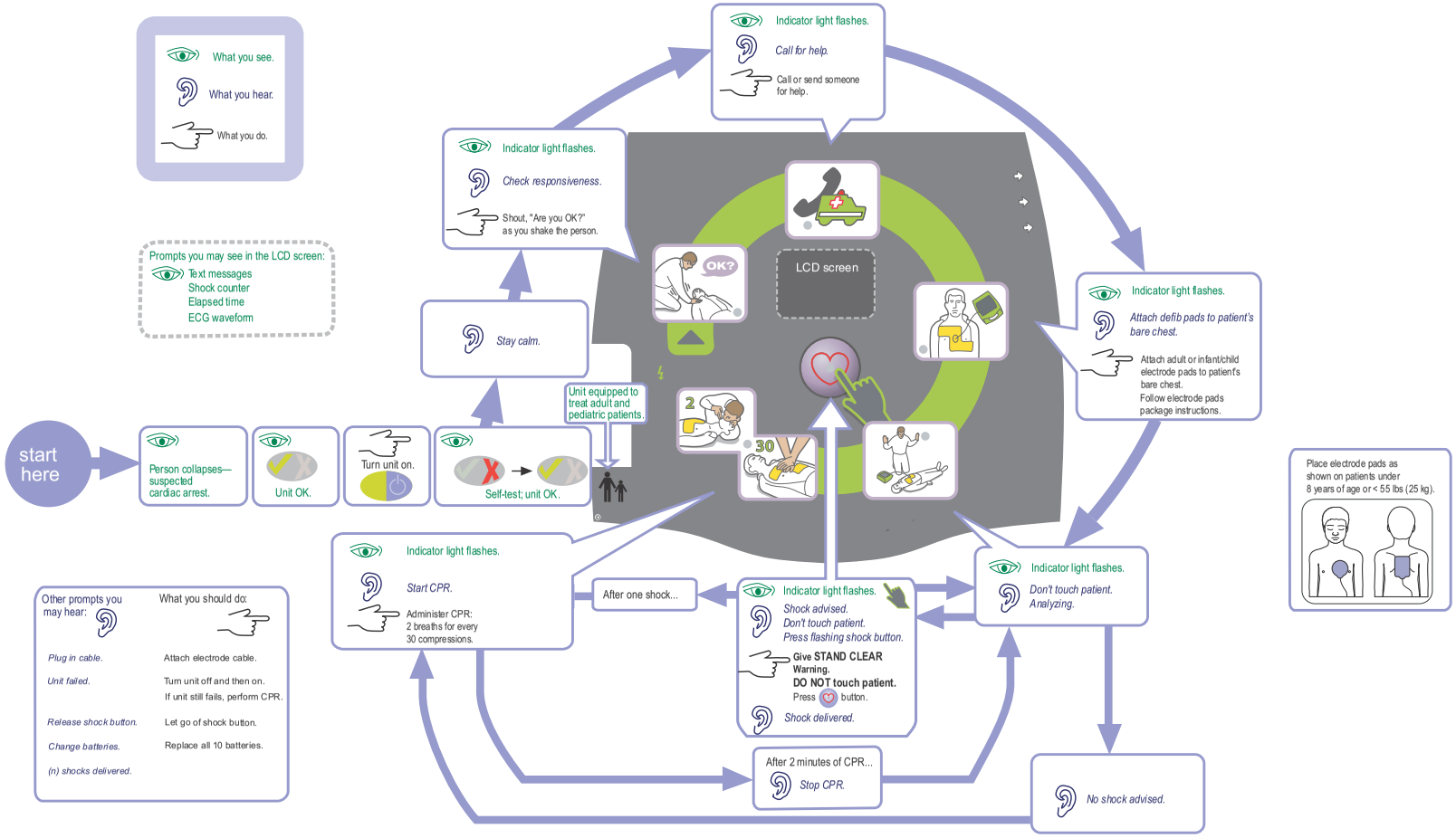
ZOLL Medical Corporation
269 Mill Rd.
Chelmsford, MA 01824-4105
978-421-9655 • 800-348-9011
Fax: 978-421-0010

EC REP
ZOLL Medical Europe
Newtonweg 18
6662 PV ELST
The Netherlands
+31 (0) 481 366410
Fax: +31 (0) 481 366411

International Service:
Contact your local distributor.

CE 0123

REF 9650-0300-01 Rev. P



INDICATIONS FOR USE

Use the AED when a suspected cardiac arrest victim has an apparent LACK OF CIRCULATION indicated by:

- Unconsciousness and
- Absence of normal breathing and
- Absence of a pulse or signs of circulation.

When a victim is less than 8 years of age, or weighs less than 55 lbs (25 kg), the ZOLL AED Plus should be used with ZOLL AED Plus Pediatric Electrodes. Therapy should not be delayed to determine the patient's exact age or weight.

CONTRAINDICATIONS FOR USE

Do NOT use when a patient:

- Is conscious; or
- Is breathing; or
- Has a detectable pulse or other signs of circulation.

INTENDED USER

The ZOLL AED Plus external defibrillator is intended to be used by personnel who are qualified by training in the use of the AED Plus device and basic life support, advanced life support, or other physician-authorized emergency medical response to defibrillate victims of cardiac arrest. The CPR monitoring function provides a metronome designed to encourage rescuers to perform chest compressions at the AHA recommended rate of 100 compressions per minute. Voice and visual prompts encourage a minimum compression depth of 2 inches for adult patients. The CPR monitoring function is not intended for use on patients under 8 years of age.

ZOLL

ZOLL Medical Corporation
269 Mill Road
Chelmsford, MA 01824-4105
978-421-9655 • 800-348-9011
www.zoll.com

APPENDIX D: Understanding Electrical Hazards

Electrical shock is a result of electrical current flowing through the body. In general, there are three contributing factors that determine the severity of the electrical shock:

1. ***The path and the amplitude of the current through the body,***
2. ***The amount of time that current flows through the body, and***
3. ***The frequency of the current that flows through the body.***

1.1 Current path and amplitude

The path that current takes through the subject's body determines the lethality of the electrical shock. It is more dangerous if the current flows through the heart muscle and lungs.

There are two ways that the electrical current can flow through human body:

- Resistive coupling in which the human body acts as a resistor.
- Capacitive coupling where the human body acts as a capacitor.

1.1.1 Resistive Coupling

In the case of resistive coupling, to close the current path a person will have to be in contact with at least two points in the live circuit. The second point of contact, however, could be the ground the subject is standing on, or any conductive element (such as a pole, or panel, etc.) which he or she is touching. *The path that current takes, and the resistance of that path, determines how much current would be generated*. Of course, the current always take the path of least resistance. The amplitude of this current is one of the main factors determining the severity of the electrical shock.

Floating power supplies (batteries or power supplies with an isolating transformer) provide current that does not seek to return current via ground, but some current may flow from stray capacitive coupling. However, the voltage sources in this lab are **not isolated**; therefore, even a single point of contact to any elements fed by these power supplies potentially completes a current path via ground.

It is estimated that a healthy, dry human body with no skin cuts can exhibit around 100,000 Ohms of resistance. This value drops rapidly if the skin is damaged or moist (down to 1,000 Ohms) or the voltage exceeds the skin puncture level of 25-50V. The resistance of the internal organs, however, is much lower at around 300-1000 Ohms. Figure 1, below, depicts the resistance model of the internal organs. As can be seen, the human body can be modelled as a resistive network with different terminals. The total resistance at low voltage is mainly present on the outer layer of the skin: the dead and dry layer of cells covering the body.

The current flowing through the human body follows Ohm's law and can be found as:

$$I = \frac{V}{R}$$

The electric shock hazard depends on the current, not the voltage. It is the amount of charge moved through the body, and the duration of charge displacement, which causes shock. Nevertheless, as Ohm's law suggests, this current is dependent on both the source voltage and the path (resistances) through the body. Therefore, a certain voltage can cause shocks with different levels of severity when applied across different parts of the body because the current that flows through the resistances of each path are different.

Body Part	Resistance
Dry Skin (no cuts or scabs)	Over 100,000 Ohms
Wet Skin	1,000 Ohms
Within the Body	500 Ohms
Ear to Ear	100 Ohms

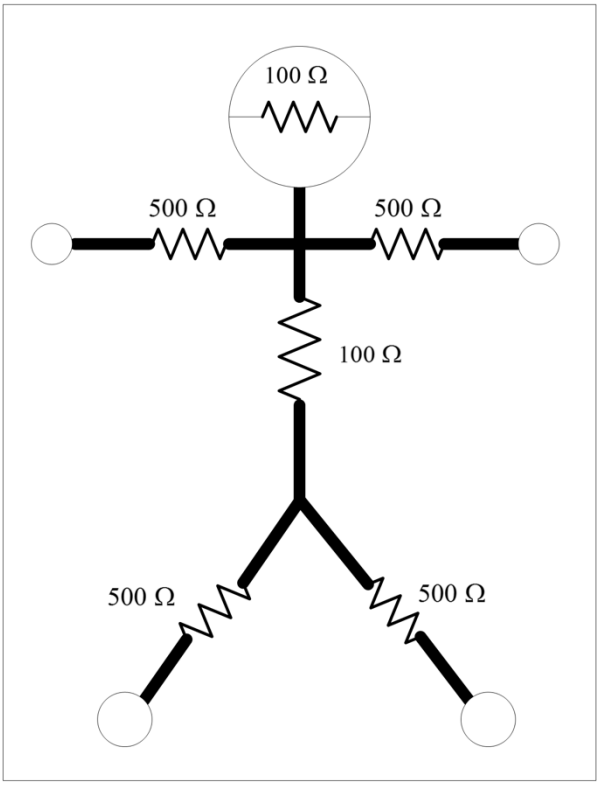


Figure 4. Human Body Resistance Model

Table 1 and Figure 5 show the harmful physiological effects of different amounts of electrical current on a human body for the duration of one second. As can be seen, the effects of electrical shock depend on the current amplitude. A certain amount of current, e.g., 5 mA, can be caused by a wide voltage range, from 5-500 V. This depends on the fact that the skin in the current path is dry and not damaged. **This is one of the reasons why liquids are prohibited to be brought to the lab**.

Humans can perceive currents as low as 1mA. A current of about 3 mA DC flows when testing a fresh 9V battery for a smoke detector across soft tissue, such as a tongue. The maximum harmless current is 5 mA. However, at current levels where a shock does no direct physiological harm, there are still possibilities of inflicting indirect injuries. The shocked individual may react voluntarily or involuntary by muscle contraction. In moving away, possibly very rapidly and by reflex action without thinking, he or she can fall over backwards, bang against a nearby chair or workbench, or just hurt their hand against the chassis of the item they are working on.

Current levels between 10 and 20 mA (depending on the body mass and gender), determine the "**let-go threshold**" current. Beyond that, the muscles are contracted, and the subject can't release the conductor. Above this limit, involuntary clasping of the conductor is present. This results in longer duration of electrical current flow through the subject's body. The severity of the electrical shock depends on the duration of the current flow. The fact that the subject can't disconnect from the live voltage increases the time that current flows through the body and therefore multiplies the severity of the shock. Moreover, as the grip tightens, resistance reduces and the increased current may burn through the subject's skin, leaving only the internal body resistance with dramatically increased current amplitude.

AC-line frequency currents larger than 30mA can cause ventricular fibrillation if it flows through the subject's upper body. The heart itself produces a dipole current of about 2.5 mA, as shown in Figure 6, and any external current of this magnitude can interfere with the normal heart rhythm. As can be seen from Table 1, ventricular fibrillation caused by a sustained 100 mA AC current can be fatal. For greater currents, besides the effects on the subject's heart and respiratory system, the tissues may burn because of the extensive heating of the tissues.

Table.1 Shock Physiological Effects *(For 1 second contact of AC source 60Hz)*

Electric Current	Physiological Effect	Voltage required to produce the current with assumed body resistance:	
		100,000 Ohms Dry Skin	1000 Ohms Wet Skin
1 mA	Threshold of feeling, tingling sensation	100 V	1 V
5 mA	Accepted as maximum harmless current	500 V	5 V
10-20 mA	Beginning of sustained muscular contraction ("Can't let go" current)	1,000 V	10 V
100-300 mA	Ventricular fibrillation, fatal if continued. Respiratory function continues	10,000 V	100 V

6 A	Sustained ventricular contraction followed by normal heart rhythm (defibrillation). Temporary respiratory paralysis and possibly burns	600,000 V	6,000 V

Source: Georgia State University website

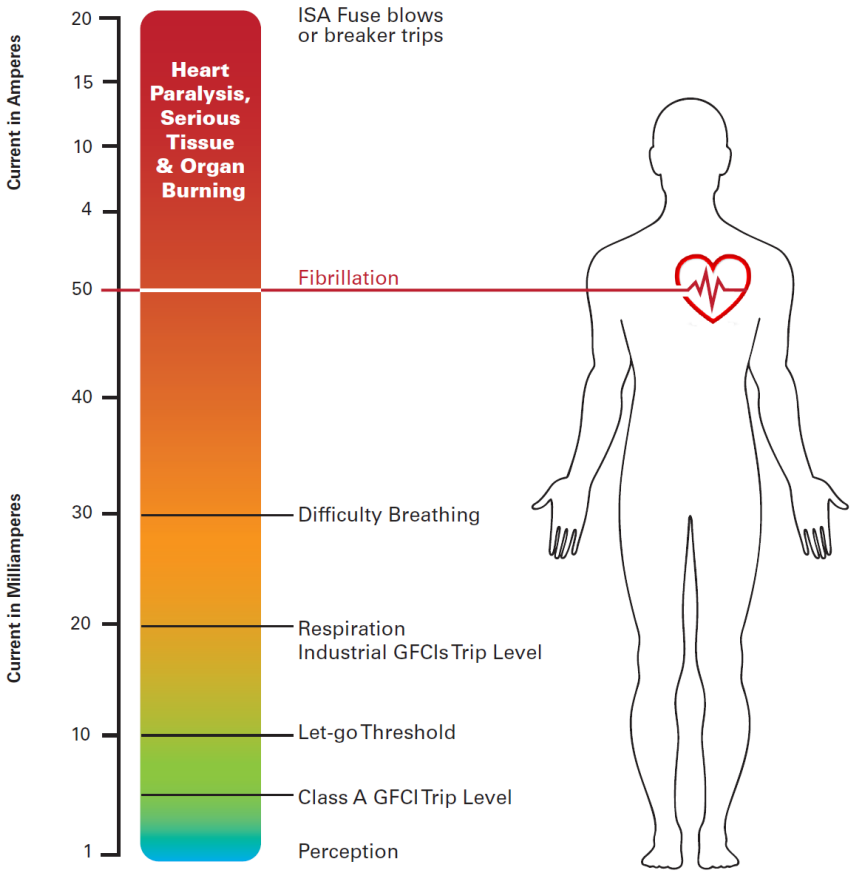


Figure 5. Current Flow Effect in Human Body

1.1.2 Capacitive Coupling

Another interesting point to consider is that beyond acting like a resistor, the epidermis acts like a capacitor. In addition to greater current flow, high voltages (over about 600 volts) may cause dielectric breakdown at the skin, thus lowering skin resistance and allowing further increased current flow. This becomes very important in the case of working with high voltages. It also becomes extremely important to consider the danger from stored energy in filter capacitors. This danger persists even if equipment has been disconnected from the supply and is only mitigated when a ground strap or crowbar has been applied across the capacitor terminals. **All capacitors**

should be considered charged and potentially deadly if a voltage tester has not been used to prove that no voltage is present.

The expression for ventricular fibrillation charge is:

$$Q\ (\text{mC}) = 13.38 \times V^{-0.354} \quad \textit{(V is in volts, Q in millicoulombs)}$$

Using the expression $Q = CV$, we develop a list of capacitors that can be lethal if discharged through the body:

Capacitance (μF)	26	10	6	3	1.2	0.45	0.13
Voltage (V)	100	200	300	500	1,000	2,000	5,000

This means that nearly all energy storage and filter capacitors in the Energy Systems Laboratory should be treated as live, and discharged as a part of the safety process, after isolating apparatus from the supply and before making adjustments.

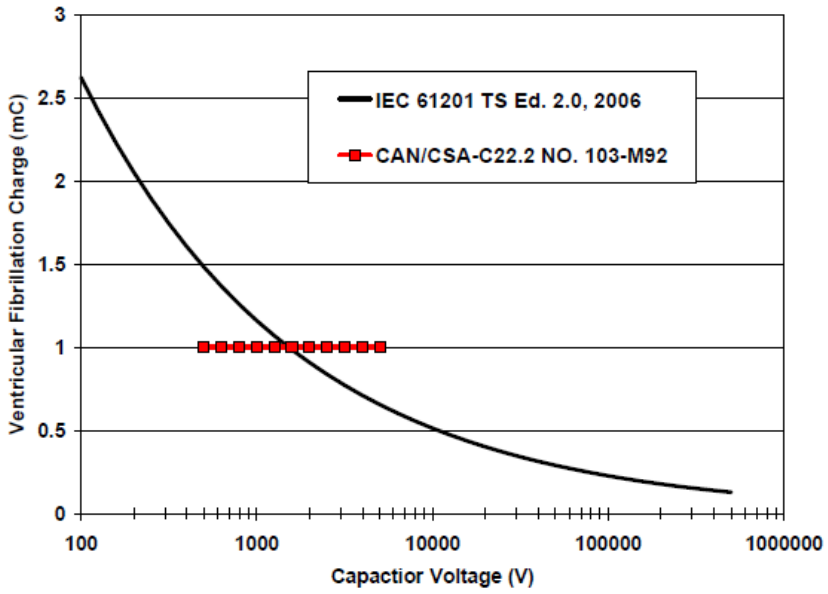


Figure 6. Capacitor Charge that causes Ventricular Fibrillation (IEC 61201) compared to 1 mC standard for Electric Fences in CAN/CSA C22.2

1.2 Time

In order to understand the effect of the time duration on a body that is exposed to an electrical shock, we should revisit the relation between electrical energy, current and voltage:

$$\boldsymbol{E = I^2 . R . t}$$

That is, if a body is exposed for a long time to even a small amount of current, the energy produced can cause burn and blister to the contact area, which results in lower resistance path and higher current, and thereby increased shock level. Duration, then, affects the intensity and severity of electrical shock.

According to IEEE Std. 80, you can determine the maximum safe shock duration for a 50-kg and 70-kg person for an AC system by the following formulas:

For 50 kg weight	***For 70 kg weight***
$t = \left(\frac{0.116}{(V/R)} \right)^2$	$t = \left(\frac{0.157}{(V/R)} \right)^2$

Where "t" is duration in seconds, "V" is the AC voltage in volts, and "R" is resistance of the person. Assume 1,000 Ohms, lowest human body resistance (see Fig. 1), the following table shows the maximum safe time duration for a 50 and 70 kg person.

	For 50 kg weight	***For 70 kg weight***
120 V	$t = 0.934\ sec$	$t = 1.71\ sec$
277 V	$t = 0.175\ sec$	$t = 0.321\ sec$

1.3. Frequency

Currents of the same amplitude with different frequencies have different levels of electrical shock severity. The power supplies in the lab are either DC (0 Hz) or power line frequency AC, i.e., 60 Hz. Both AC and DC currents can cause fibrillation of the heart at high enough levels. This typically takes place at ***30 mA of AC 60 Hz*** or ***300-500 mA of DC***. Though both AC and DC currents and shock are lethal, more DC current is required to have the same effect as AC current. For example, for a person to be electrically shocked, 0.5 to 1.5 milliamps of AC 60 Hz current, and up to 4 mA of DC current is required. For the let-go threshold in AC, a current of 3 to 22 mA is required against 15 to 88mA of DC current.

Table 2 demonstrates the hazard threshold for different electrical sources. Power line frequency 50 Hz/60 Hz and the frequency range of 1-3 kHz are the most harmful frequencies for human body. The switching frequency of the converters in the lab are usually 1 kHz. ***This means the converter output nodes contain voltages at this frequency and therefore they are hazardous to touch.***

Moreover, in the lab setup there is a large capacitor (4,800 µF) on the DC-link usually charged up to 115 V. This capacitor contains around 30 J of energy. This amount of energy is much larger than the hazard threshold for a capacitor (>1 J) according to Table 2.

Table 2. Electrical Hazard Thresholds

Source	Includes	Thresholds
AC	50-60 Hz nominal	≥ 50 V and ≥ 5 mA
DC	All	≥ 100 V and ≥ 40 mA
Capacitors	All	≥ 100 V and ≥ 1 J, or ≥ 400 V and ≥ 0.25 J
Batteries	All	≥ 100 V
Sub-RF	1 Hz to 3 kHz	≥ 50 V and ≥ 5 mA
RF	3 kHz to 100 MHz	A

Source: Environment, Health and Safety (EH&S) Division of Lawrence Berkeley National Laboratory, http://electricalsafety.lbl.gov/resources/field-program-guides/

Acknowledgement:

This document is designed to address the most critical guidelines and procedures to maintain a safe environment in the undergraduate teaching laboratories of Department of Electrical & Computer Engineering and, therefore, it may change from time to time. It also includes emergency procedures which deal with both electrical and fire accidents, as well as when a call to 911 is required. Energy Systems Group, Microwave and Photonics labs either follow their own policy document or complement this document with specific guidelines for their activities.

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