Energy Systems Lab Safety Policy *(V. 4, Rev1)*

This document describes and explains the general issues of responsibility related to electrical safety and how various rules and instructions are applied in the "Energy Systems Group" laboratory.
All who carry out electrical work and experiments in the lab must be familiar with this document. Reading and understanding this document must be acknowledged by signing the form in "Part 4", and returning it to the lab manager.

All students should review "Part I & 2", answer the questions in "Part 3", and sign the form in "Part 4" of this document before attending the first lab session.

Part 1 – Electrical Hazards and Safety Instructions

Purpose

- To become familiar with the basics of electrical hazards in the lab.
- To learn basic steps, you need to follow to work safely and prevent damages.
- To learn critical steps and procedures to follow in case of an emergency.

1. Background

At the Energy System Group Laboratory of University of Toronto, we mostly use either 115V DC or 110V AC, with the exception of one motor drives lab, which is powered by 208V AC feed. These supplies are available through the power panels, which feed a network of active and passive electrical, and electromechanical components interconnected via cables to construct an experiment or a test setup. The majority of these setups include use of IGBT (in the form of converter / inverter), and large storage components (capacitors, and inductors). The combination of these elements creates nodes in the circuits, which could be at voltage, and current levels multiple times higher than the supply values indicated above. For example, a boost converter with "no load" could theoretically provide infinite voltage at its output. Likewise, a buck converter output current is significantly higher than the input current fed to the system.

This is exactly why working in power engineering labs requires extreme caution and alertness, in addition to strict adherence to safety considerations surpassing most other electrical engineering labs.

As you will see in this note, the severity of electrical shock you might receive is affected by many factors. The ratings mentioned above are quite enough to create physiological effects from tingling to lethal ventricular and/or respiratory malfunctions. This document describes electrical hazards as well as necessary approaches to work safely in the laboratory.

2. Understanding the 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.***

2.1. 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 human body acts as a resistor.
- Capacitive coupling where human body acts as a capacitor.

2.1.1 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 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 1000 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 modeled 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 the 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 the Ohms 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 flows through the resistances of each path are different.

Body Part	Resistance
Dry Skin (no cuts or scabs)	Over 100,000 Ohms
Wet Skin	1000 Ohms
Within the Body	500 Ohms
Ear to Ear	100 Ohms

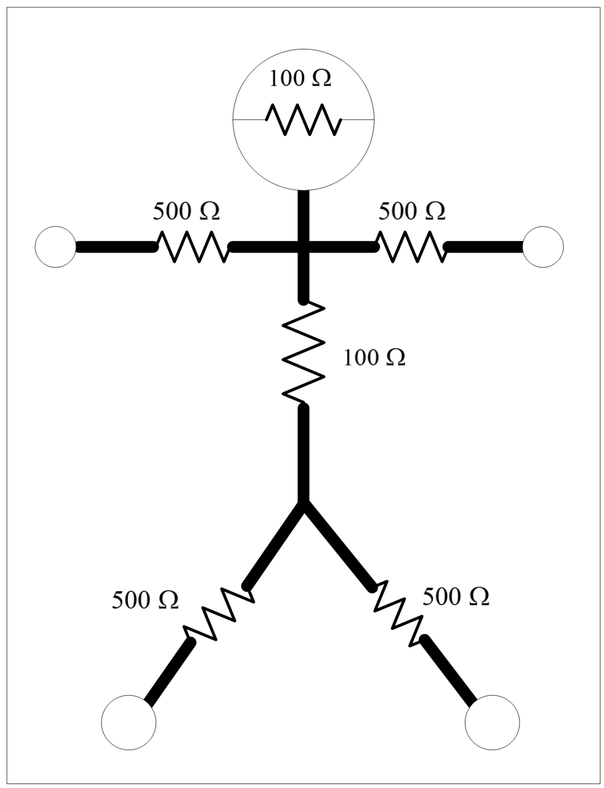


Figure 1 Human Body Resistance Model

Table 1, and Figure 2 show the harmful physiological effects of different amounts of electrical current on human body for the duration of 1 second. As can be seen, the effects of electrical shock depend on the current amplitude. A certain amount of current, e.g., 5mA can be caused by wide voltage range from 5-500V. 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 3mA dc flows when testing a fresh 9 V battery for a smoke detector across soft tissue such as a tongue. The maximum harmless current is 5mA. 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 2, 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 100mA 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	1,000 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.)	1000 V	10 V
100-300 mA	Ventricular fibrillation, fatal if continued. Respiratory function continues.	10000 V	100 V
6 A	Sustained ventricular contraction followed by normal heart rhythm (defibrillation). Temporary respiratory paralysis and possibly burns.	600000 V	6000 V

Source: Georgia State University website

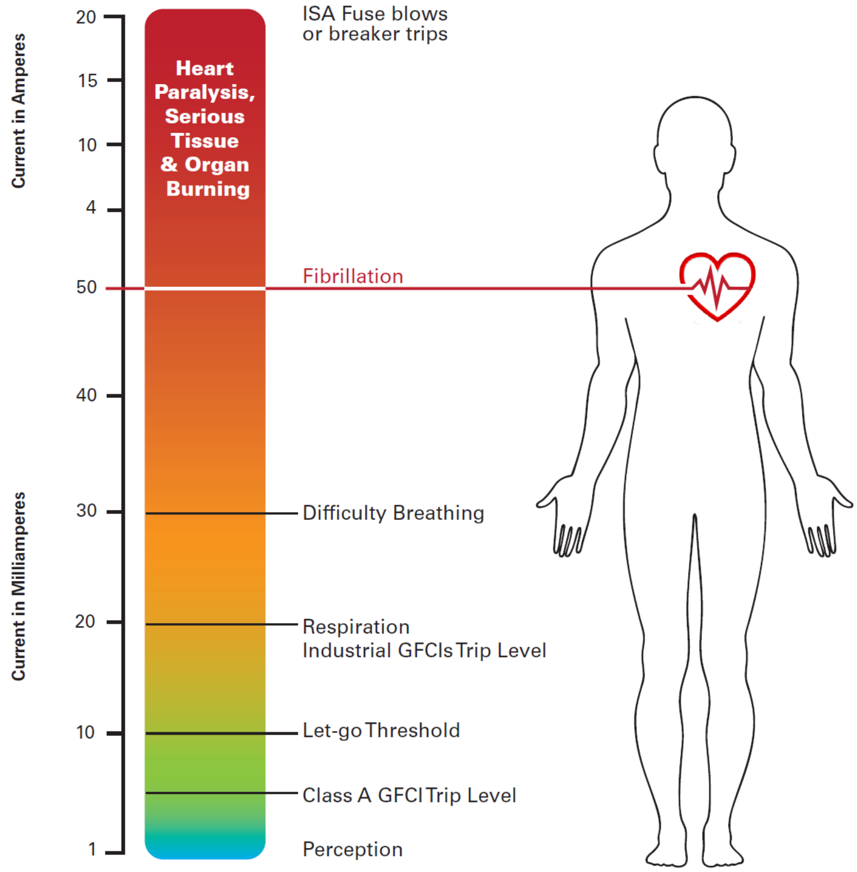


Figure 2 Current Flow Effect in Human Body

2.1.2 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 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:

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

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	1000	2000	5000

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.

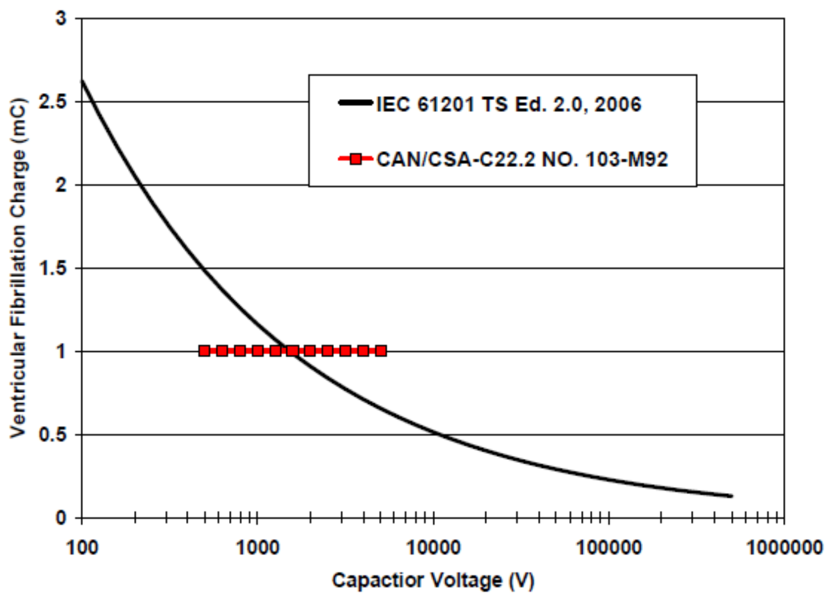


Figure 3 Capacitor Charge that causes Ventricular Fibrillation (IEC 61201) compared to 1 mC standard for Electric Fences in CAN/CSA C22.2

2.2 Time

In order to understand the effect of the time duration that a body 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 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 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 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	$t = 0.175\ sec$	$t = 0.321\ sec$

2.3. 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 (0Hz) or power line frequency AC, i.e., 60Hz. Both AC and DC currents can cause fibrillation of the heart at high enough levels. This typically takes place at ***30mA 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 50Hz/60Hz and the frequency range of 1kHz-3kHz are the most harmful frequencies for human body. The switching frequency of the converters in the lab are usually 1kHz. ***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 (4800μF) on the dc-link usually charged up to 115V. This capacitor contains around 30J of energy. This amount of energy is much larger than the hazard threshold for a capacitor (>1J) 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/

3 Safety Instruction and Precautions

In the energy systems lab for each experiment you are given a time to wire up your circuit. This circuit ***MUST*** then be reviewed by your TA for safety and functionality prior to power-up. Only after TA's inspections, you can power up your circuit and do different steps of your experiment. At each stage, 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 doubts,* ***always ask questions before you take any actions. Make sure that your hands are dry.*** The instructions and precautions to reduce the risk of electrical shock and equipment damage are explained as follows.

3.1- General instruction and precautions while wiring up the circuit

- ***You MUST familiarize yourself with the physical lab layout, the emergency procedure*** (section 4 below)***, layout of yellow power panels, and the operation of all lab equipment***.
- **No liquids in the lab.** (You need to either leave them outside the lab or put them in your bag and keep your bag in the designated area.)
- Wear proper footwear**, no slippers, flip-flops, or sandals.**
- **Do not wear loose clothing or ties near electrical equipment.**
- Cell phones may cause signal interference (as well as disturbing other laboratory users) so **do not use your phone at any time within the laboratory**.
- If you are wearing metal jewellery or bracelets, e.g., watch, long earrings or necklace, you need to take them off during the lab. Likewise, 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.
- It is not allowed to 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, which are not connected.
- **Make sure all knobs and terminals are fastened firmly**.
- Remove all tools, papers, pens, and pencils from the test table.
- **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 Power Shut Down", "Power Panel Breakers", "Rescue Devices", First Aid Kit, and "Fire Extinguishers".
- If you smell or observe smoke or fire from a *circuit*, or a *piece of equipment,* turn off power

to the circuit or the equipment using the breakers on yellow power panels, ***if you can do so safely***.

- If turning off power cannot be performed safely, turn off the main power using the "EMERGENCY POWER SHUTDOWN".
- **Report potential hazards and suspected faulty equipment to your TA, or one of the lab staffs immediately.** This includes; wires that have poor insulation, setscrews that are loose, insecure connections that may come apart, etc., In particular, 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 (judgment) and slow your reactions. ***Any student displaying such adverse effects, no matter what drugs, will be excluded from laboratory classes*** until the effect ceases. 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.***

3.2- Power Panels

A total of 29 yellow power panels are installed throughout the Energy Systems Group Lab. Each panel contains four distinguishable sections for power distribution and access as follows;

1. DC Power: Available from the front top section of the panel, the DC power can push up to +/-400V and 25A (via 4mm connectors in room 2) or 100A (via 6mm connectors in the rest of the lab). A single power supply provides both positive and negative DC power, which is hard-wired and shared amongst all 29 panels. That is, if the main DC power supply is set to operate with certain settings, that power is immediately accessible via the three terminals located on the center-top section of ALL panels (Max +400VDC, 0VDC, and Min -400VDC).
   As a safety measure, each rail is connected to the up-stream via rotary electrical circuit breakers with proper current rating (**25A** for room 2, and **100A** for the rest of the lab) along with a panel mount digital meter. Note that the negative rail meter**, only displays the absolute value of the voltages and currents**; no negative sign is displayed.

   Users must ensure that ONLY at the time of usage, the proper breaker(s) is / are ON, and note the values displayed on the meter for consistency check with power supply settings.
   Because of the hard-wired shared connections of all DC sections, it is also highly recommended to remove all wired connections from your circuit to the DC supply when no tests are being undertaken. This is to avoid equipment damage, and accidents. Again, keep the breakers off, and disconnect all wires after all experiments and tests.

2. Dedicated 208/120V AC: a three phase, 60Hz, five-wire access to the 208/120V AC is available via the front mid-section of the panel. Unlike the DC, which requires the intervention of users to turn on the supply, this AC section is hard-wired to the grid via circuit breakers and a transformer. Users must be aware that by turning the panel AC breaker on, all AC terminals (including the round connector on the side) will be live.

   Similar to the DC power above, room 2 (the undergraduate lab area) is equipped with 25A breakers and 4mm terminals, while the rest of the lab panels are designed with 6mm terminals and 100A breakers.
   It is possible to check the availability of each phase by pressing the LED push buttons on the panel.

3. There are two additional spare set terminals available to users on the front bottom section of the panels, each with its own breaker unit. Only lab personnel and trained individuals have permission to use these connections.

4. On the panels installed in the undergrad area (room 2), there are two sub sections on the side: one 20VAC, 60 Hz comprised of two breakers, each used for four wall outputs, and one 208VAC plug.

The rest of the panels only offer the 120VAC outlets as described above. Figure 4, below depicts the undergraduate version of the panel.

Users are advised to pay special attention to the markings and labels installed. The most important note of caution;

DO NOT OPEN UNDER LOAD.

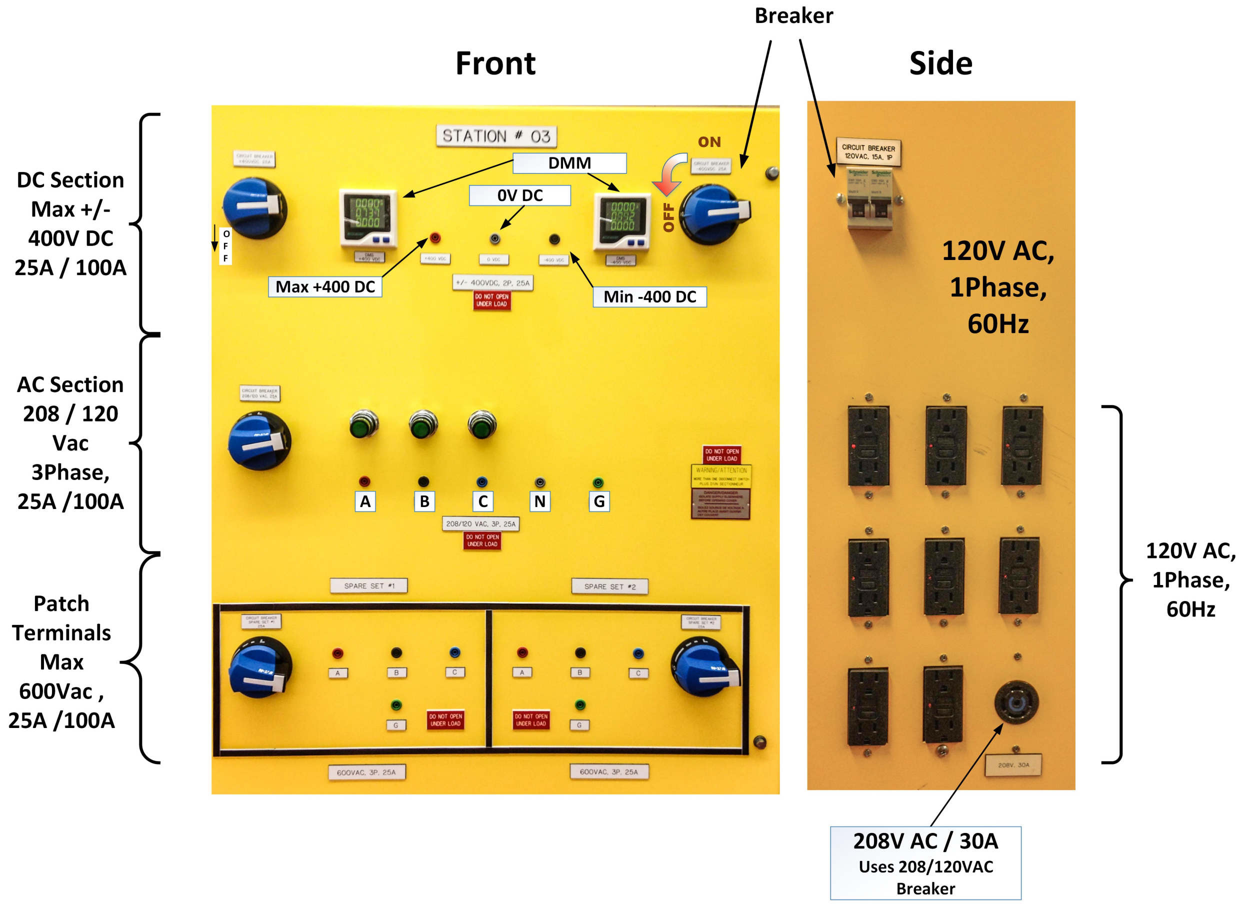


Figure 4 Main Power Panel (showing the 25A / undergraduate version)

3.3- Instruction and Precautions to be taken before powering the circuit

- Be mindful of dangers; have a hardcopy of your circuit diagram handy and review the circuit and all connections against your diagram. As you go through the circuit, double check all junctions, i.e., fasten all bolts, inspect all terminals, etc.
- If this is a setup for an undergrad lab experiment, a TA ***must*** inspect your circuit prior to power-up.
- Minimize exposure to live circuits. **Connect to the source of power as the last step** when wiring a circuit. **Disconnect from the power source as the first step** when disassembling a circuit.
- Make sure no one is close to, or touching your circuit.
- Make sure you know the power-up sequence in order not to damage the equipment. The power-up sequence is usually part of the Lab preparation. Check your marked preparation, discuss the correct power-up sequence with your partners and make sure you all understand the correct procedure.

3.4- Instruction and Precautions while doing the experiment

- Never touch the power circuit with bare hands (The power source and the power circuit in this lab are not isolated, therefore you will definitely get an electrical shock if you do so). If you need to change some parameter in your power circuit while the circuit is live, e.g., changing the resistance of the streetcar resistor, make sure you are only touching the insulation, e.g., the wooden handle of the streetcar resistor.
- If you need to change the circuit **you have to go through the shutdown procedure** and then make changes
- If possible, use only one hand, keeping the other hand disengaged from circuitry. Do not permit any part of your body to complete a circuit. Do not wear any jewelry on the working hand.
- If you smell or observe smoke or fire from a *circuit*, or a *piece of equipment,* turn off power to the circuit or the equipment using the breakers on yellow power panels, ***if you can do so safely***.
- If turning off power cannot be performed safely, turn off the main power using the "EMERGENCY POWER SHUTDOWN".

3.5- Instruction and Precautions while switching off or shutting down the circuit

- Make sure you know the shutdown sequence in order not to damage the equipment. The power sequence is usually part of the Lab preparation. Check your marked preparation, discuss the correct power-up sequence with your partners and make sure you all understand the correct procedure.
- Make sure to wait until the dc-link capacitor is completely discharged (In all the experiments, there is a dc voltage meter to monitor the dc-link voltage).

3.6- Performing Electrical Measurements

During electrical measurements with multimeter or oscilloscope, even at low voltage levels there may be significant risk of injury caused by electrical arcing. This applies when measurements are made on a circuit with high short circuit currents and low inductance to the power source. The instruments are labeled with different CAT designations depending on the insulation class they have against overvoltage that occur in power system. The higher the CAT class, the better the insulation against transients. Short circuit can occur in all labs, and they have much higher voltages then the operating voltage. Such high voltage pulses can cause insulation breakdown that can lead to a short circuit in the measuring instrument, or test leads. This can trigger an arc between the terminals on the multimeter, causing serious burns.

Make sure that all measuring instruments and leads directly connected to high power devices have class 600V CAT III. In our lab, this applies mostly to multimeters and their leads. Oscilloscopes are generally connected to output of voltage or current sensors, and thus need not have CAT III classification.

The following figures show the two most common multimeters used in the lab, both CAT III class..

 Figure 5 CAT III Multimeter, mostly used for voltage measurement	 Figure 6 CAT III Multimeter, mostly used for current measurement

When multimeter is used for current measurement, test leads are connected between the terminals marked "COM" and "A" (or "uA", "mA"). The impedance in this measuring circuit is very low, and if the terminals are mistakenly used for measuring voltage, a short circuit to ground will occur. In order to avoid high currents and possibility of triggering an arc, the terminals are protected with fuses that can withstand high amount of energy, nevertheless, special attention should be paid when connecting any measuring device.
Note that for all current measurements with a multimeter, the test leads must be connected when circuit is powered down.

Oscilloscopes must always be grounded, or connected via an appropriate isolating transformer.

3.7- Working Alone

No one is permitted to carry out any electrical work over 50V peak alone. Even for voltages less than 50V peak, it is highly recommended to secure the presence of another student or colleague familiar with safety procedures in the close vicinity of the area where work in being carried out, the provision to call for help must always be considered as the primary rule of safety. If solo work is to be performed outside normal working hours (9:00 am to 5:00 pm), the immediate supervisor and the lab manager must be informed.

FOLLOW PROCEDURES - MINIMIZE HAZARDS - AVOID UNSAFE BEHAVIOR.

THINK FIRST, ACT CAREFULLY.

4 Emergency Procedures

In the event of any emergency you must think clearly.

Remain calm.

4.1 Medical Emergency

1. ***Shut down the main power*** as your first action using the "EMERGENCY POWER SHUTDOWN" button shown below located on the north side of the laboratory. *Familiarize yourself with the location of the emergency button in the first day you enter the lab.* Warning; the circuit must still be treated as energized due to existence of large capacitors in the main power supplies, and the circuit. ***DO NOT touch any part of the circuit or the electrified person.***

Figure 7 Emergency Power Shut Off Button

2. Disconnect the electrified person from the live circuit using the rescue devices (Electrical Rescue Hook) shown in the figure below. ***Make sure you DO NOT touch the subject*** because you may become part of the circuit, and therefore electrocuted. *Familiarize yourself with the location of the rescue devices in the first day you enter the lab.*

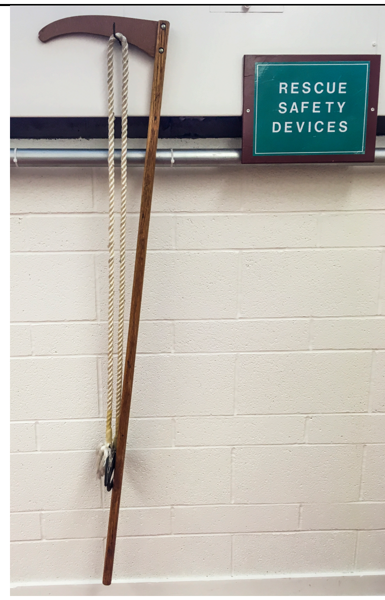


Figure 8 Rescue Safety Devices

3. **Call emergency (9-1-1**) and direct them to:

35 St. George, Room 040 (south side basement)

It is critical to inform the emergency personnel that ***it is an electrical accident*** they need to deal with. A student may be asked to meet the emergency response providers and direct them expediently to the laboratory.

4. Clear a path to the injured person – move furniture, equipment, unlock doors.

4.2 Fire Emergency

1. In case of fire, ***shut down the main power*** using the "EMERGENCY POWER SHUTDOWN" button. ***Never throw water on an electrical fire.***

If safe, attempt to extinguish the fire with a fire extinguisher. The fire extinguisher is located at both entrances to the lab;

a. Pull the pin located at the top of the level while you hold the extinguisher in an upright position by the handle.
b. Aim the nozzle of the extinguisher directly at the fire. Try to identify the point of origin, if you can.
c. Squeeze the level of the extinguisher, while directing the nozzle at the point of origin.

d. Sweep and cover the area with the extinguishing substance.

At this point**, if the fire is growing beyond your control,**

- **Get everyone out of the building / area immediately,**
- **Pull the fire alarm** (Fire alarms are located across the two entrance /exit doors to the lab)
- **Call 9-1-1** and the campus police (**416 978-2222**). Be prepared to state the address.

Figure 9 Fire Extinguisher

Figure 10 First Aid Kit

The following figure shows the entire lab layout.

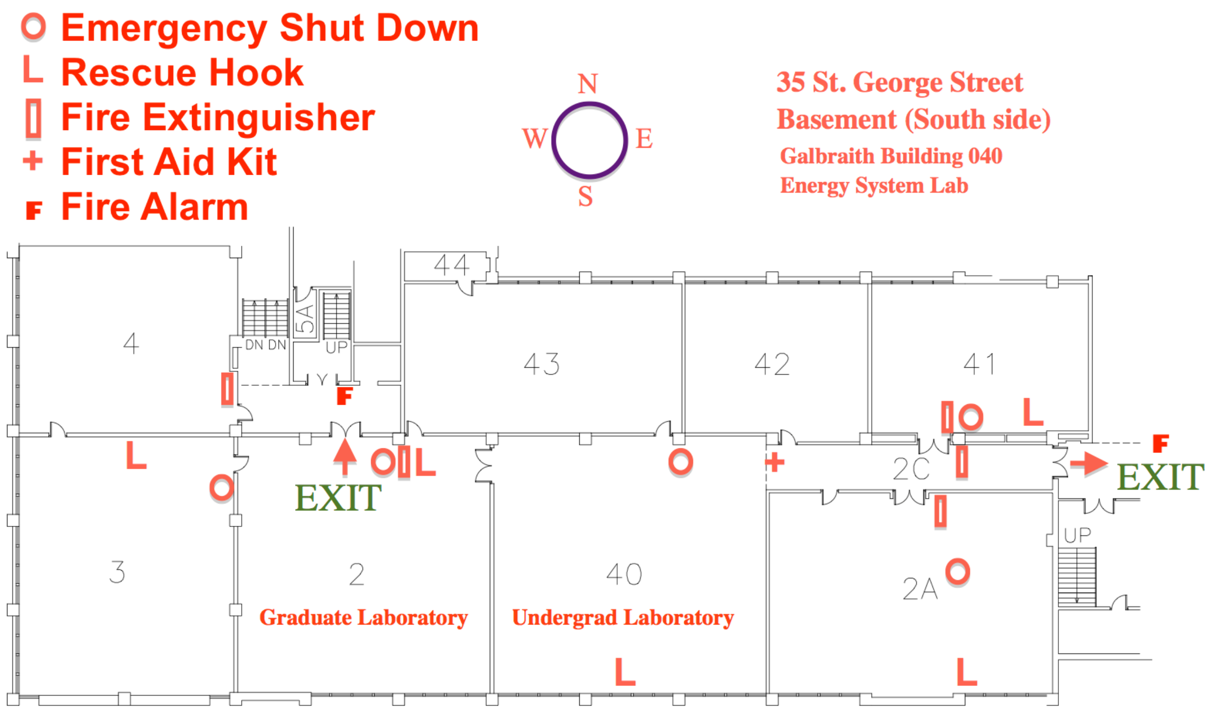


Figure 11 Layout of Energy System Lab

Emergency: 911
Campus Police: (416) 978-2222

4.3 Using Automated External Defibrillator (AED)

An AED is a small, portable, and easy-to-use device that assesses the heart of a person in cardiac arrest for a shockable rhythm. 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 12.
The following is a two page insert which describes the operating guide of this device. Please familiarize yourself with the steps described, and remember:

Do NOT use the AED when a patient:

- **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.**:

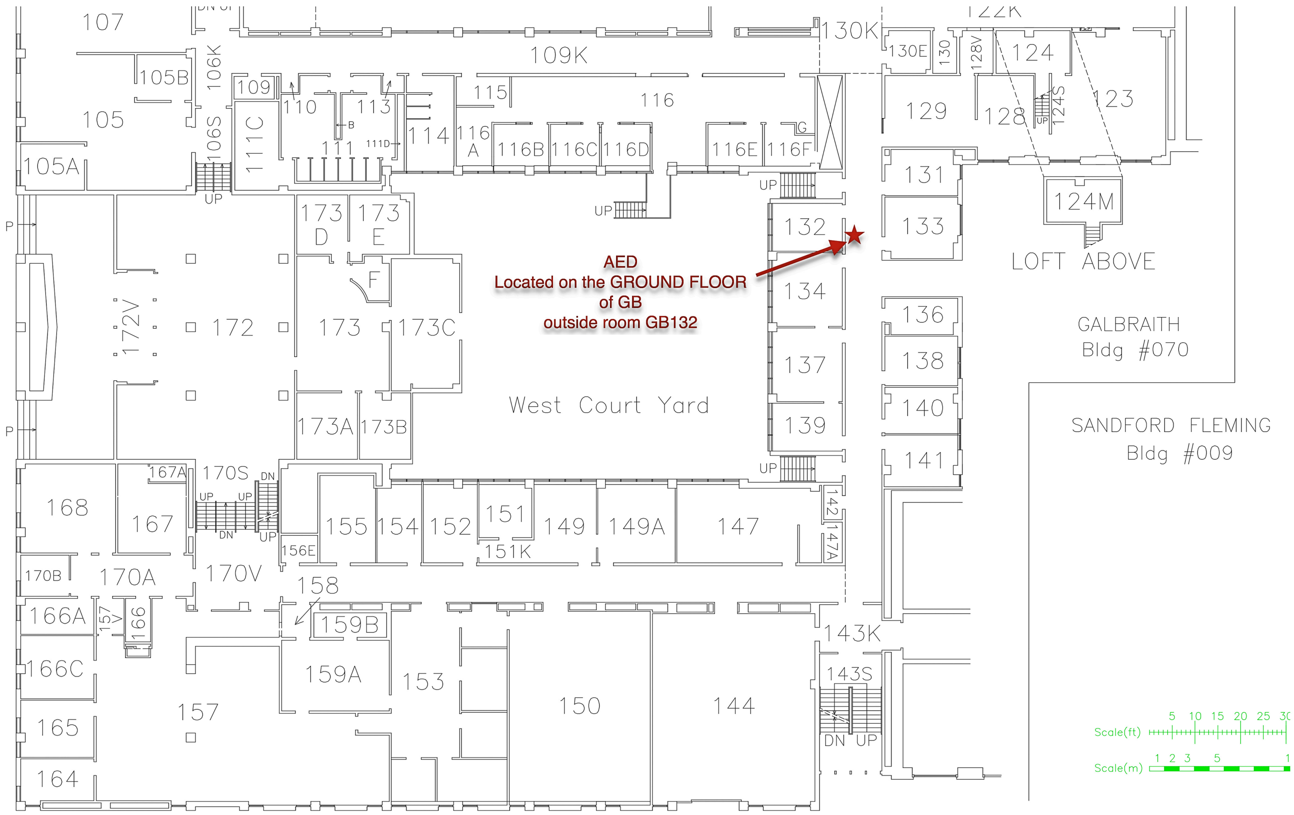


Figure 12 Location of the AED device

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

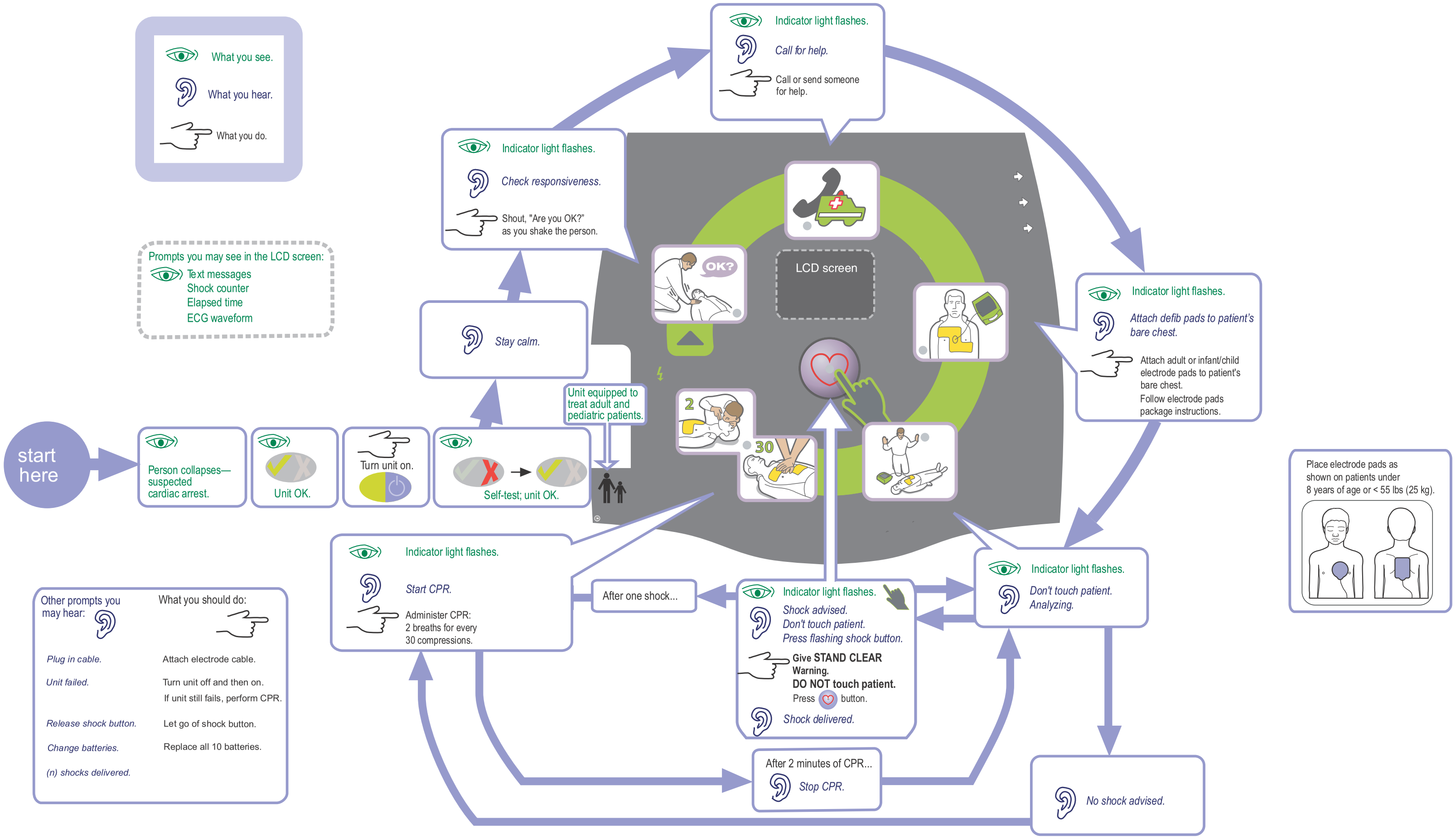
EC REP

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

Part 2 – 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 actually occurred;
- occur to any person on university premises;
- occur to a university employee during the course of his/her work either on or off university premises;
- occur to a student during the course of his/her classroom, laboratory or field work;
- occur to a student 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 6 months, you must contact the Health & Well-being Office at 416.978.2149 to extend your WSIB coverage.

Filling Out Incident/Accident 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 of 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 supervisors are 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 e-mail addresses that you provided on the form. Please also include

- The facilities co-ordinator Bianca Nagy: bianca.nagy@utoronto.ca
- Energy Systems Group Laboratory at: esg-lab@ece.utoronto.ca

If you do not immediately receive a copy via email, please contact the EHS office as your submission may have failed.

Common Errors/Omissions

- Incorrect date and time of incident are provided
    - Ensure the date the time are accurately recorded (please note the form uses a 24 hour dropbox)
- 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 & 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

Part 3 – Safety Questions

Please answer the following safety questions about the

1-what is the lowest current that can be felt by the body

a) 1uA b)1mA c)10mA d)1A

2-What is the lowest current that can cause fibrillation of the heart?

a) 30mA AC 60Hz b) 30mA DC c) 100mA AC 60Hz d) 100mA DC

3- Which of the following voltages is more dangerous?

a) 100V DC b) 100V 60Hz c) 100V 1kHz d) b and c

4-Which of the parts of the body offers the most resistance to electricity?

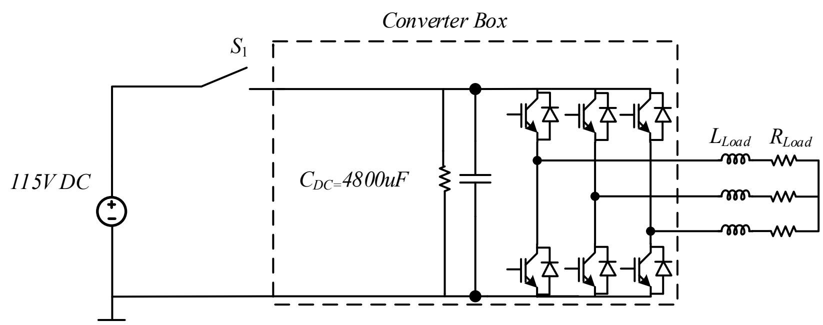
a)Fingers b)Toes c)Bones d)Thick and/or dry skin

5-The greater the body's resistance to electricity, the ____ amount of harm to the person.

a) Less b) Greater c) Resistance has no effect on electricity d) Equal

6-Consider the converter setup in the lab as shown in the figure below. Imagine you're doing an experiment and you decide to make a change in your circuit. Therefore you need to shut down the circuit. Is it safe to touch the circuit right after the panel breaker (S1 in the figure) is disconnected? Why?

A. Yes, Because the breaker disconnects the DC source which is the only source that can cause electrical shock
B. No, Because it takes time for the breaker to completely disconnect the dc sources from the circuit
C. Yes, Because after disconnecting the breaker the only source that can cause electrical shock is the capacitor which doesn't have enough energy for that
D. No, Because after disconnecting the breaker the capacitor might be still charged which has enough energy to cause electrical shock.



7- The effects of an electrical shock on the body depends on:
A. Current.
B. Path.
C. Duration.
D. All of the above.

8- Injuries from electricity can include which of the following?
A. Electric shock that may or may not result in electrocution.
B. Falls.
C. Burns.
D. All of the above.

9- If you see someone in contact with/exposed to a live source of electricity, your first response should be to:
A. Remove the victim from the hazard,
B. Interrupt the supply from the victim,
C. Remove yourself from the area and call for help
D. Apply Cardio-Pulmonary Resuscitation (CPR)

10- Indicate whether the following actions and practices would ***increase*** or ***reduce*** the risk of injury or fire when working with electrical equipment:

Increase / Reduce	Avoiding contact with energized electrical circuits.
Increase / Reduce	Connecting the power source before wiring your setup
Increase / Reduce	When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves.
Increase / Reduce	If it is safe to do so, work with only one hand, keeping the other hand at your side or in your pocket, away from all conductive material.
Increase / Reduce	Use electrical equipment in cold rooms or other areas where condensation is likely.
Increase / Reduce	If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
Increase / Reduce	If an individual comes in contact with a live electrical conductor, disconnect the power source from the circuit breaker.
Increase / Reduce	Know how to cut off the electrical supply to the laboratory in the event of an emergency.
Increase / Reduce	Know the location of the safety equipment in the laboratory, and know how to use them.
Increase / Reduce	Removing line cords by using one quick pull to remove the plug

	from the outlet.
Increase / Reduce	Be sure that all electrical potential has been discharged before any modifications on your setup containing high voltage power supplies or capacitors.
Increase / Reduce	Maintain free access to breakers, switches, multi-meters, and scopes.

11- What is an "AED" device, and when would you NOT use it?

12- Where are the locations of "Fire Alarms" and the "AED" device?

Acknowledgement:

This document is a collection of issues regarding nature and consequences of hazards and ricks associated with working with medium voltage electrical equipment, their consequences, and the safety procedures to avoid and / or control them. It also includes emergency procedures which deal with both electrical and fire accidents; all adopted for working safely at Energy Systems Group Laboratory facilities of University of Toronto.
We have used various publicly available documents from similar institutions and working environments, along with on-line resources, and also large contributions from our own experts to create this document.

Editor: Afshin Poraria

Part 4 – Sign Off Sheet

The following form should be signed and submitted to the manager of the "Energy Systems Group Laboratory" after reading and understanding the instructions in this document.

By signing this form, I acknowledge that I have read and understand the "Energy Systems Lab Safety Policy". I understand my responsibility to uphold safe conduct at all time according to and beyond instructions in this document.

Printed First and Last Name	
Student Number	
Position (Student / TA)	
Date	
Signature	