

SAFETY RULES AND SUGGESTIONS

Rev. 20141015

EMERGENCY AND INFORMATION TELEPHONE NUMBERS:

An ambulance should be called in the event of any accident requiring medical assistance.

Emergency, Ambulance and/or Fire: 911 (911 will work from Mo S&T telephone)

1. Safety glasses or prescription eyeglasses must be worn when soldering. Students should wash their hands with soap and water after they are done soldering, to remove any residual lead.
2. Students are responsible for purchasing their own safety glasses, and bringing them to each lab class where they will be needed.
3. Safety glasses are required when using power tools such as drills. Prescription eyeglasses do not offer sufficient protection.
4. 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.
5. Smoking, eating, drinking, or “horseplay” are strictly forbidden in the laboratory.
6. Haste and inattention cause many accidents. Work deliberately and carefully. Plan your activities prior to the laboratory, familiarize yourself with equipment prior to actual operation, and verify your work as you progress. Learn the location of power switches and ground fault interrupters.
7. Report potential hazards and suspected faulty equipment to the instructor immediately. 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.
8. 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.

9. Exercise caution when adjusting energized circuits. All powered circuits are dangerous.
 - Use only one hand as far as practical, keeping the other hand disengaged from circuitry. Do not permit any part of your body to complete a circuit.
 - Understand handling dangers. Keep watches, rings, and other metallic objects out of contact with live parts. Wet, sweaty, or bleeding hands increase shock hazard.
 - Note exposed wires and other potential shock hazards.
10. Close switches quickly and positively. Do not grope for switch handles with your head turned away!
11. Do not use damaged or misapplied parts. Wires that have poor insulation, setscrews that are loose, and insecure connections that may come apart are hazards. Safety devices, coverings, interlocks, etc. must be operational at all times.
12. Do not use tools or instruments for other than their original purpose.

FOLLOW PROCEDURES - MINIMIZE HAZARDS - AVOID UNSAFE BEHAVIOR

ELECTRICAL SHOCK HAZARDS

SUMMARY

Electric current damages the body in three different ways: (1) it harms or interferes with proper functioning of the nervous system and heart; (2) it subjects the body to intense heat; and (3) it causes the muscles to contract. Electrical shock can be lethal. The hazards must be understood and general safety rules must be followed.

- It's the current that kills. Voltage is not a reliable indication of danger because the body's resistance varies so widely it is impossible to predict how much current will result from a given voltage.
- The current range of 100 to 200 mA. is particularly dangerous because it is almost certain to result in lethal ventricular fibrillation. Victims of high-voltage shock usually respond better to artificial respiration than do victims of low-voltage shock, probably because the higher current clamps the heart and hence prevents fibrillation.
- Alternating Current (AC) is more dangerous than direct current (DC), and 60 Hertz current, that is used in building wiring, is more dangerous than high-frequency current.
- Skin resistance decreases when the skin is wet or when the skin area in contact with a voltage source increases. It also decreases rapidly with continued exposure to electric current.
- Prevention of electric shock requires having a healthy respect for all voltage sources and always following safety procedures when working on electrical equipment. Minimize exposure to live circuits and do not permit any part of your body to complete a circuit.
- If a person does suffer a severe shock, it is important to free the victim from the current as quickly as can be done safely. Do not touch the person until the electric power is turned off. You cannot help by becoming a second victim. The victim should be attended to immediately by a person trained in CPR (cardiopulmonary resuscitation). Also an ambulance should be called immediately.

ELECTRICAL HAZARDS

Figure 1 shows the physiological effect of various currents. Note that voltage is not a consideration. Although it takes a voltage to cause current, the amount of shock-current will vary, depending on the body resistance between the points of contact. It should be realized that the chart is based on average values and individual responses will differ. Note that a very small current can produce a lethal electric shock. *Any current over 10 milliamperes will result in serious shock.*

As shown in the chart, shock is more severe as the current rises. At values as low as 20 milliamperes, breathing becomes labored, finally ceasing completely even at values below 75 milliamperes. As the current approaches 100 milliamperes, ventricular fibrillation of the heart occurs--an uncoordinated twitching of the walls of the heart's ventricles. Above 200 milliamperes, the muscular contractions are so severe that the heart is forcibly clamped during the shock. This clamping protects the heart from going into ventricular fibrillation, and the victim's chances for survival are improved. However, there will certainly be other effects, depending upon the current level and duration of the shock.

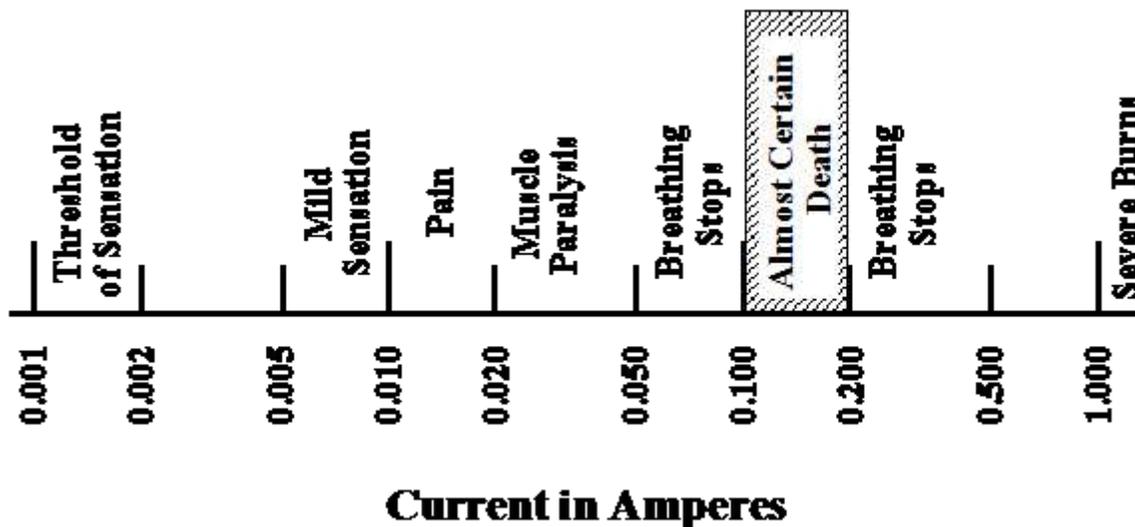


Figure 1 – Physiological Effect of Current

Alternating current (AC) is four to five times more dangerous than direct current (DC). For one thing, AC causes more severe muscular contractions. For another, AC can lower skin resistance and thereby increase the shock-current. The skin resistance goes down rapidly with continued contact because sweating is stimulated and the skin oils and even the skin itself are burned away. Consequently, it is extremely important to free the victim from contact with the current as quickly as possible before the current increases to the fibrillation-inducing level. Also, the frequency of the AC influences the effects on the human body. Unfortunately, the standard electrical power frequency of 60 Hertz is in the most harmful range. At this frequency, as little as 25 volts can kill. On the other hand, people have withstood 40,000 volts at a frequency of a million Hertz or so without fatal effects.

ELECTRICAL SAFETY

The measure of a shock's severity lies in the amount of current (amperes) passed through the body, and not the voltage. The electric current does the damage. Current equals voltage divided by resistance (e.g. Ohm's Law $I = V/R$), but the resistance of the human body varies so widely it is impossible to state that one voltage is "dangerous" and another is "safe". Any electrical device at common voltages of 120 V and 220 V can, under certain conditions, transmit a fatal current. Safe procedures minimize the hazard due to electrical shock.

The practices of using only one hand (keeping one hand in your pocket) while working on high-voltage circuits and of standing or sitting on an insulating material are good safety habits. The path through the body has much to do with the shock danger. A current passing from finger to elbow through the arm may produce only a painful shock, but the same current passing from hand to hand or from hand to foot may well be fatal.

The condition of the skin at the points of contact are critical. The actual resistance of the body may vary from 1000 ohms for wet skin to over 500,000 ohms for dry skin. However, once the skin is broken through (for example by the burning away of skin) the body presents no more than 500 ohms resistance to the current.

In addition, common protection technologies include isolation and grounding. Note that circuit breakers and fuses do not provide reliable protection upon failure of isolation and grounding. Circuit breakers and fuses are sized to protect equipment and conductors from excessive line currents. *They will not protect you.*

In some situations it is possible to isolate energized equipment so that the operator does not come in contact with it. Sometimes equipment is "double insulated," meaning that the operator is separated from current-carrying parts by a double system of insulation. Many hand-held power tools are constructed in this manner. Such devices may still present a shock hazard if they are subjected to abuse which damages the insulating materials.

Grounding is probably the most common method of protecting against electrical shock. All exposed non-current-carrying metal parts of electrical equipment should be grounded. This includes the cases for meters, power supplies, oscilloscopes, etc. used in the laboratory. The case is connected by a grounding conductor to the third prong of a grounding plug which (when inserted into a grounding receptacle) is connected to the building's grounding system. Proper equipment grounding will eliminate high voltages between the equipment and other grounded conducting surfaces. Also, if an energized conductor does touch the grounded case (due to insulation failure, for example) the resulting large current through a low impedance ground path will open the branch circuit fuse or circuit breaker. Without the grounding conductor, the case could be raised to line voltage and the current path to ground might be through the next person to touch it, resulting in a lethal shock.

A Ground Fault Interrupter, abbreviated GFI, is a device designed specifically to protect against lethal currents from *line-to-ground* shocks. The device is generally installed at the electrical receptacle. Various trip settings are available in the range of 5-20 mA. It may be easily reset. The most common type utilizes a differential transformer to detect small differences between line and neutral currents. Most of the receptacles in our laboratories do not have a GFI.