BE 3600 BIOMEDICAL INSTRUMENTATION (LAB) -

Experiment 1:

Safety and Lab Procedures

The National Academy of Engineering chose the electrification of the world as the greatest engineering achievement of the 20^{th} century. Availability of this inexpensive power allowed us to create and maintain our technologically advanced society. Effects of electricity are clearly visible in the medical care facilities as the walls of the examination rooms, surgical suites and recovery rooms are covered with electronic devices to monitor and treat the patients. Uses of electrical devices are so common that some have been integrated into our bodies, such as the cardiac pacemakers and defibrillators, neurological stimulators and electrically powered drug pumps. Although we don't think about the electrical power until there is a blackout, and consider it as a safe tool, hundreds of people loose their lives each year due to accidental electrocution.

The human body is an electrical conductor, that can carry the electrical currents applied from external sources, such as the electronic devices or the power mains. The effect of the current flowing through the body is a function of the intensity of the current and the timing of when it occurs with respect to physiologic events. Some examples of these effects for a continuous 60 Hz ac current are listed in Table 1.1 below.

20 µ Amps	Direct application to myocardium would cause fibrillation of the heart that would lead to death of the patient
Less than 1 mA	Imperceptible when externally applied through the dry skin
1-10 mA	Mild to painful sensation
>10 mA	If contacted by hand or arm, may stimulate skeletal muscle leading to a titanic contraction and make it impossible to release the grip
>30 mA	Stops breathing
75-250 mA	Causes ventricular fibrillation
>4 Amps	Paralyzes the heart
>5 Amps	Burns the tissue

Table 1.1. Effects of 60 Hz AC current on Adult Human Body

One must be very careful not to mix up the concepts of electrical voltage and current. A small 9V battery would send a tiny amount of current through the dry skin when an individual places his or her fingers across the terminals of the battery. This current is very low since the resistance of the dry skin is very high, and the current would be unnoticeable to the individual. However, if the same battery is placed over the wet tongue, a much larger current flows inducing the more familiar sensation of pain. The same battery connected to a pacemaker lead going to the heart would easily kill the patient due to the lower resistance to current provided by the direct connection of the pacemaker lead to the heart and the extreme sensitivity of the cardiac tissue to electrical currents. Notice that the voltage of the battery remains at 9V for all three conditions, but the current through the tissue and its effects are different for each case.

Throughout the world, electrical power is distributed as 50 or 60 Hz alternating current with a voltage of 100 to 240 volts. Although United States uses 60 Hz and 110 Volts, most of the countries in the world provide 50 Hz and 220 Volts for power distribution, including to the medical care facilities. Engineers designing equipment do accommodate the various power settings, and design devices to be switchable either automatically or manually. For example, most laptop computers utilize power-supplies that automatically detect and adopt to the available power. Design process is further complicated by the use of different power receptacles used in each country, a reminiscence of the days from the protectionist economical mindsets of governments in mid 20th century.

Regardless of the setting, the power mains usually consist of three leads: Neutral, Hot, and Ground. Hot and neutral are the two actual connections to the power line. Ground is the connection to the earth and is provided to prevent injury from defective electrical devices. Figure 1.1 below shows the receptacle used in the United States for power connections.

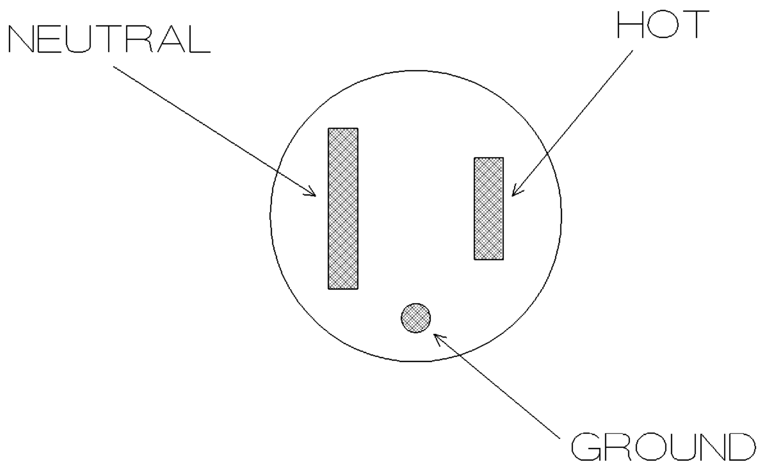

Figure 1.1. Electrical outlets used in the U.S.

In general, the case of the electrical device is grounded using the ground connector on the power outlet. In theory, no electrical connections should exist from the CASE to the HOT or the NEURAL lines of the power system. However, if by accident a connection should occur, this leakage current would be shunted by the grounded case. An example is shown in Figure 1.2 below.

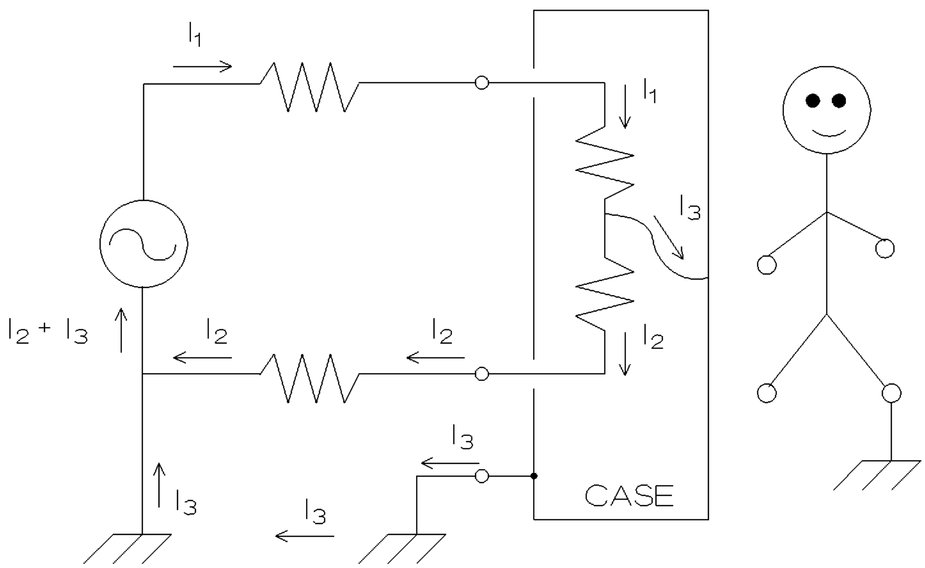

Figure 1.2. Simplified circuit diagram of an electrical device with grounded case.

In the figure above, conductor carrying the current I_1 is the HOT, conductor carrying the current I_2 is the NEUTRAL and the conductor carrying the current I_3 is the GROUND connector of the electrical outlet. Normally the leakage current I_3 is zero, so I_1 is equal to I_2. If the device malfunctions and develops a leakage current from the main power supply as shown with a curved line in the device, people getting in contact with the device case would be in danger of electrocution. This is prevented by the grounded case, which shunts the current directly to ground.

Figure 1.3 A ground fault interrupter outlet.

A more advanced version of this kind of protection is provided by ground fault interruption (GFI) circuit breakers, which are found in bathrooms of our houses. This kind of outlet monitors the difference between I_1 and I_2 and if the difference exceeds a certain threshold, it concludes that a leakage has developed and turns the power off to the device.

Further protection can be obtained if the device and the patient can be completely isolated from the power lines. A device using isolation transformers or batteries would be ideal in this case. Isolation transformers usually provide protection against not only the normal leakage currents but also against the accidental surges due to problems in the main grid such as lightning.

In this laboratory, we will use battery operated devices for added safety. You must make sure that all devices connected to a subject are powered without line power. Disconnect them all from the power lines by unplugging them and allowing them to run from internal batteries. Your Teaching Assistants will turn the main power off in the lab to make sure that you will be using batteries. However, you must not count on your TA to turn the power off to isolate you from the mains. Someone might turn the power on accidentally. Disconnect all equipment such as ECG Amplifiers, Stethoscope Amplifiers, Oscilloscopes, Voltmeters etc. from the main power. At the end of your experiments, you will store the screen containing your measurements on your hand held oscilloscope and then transfer your data to a floppy disk using a PC in the lab. Don't expect your TA to provide you with floppy disks. Bring multiple 3.5 inch floppy diskettes formatted for IBM compatibles to take your data home for analysis to prepare your lab report.

Your TA might have additional requirements. Find out his or her office hours, deadlines and preferences for reports, e.g. electronic or hard copy reports, rules for make-ups etc.