19.6: Electrical safety

The models that we have developed to describe current can inform us on ways to avoid being injured by electricity in our common lives. The two main hazards associated with electricity are fire and electrocution. Typically, an electrical fire is the result of a large current going through a resistor, as the power dissipated in a resistor is proportional the square of the current through that resistor. If you connect an appliance that draws a large current to your outlets, the wires in your house (i.e. resistors) could heat up enough to cause a fire (e.g. by heating up insulation that is close by). This danger is primarily mitigated by using “fuses” or “circuit breakers” that will interrupt the circuit if the current is too large. A fuse is a simple device with a thin wire (high resistance) that will melt and break if too much current goes through it (which is designed to happen long before the wires in your house start to overheat). A circuit breaker is a resettable switch that opens under a large current. Modern houses do not use fuses any more, since they have to be replaced every time they are “blown”.

Electrocution is a form of injury that is the result of a current crossing the body; we can think of the body as a resistor connected between the terminals of a battery. Injuries can be caused simply by burns (tissue destroyed), or by muscles contracting involuntarily due to the current. For example, one’s muscles may contract in such a way that the person cannot let go of the source of current. If a current of more than about 80mA passes through the mid section of a person, enough current could go through the heart so that it starts to beat very irregularly (“ventricular fibrillation”) which can lead to death since blood stops flowing normally. A very large current can cause the heart to simply stop beating, which could sometimes be less dangerous than ventricular fibrillation (if for a short period of time, and of course, the burns will be more severe from a larger current). A “defibrillator” is designed to provide such a high current that the heart stops briefly, with the hope that when it starts back, the beats will be regular. This can be used in cases of ventricular fibrillation (caused by electrocution or other). One often hears that “it’s current that kills”, which is a statement that being electrocuted by a certain voltage is not a good measure of the resulting injury, since the current will depend on the resistance of the person’s body.

The amount of current that will go through a person will depend on the resistance of the person’s body. Internal tissues and organs are typically quite conductive and have low resistance. The outer layer of the skin, on the other hand, has a high resistance when dry and helps to limit the current that can go through the body. The resistance of dry skin is usually considerably above $1\times 10^{4}\Omega$, while it can be much less than $1\times 10^{3}\Omega$ when wet. With wet skin, a potential difference of 120V (as in a North American outlet) can easily lead to a current above 100mA, which could easily be fatal. Note that being barefoot and in contact with the ground is usually a low resistance connection, since there is often a thin layer of sweat on your feet.

In North America, electrical outlets have a minimum of two sockets: a “live” socket (with an oscillating voltage, usually a black wire[1]), and a “neutral” socket which is connected to the ground and relative to which the oscillating voltage has an amplitude of 120V (usually a white wire). One can obviously be electrocuted by simultaneously touching the wires in both sockets, and usually simply by touching the wire in the live socket, since one’s feet are usually connected to ground. Electrocution by directly touching the socket is fairly uncommon, since most people know not to do that (right?!). Usually, one is electrocuted by an appliance with faulty wiring; perhaps the insulation on the live wire is worn out and you touch the wire by mistake, or the wiring in the appliance is faulty, causing the casing of the appliance to be live. In order to mitigate the risk of electrocution from an appliance with faulty wiring, most outlets will have a third socket, the “dedicated ground”. The dedicated ground wire is connected to the ground inside the socket, and to the casing of the appliance, as illustrated in Figure $19.6.1$. Thus, if the live wire were to be in contact with the casing of the appliance, the dedicated ground provides a low resistance path for current to take that is in parallel with your body (so that most current will go through the low resistance path).

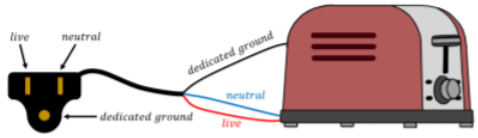

Figure 19.6.1: When an appliance has three prongs on its electrical cable, the middle prong grounds the case to the dedicated ground as a safety measure. Note that the live wire is not necessarily the right-hand side socket on an outlet!

Footnotes

1. Never trust the coloring of wires, always test them!