University of Technology, Jamaica
CEEC

Electrical installation

Noel Sinclair M.Sc., P.G.Dip.Ed,CEM

Email: nosinclair@utech.edu.jm

Ext: 2240

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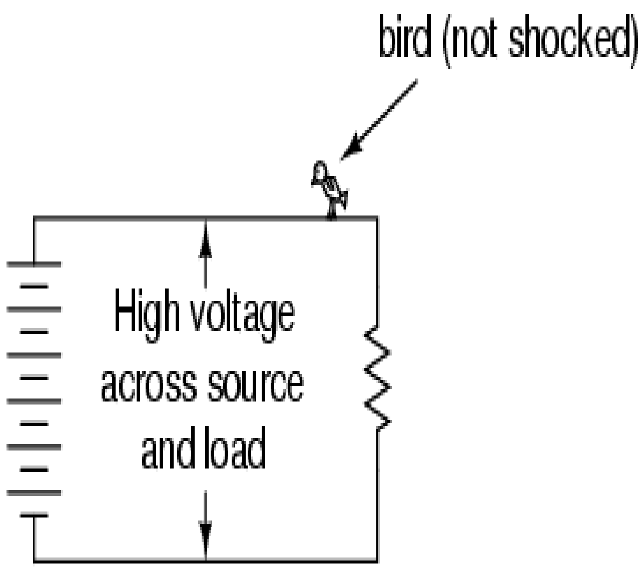
Shock Current Path (1)

- Without two contact points on the body for current to enter and exit, respectively, there is no hazard of shock. This is why birds can safely rest on high-voltage power lines without getting shocked: they make contact with the circuit at only one point.

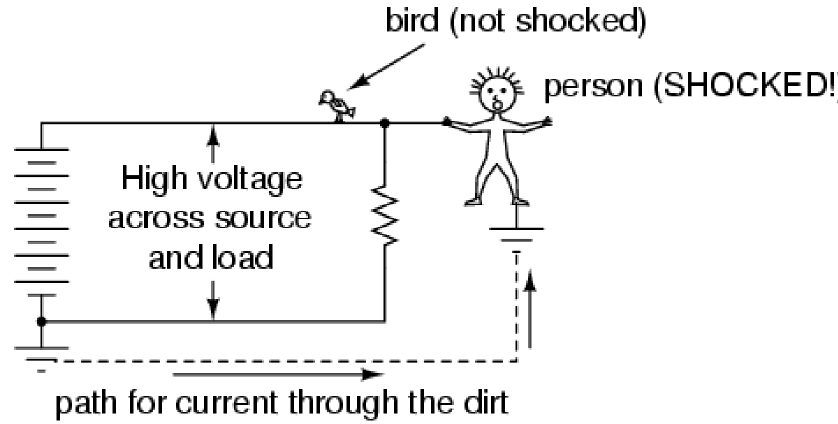
Shock Current Path (2)



- In order for electrons to flow through a conductor, there must be a voltage present to motivate them. Voltage, as you should recall, is *always relative between two points*. There is no such thing as voltage "on" or "at" a single point in the circuit, and so the bird contacting a single point in the above circuit has no voltage applied across its body to establish a current through it. Yes, even though they rest on *two* feet, both feet are touching the same wire, making them *electrically common*. Electrically speaking, both of the bird's feet touch the same point, hence there is no voltage between them to motivate current through the bird's body.

Single Point

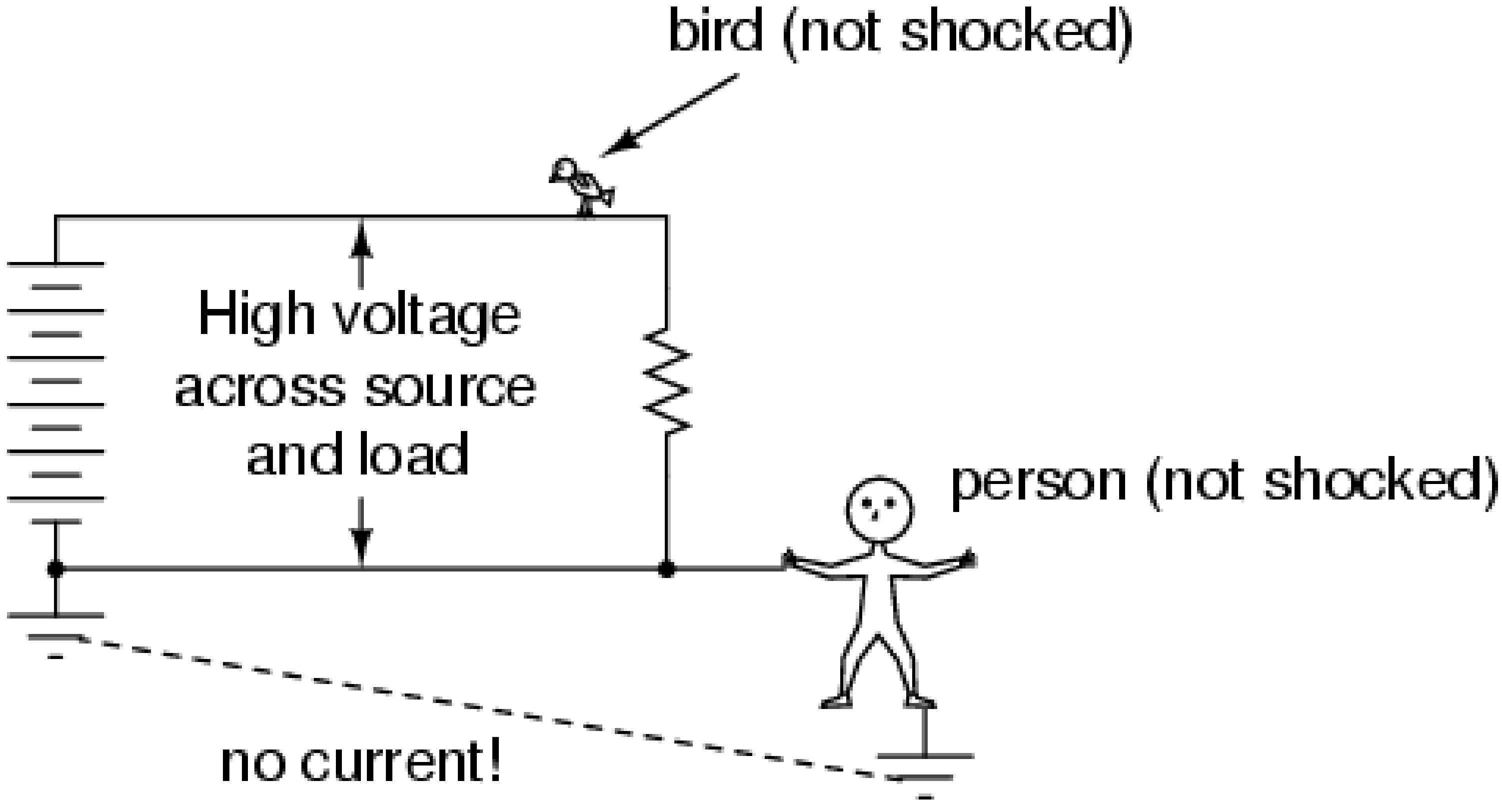
- This might lend one to believe that it's impossible to be shocked by electricity by only touching a single wire. Like the birds, if we're sure to touch only one wire at a time, we'll be safe, right? Unfortunately, this is not correct. Unlike birds, people are usually standing on the ground when they contact a "live" wire. Many times, one side of a power system will be intentionally connected to earth ground, and so the person touching a single wire is actually making contact between two points in the circuit (the wire and earth ground):



Grounding (Earthing)

- The ground symbol is that set of three horizontal bars of decreasing width located at the lower-left of the circuit shown, and also at the foot of the person being shocked. In real life the power system ground consists of some kind of metallic conductor buried deep in the ground for making maximum contact with the earth. That conductor is electrically connected to an appropriate connection point on the circuit with thick wire. The victim's ground connection is through their feet, which are touching the earth.

Common Ground

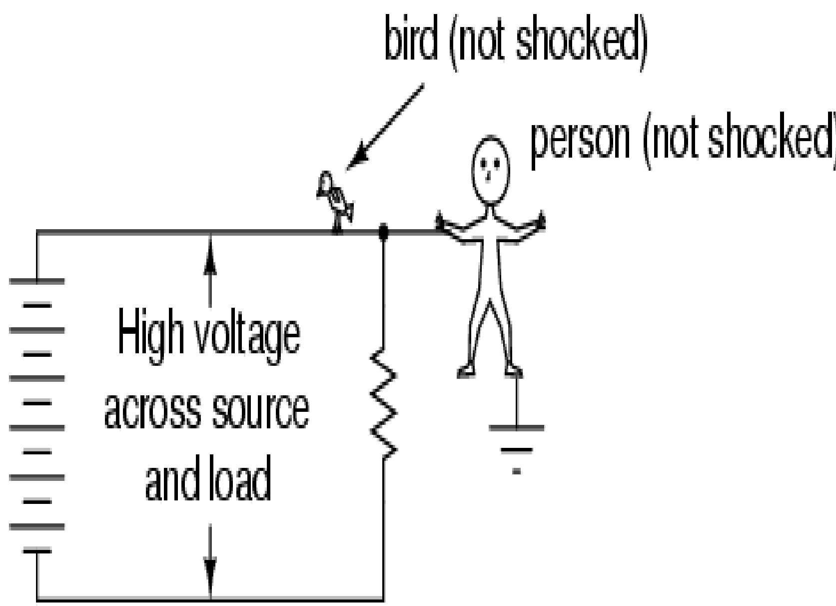


Common Ground

- Because the bottom side of the circuit is firmly connected to ground through the grounding point on the lower-left of the circuit, the lower conductor of the circuit is made *electrically common* with earth ground. Since there can be no voltage between electrically common points, there will be no voltage applied across the person contacting the lower wire, and they will not receive a shock. For the same reason, the wire connecting the circuit to the grounding rod/plates is usually left bare (no insulation), so that any metal object it brushes up against will similarly be electrically common with the earth.

One Safe Point

- Circuit grounding ensures that at least one point in the circuit will be safe to touch. But what about leaving a circuit completely ungrounded? Wouldn't that make any person touching just a single wire as safe as the bird sitting on just one? Ideally, yes. Practically, no. Observe what happens with no ground at all:

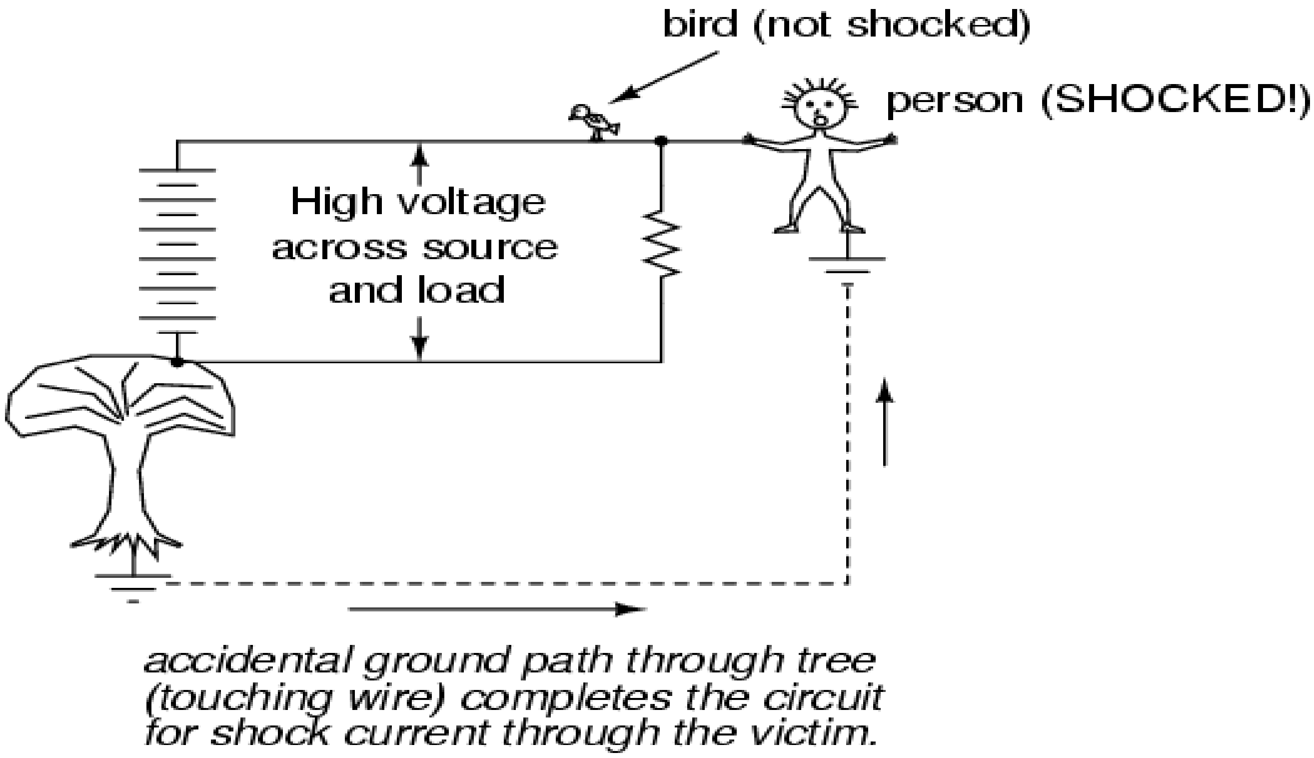


One Safe Point

- Despite the fact that the person's feet are still contacting ground, any single point in the circuit should be safe to touch. Since there is no complete path (circuit) formed through the person's body from the bottom side of the voltage source to the top, there is no way for a current to be established through the person.

Accidental Ground

However, this could all change with an accidental ground, such as a tree branch touching a power line and providing connection to earth ground:

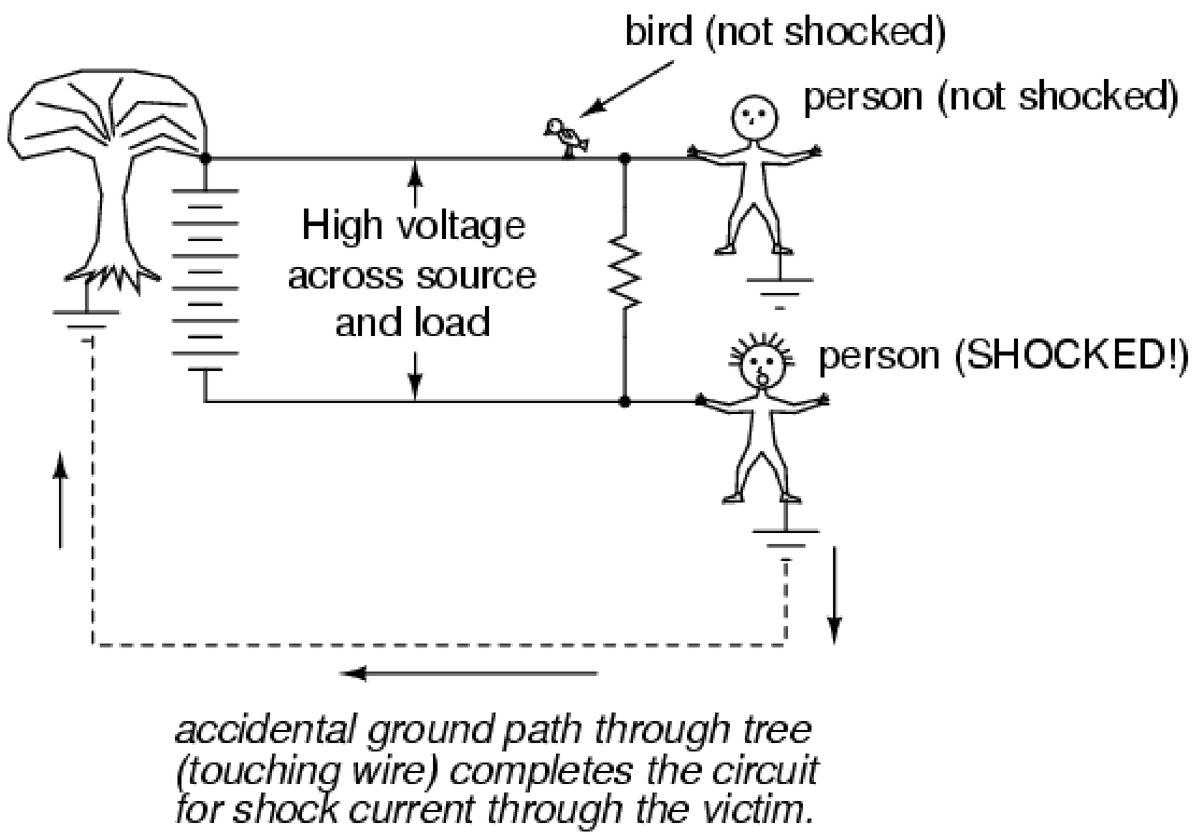


Ground Fault

- Such an accidental connection between a power system conductor and the earth (ground) is called a *ground fault*. Ground faults may be caused by many things, including dirt buildup on power line insulators (creating a dirty-water path for current from the conductor to the pole, and to the ground, when it rains), ground water infiltration in buried power line conductors, and birds landing on power lines, bridging the line to the pole with their wings. Given the many causes of ground faults, they tend to be unpredicatable. In the case of trees, no one can guarantee *which wire* their branches might touch.

Electrically Common: Earth - Ground

If a tree were to brush up against the top wire in the circuit, it would make the top wire safe to touch and the bottom one dangerous -- just the opposite of the previous scenario where the tree contacts the bottom wire:

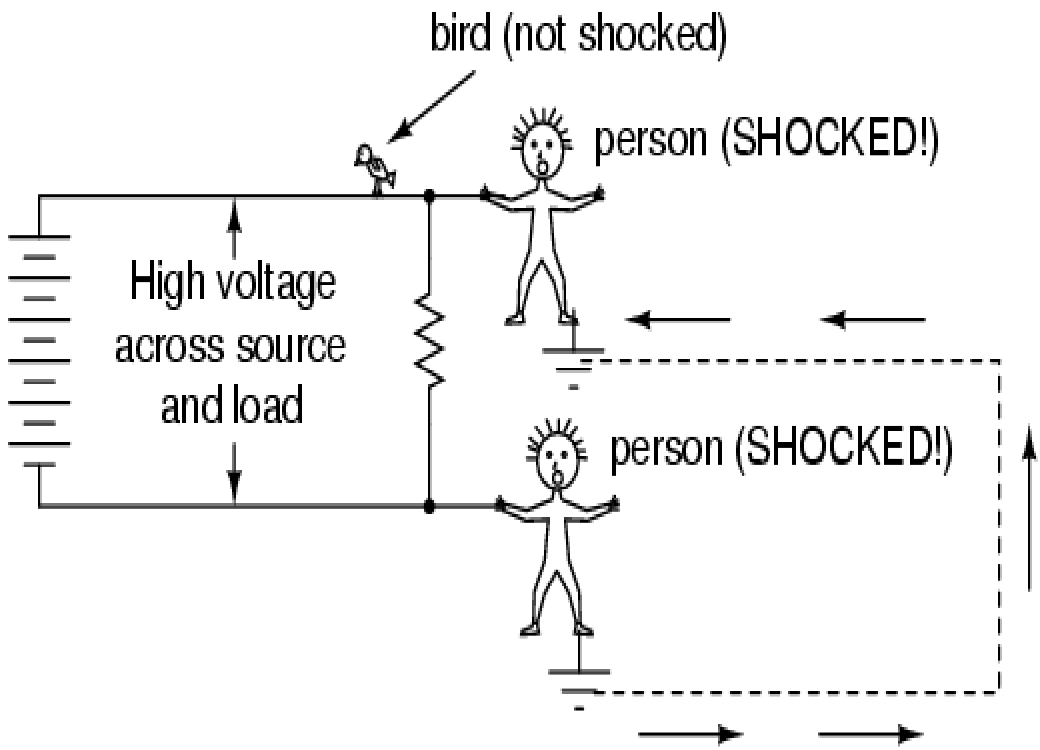


Ground Faults (1)

- With a tree branch contacting the top wire, that wire becomes the grounded conductor in the circuit, electrically common with earth ground. Therefore, there is no voltage between that wire and ground, but full (high) voltage between the bottom wire and ground. As mentioned previously, tree branches are only one potential source of **ground faults** in a power system.

Ground Faults (2)

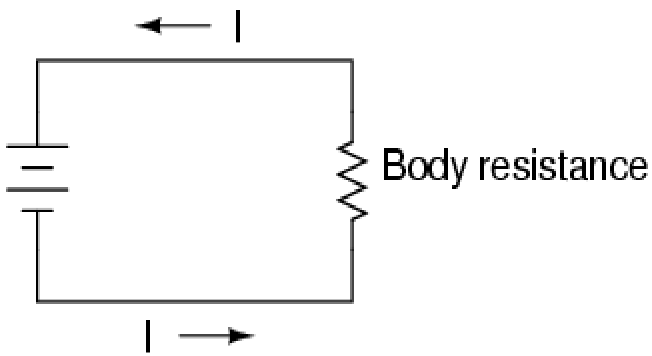
Consider an ungrounded power system with no trees in contact, but this time with *two* people touching single wires:



Ground Faults (3)

- With each person standing on the ground, contacting different points in the circuit, a path for shock current is made through one person, through the earth, and through the other person. Even though each person thinks they're safe in only touching a single point in the circuit, their combined actions create a deadly scenario. In effect, one person acts as the ground fault which makes it unsafe for the other person. This is exactly why ungrounded power systems are dangerous: the voltage between any point in the circuit and ground (earth) is unpredictable, because a ground fault could appear at any point in the circuit at any time. The only character guaranteed to be safe in these scenarios is the bird, who has no connection to earth ground at all! By firmly connecting a designated point in the circuit to earth ground ("grounding" the circuit), at least safety can be assured at that one point. This is more assurance of safety than having no ground connection at all.

Body Resistance



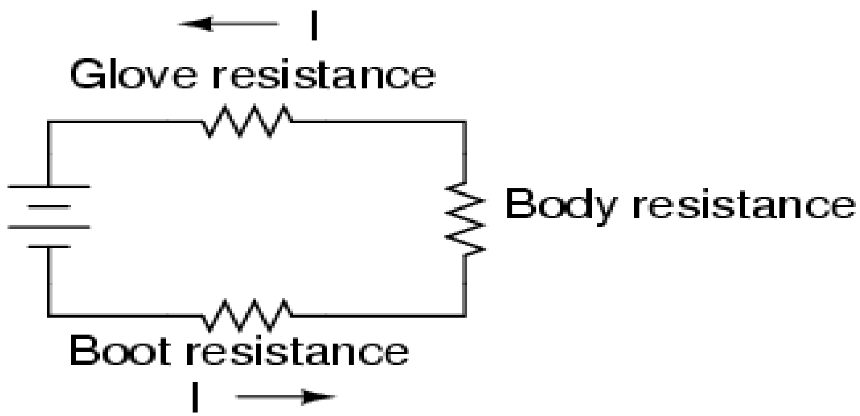
Person in direct contact with voltage source: current limited only by body resistance.

$$I = \frac{E}{R_{body}}$$

- The best protection against shock from a live circuit is resistance, and resistance can be added to the body through the use of insulated tools, gloves, boots, and other gear. Current in a circuit is a function of available voltage divided by the *total* resistance in the path of the flow. As we will investigate in greater detail later in this book, resistances have an additive effect when they're stacked up so that there's only one path for electrons to flow:

Body Resistance

Now we'll see an equivalent circuit for a person wearing insulated gloves and boots:



Person wearing insulating gloves and boots:
current now limited by *total* circuit resistance.

$$I = \frac{E}{R_{glove} + R_{body} + R_{boot}}$$

Body Resistance

- Because electric current must pass through the boot *and* the body *and* the glove to complete its circuit back to the battery, the combined total (*sum*) of these resistances opposes the flow of electrons to a greater degree than any of the resistances considered individually.

Body Resistance

- Safety is one of the reasons electrical wires are usually covered with plastic or rubber insulation: to vastly increase the amount of resistance between the conductor and whoever or whatever might contact it. Unfortunately, it would be prohibitively expensive to enclose power line conductors in sufficient insulation to provide safety in case of accidental contact, so safety is maintained by keeping those lines far enough out of reach so that no one can accidently touch them.

Summary

- Electric shock can only occur when contact is made between two points of a circuit; when voltage is applied across a victim's body.
- Power circuits usually have a designated point that is "grounded:" firmly connected to metal rods or plates buried in the dirt to ensure that one side of the circuit is always at ground potential (zero voltage between that point and earth ground).
- A *ground fault* is an accidental connection between a circuit conductor and the earth (ground).
- Special, insulated shoes and mats are made to protect persons from shock via ground conduction, but even these pieces of gear must be in clean, dry condition to be effective. Normal footwear is not good enough to provide protection from shock by insulating its wearer from the earth.
- Though dirt is a poor conductor, it can conduct enough current to injure or kill a human being.

Physiological Effects of Current

	Readings	Effects
Safe Current Values	1 mA or less	Causes no sensation - not felt.
	1 mA to 8 mA	Sensation of shock, not painful; Individual can let go at will since muscular control is not lost.

	Readings	Effects
Unsafe current values	8 mA to 15 mA	Painful shock; individual can let go at will since muscular control is not lost.
	15 mA to 20 mA	Painful shock; control of adjacent muscles lost; victim can not let go.
	50 mA to 100 mA	Ventricular fibrillation - a heart condition that can result in death - is possible.
	100 mA to 200 mA	Ventricular fibrillation occurs
	200 mA and over	Servere burns, severe muscular contractions - so severe that chest muscles clamp the heart and stop it for the duration of the shock. (This prevents ventricular fibrillation).

Example

- A person standing on the general mass of earth touches a phase conductor on a 240 V supply. If the resistance to earth through his body is 48 000Ω calculate the current flow in his body. State the physiological effects of this current.

Solution

- From Ohm's Law:

$$I = \frac{V}{R} = \frac{240}{48000} = \frac{0.1}{20} A = 5mA$$

Thank you
for Listening