

## 8. Worksheet: Human body and Ohm's Law

In simple terms the human body can be considered as a circuit through which an applied potential difference will drive a current. The body acts as a resistor with resistance  $R$  depending on the path the current flows in the body. As we know from Ohm's Law  $I = \frac{U}{R}$ , the current flowing will depend on the voltage applied as well as

on the resistance of the current path. For example, if you touch a high voltage wire in a cable, current passing from the wire through you to the ground can cause an electric shock. Your body is controlled by electrical nerve impulses, so electric currents can disrupt normal bodily functions. It is the current, not the voltage that determines the severity of the electric shock. The current travelling through a body can damage your organs, with the heart, brain and spinal cord being particularly susceptible.

### Resistance of the human body

The human body composed largely of water has very low resistance. That means that your blood and fluids with high amount of conductive chemicals are good conductors with a resistance of about  $200 \Omega$ . However, current must first pass through the skin that has very high resistance, the value depending on its nature, on the possible presence of water, and on whether it has become burned. Thus, most of the resistance to the passage of current through the human body is at the points of entry and exit through the skin. A person with naturally hard and dry skin can have a resistance of  $500\,000 \Omega$  while soft and sweaty palms may have resistance 10 to 50 times lower. The skin resistance becomes very low if it has been burned because of the presence of conducting particles of carbon or if it has been wounded because of the presence of blood or much thinner skin. A person standing in saltwater has a skin resistance of only  $500 \Omega$ .

When current travels through your body it must pass basically through three series resistances: your skin (your fingers), internal part of your body, and your skin again (your toes). Adding up the resistance of your moist fingers (e.g.  $20\,000 \Omega$ ), your body fluids (e.g.  $200 \Omega$ ) and your toes (e.g.  $30\,000 \Omega$ ) under the voltage of  $230V$  you get a current of approx.  $0,005A$  that passes through your body.

### How much current is harmful?

Individual body chemistry has a significant impact on how electric current affects on individual. Also the alternating current is more dangerous than the direct one. There are few reliable figures for shock current effects because they differ from person to person and for a particular person with time and also depend on the current path. For example, the shock current of  $500mA$  may have no lasting ill effects if its duration is less than  $20ms$ , but  $50mA$  for  $10s$  could well prove to be fatal. The most dangerous results are ventricular fibrillation (where heart beat sequence is disrupted) and compression of the chest, resulting in a failure to breathe.

Rough limits say:



- Current **greater than 1mA** causes discomfort.
- **Above 16mA** you loose control of your muscles and they undergo contractions.
- **Between 25mA and 100mA**, you have difficulty breathing and eventually respiration stops.
- **Between 100mA and 200mA**, your heart stops pumping and undergoes contractions called ventricular fibrillation.
- **Above 200mA** irreversible heart damage occurs.

### How to increase safety?

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. Wearing insulating shoes increases the total resistance. Rubber shoes have a resistance of around 20 MΩ, whereas dry leather soles provide a resistance of 100 - 500 kΩ. Wet leather soles only provide 5 - 20 kΩ.

In figure is a simplified representation of the shock path through the body, with an equivalent circuit which indicates the components of the resistance concerned.

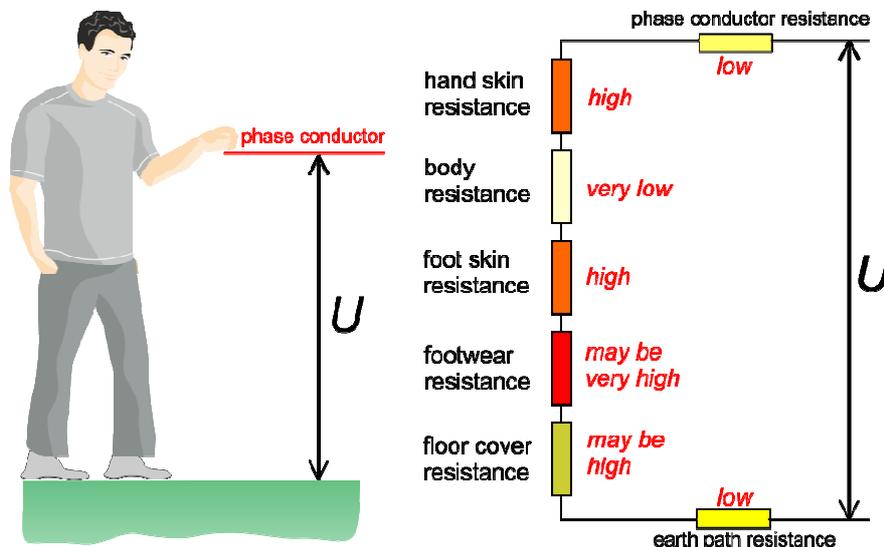


Fig. Path of the electric shock current (picture from <http://www.tlc-direct.co.uk/Book/3.4.2.htm>)

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 accidentally touch them.

### Deliberate uses of electric current in human body

#### Medical uses

Electric shock is also used as a medical therapy under the controlled conditions.

#### Bioelectrical impedance analysis



This simple device actually determines the electrical impedance, or opposition to the flow of an electric current through body tissues which can then be used to calculate an estimate of total body water and hence the body fat.

**Lie detector**

It measures skin resistance along with other physiological factors

Resources:

<http://c21.phas.ubc.ca/article/electric-shock>

<http://www.tlc-direct.co.uk/Book/3.4.2.htm>

[http://en.wikipedia.org/wiki/Electric\\_shock#Body\\_resistance](http://en.wikipedia.org/wiki/Electric_shock#Body_resistance)

[http://www.allaboutcircuits.com/vol\\_1/chpt\\_3/4.html](http://www.allaboutcircuits.com/vol_1/chpt_3/4.html)

