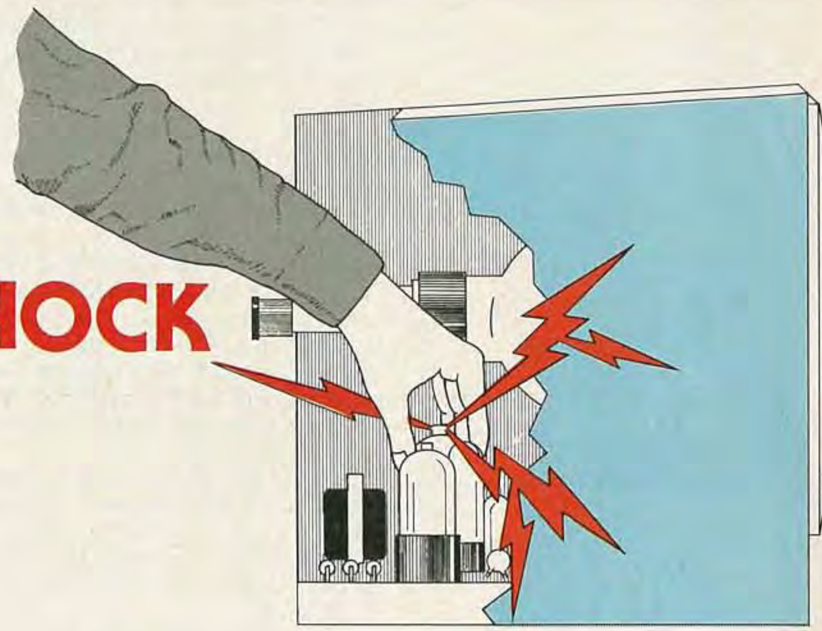

All About ELECTRIC SHOCK

All about electrical shock, and how it can affect your body.

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MOST OF US ARE FAMILIAR WITH THE effects of a mild electric shock—the sharp sting, the tingling sensation. The effects of a severe electric shock, however, can be much more devastating, even fatal. In this article, we are going to take a look at electric shock, and how it does its damage.

All about shock

Put quite simply, electric shock is the passage of a current through the body. The human body, as shown in Fig. 1, can be modeled as a network of resistances. Simply touching a voltage source is not sufficient to cause a shock (see Fig. 2-*a*). That's because, no circuit is completed. For current to flow, another part of the resistance network that is the body must be in contact with a ground or a different voltage level (see Fig. 2-*b*).

To understand more about the effects of shock, it is sometimes more useful to construct more detailed models of the body. Consider the model of an arm shown in Fig. 3. An electric shock that is applied between the hand (R_{SKIN-1}) and the elbow (R_{SKIN-2}) must pass through three separate resistances. That's because, in addition to the resistance presented by the forearm, R_{FA}, the skin surface at the hand and the elbow also resist current flow. And even more complex electrical models of the body are often made. In those models, the body is broken down into more separate parts. The parallel resistances of bone, blood vessels, nerves, and other tissues are modeled by additional resistors. The different ways that high-frequency currents are passed through various tissues can be modeled by using capacitors and inductors. For our purposes, however, the simple models we've shown you thus far are sufficient

The resistance to current flow at the skin surface depends on a number of factors. The area of contact is important. A flat piece of metal held against the skin will affect the resistance; pushing harder lowers the resistance. You can prove that to yourself by holding onto the leads from an ohmmeter. Holding them loosely will yield a reading of about 50,000 ohms; holding them more tightly will yield a reading of 10,000 ohms.

The surface of the skin is dry compared to lower layers, which causes it to offer a higher resistance. In order to reduce skin resistance, the top dry layer can be partially rubbed off with little discomfort.

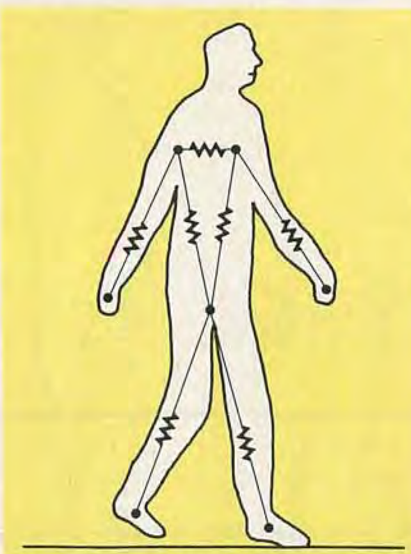

FIG. 1—A PERSON CAN be modeled as a network of resistances.

The skin surface can also be made more conductive by moistening it with water. Electrolyte solutions (such as sweat) are more effective than water in lowering skin resistance.

Those facts are taken into account when designing and using cardiac monitors and defibrillators. Some pre-packaged electrodes have an abrasive area that can be rubbed on the skin before the electrode is applied. The electrode has a relatively large (one square centimeter) surface area, which is covered by an electrolyte-containing electrode jelly.

Defibrillator paddles (a defibrillator is shown in Fig. 4) are used to deliver strong shocks that change the heart rhythm (For more about defibrillators and what they do, see the August 1984 issue of **Radio-Electronics**). The paddle surface area is roughly 50 square centimeters. Medical personnel are taught to apply about 20 pounds of force on each paddle when defibrillating (trying to apply more pressure than that causes some people to lose their balance).

Electrolyte-containing electrode jelly or saline-soaked pads are used to a make uniform electrical connection between each paddle and the skin. Saline pads have the advantage of not leaving a slippery surface that makes chest compressions (CPR) difficult. The jelly may also coat the chest between the electrodes, giving an unwanted current path. Alcohol-soaked pads are not used because they might ignite. If no conductive medium is placed between the paddles and the chest wall, a spark and burns may occur. Even so, chest-wall burns sometimes occur even when proper defibrillation techniques and equipment are used.

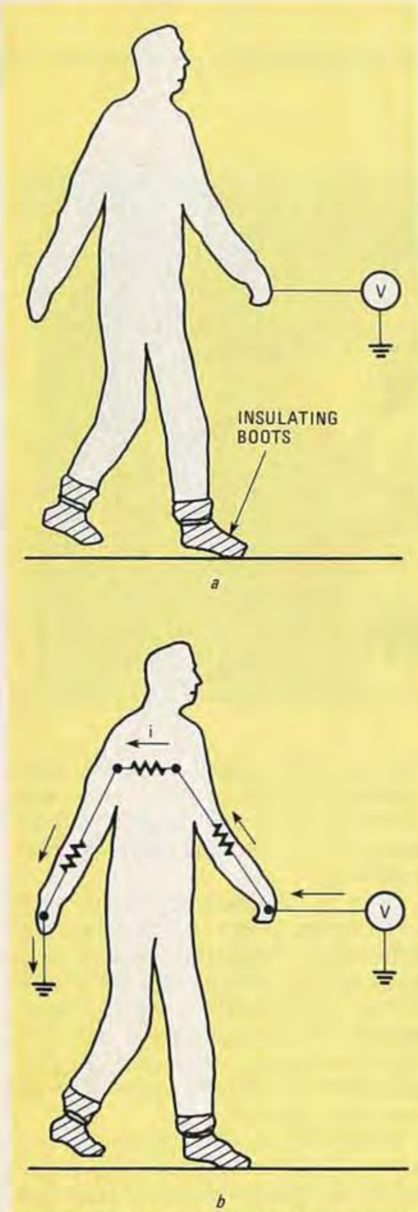

FIG. 2—MERELY TOUCHING a voltage source is not sufficient to cause shock. But when a person comes in contact with two voltage sources of different levels (such as 120 volts and ground), a circuit is completed and current flows.

The effects of electrical shock

As you might expect with current flowing through a resistance, electrical shock causes the heating of tissues. Electrical shock heats body tissues in several ways. A high voltage can give flash burns due to arcing of current through the air to the body. The arcing may even cause your clothing to catch on fire. In either case you end up with a burn.

More commonly, heat is caused by the flow of current through the resistance of bodily tissues. Burns of tissues by electrical current itself often give painless round or oval gray areas with surrounding redness.

The heat delivered to each area of tissue depends on the current flowing in that area and the resistance at that point. In some applications, such as defibrillation, a certain amount of current must be delivered. A large paddle area spreads the current over a surface area sufficiently large that skin burns are usually avoided (though, as noted above, not always).

With uncontrolled shock, burns can be significant. Temperatures up to 3000 degrees Centigrade may be generated. Much of the tissue damage with electrical burns is often under the skin. As such, many major electrical burns look deceptively minor at first. Deep injury to muscle and blood vessels is much more common than with other types of burns (such as those due to hot water and fires).

In addition to burns, electrical shock can have many other effects. Let's look at some of them next.

Contact with alternating (but not direct) current can cause a sustained contraction of muscles. That can prevent the victim from releasing the source of voltage, causing the damage to the body to be much more severe.

Electrical shock can cause death within minutes by stopping breathing or the beating of the heart. Breathing can be stopped by current passing through the respiratory centers of the brain. Electrical current passing through the heart itself can disrupt the heart's normal beating pattern. With severe shocks, such as those caused by lightning, the heart's electrical activity may cease altogether.

In cases where heart activity has been disrupted by an electrical shock, CPR should be performed to keep the brain from dying. When CPR has been performed, there have been reports of victims recovering after even hours of no spontaneous heart or respiratory activity.

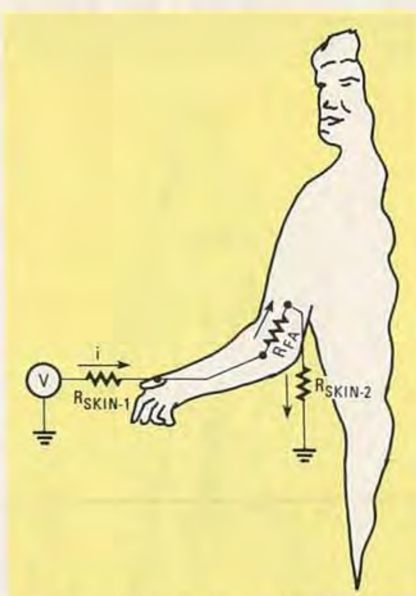

FIG. 3—WHEN A SHOCK is received between the hand and the elbow, resistance is offered by the skin at both the hand and the elbow, as well as by the arm itself.

FIG. 4—A DEFIBRILLATOR uses electrical shock to restore a heartbeat to normal.

The nervous system can be directly affected by electrical shock. Paralysis, amnesia, and other conditions all can result from nerve damage.

Kidney damage can occur if an electric current passes through that organ. Kidney damage can also occur if that organ is blocked by large amounts of a chemical (called mycoglobin) that is released from muscle cells that are damaged by the passage of an electrical current.

Finally, large and small blood vessels may bleed or develop clots after electrical shock. That can lead to deeper and more extensive tissue damage than is apparent on initial inspection.

Lightning

Lightning produces all of the above effects, and more. A person hit directly by lightning will, in all likelihood, be killed immediately. People who have been "hit by lightning" and have survived, are those who were fortunate enough to be victims only of a near miss. They were merely close enough to the lightning to receive severe electrical shocks.

If lightning hits a tree (or other object in the ground), a voltage gradient leading from the tree will exist along the ground. A cow standing facing the tree will receive more voltage between its legs than a cow standing with its side to the tree. People lying on the ground may develop burns on areas of the skin that were in contact with the ground. If the burns are not severe, they may resemble light red, fine paintings—small burns may resemble stick figures, while larger ones may look like evergreen bushes with thousands of needles on their branches. In addition to the burns, there may also be transient paralysis or transient loss of vision or hearing.

Serious effects of a lightning "strike" can include severe burns and cardiac arrest.

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Microshock

Microshock is electrical shock caused by very small amounts of current. As is shown in Table 1, currents of less than 1 milliampere are usually of no consequence. If a shock is delivered directly to the heart, however, even 20 microamperes of current can be dangerous. Current can be delivered directly to the heart through a pacemaker wire. Wires for use with external (temporary) pacemakers

TABLE 1—EFFECTS OF A 60 Hz ELECTRIC SHOCK

Current held one second	Effect (current applied to skin, unless otherwise noted)
20 μA	Ventricular fibrillation if applied directly to the heart
1 mA	Sensation
5 mA	Maximum harmless current
1–10 mA	Mild to moderate pain
10–20 mA	May cause muscular contractions, preventing release from shock source
30 mA	Breathing may stop
75–300 mA	Ventricular fibrillation may occur
5 A	Burns tissues

FIG. 5—IF A PACEMAKER'S LEADS accidentally contact a voltage source, it is easy to deliver a dangerous voltage (greater than 20 mA) to the heart.

come out of the body through the chest wall or through veins that lead to an arm, the neck, or elsewhere (see Fig. 5). If such a wire were touched by a person who was holding onto a light switch, electric bed frame, television set, or other appliance, many microamperes could be conducted to the pacemaker wire.

Many appliances will supply a good fraction of a milliampere to someone who is grounded. To see that for yourself, connect an ammeter between the metal parts of an appliance and ground. (Start on a high range to protect the meter.) Unless there is a very good third wire ground, significant currents will be measured.

Why electrical shock occurs

It is easy to receive an electrical shock. All that is required is to come into contact with two different voltages. Electrical shock can occur in a variety of settings. Electronics technicians and hobbyists can be exposed to many situations in which shock can occur. Capacitors and CRT's, for instance, store large voltages for days or longer. Tools held in the hand may conduct electric currents from objects touched. High voltages may arc across space to cause shocks.

Even if you are someone who doesn't do much electronics work or experimenting, there are many "opportunities" around the house to receive a shock. Damaged line cords, defective appliances, or accidents, such as dropping an AC-powered radio into a full bathtub, can quickly teach anyone about the dangers of electrical shocks. **R-E**