ELECTRICITY AND HUMAN BODY

ELECTRIC CURRENT, VOLTAGE AND POTENTIAL

Electric current is a flow of electric charge through a conductive medium. In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte. The reason of the charged particles movement is an electric voltage.

Electric voltage is a difference of electric potentials of two places.

Electric potential is an electric characteristic of certain place and corresponds to “concentration” of the electric charges. Free charged particles move from places with high concentration to places with low concentration. If there is an electric voltage (potential difference), free charged particles start to move in the direction from the place of the highest electric potential to the place of the lowest electric potential. The movement of free charged particles (negative or positive) from the place of highest electric potential to the place of lowest electric potential is called electric current.

There are two basic electric currents:

- **Alternating current (AC)** - the voltage is changing (electrical outlet). Number of cycles in 1 second is called frequency (measured in Hertz).
- **Direct current (DC)** - the voltage does not change (battery)

ELECTRICAL PROPERTIES OF HUMAN BODY

The electrical properties of biological tissues and cell suspensions determine the pathways of current flow through the body and, thus, are very important in the analysis of injuries by electric current and a wide range of biomedical applications such as functional electrical stimulation and the diagnosis and treatment of various physiological conditions with weak electric currents, radio-frequency hyperthermia, electrocardiography, and body composition.

ELECTROLYTES

Human body consists of up to 60% of the water. The total amount of water in a man of average weight (70 kilograms) is approximately 40 litres. The body water is broken down into the following compartments:

1. Intracellular fluid (2/3 of body water)
2. Extracellular fluid (1/3 of body water)

Intracellular as well as extracellular fluids are electrolytes full of biochemical ions, therefore well conductive. The cell membranes are isolants. If the voltage that is not changing is applied (DC) the direct current can flow through the extracellular fluids. DC cannot pass through the cell membranes, so it cannot flow intracellularly (contrary to AC).

BODY RESISTANCE AND HEAT EFFECTS OF ELECTRIC CURRENT

Body resistance (measured in ohms/cm2) is concentrated primarily in the skin and varies directly with the skin's condition.

The resistance of **dry** well-keratinized intact skin is **20-30 kΩ /cm2**.

The resistance of **moist** thin skin is about **0,5 kΩ/cm2**.

The resistance of **punctured** skin may be as low as **0,2-0,3 kΩ/cm2**.

The same resistance is in case of current applied to moist mucous membranes (e.g., mouth, rectum, vagina).

If skin resistance is low, few, if any, burns occur, although **cardiac arrest** may occur if the current reaches the heart.

If skin resistance is high, much energy may be dissipated at the surface as current passes through the skin, and large surface burns can result at the **entry and exit points**.

Internal tissues are burned depending on their resistance; **nerves, blood vessels, and muscles** conduct electricity more readily than denser tissues (e.g., fat, tendon, bone) and are preferentially damaged.

The higher the resistance is the higher production of the heat is (**heat = amperage2 × resistance Q = I2 . R . t**). If there is an element with high resistance in the circuit, it is usually hot, depending on the value of electric current (amperage) in the circuit and the resistance of the element.

ELECTRIC SHOCK

Electric shock occurs upon contact of a (human) body part with any source of electricity that causes a sufficient current through the skin, muscles, or hair. Typically, the expression is used to describe an injurious exposure to electricity.

The minimum current a human can feel depends on the current type (AC or DC) and frequency. A person can feel at least 1 mA of AC at 50-60 Hz, while at least 5 mA for DC. The current may, if it is high enough, cause tissue damage or fibrillation which leads to cardiac arrest. Current of 60 mA of AC or 300–500 mA of DC can cause fibrillation.

A sustained electric shock from AC at 120 V, 60 Hz is an especially dangerous source of ventricular fibrillation because it usually exceeds the let-go threshold, while not delivering enough initial energy to propel the person away from the source. However, the potential seriousness of the shock depends on paths through the body that the currents take. Death caused by an electric shock is called electrocution.

Three primary factors affect the severity of the shock a person receives when he or she is a part of an electrical circuit:

- Amount of current flowing through the body (measured in amperes)
- Path of the current through the body
- Length of time the body is in the circuit

Other factors that may affect the severity of the shock are:

- The voltage of the current
- The presence of moisture in the environment
- The phase of the heart cycle when the shock occurs
- The general health of the person prior to the shock
- How quickly the person is treated.

Effects can range from a barely perceptible tingle to severe burns and immediate cardiac arrest. Although it is not known the exact injuries that result from any given amperage, the following table demonstrates this general relationship for **a 60 Hz, hand-to-foot shock of 1 second's duration**:

Current level (Milliamperes)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation. Still dangerous under certain conditions.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries.
6 - 16 mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or "let-go" range.
17 – 99 mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible.
100 – 2000 mA	Ventricular fibrillation (uneven, uncoordinated pumping of the heart.) Muscular contraction and nerve damage begins to occur. Death is likely.

Wet conditions are common during low-voltage electrocutions. Under dry conditions, human skin is very resistant. Wet skin dramatically drops the body's resistance.

Dry Conditions: Current = Volts/Ohms = 120/100,000 = 1mA = a barely perceptible level of current.

Wet conditions: Current = Volts/Ohms = 120/1,000 = 120mA = sufficient current to cause ventricular fibrillation

If the extensor muscles are excited by the shock, the person may be thrown away from the circuit. Often, this can result in a fall from elevation that kills a victim even when electrocution does not. When muscular contraction caused by stimulation does not allow the victim to free himself from the circuit, even relatively low voltages can be extremely dangerous, because the degree of injury increases with the length of time the body is in the circuit.

LOW VOLTAGE DOES NOT IMPLY LOW HAZARD!
100mA for 3 seconds = 900mA for .03 seconds … causing fibrillation Note that **a difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill**. High voltage electrical energy greatly reduces the body's resistance by quickly breaking down human skin. Once the skin is punctured, the lowered resistance results in massive current flow. Ohm's law is used to demonstrate the action. At 1,000 volts, Current = Volts/Ohms = 1,000/500 = 2 Amps which can cause cardiac arrest and serious damage to internal organs.

BURNS AND OTHER INJURIES

Shock-related injuries include burns, internal injuries, and injuries due to involuntary muscle contractions.

BURNS

The most common shock-related injury is a burn. Burns suffered in electrical incidents may be one or more of the following three types: Electrical burns cause tissue damage, and are the result of heat generated by the flow of electric current through the body. Electrical burns are one of the most serious injuries you can receive and should be given immediate attention.

High temperatures near the body produced by an electric arc or explosion cause arc or flash burns. They should also be attended to promptly. Thermal contact burns occur when skin comes in contact with overheated electric equipment, or when clothing is ignited in an electrical incident.

INTERNAL INJURIES

Excessive electricity flowing through the human body can cause serious damage to internal organs. Resulting medical problems include haemorrhage (or internal bleeding), tissue destruction, and nerve or muscle damage. These internal injuries may not be immediately apparent to the victim or observers; however, left untreated, they can result in death.

INVOLUNTARY MUSCLE CONTRACTION

Normal muscle contraction is caused by very small amounts of electricity that are created within our bodies. Muscles violently contract when stimulated by excessive amounts of electricity. These involuntary contractions can damage muscles, tendons, and ligaments, and may even cause broken bones. If the victim is holding an electrocuting object, hand muscles may contract, making it impossible to drop the object and prolonging contact with the current. Also, injury or death may result when violent muscle contractions cause workers to fall from ladders and scaffolds or inadvertently strike other objects.

FIRST AID

One should call emergency immediately if any of these signs or symptoms occur:

- Cardiac arrest
- Heart rhythm problems (arrhythmias)
- Respiratory failure
- Muscle pain and contractions
- Burns
- Seizures
- Numbness and tingling
- Unconsciousness

While waiting for medical help, some steps should be followed:

- Look first. Don't touch. The person may still be in contact with the electrical source. Touching the person may pass the current through you.
- Turn off the source of electricity, if possible. If not, move the source away from you and the person, using a dry, non-conducting object made of cardboard, plastic or wood.
- Check for signs of circulation (breathing, coughing or movement). If absent, begin cardiopulmonary resuscitation (CPR) immediately.
- Prevent shock. Lay the person down and, if possible, position the head slightly lower than the trunk with the legs elevated.
- After coming into contact with electricity, the person should see a doctor to check for internal injuries, even if he or she has no obvious signs or symptoms.

CAUTION

- Don't touch the person with your bare hands if he or she is still in contact with the electrical current.
- Don't get near high-voltage wires until the power is turned off. Stay at least 20 feet away — farther if wires are jumping and sparking.
- Don't move a person with an electrical injury unless the person is in immediate danger.