Applications of Electricity and Magnetism in Medicine

ELECTRICAL SHOCK

When an electrode is connected to each hand and 60 Hz currents of different levels are passed through the body. The amount of current depends on the resistance of body between two points due to Ohms law

$$V = I \times R$$

As the current is increased from zero, the level at which we can just feel the current- the perception level is reached. About 50% of adult men fell a 60 Hz current of about 1 mA. For women about one third lower than those fell. The perception level is frequency dependent; it rise as the frequency increases above 100 Hz.

As a 60 Hz current is increased above the perception level it causes a tingling sensation in the hands.

1. At current of 10 to 20 mA.

A sustained muscular contraction takes place in hands and many subjects cannot let go of the electrodes. (Note that this current is higher at both low and high frequency) in (Fig. 6). As the current increased still further, pain and some cases fainting occur.

2. Near the 100 mA level the portion of the 60 Hz current passing through the heart is sufficient to cause ventricular fibrillation. (rapid, irregular, and ineffectual contraction of the ventricles).

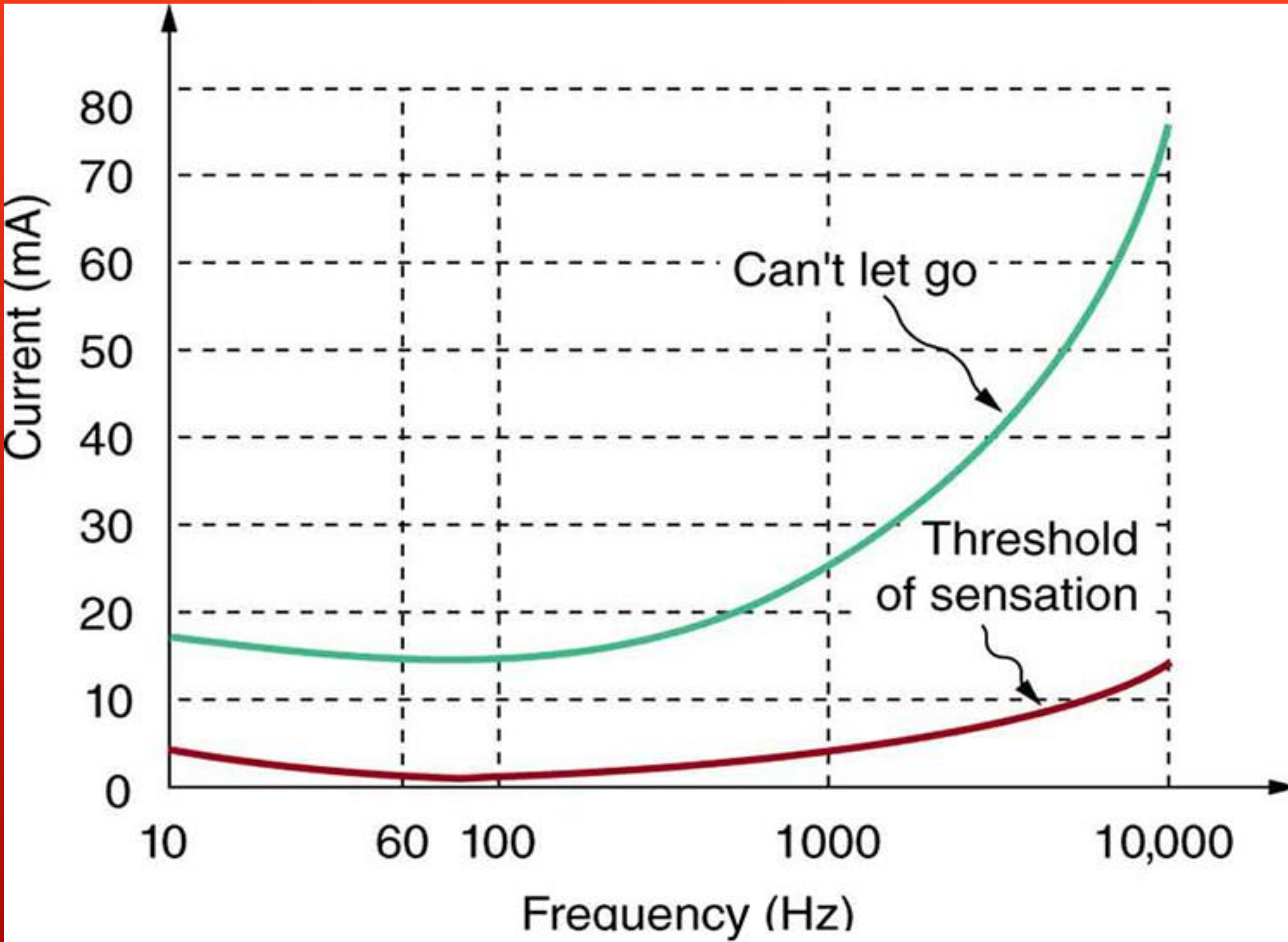
3. For a 60 Hz shock, the estimated maximum current that will not induce fibrillation in man is given by $(116/t^{1/2})$ mA, where t is the time (in seconds) the shock tests.

For example: if t = 1 s the safe current is 116 mA

If t = 4 s the safe current is 58 mA

4. Current levels of 6 A and above cause sustained muscular contraction of the heart similar to the (cannot let go) behavior of the hands. Defibrillators make use of such current levels. If a potential has ventricular defibrillation, a brief shock from a defibrillator usually restores normal coordinated pumping in the heart

. The defibrillator uses a brief pulse of up to 10 Kv. A defibrillator can also be used to synchronize the heart to its normal rhythm when a patient has atrial fibrillation, in this case the electrical pulse is applied after R wave but before T wave .



Current (mA)
80
70
60
50
40
30
20
10
0
Can't let go
Threshold
of sensation
10
60
100
1000
10,000
Frequency (Hz)

5. Continuous currents above 6 A can cause temporary respiratory paralysis and serious burns. The damage depends upon the individual, the dampness of the skin, and the contact of the skin with the conductor.

MACROSHOCK

Which occurs when electrical contact is made on the surface of the body.

MICROSHOCK

When the current is applied inside the body, microshock results.

In microshock, the current does not have to pass through the high resistance of the skin; it instead often follows the arteries and passes directly through the heart. Ventricular fibrillation can be induced with microshock current levels that are much smaller than the current levels needed to induce it under macroshock conditions. It has been estimated that about 30 μA cause ventricle fibrillation.

It is possible for microshock to occur in a medical situation, hazards of this sort are correct by modern power cords have three wires-two that supply the ac power and one that serves as ground wire. If either of power wires breaks the equipment will not operate, and if these wires touch (short) a fuse will blow and the failure will be obvious.

A break in the ground wire may go undetected and present a serious electrical hazard to patient internal electrodes, some current flow from the ac power parts to the metal case of the instrument is called Leakage current, usually flows to ground through ground wire in the power cord. The main source of the Leakage current is capacitance between the power wires and ground or between power transformer and its case.

The impedance **X_c** of a capacitance **C** for applied voltage frequency **f** is

$$X_c = 1/ 2 \pi f c$$

A typical Leakage capacitance is **2×10^{-2}μf.** If the ac potential **V** is **110 v** at a frequency of **60 Hz**, then the capacitive reactance is **$1.3 \times 10^5 \Omega$** and Leakage current

$$I = V / X_c = 110 / 1.3 \times 10^5 = 8.5 \times 10^{-4} A = 850 \mu A$$

Let us consider what would happen if this Leakage current were in a ECG instrument with broken ground wire and the unit were connected to a patient in an intensive care units who also had a pacemaker connected. Since the Leakage current could not flow to ground through the broken ground wire it would flow through the implanted cardiac pacemaker to ground.

microshock current could result in ventricular fibrillation and death.

There are a number of ways that shock hazards could be reduced.

1- The body is less sensitive to direct current than to 60 Hz current.

Since $\mathbf{X_c = \infty}$ **if** $\mathbf{f = 0}$

There would be no Leakage current due to stray capacitance if we operated our electrical equipment with direct current.

2- Hazards could also reduce at frequencies much higher than 60 Hz where the sensitivity of the heart to ventricular fibrillation is much less.

HIGH-FREQUENCY ELECTRICITY IN MEDINCINE

The heating effects produced by electrical diathermy.

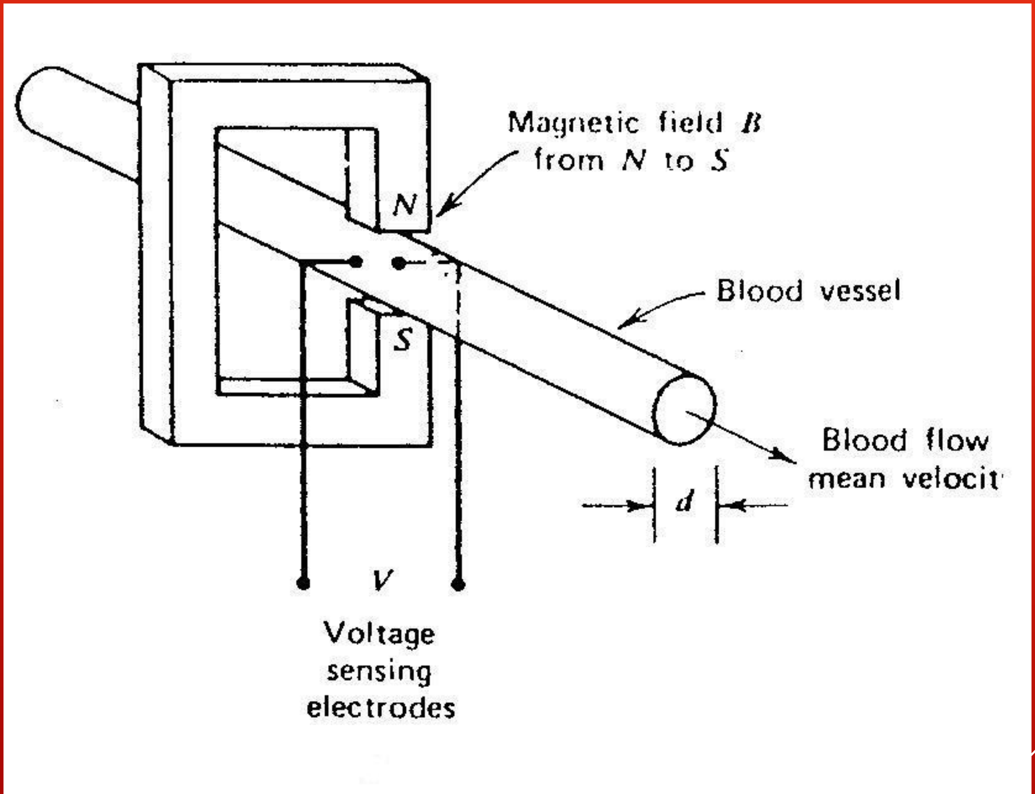
1- In short wave (30 MHz) diathermy two methods are used to get electromagnetic energy into the body: the capacitance methods and inductance method. In both methods the body part to be heated becomes a part of resonant electrical circuit.

2- In microwave (2450 MHz) diathermy.

Low-frequency electricity and magnetism in medicine

When an electrical conductor is moved perpendicular to a magnetic field, a voltage is induced in the conductor proportional to the product of the magnetic field and the voltage of the conductor (Faradays Low). This law, which also holds for a conducting fluid moving perpendicular to a magnetic field, is the basis of magnetic blood flow meters.

BLOOD ACTS AS A CONDUCTING FLUID. IF IT PASSES WITH MEAN VOLTAGE V THROUGH A MAGNETIC FIELD B AS SHOWN IN (FIG.7), A VOLTAGE V IS INDUCED BETWEEN THE ELECTRODES SUCH THAT V =BDV̄, D IS DIAMETER OF VESSEL.



The volume of blood Q through the vessel can then be calculated.

Since Q is product of mean velocity times the area of the vessel $\pi d^2/4$.

or

$$Q = \frac{\pi d^2}{4} x \frac{V}{Bd}$$

Example

A magnetic blood flow meter is positioned across blood vessel $\mathbf{5 \times 10^{-3}}$ **m** in diameter. With a magnetic field $\mathbf{3 \times 10^{-2}}$ **T**, and induced voltage of $\mathbf{15 \times 10^{-6}}$ **V** is measured.

a. Find the mean velocity in the vessel.

V = Bdv, v = V/Bd = 1.5 x 10^{-5}/(3x 10^{-2})(5 x 10^{-3}) = 0.1 m/s.

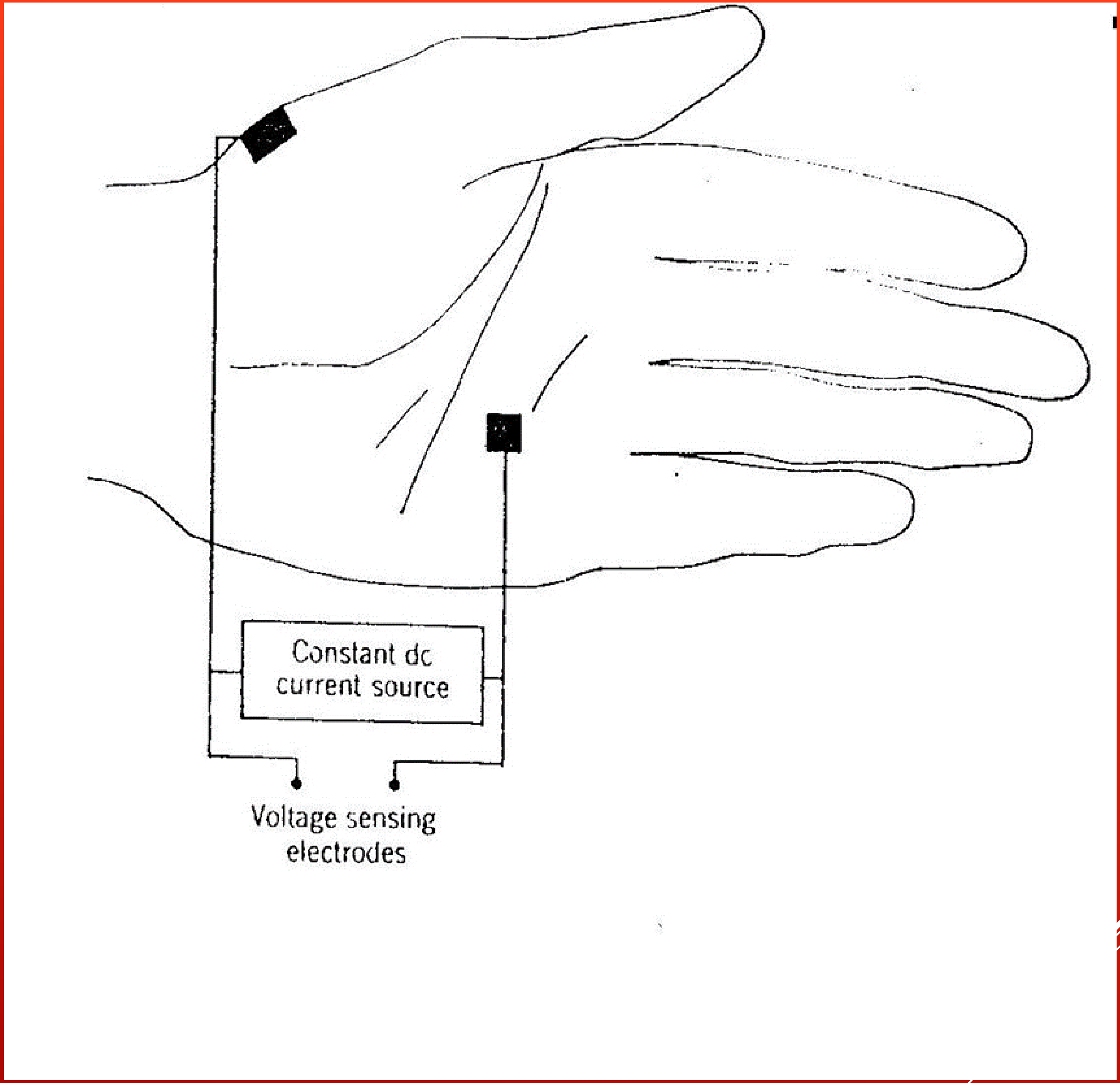
a. What is the volume flow rate.

$$Q = \frac{\pi d^2}{4} x \frac{V}{Bd}$$

Q = πd² V/4 Bd = π (1.5 x 10^{-3})^2 0.1 / 4 = 1.9 x 10^{-6} m^3/s = 1.9 cm^3 /s

GALVANIC SKIN RESPONSE (GSR)

GALVANIC SKIN RESPONSE (OR GSR), ALSO KNOWN AS ELECTRODERMAL RESPONSE (EDR) OR PSYCHOGALVANIC REFLEX (PGR), IS A METHOD OF MEASURING THE ELECTRICAL RESISTANCE OF THE SKIN AND INTERPRETING IT AS AN IMAGE OF ACTIVITY IN CERTAIN PARTS OF THE BODY.


Constant dc
current source
Voltage sensing
electrodes

Changing in perspiration (sweat gland activity) are related to skin resistance: the variation the skin resistance due to psychological changes or external stimuli is called the galvanic skin response (GSR). A decrease in skin resistance indicates increased sweat gland activity. Increase in skin resistance indicates reduced sweat gland activity. GSR measuring by two electrodes one placed on the palm of hand and other on the wrist. A constant direct current (~ 10 $\mu A/cm^2$) is passed: resulting voltage indicates the GSR

H.W

Choose the right answer

-1-How long the body could safely tolerate a macroscopic shock of 50 mA

A- 5.38 second

B- 5.38 millisecond

C- 5.38 microsecond

D- 54 millisecond

2-When the current is applied inside the body. Which of the followings is false?

A- Microshock results

B- Macroshock results

C- The current does not have to pass through the high resistance of the skin, it instead often follows the arteries and passes directly through the heart.

D- Ventricular fibrillation can be induced with microshock current

3- Galvanic skin response (or GSR), is a method of measuring the electrical resistance of the skin

a- A decrease in skin resistance indicates reduced sweat gland activity

b- A decrease in skin resistance indicates increased sweat gland activity.

c- Increase in skin resistance indicates increased sweat gland activity

d- A constant direct current (~ 100 A/cm2) is passed: resulting voltage indicates the GSR