بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِيْمِ

বিস্‌মিল্লাহির রাহ্‌মানির রাহীম

উদ্ভাস

একাডেমিক এন্ড এডমিশন কেয়ার

Class 12: Physics 2nd Paper (Chapter-3)

Current electricity

Lecture : P-07

Today's Topics:

- Resistance and specific resistance
- Effect of temperature on resistance
- Cause of heat in conductor due to current
- Joule's law for the generation of heat
- Relation between drift velocity and current
- Electric Fuse

Intro

Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points.

$$I \propto V \Rightarrow I = GV \Rightarrow V = IR$$

Where,

V = Voltage difference

R = Resistance

G = Conductance

Poll Question 1

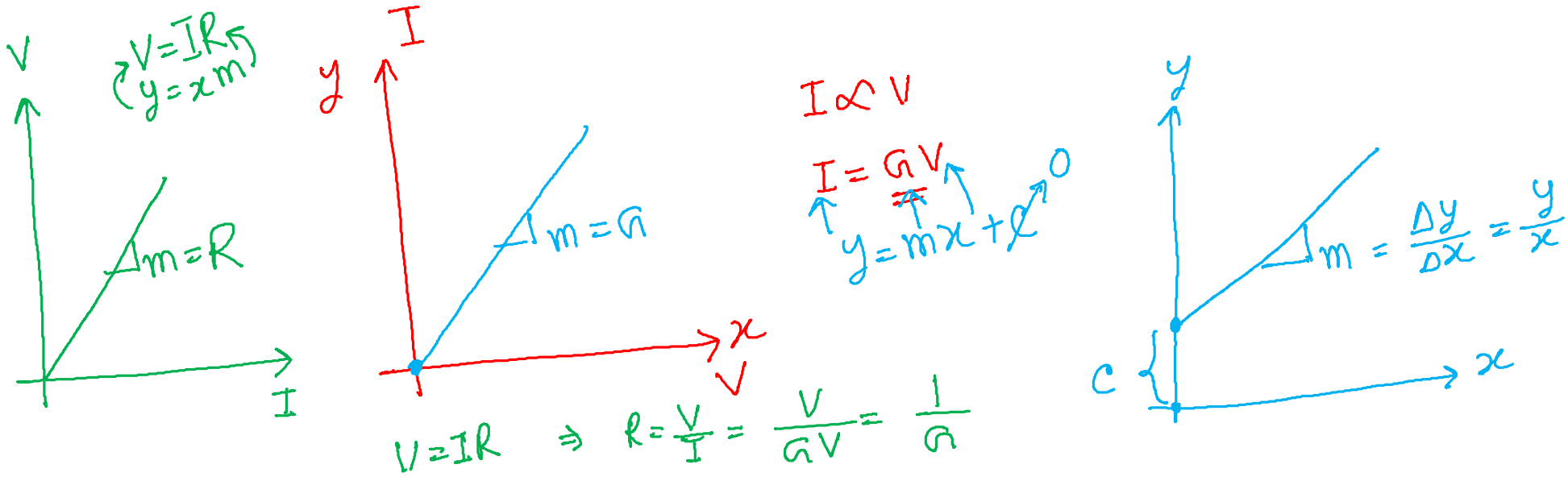
What is the slope of the graph which obeys Ohm's law?

(a) Resistance

(b) Conductance

(c) Specific resistance

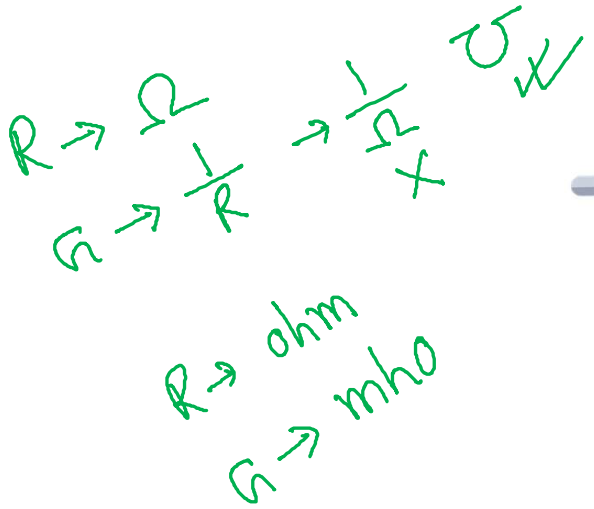
(d) Specific conductance

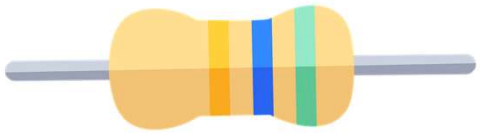


Resistance

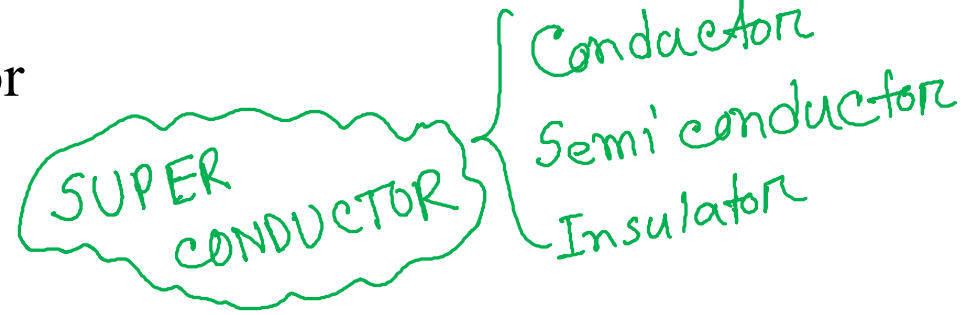
In electronics and electromagnetism, the electrical resistance of an object is a measure of its opposition to the flow of electric current.

Resistance is measured in **ohms**, symbolized by the Greek letter omega (**Ω**).





A resistor



Resistance

The resistance of any **substance** depends on the following factors:

a. Length of the substance

b. Cross sectional area of the substance

c. The nature of material of the substance

d. Temperature of the substance

At a definite temperature, a conductor made of a definite material will have 2 laws of resistance:

1. Law of length

2. Law of cross sectional area

Law of length & Cross Sectional Area

Law of length: For a conductor, if temperature, cross sectional area and material is fixed, its resistance is proportional to its length.

$$R \propto L$$

R↓L↓ L↑R↑

Law of cross sectional area: For a conductor, if temperature, length and material is fixed, its resistance is inversely proportional to its cross sectional area.

R↓A↑ A↓R↑

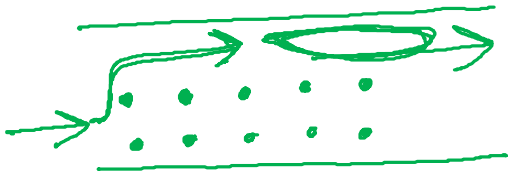
$$R \propto \frac{1}{A}$$

So, $R = \rho \frac{L}{A}$; ρ=specific resistance

L vary
R vary

(L) A mat. T
fix fix

L (A) mat. T
fix fix



Specific resistance

Specific resistance is defined as the resistance offered per unit length and unit cross-sectional area when a known amount of voltage is applied. Specific resistance is also known as resistivity. Unit of specific resistance is **Ωm**

def $R = \rho \frac{L}{A} = \rho \frac{1}{1} = \rho$

$R = \rho \frac{L}{A}$

$R \propto L$, $R \propto \frac{1}{A}$ $\Rightarrow R \propto \frac{L}{A}$

$R = \rho \frac{L}{A}$

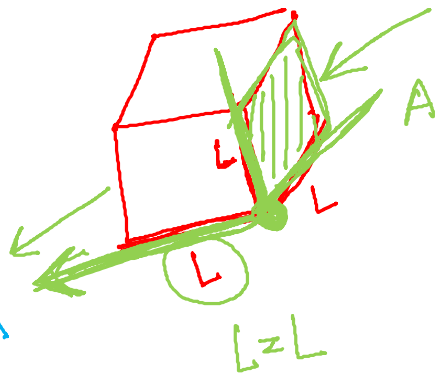
$R = \rho$

$\Omega \quad \Omega m$

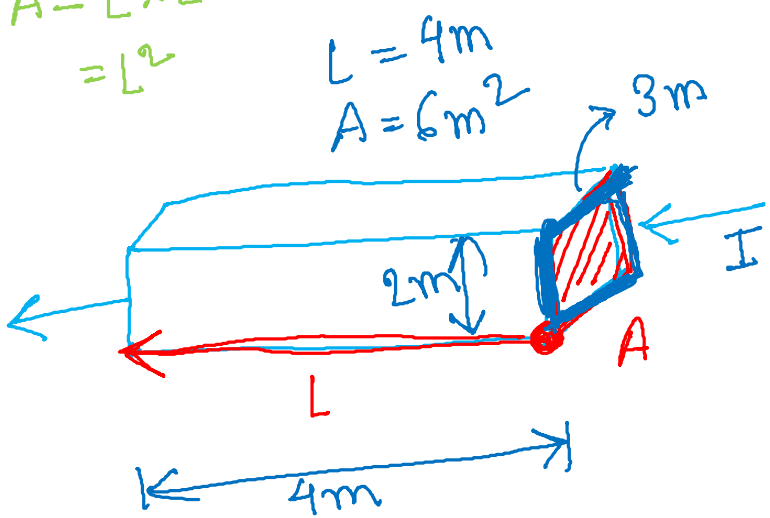
$\rho = \frac{RA}{L}$

$\frac{\Omega m^2}{m}$

$\rho \rightarrow \Omega m$



$A = L \times L = L^2$



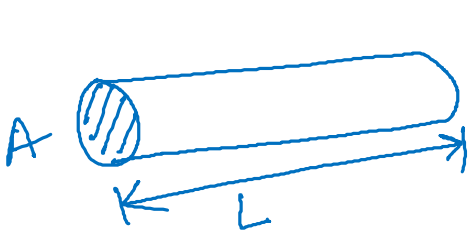
Poll Question 2

Resistivity of a wire depends on :

i. Length of wire

ii. Temperature of wire

iii. Material of wire

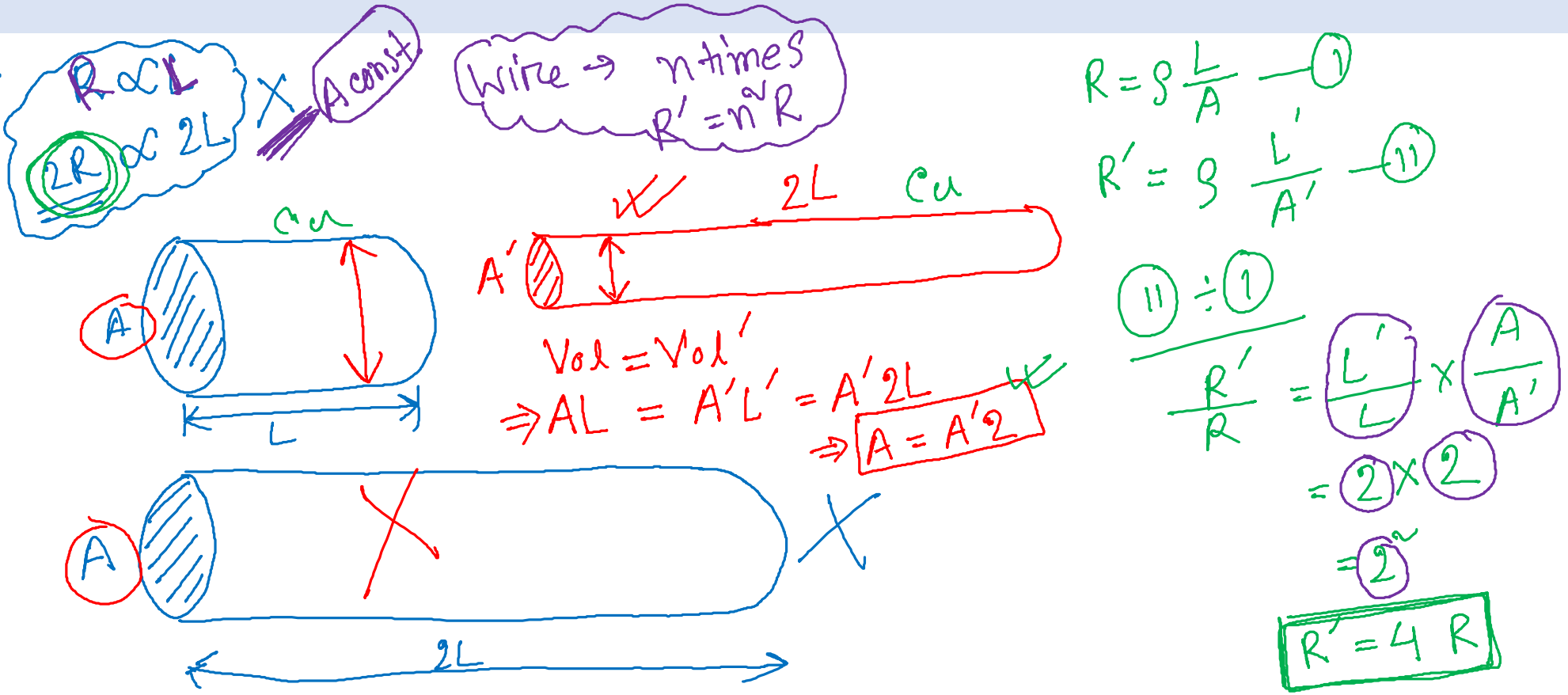


Which one is correct?

(a) i (b) ii & iii (c) i & iii (d) all of them

Math

If a wire is stretched so that it's length is doubled. What will be the new resistance?



Effect of temperature

The general rule is resistivity increases with increasing temperature in conductors and decreases with increasing temperature in insulators.

Temperature co-efficient of resistance (**α**) relates between resistance and temperature.

α can be positive(for conductors) and negative(semiconductor).

Few materials show **zero resistance** in very low temperature. They are superconductors.

Al → +ve $\alpha = 3.9 \times 10^{-3}\ ^{\circ}C^{-1}$

Carbon → -ve α = ... (not)

Semiconductor → $\alpha = -6 \times 10^{-2}\ ^{\circ}C^{-1}$

$R = \rho \frac{L}{A}$

L, A, mat. (T)

9-10

T↑ L↑ A↑ Vol↑

α

$R_t = R_0(1 + \alpha t)$

Let,

R_0 = Resistance of a conductor at 0 degree Celsius

R_t = Resistance of a conductor at t degree Celsius

α =Temperature coefficient of resistance

$R_t = R_0(1 + \alpha t)$

Remember, solve this problem in degree Celsius unit for temperature not in kelvin

$R_\theta = R_0(1 + \alpha\theta)$

$\theta^\circ C \quad 0^\circ C \quad {}^\circ C$

K

$R_t = R_0 + R_0 \alpha t$

$\alpha = \frac{R_t - R_0}{R_0 t} \Rightarrow \frac{\Omega}{\Omega\, {}^\circ C}$

$\alpha \rightarrow \frac{1}{{}^\circ C}$

$\alpha \rightarrow {}^\circ C^{-1}, K^{-1}$

Math

Resistance of a wire at 20 and 100 degree Celsius are 3 and 3.94 ohm respectively. Calculate the temperature coefficient of resistance.

$R_t = R_0(1 + \alpha t)$

$R_{20} = 3\Omega$

$R_{100} = 3.94\Omega$

$\alpha = ?$

$R_{20} = R_0(1 + \alpha 20)$ --- (i)

$R_{100} = R_0(1 + \alpha 100)$ --- (ii)

(ii) ÷ (i)

$$\frac{R_{100}}{R_{20}} = \frac{1 + 100\alpha}{1 + 20\alpha}$$

$$\Rightarrow \frac{3.94}{3} = \frac{1 + 100\alpha}{1 + 20\alpha}$$

$\alpha =$ _____ $^{\circ}C^{-1}$

(Ans)

Math

Conductor's resistance at 293K is 32 ohm. It's heated to the temperature of 373k and change in resistance is 0.22 ohm. Find out temperature coefficient of resistance.

$R_t = R_0(1 + \alpha t)$

$R_{20} = 32\,\Omega$

$R_{100} = 32 + 0.22 = 32.22\,\Omega$

$R_{20} = R_0(1 + \alpha 20)$ — (i)

$R_{100} = R_0(1 + \alpha 100)$ — (ii)

(ii) ÷ (i)

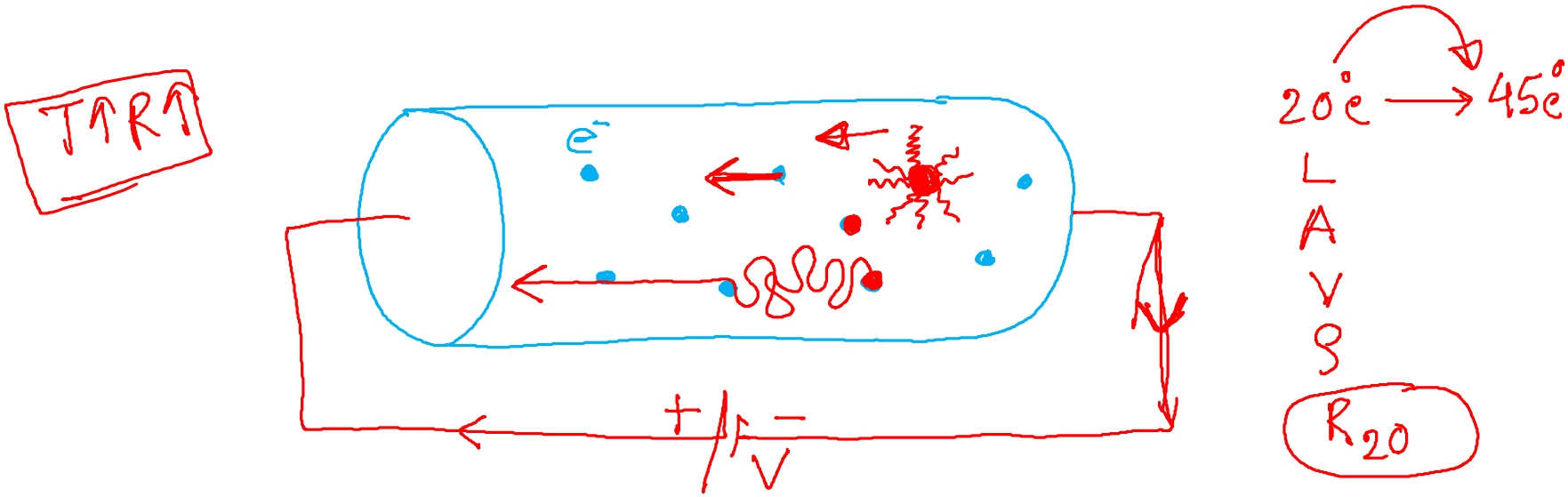
$$\frac{32.22}{32} = \frac{1 + 100\alpha}{1 + 20\alpha} \Rightarrow \alpha = \_\_\_\_\_\ {}^{\circ}C^{-1}$$

Cause of heat in conductor due to current

Resistance of a conductor is directly proportional to temperature.

Reason :

With the increase in temperature, vibrational motion of the atoms of conductor increases. Due to increase in vibration, probability of collision between atoms and electrons increases. As a result, resistance of conductor increases.



Poll Question 3

Draw graph which shows relation between resistance and temperature?

(a) Straight Upwards

(b) Straight Downwards

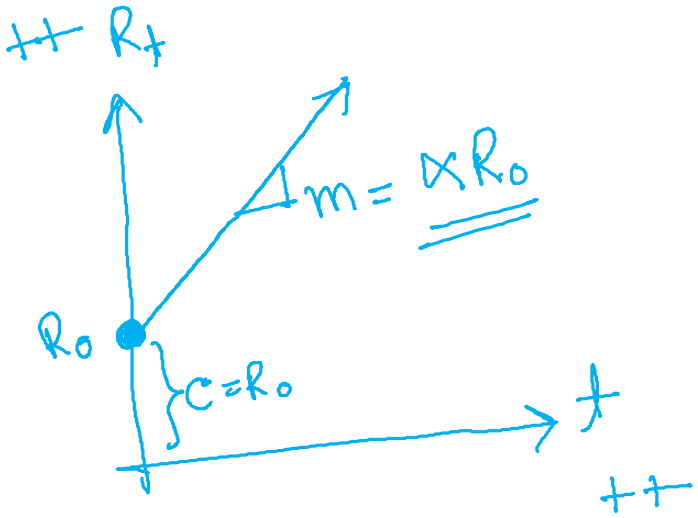
(c) Curve

(d) None of these

$R_t = R_0(1 + \alpha t)$

$\Rightarrow R_t = R_0 + R_0 \alpha t$

$y = c + mx$



Joule's law for generation of heat

1st law: If resistance of wire R, time of current flow t remain constant, produced heat due to current is proportional to the square of current flow i.

$$H \propto i^2$$

2nd law: If current flow rate i, time of current flow t remain constant, produced heat due to current is proportional to the resistance R.

$$H \propto R$$

3rd law: If resistance of wire R, current flow i remain constant, produced heat due to current is proportional to time of flow t.

$$H \propto t$$

By combining three laws,

$$H \propto i^2 Rt$$

$H = I^2 RT$

i) $H \propto I^2$ — R, t fix

ii) $H \propto R$ — I, t fix

iii) $H \propto t$ — R, I fix

Joule's law for generation of heat

Mechanical energy can be converted into heat, and heat can be converted into some mechanical energy. This important physical observation is known as the mechanical equivalent of heat.

Work done = J X Heat produced

or, $W = JH$; J = Mechanical equivalent of heat

Usually, both Work and Heat are in same unit system so $J = 1$

W=H So, $H = i^2 Rt$

But if W is in SI system and H is CGS unit system, to balance both sides

$J = 4.2$ Joule/Cal

Similarly, But if W is in CGS system and H is SI unit system, to balance both side $J = 0.24$ Cal/Joule

Amount of heat generated

$W = QV$ and $Q = It$

So, $W = VIt$

Again,

Work done = Heat produced

$W = H \Rightarrow H = VIt$

Again, $V = IR$ or, $I = \frac{V}{R}$

So, $\boldsymbol{H = i^2 Rt}$ or, $H = \boldsymbol{V^2} t/R$

$H = i^2 Rt$
$H = VIt$
$H = \frac{V^2 t}{R}$
} given

$W = QV$
$W = ItV = VIt$

$W = JH$
SI SI

$1Kg = 1000gm$
SI CGS

$W = H$
$VIt = H$

$Kg \neq gm$
$Kg = 1000gm$
$V = IR$
$I = \frac{V}{R}$

$H = VIt$
$H = (IR)It$
$H = I^2 Rt$

Poll question 04

Specific Heat of water equals to:

(a) 4200 J/gm/K

(b) 4.2J/kg/k

(c) 4.2J/gm/k

(d) 4200cal/gm/k

$1\,J \rightarrow 1\,cal$

$1\,J = 0.24\,cal$

$S = 4200\ J/kg/K$ (SI)

$= \frac{4200\ J}{1kg\ 1K}$

$= \frac{4200\ J}{1000gm\ 1K} = 4.2\ J/gm/K$

$S = \frac{1000\,cal}{1000gm\ 1°c}$

$S = 1\ cal/gm/°c$

(CGS)

Math

A heater of 100 Watts can rise the temperature of 1 liter water from 20 to 30 degree Celsius in 7 minutes. What is the value of J?

$W = JH$

$\Rightarrow Pt = J\,ms\Delta\theta$

Pt: SI, $ms\Delta\theta$: CGS

$m = 1L\ H_2O = 1kg = 1000gm$

$S = 4200\ J/kg/K = 1\ cal/gm/^\circ c$

$\Delta\theta = 30 - 20 = 10^\circ c = 10K$

$\Rightarrow 100 \times (7 \times 60) = J\ 1000 \times 1 \times 10$

$\therefore J = 4.2\ Joule/cal$

(CGS) = J(SI)

$J = 0.24\ cal/J$

$\frac{1}{4.2} = 0.24$

$1kg = 1000gm$

$1gm = 10^{-3}kg$

Math

A heater of 750 Watts can rise the temperature of 1 liter water from 20 to 100 degree Celsius in 10 minutes. Calculate the usage of energy in percentage.

$W \neq H$

$\text{input} = W = Pt = (750 \times 10 \times 60)\,J$

$= 450 \times 10^3\,J$

$\text{output} = H = mc\Delta\theta$

$= (1 \times 4200 \times 80)\,J$

$= 336\,000\,J$

in > out

loss = in − out

$\%\ \text{usage} = \dfrac{\text{output}}{\text{input}} \times 100\%$

$= 74.67\%$

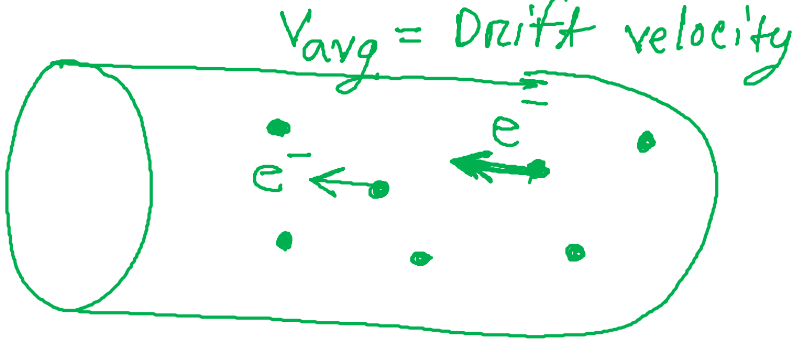
$\approx 75\%$

$\%\ \text{loss} = 25\%$

Drift velocity

Subatomic particles like electrons move in random directions all the time. When electrons are subjected to an electric field they do move randomly but they slowly drift in one direction, in the direction of the electric field applied. The net velocity at which these electrons drift is known as drift velocity.

"Drift velocity is that velocity at which electron drifts from lower potential to higher potential end during current flow."



Formula for Drift Velocity

Formula for drift velocity,

$\boldsymbol{I = nAVe} \Rightarrow V = \frac{I}{nAe}$;

I = Current flow

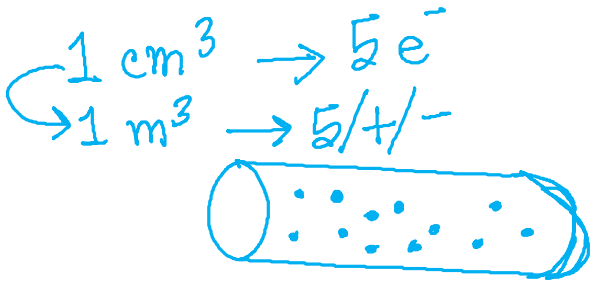
n = number of free electron in unit volume

A = cross sectional area

e = electron's charge = 1.6×10^{-1} C

Again, Current density, $j = \frac{I}{A}$

So, $V = \frac{j}{ne}$



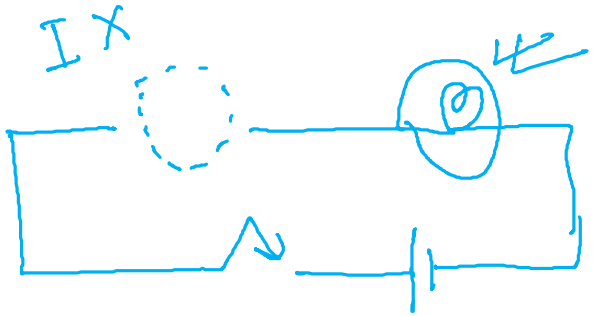
Electric fuse

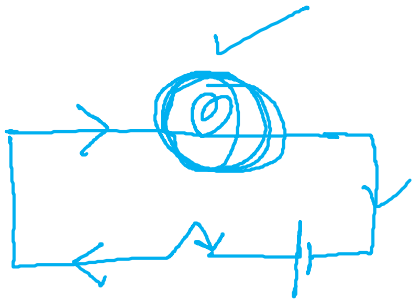
Connect in series connection

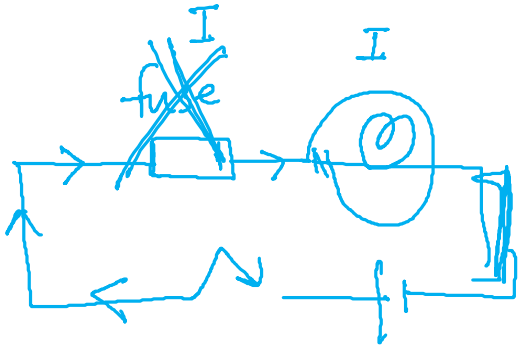
Comparatively low melting temperature

Usually the fuse is made of zinc, copper, aluminum or alloys etc

Safety fuse are made of Lead(3/4) and Tin(1/4) alloy which has melting point less than 300 degree Celsius







লেগে থাকো সৎভাবে,
স্বপ্ন জয় তোমারই হবে

উদ্ভাস-উন্মেষ শিক্ষা পরিবার

Thank You