Date: 18/05/2022 | Unit-3

Day: Wednesday | Thermal Physics

Solved Problems:-

Example: 1

A container whose capacity is 70ml is filled with a liquid up to 50ml. Then, the liquid in a container is heated. Initially, the level of the liquid falls from 50ml to 48.5ml. Then we heat more the level of the liquid rises to 51.2ml. Find the apparent and real expansion.

Solution

Given:-

Level of the liquid $L_1 = 50ml$

Level of the liquid $L_2 = 48.5ml$

Level of the liquid $L_3 = 51.2ml$

Apparent expansion = ?

Real expansion = ?

Soln:-

$$\text{Apparent expansion} = L_3 - L_1$$

$$= 51.2 - 50$$

$$\text{Apparent expansion} = 1.2ml$$

$$\text{Real expansion} = L_3 - L_2$$

$$= 51.2 - 48.5$$

$$\text{Real expansion} = 2.7ml$$

$\therefore$ Real expansion > apparent expansion.

Example: 2

Keeping the temperature as constant at a gas is compressed four times of its initial pressure. The volume of gas in the container changing from 200cc (V_1 cc) to V_2 cc. Find the final volume V_2.

Given:

Initial Pressure $P_1 = P$

Final Pressure $P_2 = 4P$

Initial Volume $V_1 = 20cc$

Final Volume $V_2 = ?$

Soln

According to Boyle's law.

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2}$$

$$V_2 = \frac{P \times 20}{4P}$$

$$V_2 = 5cc$$

(or)

$$V_2 = 5cm^3.$$

VII Numerical Problem:-

1. Find the final temperature of a copper rod. Whose area of cross section changes from $10m^2$ to $11m^2$ due to heating. The copper rod is initially kept at 90K. (coefficient of superficial expansion is 0.0021/K).

Solution

Given

Original Area $A_0 = 10m^2$

Final Area $A_f = 11m^2$

Change of Area $\Delta A = (11-10)m^2$

$\Delta A = 1m^2$

Initial temperature $T_i = 90K$

Co-efficient of superficial expansion $\alpha_A = 0.0021/K$

Final temperature $T_f = ?$

Soln

$$\frac{\Delta A}{A_0} = \alpha_A \Delta T.$$

$$\frac{1}{10} = 0.0021(T_f - T_i)$$

$$\frac{1}{10} = 0.0021(T_f - 90)$$

$$0.1 = 0.0021(T_f - 90)$$

$$T_f = \frac{0.1}{0.0021} + 90.$$

$$T_f = \frac{0.1}{0.0021} \times \frac{10000}{10000} + 90$$

$$T_f = \frac{1000}{21} + 90$$

$$T_f = 47.619 + 90$$

$$\boxed{T_f = 137.619\,K}$$

$$\boxed{T_f = 137.62K}$$

∴ Final temperature of copper rod is 137.62K

2. Calculate the coefficient of cubical expansion of a zinc bar. Whose volume increased $0.25m^3$ from $0.3m^3$ due to change in temperature of 50K.

Solution

Given

Original Volume $V_0 = 0.3m^3$

Increasing Volume $\Delta V = 0.25m^3$

Change in Temperature $\Delta T = 50K$

Coefficient of cubical expansion $\alpha_V = ?$

Soln

$$\boxed{\frac{\Delta V}{V_0} = \alpha_V \Delta T}$$

$$\alpha_V = \frac{\Delta V}{V_0 \Delta T}$$

$$\alpha_V = \frac{0.25}{0.3 \times 50}$$

$$\alpha_V = \frac{25}{30 \times 50}$$

$$\alpha_V = \frac{1}{60}$$

$$\alpha_V = 0.0166 K^{-1}$$

$$\boxed{\alpha_V = 0.0167 K^{-1}}$$

∴ The coefficient of cubical expansion is $0.0167 K^{-1}$.

Unit - 4

Electricity

Solved Problems :-

1. Two bulbs are having the ratings as 60W, 220V and 40W, 220V respectively. Which one has a greater resistance?

Solution

$$P = VI \quad \text{----} \rightarrow (1)$$

According to Ohm's law

$$I = \frac{V}{R} \rightarrow (2)$$

Substitute equation (2) in equation (1)

$$P = V \cdot \frac{V}{R}$$

$$P = \frac{V^2}{R}$$

$$\therefore P \propto \frac{1}{R}$$

For the same value of V, R is inversely proportional to P

Therefore, lesser the power, greater the resistance.

Hence, the bulb with 40N, 220V has a greater resistance.

2. Calculate the current and the resistance of a 100W, 200V electric bulb in an electric circuit

Given:

Power (P) = 100W

Voltage (V) = 200V

Current (I) = ?

Resistance (R) = ?

0.5
2 | 10
10
0

Sol^n

$P = VI$

$I = \frac{P}{V}$

$I = \frac{100}{200}$

$I = \frac{1}{2}$

$I = 0.5\ A$

∴ The current passes is 0.5 A.

$R = \frac{V}{I}$

$R = \frac{200}{0.5} \times \frac{10}{10}$

$R = \frac{2000}{5}$

$R = 400\ \Omega$

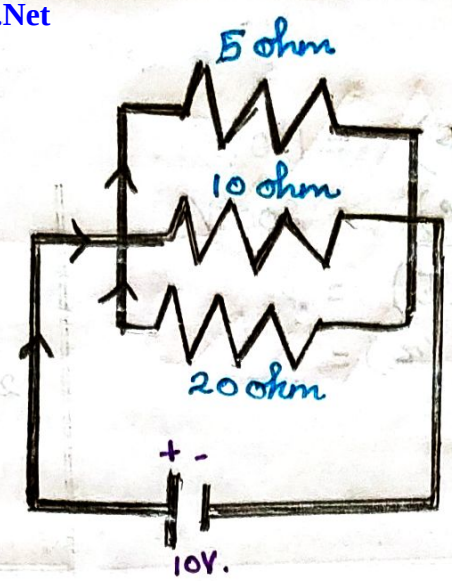
∴ The resistance of an electric circuit is 400Ω

3. In the circuit diagram given below, three resistors R_1, R_2 and R_3 of 5Ω, 10Ω and 20Ω respectively are connected as shown in the below. Calculate

a) Current through each resistor

b) Total current in the circuit.

c) Total resistance in the circuit



Solution

Given

$R_1 = 5\Omega$

$R_2 = 10\Omega$

$R_3 = 20\Omega$

$V = 10V$

a) Current $I_1 = ?$,

$I_2 = ?$,

$I_3 = ?$.

b) Total current $I_{total} = ?$

c) Total resistance $(R_p) = ?$

Soln

a) According to ohm's law

$$\boxed{I = \frac{V}{R}}$$

$$I_1 = \frac{V}{R_1}$$

$$I_1 = \frac{10}{5}$$

$$\boxed{I_1 = 2\,A}$$

$$I_2 = \frac{V}{R_2}$$

$$I_2 = \frac{10}{10}$$

$I_2 = 1\ A.$

$$I_3 = \frac{V}{R_3}$$

$$= \frac{10}{20}$$

$$\boxed{I_3 = 0.5\ A}$$

b) Total current

$$\boxed{I_{total} = I_1 + I_2 + I_3.}$$

$$= 2 + 1 + 0.5$$

$$\boxed{I_{total} = 3.5\ A}$$

c) Total resistance

$$\boxed{\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$\frac{1}{R_p} = \frac{1}{5} + \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{R_p} = \frac{1}{5} \times \frac{4}{4} + \frac{1}{10} \times \frac{2}{2} + \frac{1}{20} \times \frac{1}{1}$$

$$\frac{1}{R_p} = \frac{4}{20} + \frac{2}{20} + \frac{1}{20}.$$

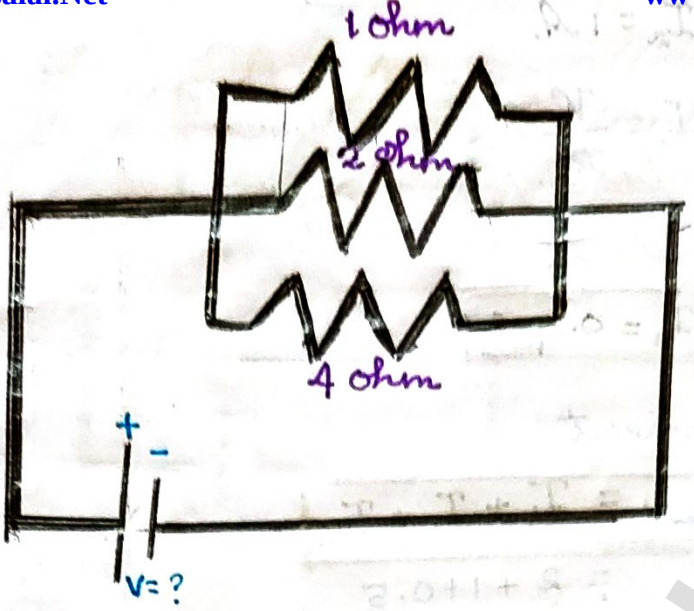
$$\frac{1}{R_p} = \frac{4+2+1}{20}$$

$$\frac{1}{R_p} = \frac{7}{20}$$

$$R_p = \frac{20}{7}.$$

$$\therefore \boxed{R_p = 2.857\ \Omega}$$

4 Three resistors of 1 ohm, 2 ohm, 4 ohm are connected in parallel in a circuit. If a 10hm resista draws a current of 1A. Find the current through the other two resistors.



Solution

Given :-

$R_1 = 1$ ohm.

$R_2 = 2$ ohm.

$R_3 = 4$ ohm.

$I_1 = 1\ A$

$I_2 = ?$

$I_3 = ?$

$V = ?$

Soln :-

According to Ohm's law

$$\boxed{V = IR}$$

$$V = I_1 \times R_1$$

$$V = 1 \times 1$$

$$\boxed{V = 1\ V}$$

Since, the resistors are connected in parallel in the circuit, the same potential difference will exist across the other resistor also.

$$\boxed{I_2 = \frac{V}{R_2}}$$

$$I_2 = \frac{1}{2}$$

$$\boxed{I_2 = 0.5\ A}$$

$$I_3 = \frac{V}{R_3}$$

$$I_3 = \frac{1}{4}$$

$$\boxed{I_3 = 0.25\ A}$$

0.25
4 | 10, 8, 20, 20, 0

Numerical Problems

(XII)

1. An electric iron consumes energy at the rate of 420 W when heating is at the maximum rate and 180 W when heating is at the minimum rate. The applied voltage is 220 V. What is the current in each case.

Solution

Given

Maximum Power (P_{max}) = 420 W

Minimum Power (P_{min}) = 180 W

Applied Voltage (V) = 220 V

Current Maximum (I_{max}) = ?

Current Minimum (I_{min}) = ?

Soln

Case (i)

$$P_{max} = V I_{max}$$

$$\boxed{I_{max} = \frac{P_{max}}{V}}$$

$$= \frac{420}{220}.$$

$$\boxed{I_{max} = 1.909\ A.}$$

1.909
22 | 42, 22, 200, 198, 200, 198, 2

9 × 22 = 198 (1)

Case (ii)

$$P_{min} = V I_{min}$$

$$\boxed{I_{min} = \frac{P_{min}}{V}}$$

$$= \frac{180}{220}$$

$$\boxed{I_{min} = 0.818\ A.}$$

0.818
22 | 280, 176, 3 40 10, 22, 180, 176, 4.

8 × 22 = 176 (1)

2. A 100 watt electric bulb is used for 5 hours daily and four 60 watt bulbs are used for 5 hours daily. Calculate the energy consumed (in KWh) in the month of January.

Solution

Given

No of 100 W bulb = 1

No of 60 W bulb = 4.

No of days in the month of January = 31.

100 W and four 60 W bulb energy consumed daily = 5 hrs

100 W and four 60 W bulb energy consumed in the month of January $t = 5 \times 31$

Total energy consumed in the month of January $E_{total} = ?$

Soln

100 W bulb energy consumed in the month of January $\Rightarrow E_1 = Pxt$

$= 100 \times 5 \times 31$

$E_1 = 15500$ Wh

$= 15.5$ KWh.

Four 60 W bulb energy consumed in the month of January $E_2 = Pxt$

$= 4 \times 60 \times 5 \times 31$

$= 240 \times 155$

$= 37220$ Wh

$E_2 = 37.2$ KWh

Total Energy consumed in the month of January $E_{total} = E_1 + E_2$

$= (15.5 + 37.2)$ KWh

$= 52.7$ KWh

3. A torch bulb is rated at 3V and 600 mA. Calculate it's
a) power b) resistance c) energy consumed if it is used for 4 hours.

Solution

Given

Voltage (V) = 3V

Current (I) = 600 mA

$I = 600 \times 10^{-3} A$

$I = 0.6 A$.

Time (t) = 4 hrs.

a) power (P) = ?

b) resistance (R) = ?

c) energy consumed (E) = ?

Soln

a) $P = VI$

$P = 3 \times 0.6$

$P = 1.8 W$

b) $R = \frac{V}{I}$

$= \frac{3}{0.6} \times \frac{10}{10}$

$= \frac{30}{6}$

$R = 5 \Omega$

c) $E = P \times t$

$= 1.8 \times 4$

$E = 7.2 Wh$

4. A piece of wire having a resistance R is cut into five equal parts.
a) How will the resistance of each part of the wire change compared with the original resistance?
b) If the five part of the wire are placed in parallel. how will the resistance of the combination change?

c) What will be ratio of the effective resistance in series the conection to that of the parallel connection?

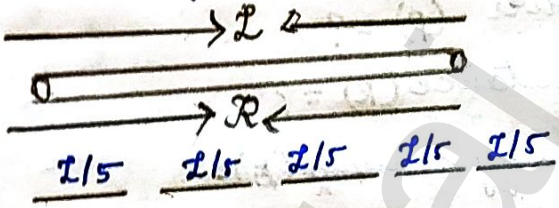
Solutions :-

Given

Original resistance (R_s) = R.

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

The resistance of a wire is directly popotional to length of wire.



$\frac{1}{5}(R)$
$= \frac{R}{5}$

$R_1 = \frac{\rho(L/5)}{A}$

$R_1 = \frac{1}{5}\left(\frac{\rho L}{A}\right)$

$R_1 = \frac{1}{5}(R)$.

$R_1 = \frac{R}{5}$.

∴ Each part of resistance is $R/5$

b) $R_1 = R/5$

The wire cut into five equal parts.

So that

$R_1 = R_2 = R_3 = R_4 = R_5 = R/5$

$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$

$\frac{1}{R_p} = \left(\frac{1}{R/5}\right) + \left[\frac{1}{R/5}\right] + \left(\frac{1}{R/5}\right) + \left[\frac{1}{R/5}\right] + \left(\frac{1}{R/5}\right)$

$\frac{1}{R_p} = \frac{25}{R}$

$$R_p = \frac{R}{25}$$

c) $\frac{R_s}{R_p} = \frac{R}{R/25}$

$$\frac{R_s}{R_p} = R \times \frac{25}{R}$$

$$\frac{R_s}{R_p} = \frac{25}{01}$$

$$R_s : R_p = 25 : 01.$$

Hots :-

1. Two resistors when connected in parallel give the resultant resistance of 2 ohm ; but when connected in series the effective resistance becomes 9 ohm. Calculate the value of each resistance.

Solution

Given

Effective resistance in Parallel (R_p) = 2 Ω

Effective resistance in series (R_s) = 9 Ω

Resistance R_1 = ?

Resistance R_2 = ?

Soln

$$R_1 + R_2 = 9$$

$$R_2 = 9 - R_1$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

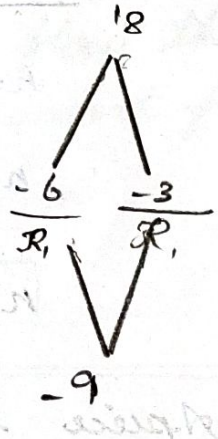
$$\frac{1}{R_p} = \frac{R_2 + R_1}{R_1 R_2}$$

$$\frac{1}{R_p} = \frac{9 - R_1 + R_1}{R_1 (9 - R_1)}$$

$$\frac{1}{R_p} = \frac{9}{9R_1 - R_1^2}$$

$$\frac{1}{2} = \frac{9}{9R_1 - R_1^2}$$

$$-R_1^2 + 9R_1 = 18.$$



$R_1^2 - 9R_1 + 18 = 0$

$(R_1 - 6)(R_1 - 3) = 0$

$R_1 = 6 \qquad R_1 = 3$

$R_2 = 9 - 6. \qquad R_2 = 9 - 3$

$R_2 = 3\,ohm \qquad R_2 = 6\,ohm.$

2. How many electrons are passing per second in a circuit in which there is a current of 5A?

Solution

Given: Current $(I) = 5A$

Time $(t) = 1sec.$

electron $(n) = ?$

Soln

$Q = ne$

$n = \frac{Q}{e}$

$n = \frac{I \times t}{e}$

$n = \frac{5 \times 1}{1.6 \times 10^{-19}}.$

$n = \frac{5}{1.6 \times 10^{-19}}$

$n = \frac{5}{1.6} \times 10^{+19}.$

$n = \left(\frac{5}{1.6} \times \frac{10}{10}\right) \times 10^{19}.$

$n = \frac{50}{16} \times 10^{19}.$

$I = Q/t$

$Q = I \times t$

$Q = I \times t$

$e = 1.6 \times 10^{-19} C.$

$n = 3.125 \times 10^{19}$ electrons

3.125

16 | 50
48
20
16
40
32
80
80
0

3. A piece of wire of resistance 10 ohm is drawn out so that the length is increased to three times its original length. Calculate the new resistance

Solution:-

Given :-

A piece of wire of resistance $R = \frac{\rho L}{A} = 10\text{ohm}$

Original length $= L$.

Increasing length $L' = 3L$

New Area $A' = A/3$.

New resistance $R' = ?$

Soln

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

$$R' = \frac{\rho(3L)}{A/3}$$

$$R' = \frac{3\rho L}{1} \times \frac{3}{A}$$

$$R' = \frac{9\rho L}{A}$$

$$R' = 9\left(\frac{\rho L}{A}\right)$$

$$R' = 9 \times 10$$

$$R' = 90\,\Omega$$

∴ The New resistance is 90 ohm.

Solved Problems-1

A charge of 12 coloumb flow through a bulb in 5 sec. What will the current flows through current?

Solution

Given :

Charge $(Q) = 12C$

Time $(t) = 5\text{sec}$

Current $(I) = ?$

Soln

$$I = \frac{Q}{t}$$

$$I = \frac{12}{5}$$

$$I = 2.4\ A$$

The current flows through a bulb is 2.4 A.

Solved Problem - 2.

The work done in moving a charges of 10 across two point in a circuit is 100J. What is the potential difference between the points

Solution

Given

Charge $(Q) = 10C$

Work done $(W) = 100J$

Potential Difference $(V) = ?$

Soln

$$V = \frac{W}{Q}$$

$$V = \frac{100}{10}$$

$$V = 10\ volt$$

∴ The potential difference between the point is 10 volt.

Solved Problems - 3.

Calculate the resistance of a conductor through which a circuit of 2A passes, when the potential difference between its end is 30V

Solution

Given

Current $(I) = 2A$

Potential Difference $(V) = 30V$

Resistance $(R) = ?$

Soln

$$R = \frac{V}{I}$$

$$R = \frac{30}{2}$$

$$R = 15\Omega$$

(or)

$$R = 15 \text{ ohm}$$

Solved Problems - 4

The resistance of a wire of length 10m is 2 ohm. If the area of a cross section of the wire is $2 \times 10^{-7} m^2$. Calculate i) resistance (ii) conductance (iii) conductivity

Solution

Length of a wire $(L) = 10m.$

Resistance of a wire $(R) = 2 \text{ ohm}$

Area of cross section $(A) = 2 \times 10^{-7} m^2$

i) resistance $(\rho) = ?$

(ii) conductance $(G) = ?$

(iii) conductivity $(\sigma) = ?$

Soln

i) Resistance (R)

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

$$\rho = \frac{2 \times 2 \times 10^{-7}}{10}.$$

$\rho = 4 \times 10^{-7} \times 10^{-1}$.

$$\rho = 4 \times 10^{-8} \text{ ohm m}$$

(ii) conductance (G)

$$G = \frac{1}{R}$$

$$= \frac{1}{2}$$

$$G = 0.5 \text{ ohm}^{-1}$$

(iii) conductivity (σ)

$$\sigma = \frac{1}{\rho}$$

$$= \frac{1}{4 \times 10^{-8}}$$

$$\sigma = 0.25 \times 10^{8} \text{ mho}^{-1} \text{ m}^{-1}$$

(or)

$$\sigma = 0.25 \times 10^{8} \ \Omega^{-1} m^{-1}.$$

Solved Problems :- 5

Three resistors of a resistance 5 ohm, 3 ohm and 2 ohm are connected in series with 10 V battery. Calculate their effective resistance and the current flowing through it.

Solution

Given

$R_1 = 5$ ohm

$R_2 = 3$ ohm

$R_3 = 2$ ohm

$R_S = ?$

$V = 10$ volt

$I = ?$

Soln

$$R_S = R_1 + R_2 + R_3$$

$R_S = 5 + 3 + 2$

$R_S = 10 \ \Omega$

Using $I = \frac{V}{R_S}$

$= \frac{10}{10}$

$\boxed{I = 1\ A}$

∴ The current flowing through is 1A.

Solved Problem-6

An electric heater of resistance 5 ohm is connected to an electric source. If a current of 6 A flows through the heater, then find the amount of heat produced in 5 minds.

Solution

Given

$R = 5$ ohm

$I = 6\ A$

$t = 5$ min

$= 5 \times 60$

$t = 300$s

$H = ?$

Soln

$\boxed{H = I^2 Rt}$

$H = (6)^2 \times 5 \times 300$

$= 36 \times 1500$

$= 54000$ J.

$\boxed{\therefore H = 54000\ J.}$

③ 36 × 1500

00

00

① 180

36

54000

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