12 PHYSICS
SOME IMPORTANT PROBLEMS WITH SOLUTION(TNBOARD)

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PROBLEMS

1.Calculate the speed of the electromagnetic wave in a medium if the amplitude of electric and magnetic fields are 3×10^4 N C-1 and 2×10^{-4} T, respectively.

solution

The amplitude of the electric field, Eo = 3×10^4 N C-1

The amplitude of the magnetic field, Bo = 2×10^{-4} T.

Therefore, speed of the electromagnetic wave in a medium $v = \frac{E_0}{B_0}$

$v = \frac{3\times10^4}{2\times10^{-4}}$ v =1.5× 10^8 m/s

2.The equation for an alternating current is given by i = 77 sin 314t. Find the peak current, frequency, time period and instantaneous value of current at t = 2 ms

Solution

i = 77 sin 314 t ; t = 2 m s = 2 × 10–3 s

The general equation of an alternating current is $i = I_M sin\omega t$.

On comparison,

(i) Peak current, Im =77A

(ii) Frequency, $f = \frac{\omega}{2\pi}$, $f = \frac{314}{2\times3.14}$ = 50Hz

(iii) Time period$T = \frac{1}{f}$ $T = \frac{1}{50}$ = 0.02s

(iv) At t = 2 m s, Instantaneous current $i = I_M sin\omega t$

$i = 77\sin(314 \times 2 \times 10^{-3})$

$i = 77\sin(0.628)$

$i = 77\sin(0.628 \times \frac{180^0}{3.14})$

$i = 77\sin36^0$

$i = 77 \times 0.5878$

$i = 45.26A$

3.A copper wire of 10^{-6} m^2 area of cross section, carries a current of 2 A. If the number of electrons per cubic meter is 8 $\times10^{28}$, calculate the current density and average drift velocity.

Given data

$A = 10^{-6}m^2, I = 2A, \ .n = 8 \times 10^{28}$

$J = ?\ , v_d = ?$

Solution

$J = \frac{I}{A}$

$J = \frac{2}{10^{-6}} = 2 \times 10^6 Am^2$

$J = nev_d$

$v_d = \frac{J}{ne} = \frac{2 \times 10^6}{8 \times 10^{28} \times 1.6 \times 10^{-19}}$

$v_d = \frac{2 \times 10^6}{128 \times 10^8}$

$v_d = \frac{100\times10^{-4}}{64}$= 15.6× $10^{-5}ms^{-1}$

Ans:

J=2×$10^6 Am^2$, v_d =15.6× $10^{-5}ms^{-1}$

4.Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows hrough it.

Solution

$I = 32A\ , t = 1s$

The charge of an electron $e = 1.6 \times 10^{-19}$

The number of free electrons per second (n)=?

$I = \frac{q}{t}$ $q = ne$

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

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

$n = \frac{32 \times 1}{1.6 \times 10^{-19}}$

$n = \frac{32 \times 1}{16 \times 10^{-20}}$

$n = 2 \times 10^{20}$

5. The magnetic flux passing through a coil perpendicular to its plane is a function of time and is given by ΦB = (2t3 + 4t2 + 8t + 8) Wb. If the resistance of the coil is 5 Ω, determine the induced current through the coil at a time t = 3 second.

Given data

$\emptyset_B = (2t^3 + 4t^2 + 8t + 8)Wb$, $t = 3s$,

$R = 5\Omega$

Solution

$$emf = \frac{d\Phi_B}{dt} = \frac{d(2t^3 + 4t^2 + 8t + 8)}{dt}$$

$$= 6t^2 + 8t + 8$$

$at\ time\ t = 3s$

$emf = 6(3^2) + 8(3) + 8$

$= 54 + 24 + 8 = 86$

$emf = 86V$

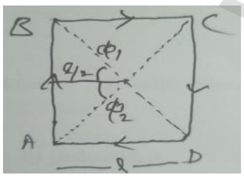
$we\ know\ that\ emf = IR$

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

$I = \frac{86}{5} = 17.2A$

ANS: I=17.2A

6.Calculate the magnetic field at the center of a square loop which carries a current of 1.5 A, length of each loop is 50 cm.



Given data

$I = 1.5A$, $l = 50cm = 0.5m$ Magnetic field at the centre of square loop B =?

Solution

Magnetic field due to current carrying straight conductors (according to biot - savart law)

$$B = \frac{\mu_0 I}{4\pi a}[sin\emptyset_1 + sin\emptyset_2]$$

for a square it has 4 sides . So at the centre of a square , the magnetic field

$$B = 4 \times \frac{\mu_0 I}{4\pi a}[sin\emptyset_1 + sin\emptyset_2]$$

$$here\ a = \frac{l}{2} \quad \emptyset_1 = 45^0 \quad \emptyset_2 = 45^0$$

$$B = 4 \times \frac{4\pi \times 10^{-7} \times 1.5}{4\pi \times \frac{l}{2}}[sin45^0 + sin45^0]$$

$$B = 4 \times \frac{4\pi \times 10^{-7} \times 1.5}{4\pi \times \frac{50 \times 10^{-2}}{2}}[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}]$$

$$B = 4 \times \frac{4\pi \times 10^{-7} \times 1.5}{4\pi \times \frac{50 \times 10^{-2}}{2}}[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}]$$

$$B = 4 \times \frac{10^{-7} \times 1.5}{25 \times 10^{-2}} \times \frac{2}{\sqrt{2}}$$

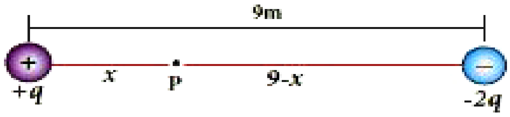
$$B = \frac{12 \times 10^{-5}}{1.414 \times 25}$$

$$B = 0.3394 \times 10^{-5}$$

$$B = 3.4 \times 10^{-6}\ T$$

7.Consider a point charge +q placed at the origin and another point charge -2q placed at a distance of 9 m from the charge +q. Determine the point between the two charges at which electric potential is zero.

According to the superposition principle, the total electric potential at a point is equal to the sum of the potentials due to each charge at tha point.Consider the point at which the total potential zero is located at a distance x from the charge +q as shown in the figure.



The total electric potential at P is zero.

$$V_{tot} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{x} - \frac{2q}{(9-x)}\right) = 0$$

$$\left(\frac{q}{x}\right) = \frac{2q}{(9-x)}$$

$$\left(\frac{1}{x}\right) = \frac{2}{(9-x)}$$

$$(9-x) = 2x$$

$$9 = 2x+x$$

$$9 = 3x$$

$$x = 3\text{m}$$

8.The self-inductance of an air-core solenoid is 4.8 mH. If its core is replaced by iron core, then its self-inductance becomes 1.8 H. Find out the relative permeability of iron.

Solution

$$L_{air} = 4.8 \times 10^{-3} H$$

$$L_{iron} = 1.8 H$$

$$L_{air} = \mu_0 n^2 Al$$

$$L_{iron} = \mu n^2 Al = \mu_0 \mu_r n^2 Al$$

$$\frac{L_{iron}}{L_{air}} = \frac{\mu_0 \mu_r n^2 Al}{\mu_0 n^2 Al}$$

$$\frac{L_{iron}}{L_{air}} = \mu_r$$

$$\mu_r = \frac{1.8}{4.8 \times 10^{-3}} = 0.375 \times 10^3 = 375$$

Relative permeability of iron $\mu_r = 375$

9.A cell supplies a current of 0.9 A through a 2 Ω resistor and a current of 0.3 A through a 7 Ω resistor. Calculate the internal resistance of the cell.

Given data

$I_1 = 0.9A$; $I_2 = 0.3A$

$R_1 = 2\Omega$; $R_2 = 7\Omega$

$internal\ resistance\ r = ?$

Solution

$$r = \frac{\xi - IR}{I}$$

$$r = \frac{\xi - I_1R_1}{I_1}$$

$$rI_1 = \xi - I_1R_1$$

$$\xi = I_1(R_1 + r)$$

Similarly

$$\xi = I_2(R_2 + r)$$

$$I_1(R_1 + r = I_2(R_2 + r))$$

$$0.9(2 + r) = 0.3(7 + r)$$

$$3(2 + r) = (7 + r)$$

$$6 + 3r = 7 + r$$

$$3r - r = 7 - 6$$

$$2r = 1$$

$$r = \frac{1}{2} = 0.5$$

$internal\ resistance\ of\ the\ cell\ (r) = 0.5\Omega$

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10. Find the impedance of a series RLC circuit if the inductive reactance, capacitive reactance and resistance are 184 Ω, 144 Ω and 30 Ω respectively. Also calculate the phase angle between voltage and current.

Solution

$X_L = 184\Omega$ $X_C = 144\Omega$ $R = 30\Omega$

i) the impedence is

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{30^2 + 184 - 144)^2}$$

$$Z = \sqrt{900 + 1600}$$

$$Z = \sqrt{2500}$$

$$Z = 50\Omega$$

(ii) Phase angle ϕ between voltage and current is

$$tan\phi = \frac{(X_L - X_C)}{R}$$

$$tan\phi = \frac{184 - 144}{30}$$

$$tan\phi = \frac{40}{30} = 1.33$$

$$\phi = tan^{-1}1.33$$

$$\phi = 53.1^0$$

Since the phase angle is positive, voltage leads current by 53.1° for this inductive circuit.

11.A copper wire of cross-sectional area 0.5 mm2 carries a current of 0.2 A. If the free electrondensity of copper wire is 8.4×1028 m−3, then compute the drift velocity of free electron.

$A = 0.5 \times 10^{-6}m^2$, $I = 0.2A$, $.n = 8.4 \times 10^{28}$

v_d =?

Solution

$$v_d = \frac{I}{neA}$$

$$= \frac{0.2}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}}$$

$$v_d = \frac{0.2 \times 10^{-3}}{8.4 \times 1.6 \times 0.5} = 0.03 \times 10^{-3}$$

$$v_d = 0.03 \times 10^{-3}ms^{-1}$$

12.If the focal length is 150 cm for a lens, what is the power of the lens ?

Given

$$focal\ length\ (f) = 150 \times 10^{-2}m$$

Solution

$$power\ of\ the\ lens\ (p) = \frac{1}{f}$$

$$power\ of\ the\ lens\ (p) = \frac{1}{150 \times 10^{-2}}$$

$$= 0.666\ D$$

$$power\ of\ the\ lens\ (p) = 0.666\ D$$

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13. If the resistance of coil is 3 Ω at 20^0C and α=0.004/^{0}C then, determine its resistance at 100^0C.

Given

$R_0 = 3\Omega$ $T = 100^0C$ $T_0 = 20^0C$ $\alpha = 0.004/^0C$

$$R_{100} = R_0(1 + \alpha(T - T_0))$$

$$R_{100} = 3(1 + 0.004(100 - 20))$$

$$R_{100} = 3(1 + 0.004(80))$$

$$R_{100} = 3(1 + 0.32)$$

$$R_{100} = (3 + .096)$$

$$R_{100} = 3.96\Omega$$

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14. The resistance of a nichrome wire at 20^0C is 10 Ω. If its temperature coefficient of resistivity of nichrom is 0.004/^{0}C, find the resistance of the wire at boiling point of water. Comment on the result.

$R_0 = 10\Omega$ $T = 100^0C$ $T_0 = 20^0C$ $\alpha = 0.004/^0C$

$$R_{100} = R_0(1 + \alpha(T - T_0))$$

$$R_{100} = 10(1 + 0.004(100 - 20))$$

$$R_{100} = 3(1 + 0.004(80))$$

$$R_{100} = 10(1 + 0.32)$$

$$R_{100} = (10 + 3.2)$$

$$R_{100} = 13.2\Omega$$

As the temperature increases the resistance of the wire also increases

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15. A potentiometer wire has a length of 4 m and resistance of 20 Ω. It is connected in series with resistance of 2980 Ω and a cell of emf 4 V. Calculate the potential gradient along the wire.

Given

$L = 4m$ $r = 20\Omega$ $R = 2980\Omega$ $\xi = 4V$

Solution

$$potential\ gradient = \frac{V}{L}$$

$I = \frac{\xi}{r+R}$ $I = \frac{4}{20+2980}$

$$I = \frac{4}{3000}$$

$potential\ drop\ across\ the\ wire\ (V) = Ir$

$$= \frac{4}{3000} \times 20$$

$$V = \frac{80}{3000} = \frac{8}{3} \times 10^{-2}$$

$$V = 2.66 \times 10^{-2}$$

$$potential\ gradient = \frac{2.66 \times 10^{-2}}{4}$$

$$potential\ gradient = 0.65 \times 10^{-2} Vm^{-1}$$

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16. An object is placed at a certain distance from a convex lens of focal length 20 cm. Find the object distance if the image obtained is magnified 4 times

Given data

$f = 20cm \qquad m = 4 \qquad u = ?$

Solution

$$m = \frac{v}{u}$$

$$4 = \frac{v}{u}$$

$$4u = v$$

The lens equation is

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{f} = \frac{1}{4u} - \frac{1}{u}$$

$$\frac{1}{f} = \frac{-3}{4u}$$

$$4u = -3f = -3 \times 20 = -60$$

$$4u = -60$$

$$u = \frac{-60}{4} = -15cm$$

$$u = -15cm$$

Alternate method:

$$m = \frac{f}{f+u}$$

$$4 = \frac{20}{20+u}$$

$$20 + u = \frac{20}{4} = 5$$

$$u = 5 - 20 = -15cm$$

$$u = -15cm$$

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17. The angle of minimum deviation for an equilateral prism is 37°. Find the refractive index of the material of the prism

given data

$A = 60^0 \qquad D = 37^0 \qquad n = ?$

$$n = \frac{\sin\left[\frac{A+D}{2}\right]}{\sin\left[\frac{A}{2}\right]}$$

$$n = \frac{\sin\left(\frac{60^0 + 37^0}{2}\right)}{\sin\left[\frac{60^0}{2}\right]}$$

$$n = \frac{\sin\left(\frac{97^0}{2}\right)}{\sin\left[\frac{60^0}{2}\right]}$$

$$n = \frac{\sin\ 48.5^0}{\sin\ 30^0}$$

$\sin 48.5^0 = 0.7489 \sin 30^0 = 0.5$

$$n = \frac{0.7489}{0.5}$$

$$n = 1.5$$

18.A coil of a tangent galvanometer of diameter 0.24 m has 100 turns. If the horizontal component of Earth's magnetic field is 25 × 10−6 T then, calculate the current which gives a deflection of 60^0.

Given data

The diameter of the coil = 0.24 m.

radius of the coil = 0.12 m.

Number of turns = 100 turns.

Earth's magnetic field B_H= 25×10−6T

Deflection is $\theta = 60^0$

Solution

$$I = \frac{2RB_H}{\mu_0 N} tan\theta$$

$$I = \frac{2 \times 0.12 \times 25 \times 10^{-6}}{4 \times 10^{-7} \times 3.14 \times 100} \times tan60^0$$

$tan60^0 = \sqrt{3} = 1.732$

$$I = \frac{2 \times 0.12 \times 25 \times 10^{-6}}{4 \times 10^{-7} \times 3.14 \times 100} \times 1.732$$

$$I = \frac{2 \times 0.3 \times 25}{314} \times 1.732$$

$I = 0.082A$

19.The resistance of a wire is 200 ohm. What will be new resistance it it is stretched uniformly 8 times of its original length?

$Initial\ length\ of\ the\ wire\ be = L$

$Initial\ cross\ sectional\ area\ be = A$

$R = 200\ ohm \qquad R' = ?$

$New\ length\ of\ the\ wire\ be\ \ L' = 8L$

Though the wire is stretched, its volume is unchanged

$$Initial\ volume\ V = A \times L$$

After stretched

$$final\ volume\ V' = A' \times L' = A' \times 8L$$

$$Initial\ volume = final\ volume$$

$$A \times L = A' \times 8L$$

$$A' = \frac{A \times L}{8L}$$

$$A' = \frac{A}{8}$$

$$New\ resistance \quad R' = \rho \times \frac{L'}{A'}$$

$$R' = \rho \times \frac{8L}{\frac{A}{8}}$$

$$R' = 64(\rho \times \frac{L}{A})$$

$$Since\ R = \rho \times \frac{L}{A} we\ can\ substitute$$

$$R' = 64R$$

Given that R=200 ohms

$$R' = 64 \times 200 = 1280\Omega$$

$$R' = 1280\Omega$$

20.Pure water has refractive index 1.33. what will be the speed of light through it ?

$Refractive\ index\ (n) = \frac{c}{v}$

$c = velocity\ of\ light\ in\ vaccum$

$= 3 \times 10^8 m/s$

$v = velocity\ of\ light\ in\ medium$

$n = \frac{c}{v}$

$v = \frac{c}{n}$

$v = \frac{3 \times 10^8}{1.33} = 2.25 \times 10^8 m/s$

$the\ speed\ of\ light\ through\ water\ (v\ )$

$= 2.25 \times 10^8 m/s$

21.Light travelling through transparent oil enters in to glass of refractive index 1.5. If the refractive index of glass with respect to the oil is 1.25, what is the refractive index of the oil?

Given

$$n_g = 1.5$$

$$n_{go} = 1.25$$

refractive index ofglass with respect oil

$$n_{go} = \frac{n_g}{n_o}$$

Rewriting for refractive index of oil,

$$n_o = \frac{n_g}{n_{go}}$$

$$n_o = \frac{1.5}{1.25} = 1.2$$

The refractive index of oil $(n_o) = 1.2$

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22. Dielectric strength of air is 4×10^6 V m^{-1}. Suppose the radius of a hollow sphere in the Van de Graff generator is R = 0.4 m, calculate the maximum potential difference created by this Van de Graaff generator

Solution

The electric field on the surface of the sphere is given by (by Gauss law)

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

The potential on the surface of the hollow metallic sphere is given by

$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

$V = ER$

SINCE

$V_{max} = E_{max}R$

Here

$E_{max} = 4 \times 10^6 Vm^{-1}$

So the maximum potential difference created is given by

$V_{max} = 4 \times 10^6 \times 0.4 = 1.6 \times 10^6 V$

$V_{max} = 1.6\ million\ volt$

23.Find the polarizing angles for glass of refractive index 1.5

solution

$Brewster's\ law, tan i_p = n$

$for\ glass\ n = 1.5$

$tan i_p = 1.5$

$i_p = tan^{-1}1.5$

$tan^{-1}1.5 = 56.3^0$

$ploarizing\ angle\ for\ glass\ i_p = 56.3^0$

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24. Find the ratio of the intensities of lights with wavelengths 500 nm and 300 nm which undergo Rayleigh scattering

solution

$According\ to\ rayleigh\ \mathrm{I} \propto \frac{1}{\lambda^4}$

$intensity\ of\ light I_1\ for\ wave\ lengh\ \lambda_1 = 500nm$

$intensity\ of\ light I_2\ for\ wave\ lengh\ \lambda_2 = 300nm$

$I_1 \propto \frac{1}{\lambda_1{}^4}$; $I_2 \propto \frac{1}{\lambda_2{}^4}$

$\frac{I_1}{I_2} = \frac{\lambda_2{}^4}{\lambda_1{}^4} = \left(\frac{\lambda_2}{\lambda_1}\right)^4$

$\frac{I_1}{I_2} = \left(\frac{300 \times 10^{-9}}{500 \times 10^{-9}}\right)^4$

$\frac{I_1}{I_2} = \left(\frac{3}{5}\right)^4$

$\frac{I_1}{I_2} = \frac{3 \times 3 \times 3 \times 3}{5 \times 5 \times 5 \times 5} = \frac{81}{625}$

$ratio\ of\ the\ insenties = 81 : 625$

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25. The radius of the 5th orbit of hydrogen atom is13.25 Å. Calculate the de broglie wavelengthof the electron orbitting in the 5th orbit.

Solution

$2\pi r = n\lambda$

$\lambda = \frac{2\pi r}{n}$

$n = 5$, $r = 13.25A^O$

$\lambda = \frac{2 \times 3.14 \times 13.25A^O}{5} = \frac{83.21A^O}{5}$

$\lambda = 16.24A^O$

26.Calculate the electric flux through the rectangle of sides 5 cm and 10 cm kept in the region of a uniform electric field 100 NC-1. The angle θ is $60^{0.}$ Suppose θ becomes zero, what is the electric flux?

$The\ eletric\ flux \emptyset_E = \vec{E}.\vec{A} = EA\cos\theta$

$\emptyset_E = 100 \times 5 \times 10 \times 10^{-4} \times \cos 60^0$

$\emptyset_E = 100 \times 5 \times 10 \times 10^{-4} \times \frac{1}{2}$

$\emptyset_E = 0.25 Nm^2C^{-1}$

$For\ \theta = 0$

$\emptyset_E = 100 \times 5 \times 10 \times 10^{-4} \times \cos 0^0$

$\emptyset_E = 100 \times 5 \times 10 \times 10^{-4} \times 1$

$\emptyset_E = 0.5 Nm^2C^{-1}$

27.A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is?

Given

$N = 50 \quad r = 5cm = 5 \times 10^{-2}m, I = 3A$

$Magnetic\ dipole\ moment\ p_m = N \times I \times A$

$p_m = N \times I \times \pi r^2$

$p_m = 50 \times 3 \times 3.14 \times 25 \times 10^{-4}$

$p_m = 11775 \times 10^{-4}$

$p_m = 1.1775 = 1.2$

$p_m = 1.2Am^2$

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28. Find the heat energy produced in a resistance of 10 Ω when 5 A current flows through it for 5 minutes.

Given

$R = 10\Omega\,, \quad I = 5A\,, \quad t = 5min = 5 \times 60s$

$Heat\ energy\ produced\ H = I^2Rt$

$H = 5 \times 5 \times 10 \times 300$

$H = 25 \times 3000$

$H = 75000J$

$H = 75KJ$

29.What should be the velocity of electron so that its momentum equals that of $4000A^0$ wave length of photon

Given data

$\lambda = 4000A^0 = 4000 \times 10^{-10} = 4 \times 10^{-7}m$

$p = ? \quad v = ?$

$$p = \frac{h}{\lambda} = \frac{6.62 \times 10^{-34}}{4 \times 10^{-7}}$$

$p = 1.655 \times 10^{-27} Kgm/s$

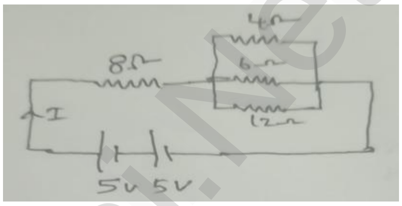
$$velocity\ of\ electron\ (v) = \frac{p}{m}$$

$$velocity\ of\ electron\ (v) = \frac{1.655 \times 10^{-27}}{9.11 \times 10^{-31}}$$

$$velocity\ of\ electron\ (v) = 1818\frac{m}{s}$$

30.Two cells each of 5V are connected in series with a 8 Ω resistor and three parallel resistors of 4 Ω, 6 Ω and 12 Ω. Draw a circuit diagram for the above arrangement. Calculate i) the current drawn from the cells (ii) current through each resistor

Circuit diagram



Equivalent resistors of 4,6. 12 resistors Connected in parallel is given by

$$\frac{1}{R_P} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$$

$$\frac{1}{R_P} = \frac{6}{12}$$

$$R_P = 2\Omega$$

$$R_{eff} = R_S + R_P$$

$$R_{eff} = 8 + 2 = 10\Omega$$

$$Total\ voltage\ V = 10V$$

$$We\ knoe\ that\ V = IR$$

$$I = \frac{V}{R_{eff}} = \frac{10}{10} = 1A$$

$$current\ drawn\ from\ the\ cell\ I = 1A$$

$$the\ current\ through\ 8\Omega, I = 1A$$

$Voltage\ across\ parallel\ combination\ of three$

$resisters\ is\ V = IR_P = 1 \times 2 = 2V$

$the\ current\ through\ 4\Omega, I = \frac{V}{R} = \frac{2}{4} = 0.5A$

$the\ current\ through\ 6\Omega, I = \frac{V}{R} = \frac{2}{6} = 0.33A$

$the\ current\ through\ 12\Omega, I = \frac{V}{R} = \frac{2}{12}$
$= 1.7A$