FINAL JEE–MAIN EXAMINATION – APRIL, 2024

(Held On Tuesday 09th April, 2024) **TIME : 3 : 00 PM to 6 : 00 PM**

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

31. A nucleus at rest disintegrates into two smaller nuclei with their masses in the ratio of 2:1. After disintegration they will move :-

(1) In opposite directions with speed in the ratio of 1:2 respectively

(2) In opposite directions with speed in the ratio of 2:1 respectively

(3) In the same direction with same speed.

(4) In opposite directions with the same speed.

Ans. (1)

Sol. By conservation of momentum

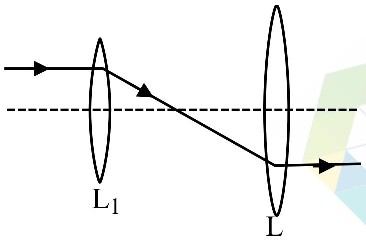
$p_i = p_f$

$O = m_1 u_1 + m_2 u_2$

$\frac{u_1}{u_2} = -\left[\frac{1}{2}\right]$ as $\frac{m_1}{m_2} = \frac{2}{1}$

move in opposite direction with speed ratio 1 : 2

32. The following figure represents two biconvex lenses L_1 and L_2 having focal length 10 cm and 15 cm respectively. The distance between L_1 & L_2 is :

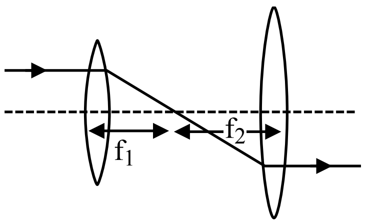


(1) 10 cm (2) 15 cm

(3) 25 cm (4) 35 cm

Ans. (3)

Sol.



$D = f_1 + f_2 = 25$ cm

Paraxial parallel rays pass through focus and ray from focus of convex lens will become parallel

33. The temperature of a gas is –78° C and the average translational kinetic energy of its molecules is K. The temperature at which the average translational kinetic energy of the molecules of the same gas becomes 2K is :

(1) –39°C (2) 117°C

(3) 127°C (4) –78°C

Ans. (2)

Sol. $K.E = \frac{nf_1RT}{2}$

$T_i = -78°C \rightarrow 273 + [-78°C] = 195K$

K.E α T

To double the K.E energy temp also become double

$T_f = 390$ K

$T_f = 117°C$

34. A hydrogen atom in ground state is given an energy of 10.2 eV. How many spectral lines will be emitted due to transition of electrons ?

(1) 6 (2) 3

(3) 10 (4) 1

Ans. (4)

Sol. Hydrogen will be in first excited state therefore it will emit one spectral line corresponding to transition b/w energy level 2 to 1

35. The magnetic field in a plane electromagnetic wave is $B_y = (3.5 \times 10^{-7}) \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)T$. The corresponding electric field will be

(1) $E_y = 1.17 \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)Vm^{-1}$

(2) $E_z = 105 \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)Vm^{-1}$

(3) $E_z = 1.17 \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)Vm^{-1}$

(4) $E_y = 10.5 \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)Vm^{-1}$

Ans. (2)

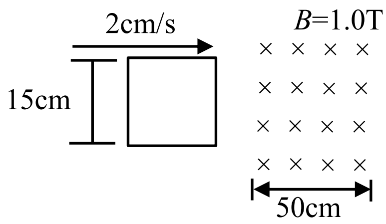
Sol. $E_0 = B_0C$

$E_0 = 3 \times 10^8 \times (3.5 \times 10^{-7}) \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)$

$E_0 = 105 \sin (1.5 \times 10^3 x + 0.5 \times 10^{11} t)Vm^{-1}$

Data inconsistent while calculating speed of wave. You can challenge for data.

36. A square loop of side 15 cm being moved towards right at a constant speed of 2 cm/s as shown in figure. The front edge enters the 50 cm wide magnetic field at t = 0. The value of induced emf in the loop at t = 10 s will be :

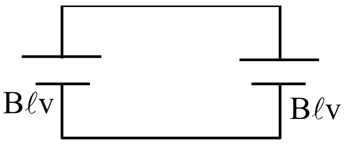


(1) 0.3 mV (2) 4.5 mV

(3) zero (4) 3 mV

Ans. (3)

Sol. At t = 10 sec complete loop is in magnetic field therefore no change in flux



$$e = \frac{d\phi}{dt} = 0$$

e = 0 for complete loop

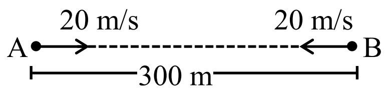
37. Two cars are travelling towards each other at speed of 20 m s^{-1} each. When the cars are 300 m apart, both the drivers apply brakes and the cars retard at the rate of 2 m s^{-2} . The distance between them when they come to rest is :

(1) 200 m (2) 50 m

(3) 100 m (4) 25 m

Ans. (3)

Sol.



$|\vec{u}_{BA}| = 40\ m/s$

$|\vec{a}_{BA}| = 4\ m/s$

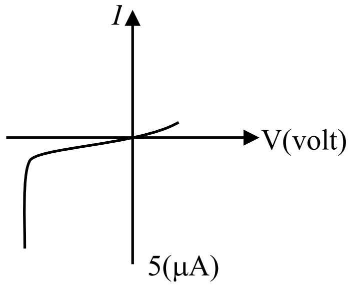
Apply $(v^2 = u^2 + 2as)_{relative}$

$O = (40)^2 + 2(-4)(S)$

S = 200 m

Remaining distance = 300 – 200 = 100 m

38. The *I-V* characteristics of an electronic device shown in the figure. The device is :



(1) a solar cell

(2) a transistor which can be used as an amplifier

(3) a zener diode which can be used as voltage regulator

(4) a diode which can be used as a rectifier

Ans. (3)

Sol. Theory

Zener diode used as voltage regulator

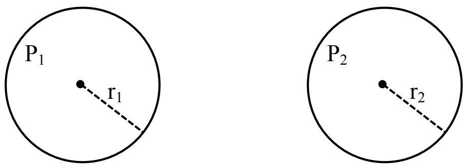
39. The excess pressure inside a soap bubble is thrice the excess pressure inside a second soap bubble. The ratio between the volume of the first and the second bubble is :

(1) 1 : 9 (2) 1 : 3

(3) 1 : 81 (4) 1 : 27

Ans. (4)

Sol.



$$P_1 - P_0 = \frac{4T}{r_1} \qquad P_2 - P_0 = \frac{4T}{r_2}$$

$$P_1 - P_0 = 3(P_2 - P_0)$$

$$\frac{4T}{r_1} = 3\frac{4T}{r_2}$$

$r_2 = 3r_1$

$$\frac{V_1}{V_2} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \frac{1}{27}$$

40. The de-Broglie wavelength associated with a particle of mass m and energy E is $h/\sqrt{2mE}$. The dimensional formula for Planck's constant is :

(1) $[ML^{-1}T^{-2}]$ (2) $[ML^{2}T^{-1}]$

(3) $[MLT^{-2}]$ (4) $[M^{2}L^{2}T^{-2}]$

Ans. (2)

Sol. $\lambda = \dfrac{h}{\sqrt{2mE}}$ or $E = h\nu$

$[ML^{2}T^{-2}] = h[T^{-1}]$

$h = [ML^{2}T^{-1}]$

41. A satellite of 10^{3} kg mass is revolving in circular orbit of radius 2R. If $\dfrac{10^{4}R}{6} J$ energy is supplied to the satellite, it would revolve in a new circular orbit of radius :

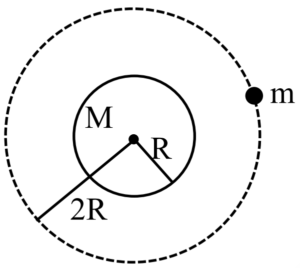
(use $g = 10 m/s^{2}$, R = radius of earth)

(1) 2.5 R (2) 3 R

(3) 4 R (4) 6 R

Ans. (4)

Sol.



Total energy $= \dfrac{-GMm}{2(2R)}$

if energy $= \dfrac{10^{4}R}{6}$ is added then

$$\frac{-GMm}{4R} + \frac{10^{4}R}{6} = \frac{-GMm}{2r}$$

where r is new radius of revolving and $g = \dfrac{GM}{R^{2}}$

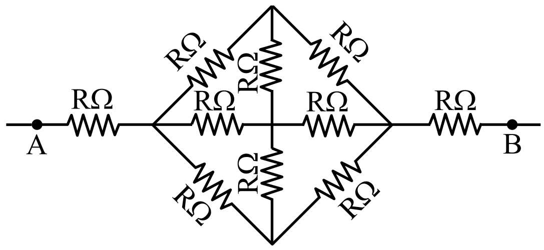
$$-\frac{mgR}{4} + \frac{10^{4}R}{6} = -\frac{mgR^{2}}{2r} \quad (m = 10^{3} \text{ kg})$$

$$-\frac{10^{3}\times 10\times R}{4} + \frac{10^{4}R}{6} = -\frac{10^{3}\times 10\times R^{2}}{2r}$$

$$-\frac{1}{4} + \frac{1}{6} = -\frac{R}{2r}$$

$r = 6R$

42. The effective resistance between A and B, if resistance of each resistor is R, will be



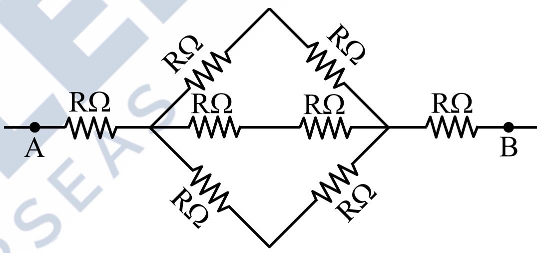
(1) $\dfrac{2}{3}R$ (2) $\dfrac{8R}{3}$

(3) $\dfrac{5R}{3}$ (4) $\dfrac{4R}{3}$

Ans. (2)

Sol. From symmetry we can remove two middle resistance.

New circuit is



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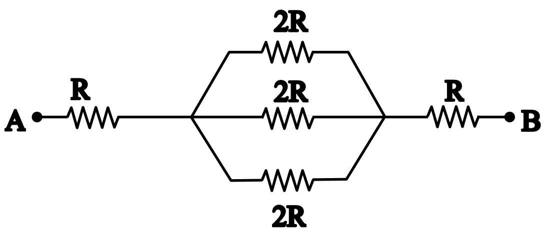

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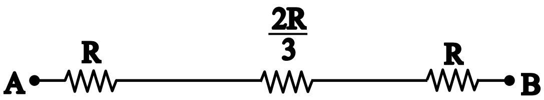

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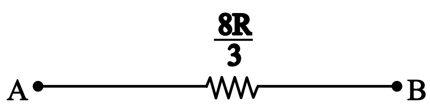
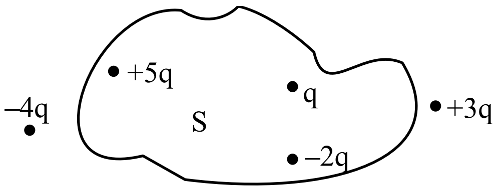


43. Five charges +q, +5q, –2q, +3q and –4q are situated as shown in the figure. The electric flux due to this configuration through the surface S is :



(1) $\frac{5q}{\epsilon_0}$ (2) $\frac{4q}{\epsilon_0}$

(3) $\frac{3q}{\epsilon_0}$ (4) $\frac{q}{\epsilon_0}$

Ans. **(2)**

Sol. As per gauss theorem,

$$\phi = \frac{q_{in}}{\epsilon_0} = \frac{q+(-2q)+5q}{\epsilon_0}$$

$$\frac{4q}{\epsilon_0}$$

44. A proton and a deutron (q= +e, m = 2.0u) having same kinetic energies enter a region of uniform magnetic field $\vec{B}$, moving perpendicular to $\vec{B}$. The ratio of the radius r_d of deutron path to the radius r_p of the proton path is :

(1) 1 : 1 (2) $1:\sqrt{2}$

(3) $\sqrt{2}:1$ (4) $1:2$

Ans. **(3)**

Sol. In uniform magnetic field,

$$R = \frac{mv}{qB} = \frac{\sqrt{2m(K.E)}}{qB}$$

Since same K.E

$$R \propto \frac{\sqrt{m}}{q}$$

$$\therefore \frac{R_{deutron}}{R_{proton}} = \sqrt{\frac{m_d}{m_p}} \times \frac{q_p}{q_d}$$

$$= \sqrt{2} \times 1$$

$$\therefore \gamma_d : \gamma_p = \sqrt{2}:1$$

45. UV light of 4.13 eV is incident on a photosensitive metal surface having work function 3.13 eV. The maximum kinetic energy of ejected photoelectrons will be :

(1) 4.13 eV (2) 1 eV

(3) 3.13 eV (4) 7.26 eV

Ans. **(2)**

Sol. E_{photon} = (work function) + K.E_{max}

$\therefore$ 4.13 = 3.13 + K.E_{max}

$\therefore$ K.E_{max} = 1 eV

46. The energy released in the fusion of 2 kg of hydrogen deep in the sun is E_H and the energy released in the fission of 2 kg of ^{235}U is E_U. The ratio $\frac{E_H}{E_U}$ is approximately :

(Consider the fusion reaction as $4\,{}^1_1H + 2e^- \rightarrow {}^4_2He + 2\nu + 6\gamma + 26.7\,MeV$, energy released in the fission reaction of ^{235}U is 200 *MeV* per fission nucleus and $N_A = 6.023\times10^{23}$)

(1) 9.13 (2) 15.04

(3) 7.62 (4) 25.6

Ans. **(3)**

Sol. In each fusion reaction, 4 ${}^1_1H$ nucleus are used.

Energy released per Nuclei of ${}^1_1H = \frac{26.7}{4}$ MeV

$\therefore$ Energy released by 2 kg hydrogen (E_H)

$$= \frac{2000}{1} \times N_A \times \frac{26.7}{4} MeV$$

&

$\therefore$ Energy released by 2 kg Vranium (E_V)

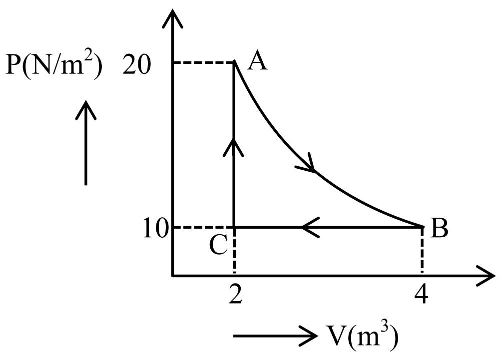
$$= \frac{2000}{235} \times N_A \times 200 MeV$$

So,

$$\frac{E_H}{E_V} = 235 \times \frac{26.7}{4\times200} = 7.84$$

$\therefore$ Approximately close to 7.62

47. A real gas within a closed chamber at 27°C undergoes the cyclic process as shown in figure. The gas obeys $PV^3 = RT$ equation for the path A to B. The net work done in the complete cycle is (assuming $R = 8$J/molK):



(1) 225 J (2) 205 J

(3) 20 J (4) –20 J

Ans. (2)

Sol. $W_{AB} = \int PdV$ (Assuming T to be constant)

$= \int \frac{RTdV}{V^3}$

$= RT\int_2^4 V^{-3}dV$

$= 8 \times 300 \times \left(-\frac{1}{2}\left[\frac{1}{4^2}-\frac{1}{2^2}\right]\right)$

$= 225$ J

$W_{BC} = P\int_4^2 dV = 10(2-4) = -20J$

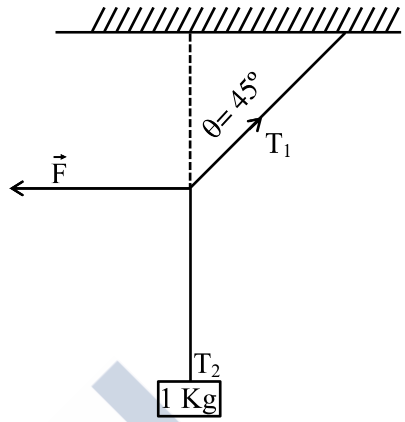
$W_{CA} = 0$

$\therefore W_{cycle} = 205$ J

Note : Data is inconsistent in process AB.

So needs to be challenged.

48. A 1 kg mass is suspended from the ceiling by a rope of length 4m. A horizontal force 'F' is applied at the mid point of the rope so that the rope makes an angle of 45° with respect to the vertical axis as shown in figure. The magnitude of F is :



(1) $\frac{10}{\sqrt{2}}$N (2) 1 N

(3) $\frac{1}{10\times\sqrt{2}}$N (4) 10 N

Ans. (4)

Sol. $T_1\sin45° = F$

$T_1 \cos45° = T_2 = 1\times g$

$\therefore \tan45° = \frac{F}{g}$

$\therefore F = 10N$

49. A spherical ball of radius 1×10^{-4} m and density 10^5 kg/m^3 falls freely under gravity through a distance h before entering a tank of water, If after entering in water the velocity of the ball does not change, then the value of h is approximately :

(The coefficient of viscosity of water is 9.8×10^{-6} N s/m^2)

(1) 2296 m (2) 2249 m

(3) 2518 m (4) 2396 m

Ans. (3)

Sol. $V_T = \frac{2g}{9}\frac{R^2[\rho_B - \rho_L]}{\eta}$

$\Rightarrow V_T = \frac{2}{9} \times \frac{10 \times \left(10^{-4}\right)^2}{9.8 \times 10^{-6}}\left[10^5 - 10^3\right]$

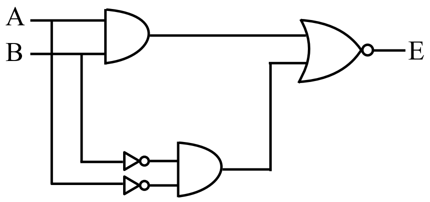
$\Rightarrow V_T = 224.5$

when ball fall from height (h)

$V = \sqrt{2gh}$

$h = \left(\frac{V^2}{2g}\right) = 2518\text{m}$

50.



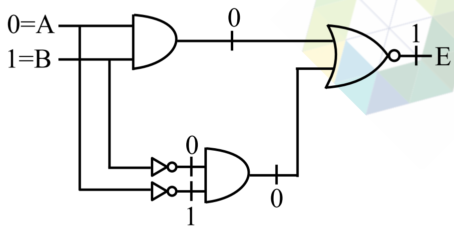
A	B	E
0	0	0
0	1	X
1	0	Y
1	1	0

In the truth table of the above circuit the value of X and Y are :

(1) 1, 1
(2) 1, 0
(3) 0, 1
(4) 0, 0

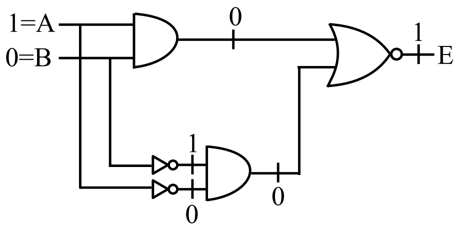
Ans. (1)

Sol. **For x**



x = 1

For y



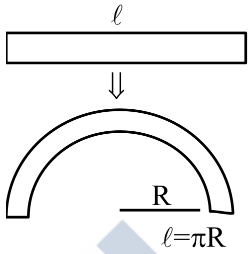
SECTION-B

51. A straight magnetic strip has a magnetic moment of 44 Am^2. If the strip is bent in a semicircular shape, its magnetic moment will be ………. Am^2.

(Given $\pi = \frac{22}{7}$)

Ans. **(28)**

Sol. Magnetic moment of straight wire = $m x\ell = 44$



Magnetic moment of arc

$= m \times 2r$

$= m \times \frac{2\ell}{\pi}$

$= \frac{44 \times 2}{\pi} = \frac{88}{\pi} = 28$

52. A particle of mass 0.50 kg executes simple harmonic motion under force $F = -50(Nm^{-1})x$. The time period of oscillation is $\frac{x}{35}$s. The value of x is ……………..

(Given $\pi = \frac{22}{7}$)

Ans. **(22)**

Sol. m = 0.5 kg

F = – 50 (x)

ma = (–50x)

0.5 a = – 50x

a = (–100x)

$W^2 = 100 \Rightarrow (w = 10)$

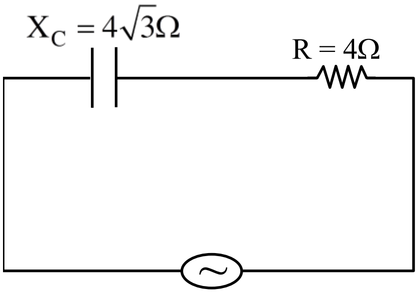
$T = \frac{2\pi}{10} = \left(\frac{\pi}{5}\right) = \frac{22}{7 \times 15} = \left(\frac{22}{35}\right)$

$\frac{\pi}{35} = \frac{22}{35} \Rightarrow \boxed{x = 22}$

53. A capacitor of reactance $4\sqrt{3}\Omega$ and a resistor of resistance 4Ω are connected in series with an ac source of peak value $8\sqrt{2}V$. The power dissipation in the circuit is ……………..W.

Ans. (4)

Sol.



$Z = \sqrt{R^2 + X^2L}$

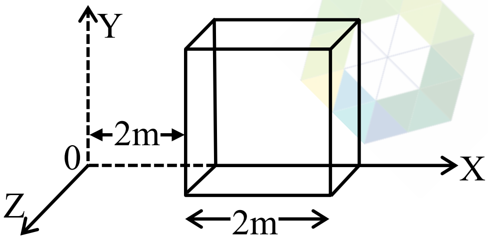
$Z = \sqrt{4^2 + \left(4\sqrt{3}\right)^2} = 8\Omega$

$V_{rms} = \frac{V}{\sqrt{2}} = \frac{8\sqrt{2}}{\sqrt{2}} = (8V)$

$I_{rms} = \frac{V_{rms}}{z} = \frac{8}{8} = 1A$

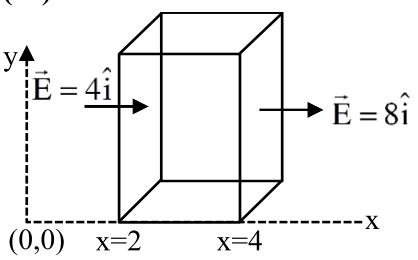
Power dissipated = $I^2_{rms} \times R = 1 \times 4 = (4W)$

54. An electric field $\vec{E} = (2x\hat{i})NC^{-1}$ exists in space. A cube of side 2m is placed in the space as per figure given below. The electric flux through the cube is ……………… Nm^2/C.



Ans. (16)

Sol.



$\vec{E} = 2x\hat{i}$

$\phi = \vec{E}.\vec{A}$

$\phi_{in} = -4 \times 4 = -16 Nm^2/c$

$\phi_{out} = 8 \times 4 = 32 Nm^2/c$

$d_{net} = \phi_{in} + \phi_{out} = -16 + 32 = 16 Nm^2/c$

55. A circular disc reaches from top to bottom of an inclined plane of length *l*. When it slips down the plane, if takes t s. When it rolls down the plane then it takes $\left(\frac{\alpha}{2}\right)^{1/2}$ t s, where α is ………..

Ans. (3)

Sol. For slipping

$a = g\sin\theta$

$\ell = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2\ell}{g\sin\theta}}$

For rolling

$a' = \frac{g\sin\theta}{1 + \frac{k^2}{R^2}} \left[k = \frac{R}{\sqrt{2}}\right]$

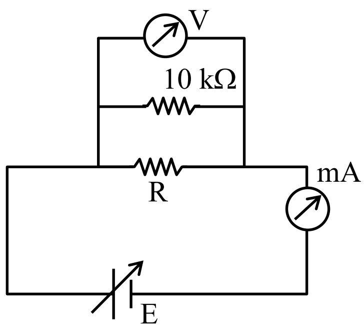
$\Rightarrow a' = \frac{2g\sin\theta}{3}$

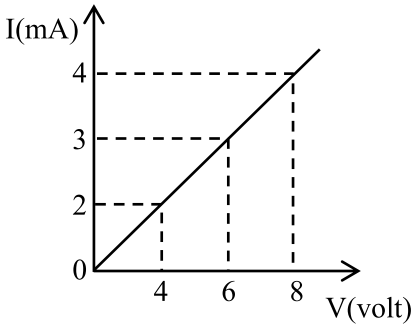
$\ell = \frac{1}{2}a'(t')^2$

$\Rightarrow t' = \sqrt{\frac{6\ell}{2g\sin\theta}} = \sqrt{\frac{\alpha}{2}}\sqrt{\frac{2\ell}{g\sin\theta}}$

$\Rightarrow \boxed{\alpha = 3}$

56. To determine the resistance (R) of a wire, a circuit is designed below, The V-I characteristic curve for this circuit is plotted for the voltmeter and the ammeter readings as shown in figure. The value of R is ………… Ω.





Ans. (2500)

Sol. $\text{Req} = \dfrac{10^4 R}{10^4 + R}$

$E = 4V, I = 2mA$

$I = \dfrac{E}{\text{Req}} \Rightarrow 2 \times 10^{-3} = \dfrac{4(10^4 + R)}{10^4 R}$

$\Rightarrow 20R = 40000 + 4R$

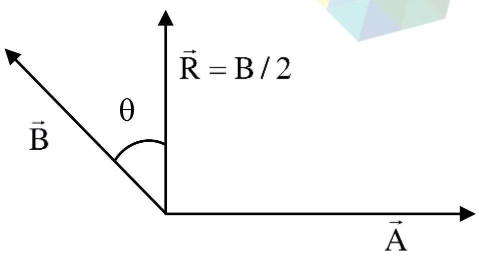
$16R = 40000$

$R = 2500\Omega$

57. The resultant of two vectors $\vec{A}$ and $\vec{B}$ is perpendicular to $\vec{A}$ and its magnitude is half that of $\vec{B}$. The angle between vectors $\vec{A}$ and $\vec{B}$ is …………

Ans. (150)

Sol.



$B\cos\theta = \dfrac{B}{2}$

$\Rightarrow \theta = 60°$

So, angle between $\vec{A}$ & $\vec{B}$ is 90° + 60° = 150°

58. Monochromatic light of wavelength 500 nm is used in Young's double slit experiment. An interference pattern is obtained on a screen When one of the slits is covered with a very thin glass plate (refractive index = 1.5), the central maximum is shifted to a position previously occupied by the 4^{th} bright fringe. The thickness of the glass-plate is ……………….µm.

Ans. (4)

Sol. $(\mu - 1)\, t = n\lambda$

$(1.5 - 1)\, t = 4 \times 500 \times 10^{-9}$ m

$t = 4000 \times 10^{-9}$ m

$t = 4\mu m$

59. A force $(3x^2 + 2x - 5)$ N displaces a body from x = 2 m to x = 4m. Work done by this force is ………..J.

Ans. (58)

Sol. $W = \int_{x_1}^{x_2} F dx$

$W = \int_2^4 (3x^2 + 2x - 5)dx$

$W = \left[x^3 + x^2 - 5x\right]_2^4$

$W = [60 - 2]J = 58J$

60. At room temperature (27ºC), the resistance of a heating element is 50Ω. The temperature coefficient of the material is 2.4×10^{-4} ºC^{-1}. The temperature of the element, when its resistance is 62 Ω, is ………… ºC.

Ans. (1027)

Sol. $R = R_0(1 + \alpha\Delta T)$

$62 = 50\,[1 + 2.4 \times 10^{-4}\Delta T]$

$\Delta T = 1000°C$

$\Rightarrow T - 27° = 1000°C$

$\boxed{T = 1027°C}$