FINAL JEE–MAIN EXAMINATION – APRIL, 2024

(Held On Thursday 04th April, 2024) TIME : 9 : 00 AM to 12 : 00 NOON

SECTION-A

31. An electron is projected with uniform velocity along the axis inside a current carrying long solenoid. Then :

(1) the electron will be accelerated along the axis.

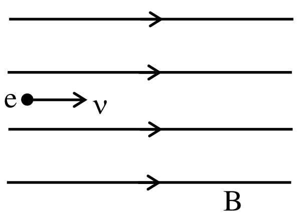
(2) the electron will continue to move with uniform velocity along the axis of the solenoid.

(3) the electron path will be circular about the axis.

(4) the electron will experience a force at 45° to the axis and execute a helical path.

Ans. (2)

Sol.



Since $\vec{v} \parallel \vec{B}$ so force on electron due to magnetic field is zero. So it will move along axis with uniform velocity.

32. The electric field in an electromagnetic wave is given by $\vec{E} = \hat{i}40\cos\omega\left(t - \frac{z}{c}\right)NC^{-1}$. The magnetic field induction of this wave is (in SI unit):

(1) $\vec{B} = \hat{i}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

(2) $\vec{B} = \hat{j}40\cos\omega\left(t - \frac{z}{c}\right)$

(3) $\vec{B} = \hat{k}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

(4) $\vec{B} = \hat{j}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

Ans. (4)

Sol. $\vec{E} = \hat{i}40\cos\omega\left(t - \frac{z}{c}\right)$

$\vec{E}$ is along +x direction

$\vec{v}$ is along +z direction

So direction of $\vec{B}$ will be along +y and magnitude of B will be $\frac{E}{c}$

So answer is $\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)\hat{j}$

33. Which of the following nuclear fragments corresponding to nuclear fission between neutron $\left({}_0^1n\right)$ and uranium isotope $\left({}_{92}^{235}U\right)$ is correct:

(1) ${}_{56}^{144}Ba + {}_{36}^{89}Kr + 4{}_0^1n$ (2) ${}_{56}^{140}Xe + {}_{38}^{94}Sr + 3{}_0^1n$

(3) ${}_{51}^{153}Sb + {}_{41}^{99}Nb + 3{}_0^1n$ (4) ${}_{56}^{144}Ba + {}_{36}^{89}Kr + 3{}_0^1n$

Ans. (4)

Sol. Balancing mass number and atomic number

$${}_{92}^{235}U + {}_0^1n \rightarrow {}_{56}^{144}Ba + {}_{36}^{89}Kr + 3{}_0^1n$$

34. In an experiment to measure focal length (f) of convex lens, the least counts of the measuring scales for the position of object (u) and for the position of image (v) are Δu and Δv, respectively. The error in the measurement of the focal length of the convex lens will be :

(1) $\frac{\Delta u}{u} + \frac{\Delta v}{v}$ (2) $f^2\left[\frac{\Delta u}{u^2} + \frac{\Delta v}{v^2}\right]$

(3) $2f\left[\frac{\Delta u}{u} + \frac{\Delta v}{v}\right]$ (4) $f\left[\frac{\Delta u}{u} + \frac{\Delta v}{v}\right]$

Ans. (2)

Sol. $f^{-1} = v^{-1} - u^{-1}$

$-f^{-2}\,df = -v^{-2}dv - u^{-2}du$

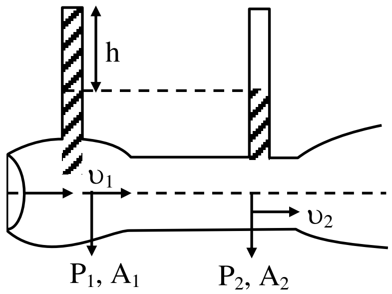
$$\frac{df}{f^2} = \frac{dv}{v^2} + \frac{du}{u^2}$$

$$df = f^2\left[\frac{dv}{v^2} + \frac{du}{u^2}\right]$$

35. Given below are two statements :

Statement I : When speed of liquid is zero everywhere, pressure difference at any two points depends on equation $P_1 - P_2 = \rho g (h_2 - h_1)$

Statement II : In ventury tube shown $2gh = \upsilon_1^2 - \upsilon_2^2$



In the light of the above statements, choose the most appropriate answer from the options given below.

(1) Both Statement I and Statement II are correct.

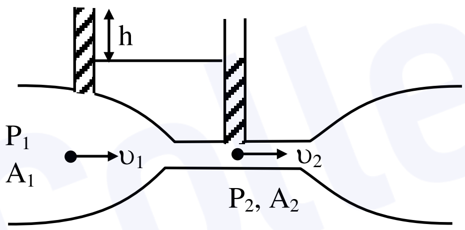
(2) Statement I is incorrect but Statement II is correct.

(3) Both Statement I and Statement II are incorrect.

(4) Statement I is correct but Statement II is incorrect.

Ans. (4)

Sol.



Applying Bernoulli's equation

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

[h_1 & h_2 are height of point from any reference level]

Given $V_1 = V_2 = 0$ (for statement-1)

$\therefore P_1 - P_2 = \rho g(h_2 - h_2)$

For statement-2

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$P_1 - P_2 = \rho g h$

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$$

$$\rho g h = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$$

$$2gh = v_2^2 - v_1^2$$

Hence answer (4)

36. The resistances of the platinum wire of a platinum resistance thermometer at the ice point and steam point are 8 Ω and 10 Ω respectively. After inserting in a hot bath of temperature 400°C, the resistance of platinum wire is :

(1) 2Ω (2) 16 Ω (3) 8 Ω (4) 10 Ω

Ans. (2)

Sol. Given $R_0 = 8\Omega$, $R_{100} = 10\Omega$

$\therefore R_{100} = R_0 (1 + \alpha\Delta T)$

Also, $R_{400} = R_0 (1 + \alpha\Delta T^1)$

$\therefore 10 = 8 (1 + \alpha \times 100) \Rightarrow 100\alpha = \frac{1}{4}$

$\therefore R_{400} = 8 (1 + 400\alpha) = 8 (1 + 1) = 16\Omega$

Hence option (2)

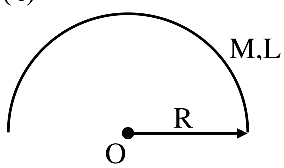
37. A metal wire of uniform mass density having length L and mass M is bent to form a semicircular arc and a particle of mass m is placed at the centre of the arc. The gravitational force on the particle by the wire is:

(1) $\frac{GMm\pi}{2L^2}$ (2) 0

(3) $\frac{GmM\pi^2}{L^2}$ (4) $\frac{2GmM\pi}{L^2}$

Ans. (4)

Sol.



We have $R = \frac{L}{\pi}$

$$g_0 = \frac{2G\frac{M}{L}}{R} = \frac{2GM\pi}{L^2}$$

$$\therefore F_m = mg_0 = \frac{2GM\pi m}{L^2}$$

Hence option (4)

38. On celcius scale the temperature of body increases by 40°C. The increase in temperature on Fahrenheit scale is:

(1) 70°F

(2) 68°F

(3) 72°F

(4) 75°F

Ans. **(3)**

Sol. We know that per °C change is equivalent to 1.8° change in °F.

$\therefore$ 40° change on celcius scale will corresponds to 72° change on Fahrenheit scale.

Hence option (3)

39. An effective power of a combination of 5 identical convex lenses which are kept in contact along the principal axis is 25 D. Focal length of each of the convex lens is :

(1) 20 cm

(2) 50 cm

(3) 500 cm

(4) 25 cm

Ans. **(1)**

Sol. We know that $P_{eq} = \Sigma P_i$

$\therefore$ given all lenses are identical

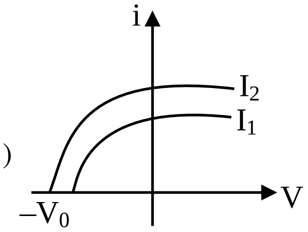
$\therefore$ 5P = 25D

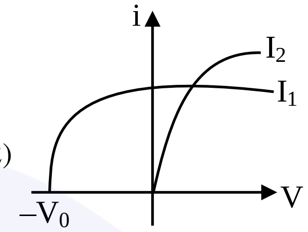
$\therefore$ P = 5D

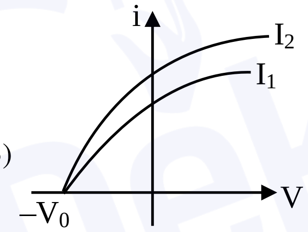
$$\therefore \frac{1}{f} = 5 \Rightarrow f = \frac{1}{5} m = 20cm$$

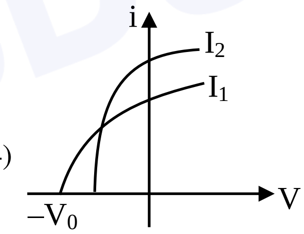
Hence option (1)

40. Which figure shows the correct variation of applied potential difference (V) with photoelectric current (I) at two different intensities of light ($I_1 < I_2$) of same wavelengths :

(1)


(2)


(3)


(4)


Ans. **(3)**

Sol. Given lights are of same wavelength.

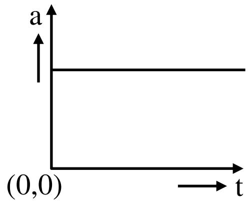
Hence stopping potential will remain same.

Since $I_2 > I_1$, hence saturation current corresponding to I_2 will be greater than that corresponding to I_1.

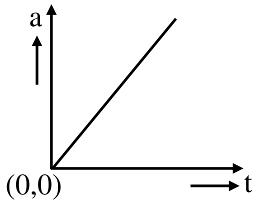
Hence option (3)

41. A wooden block, initially at rest on the ground, is pushed by a force which increases linearly with time t. Which of the following curve best describes acceleration of the block with time :

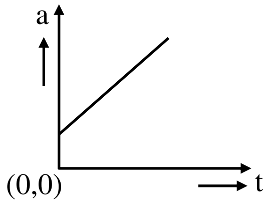
(1)



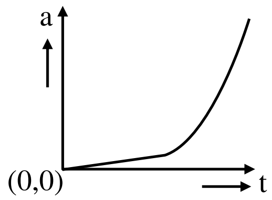
(2)



(3)

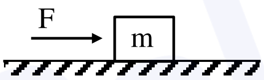


(4)



Ans. **(2)**

Sol.



$$F = ma \Rightarrow a = \frac{F}{m} = \frac{kt}{m}$$

a vs t will be straight line passing through origin.

Since option (2).

42. If a rubber ball falls from a height h and rebounds upto the height of h/2. The percentage loss of total energy of the initial system as well as velocity ball before it strikes the ground, respectively, are :

(1) 50%, $\sqrt{\frac{gh}{2}}$ (2) 50%, $\sqrt{gh}$

(3) 40%, $\sqrt{2gh}$ (4) 50%, $\sqrt{2gh}$

Ans. **(4)**

Sol. Velocity just before collision = $\sqrt{2gh}$

Velocity just after collision = $\sqrt{2g\left(\frac{h}{2}\right)}$

$$\therefore \Delta KE = \frac{1}{2}m(2gh) - \frac{1}{2}mgh$$

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

$\therefore$ % loss in energy

$$= \frac{\Delta KE}{KE_i} \times 100 = \frac{\frac{1}{2}mgh}{\frac{1}{2}mg2h} \times 100 = 50\%$$

Hence option (4)

43. The equation of stationary wave is :

$$y = 2a\sin\left(\frac{2\pi nt}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right)$$

Which of the following is NOT correct

(1) The dimensions of nt is [L]

(2) The dimensions of n is [LT^{-1}]

(3) The dimensions of n/λ is [T]

(4) The dimensions of x is [L]

Ans. **(3)**

Sol. Comparing the given equation with standard equation of standing $\frac{2\pi n}{\lambda} = \omega$ & $\frac{2\pi}{\lambda} = k$

$$\left[\frac{n}{\lambda}\right] = [\omega] = T^{-1}$$

$[nt] = [\lambda] = L$

$[n] = [\lambda\omega] = LT^{-1}$

$[x] = [\lambda] = L$

Hence option (3)

44. A body travels 102.5 m in n^{th} second and 115.0 m in $(n + 2)^{th}$ second. The acceleration is :

(1) 9 m/s^2 (2) 6.25 m/s^2

(3) 12.5 m/s^2 (4) 5 m/s^2

Ans. **(2)**

Sol. Given, $102.5 = u + \frac{a}{2}(2n - 1)$ &

$$115 = u + \frac{a}{2}(2n + 3)$$

$$\Rightarrow 102.5 = u + an - \frac{a}{2} \;\&$$

$$115 = u + an + \frac{3a}{2}$$

$12.5 = 2a \Rightarrow a = 6.25\ m/s^2$

Hence option (2)

45. To measure the internal resistance of a battery, potentiometer is used. For R = 10 Ω, the balance point is observed at ℓ = 500 cm and for R = 1 Ω the balance point is observed at ℓ = 400 cm. The internal resistance of the battery is approximately :

(1) 0.2 Ω (2) 0.4 Ω

(3) 0.1 Ω (4) 0.3 Ω

Ans. **(4)**

Sol. Let potential gradient be λ.

$\therefore\ i \times 10 = \lambda \times 500 = \varepsilon - ir_s$

$\Rightarrow 500\lambda = \varepsilon - 50\lambda r_s$

Also,

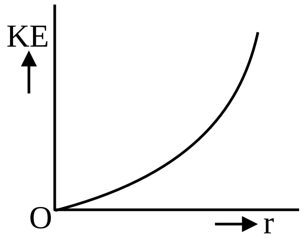
$i' \times 1 = \lambda \times 400 = \varepsilon - i'r_s$

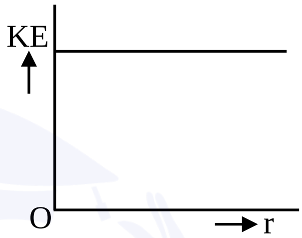
$\Rightarrow 400\lambda = \varepsilon - 400\,\lambda r_s$

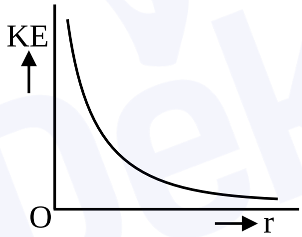
$\therefore\ 100\lambda = 350\lambda\, r_s \Rightarrow r_s = \frac{10}{35} \approx 0.3\Omega$

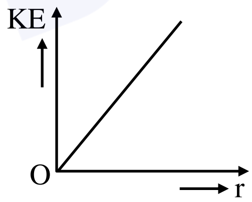
Hence option (4)

46. An infinitely long positively charged straight thread has a linear charge density λ Cm^{-1}. An electron revolves along a circular path having axis along the length of the wire. The graph that correctly represents the variation of the kinetic energy of electron as a function of radius of circular path from the wire is :

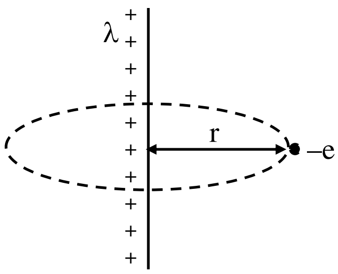
(1)


(2)


(3)


(4)


Ans. **(2)**

Sol.


Electric field E at a distance r due to infinite long wire is $E = \frac{2k\lambda}{r}$

Force of electron $\Rightarrow F = eE$

$$F = e\left(\frac{2k\lambda}{r}\right)$$

$$F = \frac{2k\lambda e}{r}$$

This force will provide required centripetal force

$$F = \frac{mv^2}{r} = \frac{2k\lambda e}{r}$$

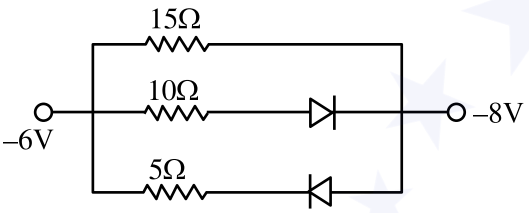
$$v = \sqrt{\frac{2k\lambda e}{m}}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{2k\lambda e}{m}\right)$$

$$= k\lambda e$$

This is constant so option (2) is correct.

47. The value of net resistance of the network as shown in the given figure is :

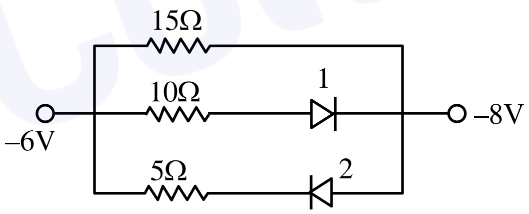


(1) $\left(\frac{5}{2}\right)\Omega$ (2) $\left(\frac{15}{4}\right)\Omega$

(3) 6Ω (4) $\left(\frac{30}{11}\right)\Omega$

Ans. **(3)**

Sol.

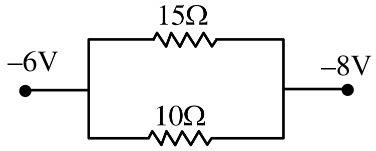


Diode 2 is in reverse bias

So current will not flow in branch of 2^{nd} diode, So we can assume it to be broken wire.

Diode 1 is in forward bias

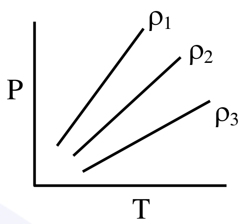
So it will behave like conducting wire. So new circuit will be



$$R_{eq} = \frac{15\times10}{15+10} = \frac{15\times10}{25} = 6\Omega$$

Correct answer (3)

48. P-T diagram of an ideal gas having three different densities ρ_1, ρ_2, ρ_3 (in three different cases) is shown in the figure. Which of the following is correct :



(1) $\rho_2 < \rho_3$ (2) $\rho_1 > \rho_2$

(3) $\rho_1 < \rho_2$ (4) $\rho_1 = \rho_2 = \rho_3$

Ans. **(2)**

Sol. For ideal gas

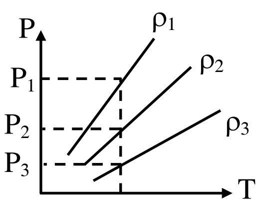
$$PV = nRT$$

$$PV = \frac{m}{M}RT$$

$$P = \left(\frac{M}{V}\right)\frac{RT}{M}$$

$$P = \frac{\rho RT}{M}$$

(Where m is mass of gas and M is molecular mass of gas)



for same temperature $P_1 > P_2 > P_3$

So $\rho_1 > \rho_2 > \rho_3$

So correct answer is (2)

49. The co-ordinates of a particle moving in x-y plane are given by :

$x = 2 + 4t$, $y = 3t + 8t^2$.

The motion of the particle is :

(1) non-uniformly accelerated.

(2) uniformly accelerated having motion along a straight line.

(3) uniform motion along a straight line.

(4) uniformly accelerated having motion along a parabolic path.

Ans. **(4)**

Sol. $x = 2 + 4t$

$$\frac{dx}{dt} = v_x = 4$$

$$\frac{dv_x}{dt} = a_x = 0$$

$y = 3t + 8t^2$

$$\frac{dy}{dt} = v_y = 3 + 16t$$

the motion will be uniformly accelerated motion.

For path

$x = 2 + 4t$

$$\frac{(x-2)}{4} = t$$

Put this value of t is equation of y

$$y = 3\left(\frac{x-2}{4}\right) + 8\left(\frac{x-2}{4}\right)^2$$

this is a quadratic equation so path will be parabola.

Correct answer (4)

50. In an ac circuit, the instantaneous current is zero, when the instantaneous voltage is maximum. In this case, the source may be connected to :

A. pure inductor.

B. pure capacitor.

C. pure resistor.

D. combination of an inductor and capacitor.

Choose the correct answer from the options given below :

(1) A, B and C only (2) B, C and D only

(3) A and B only (4) A, B and D only

Ans. **(4)**

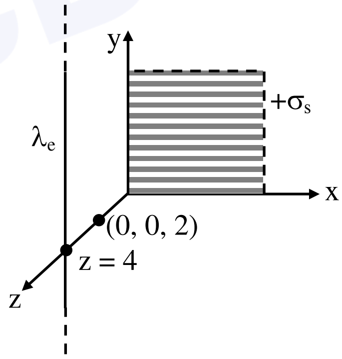
Sol. This is possible when phase difference is $\frac{\pi}{2}$ between current and voltage so correct answer will be (4)

SECTION-B

51. An infinite plane sheet of charge having uniform surface charge density $+\sigma_s$ C/m^2 is placed on x-y plane. Another infinitely long line charge having uniform linear charge density $+\lambda_e$ C/m is placed at z = 4m plane and parallel to y-axis. If the magnitude values $|\sigma_s| = 2|\lambda_e|$ then at point (0, 0, 2), the ratio of magnitudes of electric field values due to sheet charge to that of line charge is $\pi\sqrt{n} : 1$. The value of n is________.

Ans. **(16)**

Sol.



$$\frac{E_S}{E_\ell} = \frac{\sigma}{2\epsilon_0} \times \frac{2\pi\epsilon_0 r}{\lambda}$$

$$= \frac{\pi \times \sigma r}{\lambda}$$

$$= \frac{\pi \times 2\lambda \times 2}{\lambda} = \frac{4\pi}{1}$$

$\therefore$ n = 16

52. A hydrogen atom changes its state from n = 3 to n = 2. Due to recoil, the percentage change in the wave length of emitted light is approximately 1×10^{-n}. The value of n is___________.

[Given Rhc = 13.6 eV, hc = 1242 eV nm, $h = 6.6 \times 10^{-34}$ J s, mass of the hydrogen atom $= 1.6 \times 10^{-27}$ kg]

Ans. (7)

Sol. $\Delta E = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ = 1.9 eV

$$\Delta E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E}$$

$P_i = P_f$

$$0 = -mv + \frac{h}{\lambda'}$$

$$\Rightarrow v = \frac{h}{m\lambda'}$$

$$\Delta E = \frac{1}{2}mv^2 + \frac{hc}{\lambda'}$$

$$= \frac{1}{2}m\left(\frac{h}{m\lambda'}\right)^2 + \frac{hc}{\lambda'}$$

Now

$$\Delta E = \frac{h^2}{2m\lambda'^2} + \frac{hc}{\lambda'}$$

$$\lambda'^2 \Delta E - hc\lambda' - \frac{h^2}{2m} = 0$$

$$\lambda' = \frac{hc \pm \sqrt{h^2c^2 + \frac{4\Delta E h^2}{2m}}}{2\Delta E}$$

$$\lambda' = \frac{hc \pm hc\sqrt{1 + \frac{2\Delta E}{mc^2}}}{2\Delta E}$$

$$\frac{\lambda'}{\lambda} = \frac{1 + \left(1 + \frac{2\Delta E}{mc^2}\right)^{\frac{1}{2}}}{2} = \frac{1 + 1 + \frac{\Delta E}{mc^2}}{2}$$

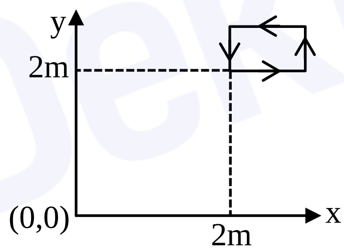
$$\frac{\lambda'}{\lambda} = 1 + \frac{\Delta E}{2mc^2}$$

$$\frac{\lambda' - \lambda}{\lambda} = \frac{\Delta E}{2mc^2} = \frac{1.9 \times 1.6 \times 10^{-19}}{2 \times 1.67 \times 10^{-27} \times 9 \times 10^{16}} = 10^{-9}$$

$\therefore$ % change $\approx 10^{-7}$

Correct answer 7

53. The magnetic field existing in a region is given by $\vec{B} = 0.2(1 + 2x)\hat{k}$ T. A square loop of edge 50 cm carrying 0.5 A current is placed in x-y plane with its edges parallel to the x-y axes, as shown in figure. The magnitude of the net magnetic force experienced by the loop is______ mN.



Ans. (50)

Sol. Force on segment parallel to x-axis will cancel each other. Hence F_{net} will be due to portion parallel to y-axis.

F = 0.5 × 0.5 × 6 × 0.2 – 0.5 × 0.5 × 0.2 × 5

= 0.5 × 0.5 × 0.2

= 0.25 × 0.2

= 50×10^{-3} N

= 50 mN

54. A alternating current at any instant is given by $i = \left[6 + \sqrt{56}\sin\left(100\pi t + \frac{\pi}{3}\right)\right] A$. The rms value of the current is___________ A.

Ans. **(8)**

Sol. $I_{rms} = \sqrt{\frac{\int i^2 dt}{\int dt}}$

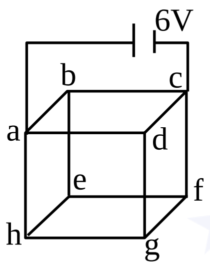
$$I_{rms} = \sqrt{(6)^2 + \frac{(\sqrt{56})^2}{2}}$$

$= \sqrt{36 + 28}$

$= \sqrt{64}$

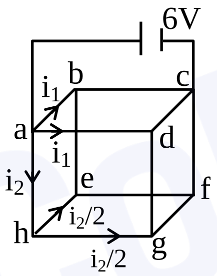
= 8A

55. Twelve wires each having resistance 2Ω are joined to form a cube. A battery of 6 V emf is joined across point a and c. The voltage difference between e and f is_____ V.



Ans. **(1)**

Sol.



From symmetry, current through e-b & g-d = 0

$\therefore R_{eq} = \frac{3}{4} \times R = \frac{3}{2}\Omega$

$\therefore$ Current through battery $= \frac{6 \times 2}{3} = 4A$

$i_2 = \frac{4}{8} \times 2 = 1A$

$\therefore$ ΔV across e-f $= \frac{i_2}{2} \times R = \frac{1}{2} \times 2 = 1V$

56. A soap bubble is blown to a diameter of 7 cm. 36960 erg of work is done in blowing it further. If surface tension of soap solution is 40 dyne/cm then the new radius is ______ cm. Take : $\left(\pi = \frac{22}{7}\right)$.

Ans. **(7)**

Sol. $\omega = \Delta U = S\Delta A$

$$36960 \text{ erg} = \frac{40 \text{dyne}}{\text{cm}} 8\pi\left[(r)^2 - \left(\frac{7}{2}\right)^2\right]\text{cm}^2$$

r = 7 cm

57. Two wavelengths λ_1 and λ_2 are used in Young's double slit experiment λ_1 = 450 nm and λ_2 = 650 nm. The minimum order of fringe produced by λ_2 which overlaps with the fringe produced by λ_1 is n. The value of n is ____.

Ans. **(9)**

Sol. $n_2\lambda_2 = n_1\lambda_1$

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} = \frac{450}{650} = \frac{9}{13}$$

$n_2 = 9$

58. An elastic spring under tension of 3 N has a length a. Its length is b under tension 2 N. For its length (3a – 2b), the value of tension will be_____ N.

Ans. **(5)**

Sol. $3 = K(a - \ell)$

$2 = K(b - \ell)$

$T = K(3a - 2b - \ell)$

$T = K(3(a - \ell) - 2(b - \ell)$

$$= K\left[3\left(\frac{3}{K}\right) - 2\left(\frac{2}{K}\right)\right]$$

= 9 – 4

= 5 N

59. Two forces $\vec{F}_1$ $\vec{F}_2$ ng on a body. One force has magnitude thrice that of the other force and the resultant of the two forces is equal to the force of larger magnitude. The angle between $\vec{F}_1$ and $\vec{F}_2$ is $\cos^{-1}\left(\frac{1}{n}\right)$. The value of $|n|$ is ____.

Ans. **(6)**

Sol. $|\vec{F}_1| = F$

$|\vec{F}_R| = |\vec{F}_2| = 3F$

$F_R^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$

$9F^2 = F^2 + 9F^2 + 6F^2\cos\theta$

$\cos\theta = -\frac{1}{6}$

$\theta = \cos^{-1}\left(\frac{1}{-6}\right)$

$n = -6$

$|n| = 6$

60. A solid sphere and a hollow cylinder roll up without slipping on same inclined plane with same initial speed v. The sphere and the cylinder reaches upto maximum heights h_1 and h_2, respectively, above the initial level. The ratio $h_1 : h_2$ is $\frac{n}{10}$. The value of n is_____.

Ans. **(7)**

Sol Gain in P.E. = Loss in K.E.

$$mgh = \frac{1}{2}mv^2\left(1+\frac{K^2}{R^2}\right)$$

$$h \propto 1+\frac{K^2}{R^2}$$

$$\frac{h_1}{h_2} = \frac{1+\frac{2}{5}}{1+1} = \frac{7}{5\times 2} = \frac{7}{10}$$

$n = 7$