JEE MAIN 2024
Paper with Solution

PHYSICS | 1st February 2024 _ Shift-1

SECTION – A

31. With rise in temperature, the Young's modules of elasticity:

(1) changes erratically (2) decreases (3) increases (4) remains unchanged

Sol. **2**

$y = \frac{F/A}{\Delta\ell/\ell} = \frac{F/A}{\alpha\Delta T}$ as $\Delta T \uparrow$, $y \downarrow$

32. If R is the radius of the earth and the acceleration due to gravity on the surface of earth is $g = \pi^2$ m/s^2, then the length of the second's pendulum at a height h = 2R from the surface of earth will be, :

(1) $\frac{2}{9}$m (2) $\frac{1}{9}$m (3) $\frac{4}{9}$m (4) $\frac{8}{9}$m

Sol. **2**

$g = \frac{GM}{R^2} = \pi^2$

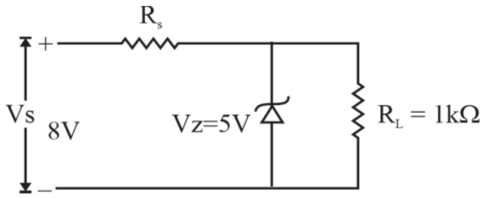
$g' = \frac{GM}{9R^2} = \frac{\pi^2}{9}$

We know, $T = 2\pi\sqrt{\frac{\ell}{g}}$

$2 = 2\pi\sqrt{\frac{\ell \times 9}{\pi^2}}$

On solving, $\ell = \frac{1}{9}$ m

33. In the given circuit if the power rating of Zener diode is 10 mW, the value of series resistance R_s to regulate the input unregulated supply is:



(1) 5 kΩ (2) 10 Ω (3) 1 kΩ (4) 10 kΩ

Sol. **3 (by NTA)**

$V_{RS} = 3V$

$I_{LR} = \frac{5}{10^3} = 5mA$

$I_{Z(Max.)} = \frac{10}{5} = 2mA$

$I_{Z(Min.)} = 0$

$I_{S(Max.)} = 7mA$

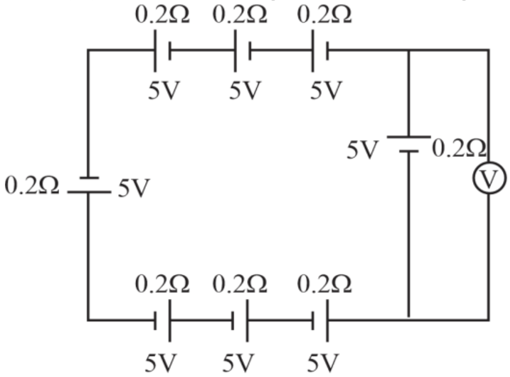
$I_{S(Min.)} = 5mA$

$R_{S(Max.)} = \frac{3}{5}$ KΩ

$R_{S(Min.)} = \frac{3}{7}$ KΩ

$\frac{3}{7}k\Omega < R_S < \frac{3}{5}k\Omega$

34. The reading in the ideal voltmeter (V) shown in the given circuit diagram is:



(1) 5V (2) 10V (3) 0V (4) 3V

Sol. **3**

$i = \frac{40}{1.6}$

i = 25A

Reading of voltmeter = 5 – I × R

= 5 – 25 × .2

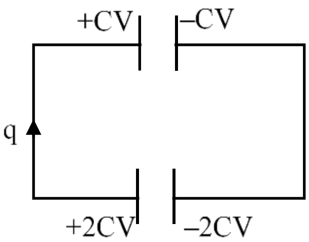
= 0

35. Two identical capacitors have same capacitance C. One of them is charged to the potential V and other to the potential 2V. The negative ends of both are connected together. When the positive ends are also joined together, the decrease in energy of the combined system is:

(1) $\frac{1}{4}CV^2$ (2) $2CV^2$ (3) $\frac{1}{2}CV^2$ (4) $\frac{3}{4}CV^2$

Sol. **1**

Initial energy = $\frac{1}{2}CV^2 + \frac{1}{2}C \times 4V^2 = \frac{5CV^2}{2}$



$\frac{2CV - q}{C} = \frac{CV + q}{C}$

2CV – CV = 2q

$q = \frac{CV}{2}$

Final charge on capacitor = $\frac{3CV}{2}$

$\text{Energy}_{\text{final}} = 2 \times \left(\frac{3CV}{2}\right)^2 \times \frac{1}{2C} = \frac{9CV^2}{4}$

Decrease in energy = $\frac{5CV^2}{2} - \frac{9CV^2}{4} = \frac{CV^2}{4}$

36. Two moles a monoatomic gas is mixed with six moles of a diatomic gas. The molar specific heat of the mixture at constant volume is:

(1) $\frac{9}{4}R$ (2) $\frac{7}{4}R$ (3) $\frac{3}{2}R$ (4) $\frac{5}{2}R$

Sol. **1**

$$C_{V_{mix}} = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}$$

$$= \frac{2\times\frac{3R}{2} + 6\times\frac{5R}{2}}{8}$$

$$= \frac{9R}{4}$$

37. A ball of mass 0.5 kg is attached to a string of length 50cm. The balls is rotated on a horizontal circular path about its vertical axis. The maximum tension that the string can bear is 400 N. The maximum possible value of angular velocity of the ball in rad/s is,:

(1) 1600 (2) 40 (3) 1000 (4) 20

Sol. **2**

$T = m\omega^2R$

$400 = \frac{1}{2} \times \omega^2 \times \frac{1}{2}$

$\omega^2 = 1600$

$\omega = 40$ rad/sec.

38. A parallel plate capacitor has a capacitance C = 200 pF. It is connected to 230 V ac supply with an angular frequency 300 rad/s. The rms value of conduction current in the circuit and displacement current in the capacitor respectively are:

(1) 1.38 μA and 1.38 μA (2) 14.3 μA and 143 μA

(3) 13.8 μA and 138 μA (4) 13. 8 μA and 13. 8 μA

Sol. **4**

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

$$= \frac{230\times200\times10^{-12}\times300}{1}$$

= 13.8 μA

39. The pressure and volume of an ideal gas are related as $PV^{\frac{3}{2}}$ = K(Constant). The work done when the gas is taken from state A (P_1, V_1, T_1) to state B (P_2, V_2, T_2) is:

(1) $2(P_1V_1 - P_2V_2)$ (2) $2(P_2V_2 - P_1V_1)$ (3) $2\left(\sqrt{P_1}V_1 - \sqrt{P_2}V_2\right)$ (4) $2\left(P_2\sqrt{V_2} - P_1\sqrt{V_1}\right)$

Sol. **1**

$Pv^{3/2} = K$

$$WD = \frac{P_2V_2 - P_1V_1}{1 - x}$$

$$= \frac{P_2V_2 - P_1V_1}{1 - \frac{3}{2}}$$

$= 2(P_1V_1 - P_2V_2)$

40. A galvanometer has a resistance of 50Ω and it allows maximum current of 5 mA. It can be converted into voltmeter to measure upto 100V by connecting in series a resistor of resistance:

(1) 5975 Ω (2) 20050 Ω (3) 19950 Ω (4) 19500 Ω

Sol. **3**

$i_g = 5mA$

$R_g = 50\Omega$

$100 = 5 \times 10^{-3} (50 + S)$

$10^5 = 5(50 + S)$

$20000 - 50 = S$

$S = 19950\Omega$

41. The de Broglie wavelengths of a proton and an α particle are λ and 2λ respectively. The ratio of the velocities of proton and α particle will be:

(1) 1 : 8 (2) 1 : 2 (3) 4 : 1 (4) 8 : 1

Sol. **4**

$P = \frac{h}{\lambda}$

$mv = \frac{h}{\lambda} \quad \Rightarrow \quad v = \frac{h}{m\lambda}$

$\frac{v_p}{v_\alpha} = \frac{m_\alpha \lambda_\alpha}{m_p \lambda_p} = \frac{4m_p \times 2\lambda}{m_p \times \lambda} = 8:1$

42. 10 divisions on the main scale of a Vernier calliper coincide with 11 divisions on the Vernier scale. If each division on the main scale is of 5 units, the least count of the instrument is:

(1) $\frac{1}{2}$ (2) $\frac{10}{11}$ (3) $\frac{50}{11}$ (4) $\frac{5}{11}$

Sol. **4**

11VSD = 10MSD

$1VSD = \frac{10}{11} MSD$

$= \frac{50}{11}$ units

Least count = 1MSD – 1VSD

$= 5 - \frac{50}{11} = \frac{5}{11}$ units

43. In series LCR circuit, the capacitance is changed from C to 4C. To keep the resonance frequency unchanged, the new inductance should be:

(1) reduced by $\frac{1}{4}L$ (2) increased by 2L (3) reduced by $\frac{3}{4}L$ (4) increased to 4L

Sol. **3**

$\omega = \frac{1}{\sqrt{LC}}$ …(i)

$\omega = \frac{1}{\sqrt{L' \times 4C}}$ …(ii)

on comparing (i) & (ii)

$\left(L' = \frac{L}{4}\right)$

44. The radius (r), length (l) and resistance (R) of a metal wire was measured in the laboratory as

r = (0.35 ± 0.05) cm

R = (100 ± 10) ohm

l = (15 ± 0.2) cm

The percentage error in resistivity of the material of the wire is:

(1) 25.6 % (2) 39.9% (3) 37.3% (4) 35.6%

Sol. **2**

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

$\rho = \frac{R\pi r^2}{L}$

$$\frac{d\rho}{\rho} = \frac{dR}{R} + \frac{dL}{L} + 2\frac{dr}{r}$$

$$\frac{d\rho}{\rho} = \left(\frac{10}{100} + \frac{.2}{15} + 2\times\frac{.05}{.35}\right)\times 100\%$$

$$\left(\frac{d\rho}{\rho}\right)\times 100 = 39.9\%$$

45. The dimensional formula of angular impulse is:

(1) $[ML^{-2}T^{-1}]$ (2) $[ML^2T^{-2}]$ (3) $[MLT^{-1}]$ (4) $[ML^2T^{-1}]$

Sol. **4**

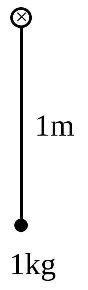
Angular Impulse = change in angular momentum

$[A.I.] = [ML^2T^{-1}]$

46. A simple pendulum of length 1m has a wooden bob of mass 1kg. It is struck by a bullet of mass 10^{-2} kg moving with a speed of 2×10^2 ms^{-1}. The bullet gets embedded into the bob. The height to which the bob rises before swinging back is. (use g = 10 m/s^2)

(1) 0.30 m (2) 0.20 m (3) 0.35 m (4) 0.40 m

Sol. **2**



$P_i = P_f \Rightarrow 10^{-2} \times 2 \times 10^2 = (1 + .01)v$

$v = \frac{2}{1.01} = 1.98$ m/sec.

$\frac{1}{2} \times m_T \times v^2 = m_T gh$

$h = \frac{v^2}{2g} = \frac{1.98\times 1.98}{20}$

h = 0.20m

47. A particle moving in a circle of radius R with uniform speed takes time T to complete one revolution. If this particle is projected with the same speed at an angle θ to the horizontal, the maximum height attained by it is equal to 4R. The angle of projection θ is then given by:

(1) $\sin^{-1}\left[\frac{2gT^2}{\pi^2 R}\right]^{\frac{1}{2}}$ (2) $\sin^{-1}\left[\frac{\pi^2 R}{2gT^2}\right]^{\frac{1}{2}}$ (3) $\cos^{-1}\left[\frac{2gT^2}{\pi^2 R}\right]^{\frac{1}{2}}$ (4) $\cos^{-1}\left[\frac{\pi R}{2gT^2}\right]^{\frac{1}{2}}$

Sol. **1**

$T = \frac{2\pi R}{v}$

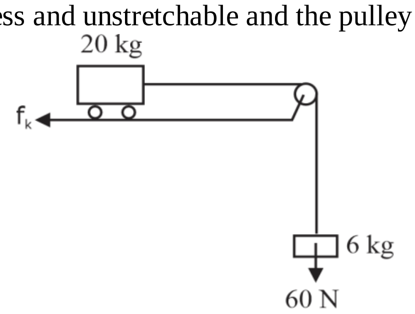
$\Rightarrow v = \frac{2\pi R}{T}$

$4R = \frac{v^2 \sin^2\theta}{2g}$

$\sin^2\theta = \frac{8RgT^2}{4\pi^2 R^2} = \frac{2gT^2}{\pi^2 R}$

$\theta = \sin^{-1}\left(\frac{2gT^2}{\pi^2 R}\right)^{1/2}$

48. Consider a block and trolley system as shown in figure. If the coefficient of kinetic friction between the trolley and the surface is 0.04, the acceleration of the system in ms^{-2} is:
(Consider that the string is massless and unstretchable and the pulley is also massless and frictionless) :



(1) 3 (2) 4 (3) 2 (4) 1.2

Sol. **3**

$f_{max.} = .04 \times 200 = 8N$

Acceleration = $\frac{60 - 8}{26}$ = $2m/s^2$

49. The minimum energy required by a hydrogen atom in ground state to emit radiation in Balmer series is nearly:

(1) 1.5 eV (2) 13.6 eV (3) 1.9 eV (4) 12.1 eV

Sol. **4**

Transition from $n \rightarrow 1$ to $n \rightarrow 3$

$E = 13.6 \times Z\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$

$= 13.6 \times 1 \times \left[\frac{1}{1} - \frac{1}{9}\right]$

$= 13.6 \times \frac{8}{9} = 12.1$ eV

50. A monochromatic light of wavelength 6000 Å is incident on the single slit of width 0.01 mm. If the diffraction pattern is formed at the focus of the convex lens of focal length 20cm, the linear width of the central maximum is:

(1) 60 mm (2) 24 mm (3) 120 mm (4) 12 mm

Sol. **2**

Angular width = $\frac{2\lambda}{a}$

Linear width = $\frac{2\lambda}{a} \cdot f$

$= \frac{2 \times 6000 \times 10^{-10} \times 20 \times 10^{-2}}{.01 \times 10^{-3}}$

$= 24 \times 10^{-3}$ m

= 24 mm

SECTION – B

51. A regular polygon of 6 sides is formed by bending a wire of length 4π meter. If an electric current of $4\pi\sqrt{3}$ A is flowing through the sides of the polygon, the magnetic field at the centre of the polygon would be $x \times 10^{-7}$ T. The value of x is __________.

Sol. **72**

$B_C = \frac{\mu_0 i}{4\pi \times a\cos 30} \times 2\sin 30 \times n$

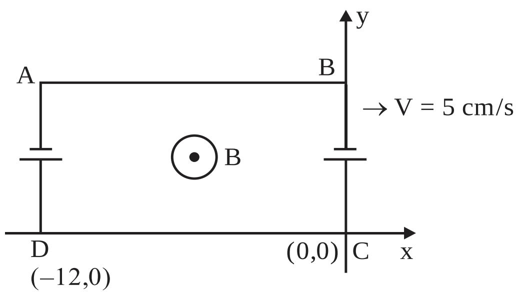
$= \frac{10^{-7} \times 4\pi\sqrt{3} \times 2 \times \tan 30 \times 6 \times 3}{2\pi}$

$= 72 \times 10^{-7} = x \times 10^{-7}$

x = 72

52. A rectangular loop of sides 12cm and 5cm, with its sides parallel to the x-axis and y-axis respectively, moves with a velocity of 5cm/s in the positive x axis direction, in a space containing a variable magnetic field in the positive z direction. The field has a gradient of 10^{-3} T/cm along the negative x direction and it is decreasing with time at the rate of 10^{-3} T/s. If the resistance of the loop is 6 mΩ, the power dissipated by the loop as heat is _____ $\times 10^{-9}$ W.

Sol. **216**



$\frac{dB}{dx} = \frac{-10^{-3}}{10^{-2}}$

$$\int_{B}^{B_0} dB = -\int_{0}^{-x} 10^{-1} dx$$

$$B_0 - B = -\left[-\frac{x}{10}\right]$$

$$B = B_0 - \frac{x}{10}$$

$$B = B_0 - \frac{x}{10}$$

Motional emf in AB & CD = 0

Motional emf in BC = $B_0\ell v = \varepsilon_1$

Motional emf in AD = $\left(B_0 - \left(\frac{-12\times10^{-2}}{10}\right)\right)\ell v$

Motional emf in $\varepsilon_2 = (B_0 + 12 \times 10^{-3})\ell v$

$\varepsilon_{eq} = \varepsilon_2 - \varepsilon_1 = 12 \times 10^{-3} \times 5 \times 10^{-2} \times 5 \times 10^{-2}$
$= 300 \times 10^{-7}$ v

$\varepsilon = \frac{AdB}{dt} = 60 \times 10^{-4} \times 10^{-3}$
$= 60 \times 10^{-7}$ v

$\varepsilon_{net} = (300 + 60) \times 10^{-7} = 360 \times 10^{-7}$

$P = \frac{(\varepsilon_{net})^2}{R} = \frac{360\times360\times10^{-14}}{6\times10^{-3}}$
$= 21600 \times 10^{-11}$
$= 216 \times 10^{-9}$ w

53. The distance between object and its 3 times magnified virtual image as produced by a convex lens is 20 cm. The focal length of the lens used is ______ cm.

Sol. **15**

$m = \frac{v}{u} \quad \Rightarrow \quad v = 3u$

$\because v - u = 20$

$3u - u = 20 \quad \Rightarrow \quad u = 10$ cm, $v = 30$ cm

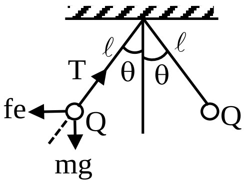
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$= -\frac{1}{30} + \frac{1}{10} = \frac{-1+3}{30} = \frac{2}{30}$

f = 15 cm

54. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle θ with each other. When suspended in water the angle remains the same. If density of the material of the sphere is 1.5 g/cc, the dielectric constant of water will be _______ (Take density of water = 1 g/cc)

Sol. **3**



$$\tan\theta = \frac{KQ^2}{(2\ell\sin\theta)^2 \times \rho v g} \quad \ldots(i)$$

$$\tan\theta = \frac{KQ^2}{\varepsilon(2\ell\sin\theta)^2 \times (\rho v - \rho_w v)g} \quad \ldots(ii)$$

Compare (i) & (ii)

$\varepsilon(\rho v - \rho_w v)g = \rho v g$

$$\varepsilon = \frac{1.5}{1.5-1} = \frac{1.5}{.5} = 3$$

$\varepsilon = 3$

55. The radius of a nucleus of mass number 64 is 4.8 fermi. Then the mass number of another nucleus having radius of 4 fermi is $\frac{1000}{x}$, where x is _______.

Sol. **27**

$R = R_0A^{1/3}$

$4.8 = R_0(64)^{1/3}$

$4.8 = R_04 \quad \ldots(i)$

$4 = R_0\,(A)^{1/3} \quad \ldots(ii)$

(i) divided (ii)

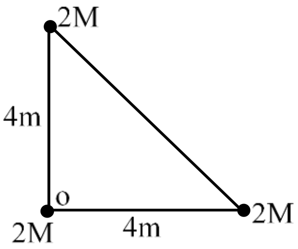
$$1.2 = \frac{4}{(A)^{1/3}}$$

$$A = \frac{64}{1.728} = \frac{1000}{x}$$

$$x = \frac{1728}{64} = 27$$

56. The identical spheres each of mass 2M are placed at the corners of a right angled triangle with mutually perpendicular sides equal to 4m each. Taking point of intersection of these two sides as origin, the magnitude of positon vector of the centre of mass of the system is $\frac{4\sqrt{2}}{x}$, where the value of x is _______.

Sol. **3**



$$X_{COM} = \frac{2M \times 4}{6M} = \frac{4}{3}m$$

$$Y_{COM} = \frac{2M \times 4}{6M} = \frac{4}{3}m$$

$$|\vec{r}| = \sqrt{\left(\frac{4}{3}\right)^2 + \left(\frac{4}{3}\right)^2} = \frac{4}{3}\sqrt{2} = \frac{4\sqrt{2}}{x}$$

x = 3

57. A tuning fork resonates with a sonometer wire of length 1m stretched with a tension of 6N. When the tension in the wire is changed to 54N, the same tuning fork produces 12 beats per second with it. The frequency of the tuning fork is __________ Hz.

Sol. **6**

$$f_1 = \frac{1}{2\times1}\sqrt{\frac{6}{\mu}} \qquad \ldots(i)$$

$$f_2 = \frac{1}{2\times1}\sqrt{\frac{54}{\mu}} \qquad \ldots(ii)$$

$$f_2 - f_1 = \frac{1}{2}\left[3\sqrt{\frac{6}{\mu}} - \sqrt{\frac{6}{\mu}}\right] = 12$$

$$2\sqrt{\frac{6}{\mu}} = 24$$

$$f_1 = \frac{1}{2} \times 12 = 6Hz$$

f_1 = 6Hz

58. A plane is in level flight at constant speed and each of its two wings has an area of 40 m^2. If the speed of the air is 180 km/h over the lower wing surface and 252 km/h over the upper wing surface, the mass of the plane is ____ kg. (Take air density to be 1 kg m^{-3} and g = 10 ms^{-2})

Sol. **9600**

By Bernoulli's equation

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

$$\frac{1}{2}\times\rho\times[4900-2500]=\frac{mg}{A}$$

$$\frac{1}{2}\times 1\times 2400=\frac{m\times 10}{80}$$

m = 9600 kg

59. The current in a conductor is expressed as $I = 3t^2 + 4t^3$, where I is in Ampere and t is in second. The amount of electric charge that flows through a section of the conductor during t = 1s to t = 2s is ______ C.

Sol. **22**

$I = 3t^2 + 4t^3$

$$\int dQ = \int I dt$$

$$Q = \int_1^2 \left(3t^2 + 4t^3\right) dt$$

$$= \left[t^3 + t^4\right]_1^2$$

= (8 + 16) – (2) = 22C

60. A particle is moving in one dimension (along x axis) under the action of a variable force. It's initial position was 16m right of origin. The variation of its position (x) with time (t) is given as $x = -3t^3 + 18t^2 + 16t$, where x is in m and t is in s. The velocity of the particle when its acceleration becomes zero is ______ m/s.

Sol. **52**

$x = -3t^3 + 18t^2 + 16t$

$v = -9t^2 + 36t + 16$

$a = -18t + 36 = 0$

t = 2sec.

at t = 2 sec.

$v = -9 \times 4 + 72 + 16$

= 88 – 36 = 52 m/sec.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