JEE–MAIN EXAMINATION – JANUARY 2025

(HELD ON FRIDAY 24th JANUARY 2025) **TIME : 3 : 00 PM TO 6 : 00 PM**

PHYSICS — TEST PAPER WITH SOLUTION

SECTION-A

26. Young's double slit interference apparatus is immersed in a liquid of refractive index 1.44. It has slit separation of 1.5mm. The slits are illuminated by a parallel beam of light whose wavelength in air is 690 nm. The fringe-width on a screen placed behind the plane of slits at a distance of 0.72m, will be :

(1) 0.23 mm (2) 0.33 mm

(3) 0.63 mm (4) 0.46 mm

Ans. (1)

Sol. $\beta = \left(\frac{\lambda_0}{\mu}\right) \times \frac{D}{d} = \frac{690 \times 10^{-9} \times 0.72}{1.44 \times 1.5 \times 10^{-3}} = 0.23 \text{ mm}$

27. Arrange the following in the ascending order of wavelength (λ) :

(A) Microwaves (λ_1)

(B) Ultraviolet rays (λ_2)

(C) Infrared rays (λ_3)

(D) X-rays (λ_4)

Choose the **most appropriate** answer from the options given below :-

(1) $\lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$

(2) $\lambda_3 < \lambda_4 < \lambda_2 < \lambda_1$

(3) $\lambda_4 < \lambda_2 < \lambda_3 < \lambda_1$

(4) $\lambda_4 < \lambda_3 < \lambda_1 < \lambda_2$

Ans. (3)

Sol.

γ-rays	X-rays	U.V rays	Visible rays	IR rays	Micro waves	Radio waves

$\longrightarrow$ $\lambda\uparrow$

28. Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason(R).**

Assertion (A) : A electron in a certain region of uniform magnetic field is moving with constant velocity in a straight line path.

Reason (A) : The magnetic field in that region is along the direction of velocity of the electron.

In the light of the above statements, choose the **correct** answer from the options given below :

(1) **(A)** is false but **(R)** is true

(2) Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**

(3) Both **(A)** and **(R)** are true but **(R)** is **NOT** the correct explanation of **(A)**

(4) **(A)** is true but **(R)** is false

Ans. (2)

Sol. $\bar{F} = q(\bar{v} \times \bar{B})$

$\bar{F} = 0$

$\bar{V} \parallel \bar{B}$

$\theta = 0$ or 180

29. A solid sphere is rolling without slipping on a horizontal plane. The ratio of the linear kinetic energy of the centre of mass of the sphere and rotational kinetic energy is :

(1) $\frac{2}{5}$ (2) $\frac{5}{2}$

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

Ans. (2)

Sol. $\frac{\text{Linear KE}}{\text{Rotational K.E}} = \frac{\frac{1}{2}mv_{cm}^2}{\frac{1}{2}I\omega^2}$

$\frac{mv_{cm}^2}{\frac{2}{5}mR^2\omega^2} = \frac{5}{2}$ $(V = \omega R)$

30. A long straight wire of a circular cross-section with radius 'a' carries a steady current I. The current I is a uniformly distributed across this cross-section. The plot of magnitude of magnetic field B with distance r from the centre of the wire is given by

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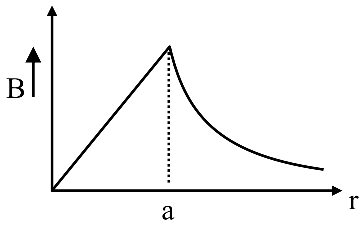

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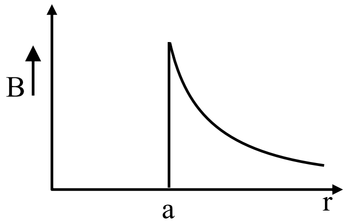

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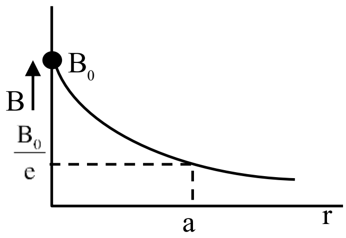

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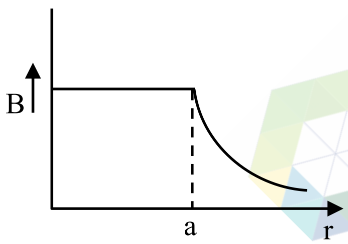
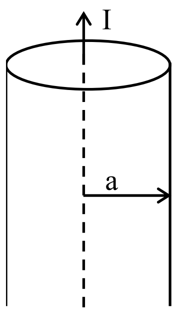


Ans. **(1)**

Sol.


$B_{in} = \frac{\mu_0(\vec{J} \times \vec{r})}{2}$

$B_{in} \propto r$

$B_{out} = \frac{\mu_0 I}{2\pi r}$

$B_{net} \propto \frac{1}{r}$

31. Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason(R).**

Assertion (A) : In an insulated container, a gas is adiabatically shrunk to half of its initial volume. The temperature of the gas decreases.

Reason (R) : Free expansion of an ideal gas is an irreversible and an adiabatic process.

In the light of the above statement, choose the **correct** answer from the options given below :

(1) Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**

(2) **(A)** is true but **(R)** is false

(3) **(A)** is false but **(R)** is true

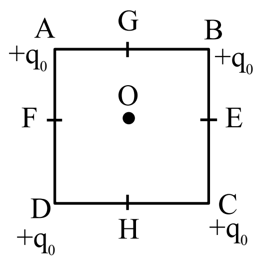
(4) Both **(A)** and **(R)** are true but **(R)** is **NOT** the correct explanation of (A)

Ans. **(3)**

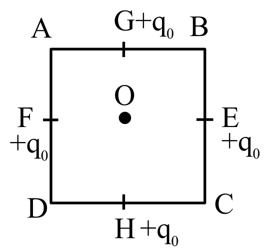
Sol. (A) $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

Temp increases

R) Free expansion is assumed fast, so Adiabatic

32.


Configuration(1)



Configuration(2)

In the first configuration (1) as shown in the figure, four identical charges (q_0) are kept at the corners A,B,C and D of square of side length 'a'. In the second configuration (2), the same charges are shifted to mid points G,E,H and F, of the square, If $K = \frac{1}{4\pi\varepsilon_0}$, the difference between the potential energies of configuration (2) and (1) is given by :

(1) $\frac{Kq_0^2}{a}\left(4\sqrt{2}-2\right)$ (2) $\frac{Kq_0^2}{a}\left(3-\sqrt{2}\right)$

(3) $\frac{Kq_0^2}{a}\left(4-2\sqrt{2}\right)$ (4) $\frac{Kq_0^2}{a}\left(3\sqrt{2}-2\right)$

Ans. **(4)**

Sol. $U_1 = \frac{4Kq_0^2}{a} + \frac{2Kq_0^2}{\sqrt{2}a} = \frac{Kq_0^2}{a}\left(4+\sqrt{2}\right)$

$$U_2 = \frac{Kq_0^2}{\left(\frac{a}{\sqrt{2}}\right)}\left(4+\sqrt{2}\right) = \frac{Kq_0^2}{a}\left(4\sqrt{2}+2\right)$$

$$U_2 - U_1 = \frac{Kq_0^2}{a}\left(3\sqrt{2}-2\right)$$

33. The position vector of a moving body at any instant of time is given as $\vec{r} = \left(5t^2\hat{i} - 5t\hat{j}\right)m$. The magnitude and direction of velocity at $t = 2s$ is,

(1) $5\sqrt{15}$ m/s, making an angle of $\tan^{-1} 4$ with –ve Y axis

(2) $5\sqrt{15}$ m/s, making an angle of $\tan^{-1} 4$ with +ve X axis

(3) $5\sqrt{17}$ m/s, making an angle of $\tan^{-1} 4$ with –ve Y axis

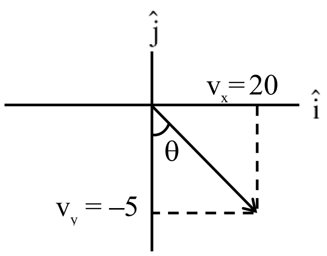
(4) $5\sqrt{17}$ m/s, making an angle of $\tan^{-1} 4$ with +ve X axis

Ans. **(3)**

Sol. $\vec{r} = 5t^2\hat{i} - 5t\hat{j}$

$\vec{v} = 10t\hat{i} - 5\hat{j}$

$\vec{v} = 20\hat{i} - 5\hat{j}$ at $t = 2sec$



$$\tan\theta = \frac{20}{5} = 4$$

$\theta = \tan^{-1} 4$

From –veY-axis

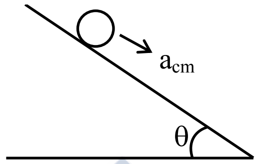
34. A solid sphere and a hollow sphere of the same mass and of same radius are rolled on an inclined plane. Let the time taken to reach the bottom by the solid sphere and the hollow sphere be t_1 and t_2, respectively, then

(1) $t_1 < t_2$ (2) $t_1 = t_2$

(3) $t_1 = 2t_2$ (4) $t_1 > t_2$

Ans. **(1)**

Sol.



$$t = \sqrt{\frac{2\ell}{a_{cm}}}$$

$$a_{cm} = \frac{g\sin\theta}{1+\frac{I_{cm}}{MR^2}}$$

$a_1 = a_{cm_1} = \frac{5g\sin\theta}{7}$ ..... Solid

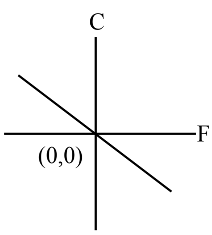
$a_2 = a_{cm_2} = \frac{3g\sin\theta}{5}$ ..... Hollow

$a_1 > a_2$

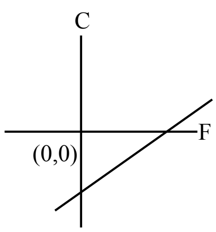
$t_1 < t_2$

35. Which of the following figure represents the relation between Celsius and Fahrenheit temperatures?

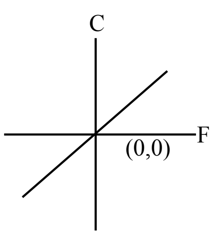
(1)



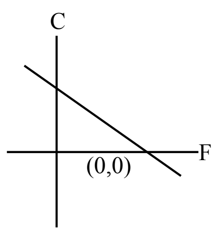
(2)



(3)

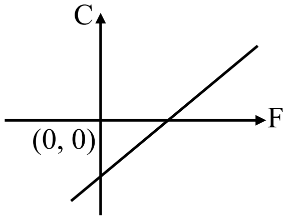


(4)

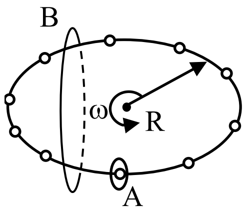


Ans. **(2)**

Sol. $\frac{C}{5}=\frac{F-32}{9} \Rightarrow C=\frac{5F}{9}-\frac{160}{9}$



36.



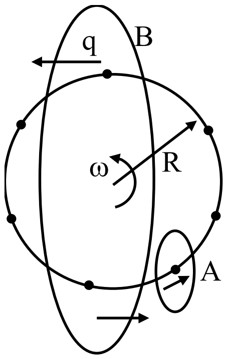
N equally spaced charges each of value q, are placed on a circle of radius R. The circle rotates about its axis with an angular velocity ω as shown in the figure. A bigger Amperian loop B encloses the whole circle where as a smaller Amperian loop A encloses a small segment. The difference between enclosed currents, $I_A - I_B$, for the given Amperian loops is

(1) $\frac{N^2}{2\pi}q\omega$ (2) $\frac{2\pi}{N}q\omega$

(3) $\frac{N}{2\pi}q\omega$ (4) $\frac{N}{\pi}q\omega$

Ans. **(3)**

Sol.



$$I_A=\frac{Nq}{\frac{2\pi}{\omega}}$$

$$I_A=\frac{Nq\omega}{2\pi},\ I_B=0$$

$$I_A-I_B=\frac{Nq\omega}{2\pi}$$

37. In photoelectric effect, the stopping potential (V_0) v/s frequency (ν) curve is plotted.

(h is the Planck's constant and ϕ_0 is work function of metal)

(A) V_0 v/s ν is linear

(B) The slope of V_0 v/s ν curve = $\frac{\phi_0}{h}$

(C) h constant is related to the slope of V_0 v/s ν line

(D) The value of electric charge of electron is not required to determine h using the V_0 v/s ν curve.

(E) The work function can be estimated without knowing the value of h.

Choose the **correct** answer from the options given below :

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

(2) (C) and (D) only

(3) (A),(C) and (E) only

(4) (D) and (E) only

Ans. **(3)**

Sol. $h\nu = \phi + KE_{max}$

$KE_{max} = eV_0$

$$V_0=\frac{h\nu-\phi}{e}$$

(A) V_0 v/s V is linear correct

(B) Slope

$$v_0=\left(\frac{h}{e}\right)\nu-\frac{\phi}{e} \quad \text{Wrong}$$

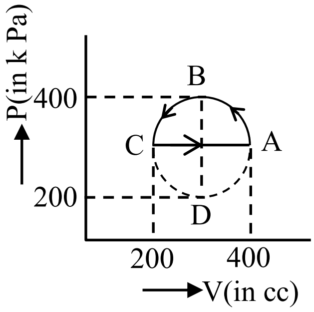
Slope $\frac{h}{e}$

(C) Correct

(D) Incorrect

(E) Correct

38. The magnitude of heat exchanged by a system for the given cyclic process ABCA (as shown in figure) is (in SI unit)

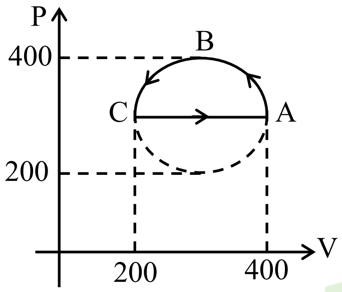


(1) 10π (2) 5π

(3) zero (4) 40π

Ans. (2)

Sol.



$$W = \frac{1}{2}\pi R^2$$

$$= \frac{1}{2} \times \pi \times \left(\frac{200}{2} \times 10^3\right) \times \frac{200}{2} \times 10^{-6}$$

$$= \frac{10\pi}{2} = 5\pi J$$

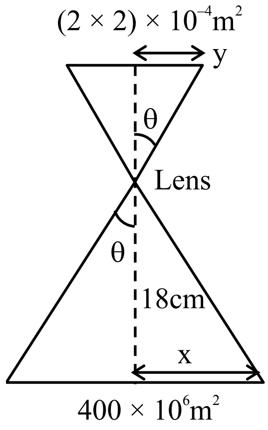
39. A photograph of a landscape is captured by a drone camera at a height of 18 km. The size of the camera film is 2 cm × 2 cm and the area of the landscape photographed is 400 km^2. The focal length of the lens in the drone camera is :

(1) 1.8 cm (2) 2.8 cm

(3) 2.5 cm (4) 0.9 cm

Ans. (1)

Sol.



H = 18 km

Size of camera film = 2cm × 2cm

$A_{image} = 400\ km^2$

$x = 20 \times 10^3\ m = 2 \times 10^4\ m$

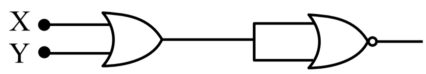
$y = 2 \times 10^{-2}\ m$

$$\frac{x}{y} = 10^6 = \frac{18Km}{f}$$

$f = 18 \times 10^{-3}\ m = 18\ mm$

f = 1.8 cm

40. The output of the circuit is low (zero) for :



(A) X = 0, Y= 0 (B) X = 0, Y= 1

(C) X = 1, Y= 0 (D) X = 1, Y= 1

Choose the **correct** answer from the options given below :

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

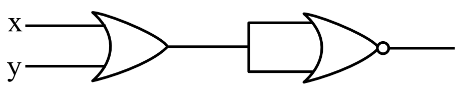
(2) (A), (B) and (C) only

(3) (B), (C) and (D) only

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

Ans. (3)

Sol.



x	y	
0	0	1
0	1	0
1	0	0
1	1	0

41. The temperature of a body in air falls from 40°C to 24°C in 4 minutes. The temperature of the air is 16°C. The temperature of the body in the next 4 minutes will be :

(1) $\frac{14}{3}$°C (2) $\frac{28}{3}$°C

(3) $\frac{56}{3}$°C (4) $\frac{42}{3}$°C

Ans. **(3)**

Sol. $\frac{T_2 - T_1}{t} = K\left[T_{avg} - T_s\right]$

$T_1 = 24°C;\ T_2 = 40°C,\ t = 4,\ T_S = 16°C$

$\frac{40-24}{4} = K[32-16]$

$K == \frac{4}{16} = \frac{1}{4}$

Now $\frac{24-T}{4} = K\left[\frac{T+24}{2} - 16\right]$

$24 - T = \frac{T-16}{2} + 16$

$\frac{3T}{2} = 28$

$T = \frac{56}{3}C$

42. The energy E and momentum p of a moving body of mass m are related by some equation. Given that c represents the speed of light, identify the correct equation.

(1) $E^2 = pc^2 + m^2c^4$ (2) $E^2 = pc^2 + m^2c^2$

(3) $E^2 = p^2c^2 + m^2c^2$ (4) $E^2 = p^2c^2 + m^2c^4$

Ans. **(4)**

Sol. $[E] = M^1L^2T^{-2}$

$[Pc] = M^1L^1T^{-1} . L^1T^{-1} = M^1L^2T^{-2}$

$[mc^2] = M^1L^2T^{-2}$

$E^2 = M^1L^2T^{-2}$

$E^2 = P^2c^2 + m^2c^4$

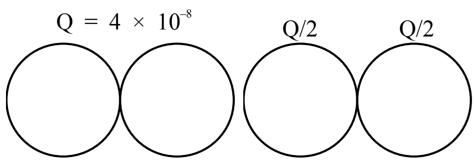
43. A small uncharged conducting sphere is placed in contact with an identical sphere but having 4×10^{-8} C charge and then removed to a distance such that the force of repulsion between them is 9×10^{-3} N. The distance between them is (Take $\frac{1}{4\pi\varepsilon_0}$ as 9×10^9 in SI units)

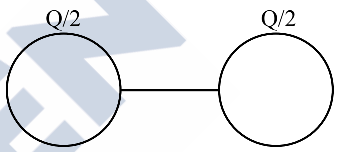
(1) 2 cm (2) 3 cm

(3) 4 cm (4) 1 cm

Ans. **(1)**

Sol.





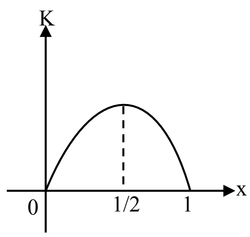
$F = \frac{k\left(\frac{\theta}{2}\right)\left(\frac{\theta}{2}\right)}{r^2}$

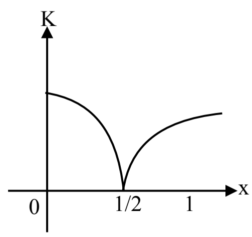
$9\times10^{-3} = \frac{9\times10^9\times(4\times10^{-8})\times4\times10^{-8}}{4\times r^2}$

$r^2 = \frac{9\times10^9\times16\times10^{-16}}{4\times9\times10^{-3}} = 4\times10^{-4}$

$r = 2 \times 10^{-2}$ m $\Rightarrow$ 2 cm

44. A particle oscillates along the x-axis according to the law, $x(t) = x_0 \sin^2\left(\frac{t}{2}\right)$ where $x_0 = 1$ m. The kinetic energy (K) of the particle as a function of x is correctly represented by the graph.

(1)


(2)


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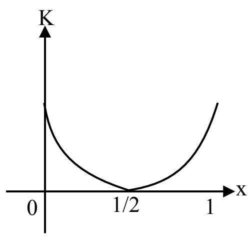

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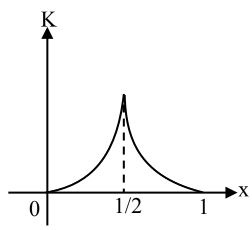


Ans. **(1)**

Sol. $x = x_0 \sin^2 \frac{t}{2} = x_0\left(\frac{1-\cos t}{2}\right)$

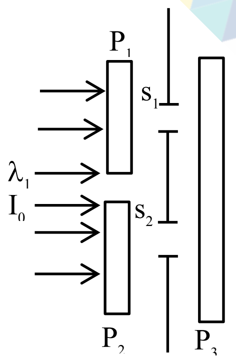
$x - \frac{x_0}{2} = \frac{-\cos t}{2}$

where $x_0 = 1$

$x - \frac{1}{2} = \frac{-\cos t}{2}$

Particle is oscillating between x = 0 to x = 1

45. In a Young's double slit experiment, three polarizers are kept as shown in the figure. The transmission axes of P_1 and P_2 are orthogonal to each other. The polarizer P_3 covers both the slits with its transmission axis at 45° to those of P_1 and P_2. An unpolarized light of wavelength λ and intensity I_0 is incident on P_1 and P_2. The intensity at a point after P_3 where the path difference between the light waves from s_1 and s_2 is $\frac{\lambda}{3}$, is

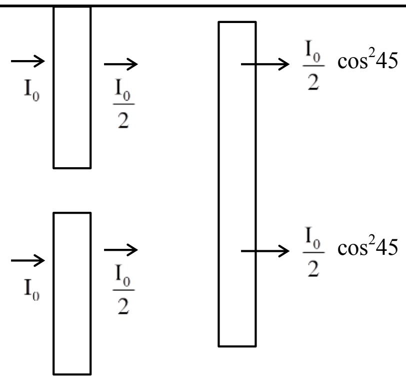


(1) $\frac{I_0}{2}$ (2) $\frac{I_0}{4}$

(3) I_0 (4) $\frac{I_0}{3}$

Ans. **(3)**

Sol.



(Unpolerised light) (Polerised light)

after passing through third poleriser, Intensity of both the waves must be $\frac{I_0}{4}$

now, at a point where path diff is $\frac{\lambda}{3}$, phase difference

$$\Delta\phi = 2K\left(\frac{\Delta x}{\lambda}\right) = \frac{2\pi}{3}$$

$$\therefore I_{res} = \sqrt{\left(\frac{I_0}{4}\right)^2 + \left(\frac{I_0}{4}\right)^2 + 2\left(\frac{I_0}{4}\right)^2 \cos\frac{2\pi}{3}}$$

$$= \frac{I_0}{4}$$

46. A tightly wound long solenoid carries a current of 1.5 A. An electron is executing uniform circular motion inside the solenoid with a time period of 75ns. The number of turns per metre in the solenoid is_______.
[Take mass of electron $m_e = 9 \times 10^{-31}$ kg, charge of electron $|q_e| = 1.6 \times 10^{-19}$ C,
$\mu_0 = 4\pi \times 10^{-7} \frac{N}{A^2}$, 1 ns = 10^{-9} s]

Ans. **(250)**

Sol. Since time period of a revolving charge is $\frac{2\pi m}{qB}$

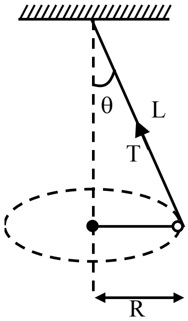
Where B = magnetic field
due to a solenoid = $\mu_0 nI$

$$\therefore\ T = \frac{2\pi m}{q(\mu_0 nI)}$$

$$75\times10^{-9} = \frac{(2\pi)(9\times10^{-31})}{1.6\times10^{-19}\times4\pi\times10^{-7}\times n\times1.5}$$

N = 250

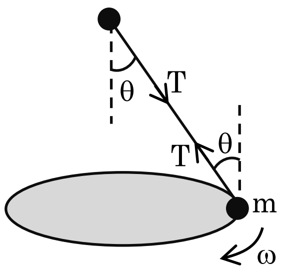
47.



A string of length L is fixed at one end and carries a mass of M at the other end. The mass makes $\left(\frac{3}{\pi}\right)$ rotations per second about the vertical axis passing through end of the string as shown. The tension in the string is _____ ML.

Ans. **(36)**

Sol.



$T\cos\theta = mg$ ...(1)

$T\sin\theta = M\omega^2 R$ ...(2)

Using equation (2)

$T\sin\theta = M\omega^2(L\sin\theta)$

$T = M\omega^2 L = M\left(\frac{3}{\pi}\times 2\pi\right)^2 L$

$T = 36$ ML

48. The ratio of the power of a light source S_1 to that the light source S_2 is 2. S_1 is emitting 2×10^{15} photons per second at 600 nm. If the wavelength of the source S_2 is 300 nm, then the number of photons per second emitted by S_2 is_____$\times10^{14}$.

Ans. **(5)**

Sol. Since power emitting by a source is given as

$$=\frac{\text{Total energy emitted}}{\text{time}}$$

$$=\frac{(E_1\ \text{photon})\times\text{Number of photons(N)}}{t}$$

$P_1 = (E_1)n$

$$\frac{P_1}{P_2}=\frac{(E_1)n_1}{(E_2)n_2}=\frac{\left(\frac{hC}{\lambda_1}\right)n_1}{\left(\frac{hC}{\lambda_2}\right)n_2}$$

$$\frac{P_1}{P_2}=\left(\frac{\lambda_2}{\lambda_1}\right)\frac{n_1}{n_2}$$

Substituting the given values

$$2=\left(\frac{300}{600}\right)\times\frac{2\times10^{15}}{n_2}$$

$$n_2=\frac{1}{2}\times10^{15}=5\times10^{14}\ \text{Photon/sec}$$

49. The increase in pressure required to decrease the volume of a water sample by 0.2% is $P\times10^5\,Nm^{-2}$. Bulk modulus of water is $2.15\times10^9\ Nm^{-2}$. The value of P is ________.

Ans. **(43)**

Sol. Since bulk modulus is given as

$$B=\frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)}$$

$$2.15\times10^9=\frac{-\Delta P}{-\left(\frac{0.2}{100}\right)}$$

$\Delta P = 2.15\times10^9\times2\times10^{-3}$

$=4.3\times10^6 = 43\times10^5\ N/m^2$

50. Acceleration due to gravity on the surface of earth is 'g'. If the diameter of earth is reduced to one third of its original value and mass remains unchanged, then the acceleration due to gravity on the surface of the earth is ____g.

Ans. **(9)**

Sol. $\because$ acceleration due to gravity on surface is given by

$$g=\frac{GM}{R_e^2}$$

Now since diameter is reduced to 1/3rd, radius also reduces to 1/3rd, keeping mass constant

New value of acceleration due to gravity on Earth's surface is

$$g'=\frac{GM}{\left(\frac{R_e}{3}\right)^2}=9\frac{GMe}{R_e^2}=9g$$