FINAL JEE–MAIN EXAMINATION – APRIL,2019

(Held On Friday 12th APRIL, 2019) TIME : 2 : 30 PM To 5 : 30 PM

PHYSICS

TEST PAPER WITH ANSWER & SOLUTION

1. The electron in a hydrogen atom first jumps from the third excited state to the second excited state and subsequently to the first excited state. The ratio of the respective wavelengths, λ_1/λ_2, of the photons emitted in this process is :

(1) 9/7 (2) 7/5

(3) 27/5 (4) 20/7

Official Ans. by NTA (4)

Sol. $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$$\frac{1}{\lambda_1} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$

$$\frac{1}{\lambda_1} = R\left(\frac{7}{9\times16}\right)$$

$$\frac{1}{\lambda_2} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$= R\left(\frac{5}{4\times9}\right)$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{5}{36}}{\frac{7}{9\times16}}$$

$$= \frac{20}{7}$$

2. One kg of water, at 20ºC, is heated in an electric kettle whose heating element has a mean (temperature averaged) resistance of 20 Ω. The rms voltage in the mains is 200 V. Ignoring heat loss from the kettle, time taken for water to evaporate fully, is close to :

[Specific heat of water = 4200 J/kg ºC), Latent heat of water = 2260 kJ/kg]

(1) 3 minutes (2) 22 minutes

(3) 10 minutes (4) 16 minutes

Official Ans. by NTA (2)

Sol. Q = P × t

Q = mcΔT + mL

$$P = \frac{V_{rms}^2}{R}$$

$$4200 \times 80 + 2260 \times 10^3 = \frac{(200)^2}{20} \times t$$

t = 1298 sec

t ≃ 22 min

3. A tuning fork of frequency 480 Hz is used in an experiment for measuring speed of sound (ν) in air by resonance tube method. Resonance is observed to occur at two successive lengths of the air column, l_1 = 30 cm and l_2 = 70 cm. Then ν is equal to :

(1) 332 ms^{-1} (2) 379 ms^{-1}

(3) 384 ms^{-1} (4) 338 ms^{-1}

Official Ans. by NTA (3)

Sol. $\nu = 2f(l_2 - l_1)$

$\nu = 2 \times 480 \times (70 - 30) \times 10^{-2}$

$\nu = 960 \times 40 \times 10^{-2}$

$\nu = 38400 \times 10^{-2}$ m/s

$\nu = 384$ m/s

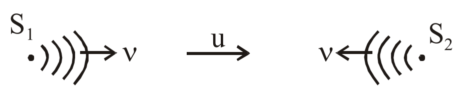
4. Two sources of sound S_1 and S_2 produce sound waves of same frequency 660 Hz. A listener is moving from source S_1 towards S_2 with a constant speed u m/s and he hears 10 beats/s. The velocity of sound is 330 m/s. Then, u equals:

(1) 2.5 m/s (2) 15.0 m/s

(3) 5.5 m/s (4) 10.0 m/s

Official Ans. by NTA (1)

Sol. f = 660 Hz, ν = 330 m/s



$$f_1 = f\left(\frac{\nu - u}{\nu}\right)$$

$$f_2 = f\left(\frac{v+u}{v}\right)$$

$$f_2 - f_1 = \frac{f}{v}[v + u - (v - u)]$$

$$10 = f_2 - f_1 = \frac{f}{v}[2u]$$

$u = 2.5$ m/s

5. A particle is moving with speed $v = b\sqrt{x}$ along positive x-axis. Calculate the speed of the particle at time $t = \tau$ (assume that the particle is at origin at $t = 0$).

(1) $\frac{b^2\tau}{4}$ (2) $\frac{b^2\tau}{2}$

(3) $b^2 \tau$ (4) $\frac{b^2\tau}{\sqrt{2}}$

Official Ans. by NTA (2)

Sol. $v = b\sqrt{x}$

$$\frac{dv}{dt} = \frac{b}{2\sqrt{x}}\frac{dx}{dt}$$

$$a = \frac{bv}{2\sqrt{x}}$$

$$a = \frac{b\left(b\sqrt{x}\right)}{2\sqrt{x}}$$

$$\frac{dv}{dt} = a = \frac{b^2}{2}$$

$$v = \frac{b^2}{2}\tau$$

6. Consider an electron in a hydrogen atom, revolving in its second excited state (having radius 4.65Å). The de-Broglie wavelength of this electron is :

(1) 12.9 Å (2) 3.5 Å

(3) 9.7 Å (4) 6.6 Å

Official Ans. by NTA (3)

Sol. $2\pi r_n = n\lambda_n$

$$\lambda_3 = \frac{2\pi(4.65\times10^{-10})}{3}$$

$\lambda_3 = 9.7$ Å

7. A moving coil galvanometer, having a resistance G, produces full scale deflection when a current I_g flows through it. This galvanometer can be converted into (i) an ammeter of range 0 to I_0 ($I_0 > I_g$) by connecting a shunt resistance R_A to it and (ii) into a voltmeter of range 0 to $V(V = GI_0)$ by connecting a series resistance R_V to it. Then,

(1) $R_AR_V = G^2\left(\frac{I_g}{I_0 - I_g}\right)$ and $\frac{R_A}{R_V} = \left(\frac{I_0 - I_g}{I_g}\right)^2$

(2) $R_AR_V = G^2$ and $\frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

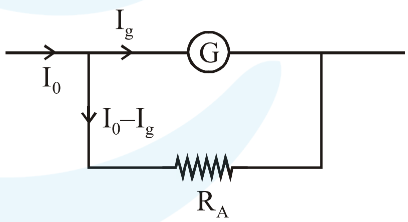
(3) $R_AR_V = G^2$ and $\frac{R_A}{R_V} = \frac{I_g}{(I_0 - I_g)}$

(4) $R_AR_V = G^2\left(\frac{I_0 - I_g}{I_g}\right)$ and $\frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

Official Ans. by NTA (2)

Sol. When galvanometer is used as an ammeter shunt is used in parallel with galvanometer.

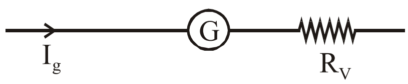
$\therefore$



$\therefore$ $I_gG = (I_0 - I_g)R_A$

$$\therefore R_A = \left(\frac{I_g}{I_0 - I_g}\right)G$$

When galvanometer is used as a voltmeter, resistance is used in series with galvanometer.



$I_g(G + R_V) = V = GI_0$ (given $V = GI_0$)

$$\therefore\ R_V = \frac{(I_0 - I_g)G}{I_g}$$

$$\therefore\ R_A R_V = G^2 \ \ \& \ \ \frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$$

8. The number density of molecules of a gas depends on their distance r from the origin as, $n(r) = n_0 e^{-\alpha r^4}$. Then the total number of molecules is proportional to :

(1) $n_0\alpha^{1/4}$ (2) $n_0\alpha^{-3}$

(3) $n_0\alpha^{-3/4}$ (4) $\sqrt{n_0}\,\alpha^{1/2}$

Official Ans. by NTA (3)

Sol. Given number density of molecules of gas as a function of r is

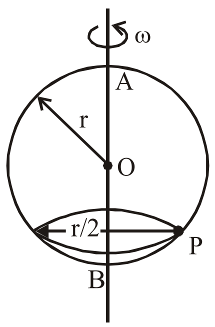
$$n(r) = n_0 e^{-\alpha r^4}$$

$$\therefore\ \text{Total number of molecule} = \int_0^\infty n(r)\,dV$$

$$= \int_0^\infty n_0 e^{-\alpha r^4} 4\pi r^2\,dr$$

$\therefore$ Number of molecules is proportional to $n_0\alpha^{-3/4}$

9. A smooth wire of length $2\pi r$ is bent into a circle and kept in a vertical plane. A bead can slide smoothly on the wire. When the circle is rotating with angular speed ω about the vertical diameter AB, as shown in figure, the bead is at rest with respect to the circular ring at position P as shown. Then the value of ω^2 is equal to :



(1) $\left(g\sqrt{3}\right)/r$

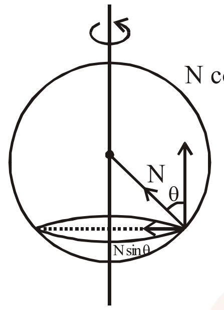
(2) $\frac{\sqrt{3}\,g}{2r}$

(3) $2g/r$

(4) $2g/\left(r\sqrt{3}\right)$

Official Ans. by NTA (4)

Sol.



$N \sin\theta = m\frac{r}{2}\omega^2$ ......(1)

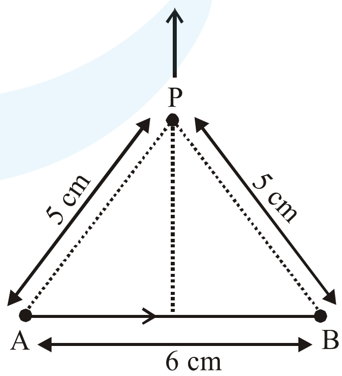
$N \cos\theta = mg$ ....(2)

$$\tan\theta = \frac{r\omega^2}{2g}$$

$$\frac{r}{2\frac{\sqrt{3}\,r}{2}} = \frac{r\omega^2}{2g}$$

$$\omega^2 = \frac{2g}{\sqrt{3}\,r}$$

10. Find the magnetic field at point P due to a straight line segment AB of length 6 cm carrying a current of 5 A. (See figure)
($\mu_0 = 4\pi \times 10^{-7}$ N-A^{-2})

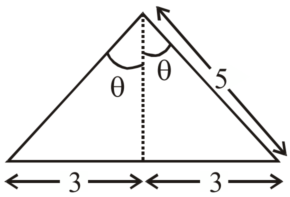


(1) 3.0×10^{-5} T (2) 2.5×10^{-5} T

(3) 2.0×10^{-5} T (4) 1.5×10^{-5} T

Official Ans. by NTA (4)

Sol.

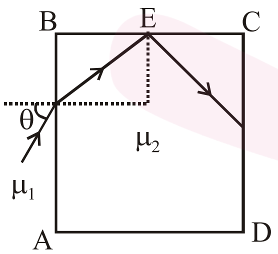


$$B = \frac{\mu_0 I}{4\pi d}\ 2\sin\theta$$

d = 4 cm

$$\sin\theta = \frac{3}{5}$$

11. A transparent cube of side d, made of a material of refractive index μ_2, is immersed in a liquid of refractive index $\mu_1(\mu_1 < \mu_2)$. A ray is incident on the face AB at an angle θ(shown in the figure). Total internal reflection takes place at point E on the face BC.



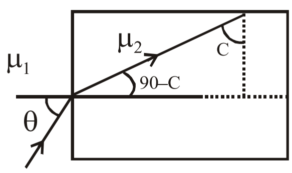
The θ must satisfy :

(1) $\theta < \sin^{-1}\frac{\mu_1}{\mu_2}$ (2) $\theta < \sin^{-1}\sqrt{\frac{\mu_2^2}{\mu_1^2}-1}$

(3) $\theta > \sin^{-1}\frac{\mu_1}{\mu_2}$ (4) $\theta > \sin^{-1}\sqrt{\frac{\mu_2^2}{\mu_1^2}-1}$

Official Ans. by NTA (2)

Sol.



$$\sin c = \frac{\mu_1}{\mu_2}$$

$$\mu_1 \sin\theta = \mu_2 \sin(90^\circ - C)$$

$$\sin\theta = \frac{\mu_2\sqrt{1-\frac{\mu_1^2}{\mu_2^2}}}{\mu_1}$$

$$\theta = \sin^{-1}\sqrt{\frac{\mu_2^2-\mu_1^2}{\mu_1^2}}$$

For TIR

$$\theta < \sin^{-1}\sqrt{\frac{\mu_2^2}{\mu_1^2}-1}$$

12. Let a total charge 2Q be distributed in a sphere of radius R, with the charge density given by $\rho(r) = kr$, where r is the distance from the centre. Two charges A and B, of –Q each, are placed on diametrically opposite points, at equal distance, a, from the centre. If A and B do not experience any force, then :

(1) $a = \frac{3R}{2^{1/4}}$ (2) $a = R/\sqrt{3}$

(3) $a = 8^{-1/4}R$ (4) $a = 2^{-1/4}\ R$

Official Ans. by NTA (3)

Sol. $$E\,4\pi a^2 = \frac{\int_0^a kr\,4\pi r^2\,dr}{\varepsilon_0}$$

$$E = \frac{k\,4\pi a^4}{4\times 4\pi\varepsilon_0}$$

$$2Q = \int_0^R kr\,4\pi r^2\,dr$$

$$k = \frac{2Q}{\pi R^4}$$

$$QE = \frac{1}{4\pi\varepsilon_0}\ \frac{QQ}{(2a)^2}$$

$$R = a8^{1/4}$$

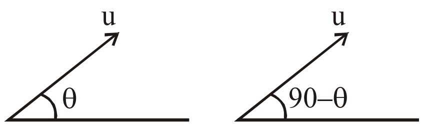
13. Two particles are projected from the same point with the same speed u such that they have the same range R, but different maximum heights, h_1 and h_2. Which of the following is correct ?

(1) $R^2 = 2\,h_1h_2$ (2) $R^2 = 16h_1h_2$

(3) $R^2 = 4\,h_1h_2$ (4) $R^2 = h_1h_2$

Official Ans. by NTA (2)

Sol.



For same range angle of projection will be θ & 90 – θ

$$R = \frac{u^2 2\sin\theta\cos\theta}{g}$$

$$h_1 = \frac{u^2\sin^2\theta}{g}$$

$$h_2 = \frac{u^2\sin^2(90-\theta)}{g}$$

$$\frac{R^2}{h_1h_2} = 16$$

14. A spring whose unstretched length is l has a force constant k. The spring is cut into two pieces of unstretched lengths l_1 and l_2 where, $l_1 = nl_2$ and n is an integer. The ratio k_1/k_2 of the corresponding force constants, k_1 and k_2 will be :

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

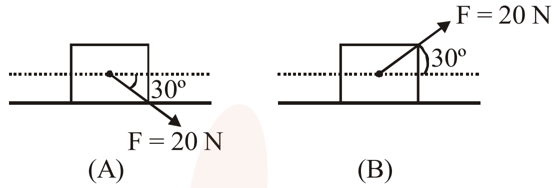
Official Ans. by NTA (3)

Sol. $k_1 = \frac{C}{\ell_1}$

$$k_2 = \frac{C}{\ell_2}$$

$$\frac{k_1}{k_2} = \frac{C\ell_2}{\ell_1 C}\ell_2 = \frac{\ell_2}{n\,\ell_2} = \frac{1}{n}$$

15. A block of mass 5 kg is (i) pushed in case (A) and (ii) pulled in case (B), by a force F = 20 N, making an angle of 30º with the horizontal, as shown in the figures. The coefficient of friction between the block and floor is μ = 0.2. The difference between the accelerations of the block, in case (B) and case (A) will be : ($g = 10\ ms^{-2}$)

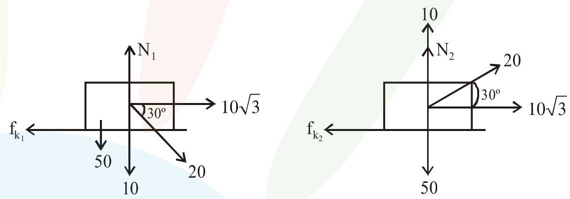


(1) $0\ ms^{-2}$ (2) $0.8\ ms^{-2}$

(3) $0.4\ ms^{-2}$ (4) $3.2\ ms^{-2}$

Official Ans. by NTA (2)

Sol.

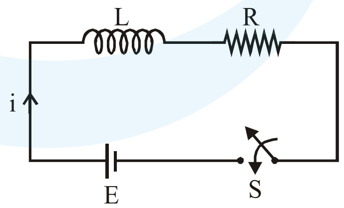


$N_1 = 60$ $N_2 = 40$

$$a_1 = \frac{10\sqrt{3}-0.2\times 60}{5} \qquad a_2 = \frac{10\sqrt{3}-0.2\times 40}{5}$$

$a_1 - a_2 = 0.8$

16. Consider the LR circuit shown in the figure. If the switch S is closed at t = 0 then the amount of charge that passes through the battery between t = 0 and $t = \frac{L}{R}$ is :



(1) $\frac{EL}{7.3R^2}$ (2) $\frac{EL}{2.7R^2}$

(3) $\frac{7.3EL}{R^2}$ (4) $\frac{2.7EL}{R^2}$

Official Ans. by NTA (2)

Sol. $q = \int I\,dt$

$$q = \int_0^{L/R} \frac{E}{R}\left[1 - e^{\frac{-Rt}{L}}\right]dt$$

$$q = \frac{EL}{R^2}\frac{1}{e}$$

$$q = \frac{EL}{2.7R^2}$$

17. A system of three polarizers P_1, P_2, P_3 is set up such that the pass axis of P_3 is crossed with respect to that of P_1. The pass axis of P_2 is inclined at 60º to the pass axis of P_3. When a beam of unpolarized light of intensity I_0 is incident on P_1, the intensity of light transmitted by the three polarizers is I. The ratio (I_0/I) equals (nearly) :

(1) 16.00 (2) 1.80

(3) 5.33 (4) 10.67

Official Ans. by NTA (4)

Sol. Since unpolarised light falls on $P_1 \Rightarrow$ intensity of light transmitted from $P_1 = \frac{I_0}{2}$

Pass axis of P_2 will be at an angle of 30º with P_1

$\therefore$ Intensity of light transmitted from

$$P_2 = \frac{I_0}{2}\cos^2 30^\circ = \frac{3I_0}{8}$$

Pass axis of P_3 is at an angle of 60º with P_2

$\therefore$ Intensity of light transmitted from

$$P_3 = \frac{3I_0}{8}\cos^2 60^\circ = \frac{3I_0}{32}$$

$$\therefore \left(\frac{I_0}{I}\right) = \frac{32}{3} = 10.67$$

18. Half lives of two radioactive nuclei A and B are 10 minutes and 20 minutes, respectively. If, initially a sample has equal number of nuclei, then after 60 minutes, the ratio of decayed numbers of nuclei A and B will be :

(1) 9 : 8 (2) 1 : 8

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

Official Ans. by NTA (1)

Sol. $N_A = N_{OA}e^{-\lambda t} = \frac{N_{OA}}{2^{t/t_{1/2}}} = \frac{N_{OA}}{2^6}$

$\therefore$ Number of nuclei decayed

$$= N_{OA} - \frac{N_{OA}}{2^6} = \frac{63N_{OA}}{64}$$

$$N_B = N_{OB}e^{-\lambda t} = \frac{N_{OB}}{2^{t/t_{1/2}}} = \frac{N_{OB}}{2^3}$$

$\therefore$ Number of nuclei decayed

$$= N_{OB} - \frac{N_{OB}}{2^3} = \frac{7N_{OB}}{8}$$

Since $N_{OA} = N_{OB}$

$\therefore$ Ratio of decayed numbers of nuclei

$$A \ \& \ B = \frac{63N_{OA} \times 8}{64 \times 7N_{OB}} = \frac{9}{8}$$

19. A solid sphere, of radius R acquires a terminal velocity v_1 when falling (due to gravity) through a viscous fluid having a coefficient of viscosity η. The sphere is broken into 27 identical solid spheres. If each of these spheres acquires a terminal velocity, v_2, when falling through the same fluid, the ratio (v_1/v_2) equals :

(1) 1/27 (2) 1/9

(3) 27 (4) 9

Official Ans. by NTA (4)

Sol. We have

$$V_T = \frac{2}{9}\frac{r^2}{\eta}(\rho_0 - \rho_\ell)g \Rightarrow v_T \propto r^2$$

since mass of the sphere will be same

$$\therefore \rho\frac{4}{3}\pi R^3 = 27.\frac{4}{3}\pi r^3\rho \Rightarrow r = \frac{R}{3}$$

$$\therefore \frac{v_1}{v_2} = \frac{R^2}{r^2} = 9$$

20. The ratio of the weights of a body on the Earth's surface to that on the surface of a planet is 9 : 4. The mass of the planet is $\frac{1}{9}$ th of that of the Earth. If 'R' is the radius of the Earth, what is the radius of the planet ? (Take the planets to have the same mass density)

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

Official Ans. by NTA (2)

Sol. Since mass of the object remains same

$\therefore$ Weight of object will be proportional to 'g' (acceleration due to gravity)

Given

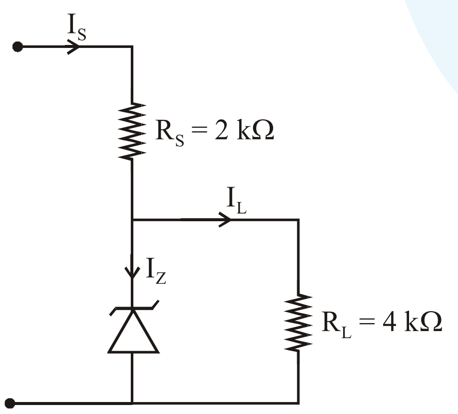
$$\frac{W_{earth}}{W_{planet}} = \frac{9}{4} = \frac{g_{earth}}{g_{planet}}$$

Also, $g_{surface} = \frac{GM}{R^2}$ (M is mass planet, G is universal gravitational constant, R is radius of planet)

$$\therefore \frac{9}{4} = \frac{GM_{earth}\,R^2_{planet}}{GM_{planet}\,R^2_{earth}} = \frac{M_{earth}}{M_{planet}} \times \frac{R^2_{Planet}}{R^2_{earth}} = 9\frac{R^2_{Planet}}{R^2_{earth}}$$

$$\therefore R_{planet} = \frac{R_{earth}}{2} = \frac{R}{2}$$

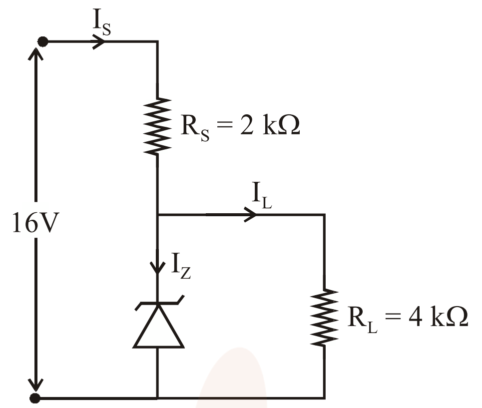
21. Figure shown a DC voltage regulator circuit, with a Zener diode of breakdown voltage = 6V. If the unregulated input voltage varies between 10 V to 16 V, then what is the maximum Zener current ?



(1) 2.5 mA (2) 3.5 mA
(3) 7.5 mA (4) 1.5 mA

Official Ans. by NTA (2)

Sol. Maximum current will flow from zener if input voltage is maximum.



When zener diode works in breakdown state, voltage across the zener will remain same.

$\therefore$ $V_{across\ 4k\Omega} = 6V$

$\therefore$ Current through 4KΩ = $\frac{6}{4000}A = \frac{6}{4}mA$

Since input voltage = 16V

$\therefore$ Potential difference across 2KΩ = 10V

$\therefore$ Current through 2kΩ = $\frac{10}{2000} = 5mA$

$\therefore$ Current through zener diode

$= (I_S - I_L) = 3.5$ mA

22. A Carnot engine has an efficiency of 1/6. When the temperature of the sink is reduced by 62ºC, its efficiency is doubled. The temperatures of the source and the sink are, respectively

(1) 124ºC, 62ºC (2) 37ºC, 99ºC
(3) 62ºC, 124ºC (4) 99ºC, 37ºC

Official Ans. by NTA (2)

Sol. Efficiency of Carnot engine = $1 - \frac{T_{sink}}{T_{source}}$

Given,

$$\frac{1}{6} = 1 - \frac{T_{sink}}{T_{source}} \Rightarrow \frac{T_{sink}}{T_{source}} = \frac{5}{6} \quad .....(1)$$

Also,

$$\frac{2}{6} = 1 - \frac{T_{sink} - 62}{T_{source}} \Rightarrow \frac{62}{T_{source}} = \frac{1}{6} \quad .....(2)$$

$\therefore\ T_{source} = 372\ K = 99°C$

Also, $T_{sink} = \frac{5}{6} \times 372 = 310\ K = 37°C$

(**Note :-** Temperature of source is more than temperature of sink)

23. A diatomic gas with rigid molecules does 10 J of work when expanded at constant pressure. What would be the heat energy absorbed by the gas, in this process ?

(1) 35 J (2) 40 J

(3) 25 J (4) 30 J

Official Ans. by NTA (1)

Sol. For a diatomic gas, $C_p = \frac{7}{2}R$

Since gas undergoes isobaric process

$\Rightarrow\ \Delta Q = nC_P\Delta T$

Also, $\Delta W = nR\Delta T = 10J(\text{given})$

$\therefore\ \Delta Q = n\frac{7}{2}R\Delta T = \frac{7}{2}(nR\Delta T) = 35\ J$

24. A small speaker delivers 2 W of audio output. At what distance from the speaker will one detect 120 dB intensity sound ? [Given reference intensity of sound as $10^{-12}W/m^2$]

(1) 10 cm (2) 30 cm

(3) 40 cm (4) 20 cm

Official Ans. by NTA (3)

Sol. Loudness of sound is given by

$$dB = 10 \log \frac{I}{I_0} \left(\begin{array}{c} I \text{ is intensity of sound} \\ I_0 \text{ is reference intensity of sound} \end{array} \right)$$

$$\therefore\ 120 = 10 \log\left(\frac{I}{I_0}\right)$$

$\Rightarrow\ I = 1\ W/m^2$

$$\text{Also}\quad I = \frac{P}{4\pi r^2} = \frac{2}{4\pi r^2}$$

$$\therefore\ r = \sqrt{\frac{2}{4\pi}} = \sqrt{\frac{1}{2\pi}}\ m = 0.399\ m \approx 40\ cm$$

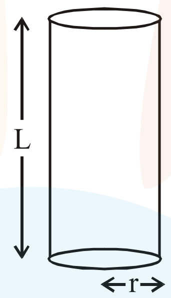
25. A uniform cylindrical rod of length L and radius r, is made from a material whose Young's modulus of Elasticity equals Y. When this rod is heated by temperature T and simultaneously subjected to a net longitudinal compressional force F, its length remains unchanged. The coefficient of volume expansion, of the material of the rod, is (nearly) equals to :

(1) $F/(3\pi r^2YT)$ (2) $3F/(\pi r^2YT)$

(3) $6F/(\pi r^2YT)$ (4) $9F/(\pi r^2YT)$

Official Ans. by NTA (2)

Sol.



$\because$ Length of cylinder remains unchanged

$$\text{so}\ \left(\frac{F}{A}\right)_{\text{Compressive}} = \left(\frac{F}{A}\right)_{\text{Thermal}}$$

$$\frac{F}{\pi r^2} = Y\alpha T$$

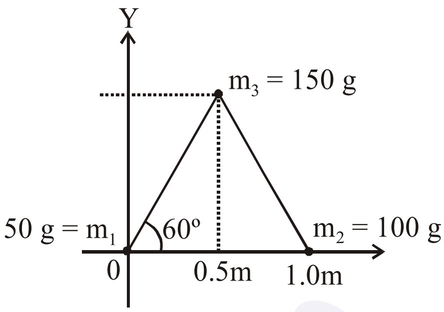
(α is linear coefficient of expansion)

$$\therefore\ \alpha = \frac{F}{YT\pi r^2}$$

$\therefore$ The coefficient of volume expansion $\gamma = 3\alpha$

$$\therefore\ \gamma = 3\frac{F}{YT\pi r^2}$$

26. Three particles of masses 50 g, 100 g and 150 g are placed at the vertices of an equilateral triangle of side 1 m (as shown in the figure). The (x, y) coordinates of the centre of mass will be :

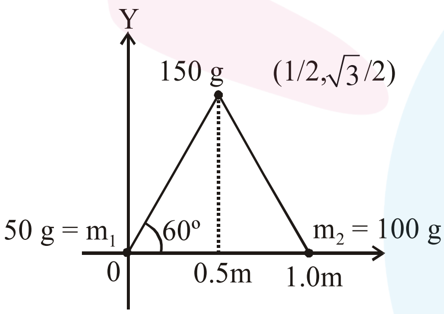


(1) $\left(\frac{7}{12}m, \frac{\sqrt{3}}{8}m\right)$ (2) $\left(\frac{\sqrt{3}}{4}m, \frac{5}{12}m\right)$

(3) $\left(\frac{7}{12}m, \frac{\sqrt{3}}{4}m\right)$ (4) $\left(\frac{\sqrt{3}}{8}m, \frac{7}{12}m\right)$

Official Ans. by NTA (3)

Sol.



The co-ordinates of the centre of mass

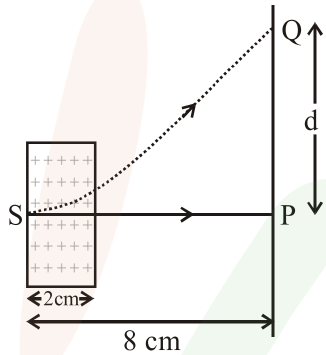
$$\vec{r}_{cm} = \frac{0 + 150 \times \left(\frac{1}{2}\hat{i} + \frac{\sqrt{3}}{2}\hat{j}\right) + 100 \times \hat{i}}{300}$$

$$\vec{r}_{cm} = \frac{7}{12}\hat{i} + \frac{\sqrt{3}}{4}\hat{j}$$

$\therefore$ Co-ordinate $\left(\frac{7}{12}, \frac{\sqrt{3}}{4}\right)$ m

27. An electron, moving along the x-axis with an initial energy of 100 eV, enters a region of magnetic field $\vec{B} = (1.5 \times 10^{-3} T)\hat{k}$ at S (See figure). The field extends between x = 0 and x = 2 cm. The electron is detected at the point Q on a screen placed 8 cm away from the point S. The distance d between P and Q (on the screen) is :

(electron's charge = 1.6×10^{-19} C, mass of electron = 9.1×10^{-31} kg)



(1) 12.87 cm (2) 1.22 cm

(3) 11.65 cm (4) 2.25 cm

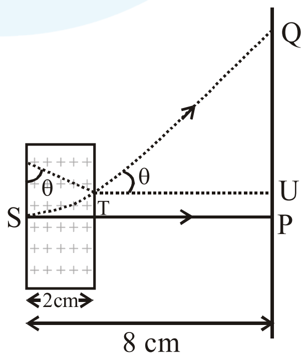
Official Ans. by NTA (1)

Sol. $R = \frac{mv}{qB}$

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

$$R = \frac{\sqrt{2 \times 9.1 \times 10^{-31} \times (100 \times 1.6 \times 10^{-19})}}{1.6 \times 10^{-19} \times 1.5 \times 10^{-3}}$$

R = 2.248 cm



$\sin\theta = \frac{2}{2.248}$

$\tan\theta = \frac{QU}{TU}$

$\frac{2}{1.026} = \frac{QU}{6}$

QU = 11.69

PU = R(1 – cos θ)

= 1.22

d = QU + PU

28. A plane electromagnetic wave having a frequency ν = 23.9 GHz propagates along the positive z-direction in free space. The peak value of the electric field is 60 V/m. Which among the following is the acceptable magnetic field component in the electromagnetic wave ?

(1) $\vec{B} = 2\times10^{7}\sin(0.5\times10^{3}z + 1.5\times10^{11}t)\hat{i}$

(2) $\vec{B} = 2\times10^{-7}\sin(1.5\times10^{2}x + 0.5\times10^{11}t)\hat{j}$

(3) $\vec{B} = 2\times10^{-7}\sin(0.5\times10^{3}z - 1.5\times10^{11}t)\hat{i}$

(4) $\vec{B} = 60\sin(0.5\times10^{3}x + 1.5\times10^{11}t)\hat{k}$

Official Ans. by NTA (3)

Sol. Magnetic field when electromagnetic wave propagates in +z direction

$B = B_0 \sin(kz - \omega t)$

where

$B_0 = \frac{60}{3\times10^8} = 2\times10^{-7}$

$k = \frac{2\pi}{\lambda} = 0.5\times10^3$

$\omega = 2\pi f = 1.5\times10^{11}$

29. In an amplitude modulator circuit, the carrier wave is given by,

C(t) = 4 sin (20000 πt) while modulating signal is given by, m(t) = 2 sin (200 πt). The values of modulation index and lower side band frequency are :

(1) 0.5 and 9 kHz (2) 0.5 and 10 kHz

(3) 0.3 and 9 kHz (4) 0.4 and 10 kHz

Official Ans. by NTA (1)

Sol. Modulation index is given by

$m = \frac{A_m}{A_c} = \frac{2}{4} = 0.5$

& (a) carrier wave frequency is given by

$= 2\pi f_c = 2\times10^4\pi$

$f_c = 10$ kHz

(b) modulating wave frequency (f_m)

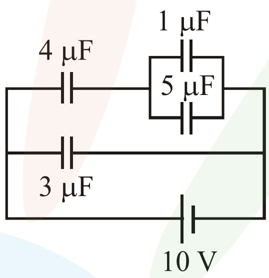
$2\pi f_m = 2000\pi$

$\Rightarrow f_m = 1$ kHz

lower side band frequency $\Rightarrow f_c - f_m$

$\Rightarrow$ 10 kHz – 1 kHz = 9 kHz

30. In the given circuit, the charge on 4 μF capacitor will be :

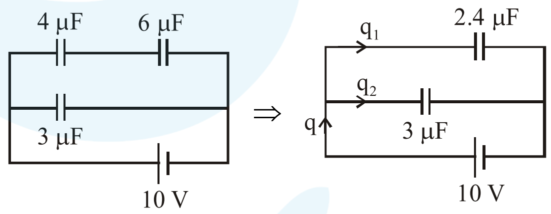


(1) 5.4 μC (2) 24 μC

(3) 13.4 μC (4) 9.6 μC

Official Ans. by NTA (2)

Sol.



So total charge flow = q = 5.4 μF × 10V

= 54 μC

The charge will be distributed in the ratio of capacitance

$\Rightarrow \frac{q_1}{q_2} = \frac{2.4}{3} = \frac{4}{5}$

∴ 9X = 54 μC ⇒ X = 6 μC

∴ charge on 4 μF capacitor

will be = 4X = 4 × 6 μC

= 24 μC