FINAL JEE–MAIN EXAMINATION – FEBRUARY, 2021

(Held On Friday 26th February, 2021) TIME : 3 : 00 PM to 6 : 00 PM

PHYSICS — TEST PAPER WITH ANSWER & SOLUTIONS

SECTION-A

1. If 'C' and 'V' represent capacity and voltage respectively then what are the dimensions of λ, where $\frac{C}{V} = \lambda$?

(1) $[M^{-2}L^{-3}I^{2}T^{6}]$ (2) $[M^{-3}L^{-4}I^{3}T^{7}]$

(3) $[M^{-1}L^{-3}I^{-2}T^{-7}]$ (4) $[M^{-2}L^{-4}I^{3}T^{7}]$

Official Ans. by NTA (4)

Sol. $\lambda = \frac{C}{V} = \frac{Q/V}{V} = \frac{Q}{V^2}$

$$V = \frac{\text{work}}{Q}$$

$$\lambda = \frac{Q^3}{(\text{work})^2} = \frac{(It)^3}{(F.s)^2}$$

$$= \frac{[I^3T^3]}{[ML^2T^{-2}]^2} = [M^{-2}L^{-4}I^3T^7]$$

2. The length of metallic wire is ℓ_1 when tension in it is T_1. It is ℓ_2 when the tension is T_2. The original length of the wire will be -

(1) $\frac{\ell_1 + \ell_2}{2}$ (2) $\frac{T_2\ell_1 + T_1\ell_2}{T_1 + T_2}$

(3) $\frac{T_2\ell_1 - T_1\ell_2}{T_2 - T_1}$ (4) $\frac{T_1\ell_1 - T_2\ell_2}{T_2 - T_1}$

Official Ans. by NTA (3)

Sol. Assuming Hooke's law to be valid.

$T \propto (\Delta\ell)$

$T = k(\Delta\ell)$

Let, ℓ_0 = natural length (original length)

$\Rightarrow T = k(\ell - \ell_0)$

so, $T_1 = k(\ell_1 - \ell_0)$ & $T_2 = k(\ell_2 - \ell_0)$

$$\Rightarrow \frac{T_1}{T_2} = \frac{\ell_1 - \ell_0}{\ell_2 - \ell_0}$$

$$\Rightarrow \ell_0 = \frac{T_2\ell_1 - T_1\ell_2}{}$$

3. An aeroplane, with its wings spread 10 m, is flying at a speed of 180 km/h in a horizontal direction. The total intensity of earth's field at that part is 2.5×10^{-4} Wb/m² and the angle of dip is 60°. The emf induced between the tips of the plane wings will be :-

(1) 108.25 mV (2) 54.125 mV

(3) 88.37 mV (4) 62.50 mV

Official Ans. by NTA (1)

Sol. $\in = [\vec{B}\vec{V}\vec{L}] = BVL \sin\theta$

$$= (2.5 \times 10^{-4}T)\left(180 \times \frac{5}{18} m/s\right)(10m)\sin 60°$$

$= 108.25 \times 10^{-3}V$

4. A tuning fork A of unknown frequency produces 5 beats/s with a fork of known frequency 340 Hz. When fork A is filed, the beat frequency decreases to 2 beats/s. What is the frequency of fork A ?

(1) 342 Hz (2) 345 Hz

(3) 335 Hz (4) 338 Hz

Official Ans. by NTA (3)

Sol. Initially beat frequency = 5 Hz

so, $\rho_A = 340 \pm 5 = 345$ Hz, or 335 Hz

after filing frequency increases slightly

so, new value of frequency of A > ρ_A

Now, beat frequency = 2Hz

$\Rightarrow$ new $\rho_A = 340 \pm 2 = 342$ Hz, or 338 Hz

hence, original frequency of A is $\rho_A = 335$ Hz

5. A particle executes S.H.M., the graph of velocity as a function of displacement is :-

(1) A circle (2) A parabola

(3) An ellipse (4) A helix

Official Ans. by NTA (3)

Sol. $v^2 = \omega^2(A^2 - x^2)$

$$\frac{v^2}{\omega^2} + x^2 = A^2$$

$$\frac{v^2}{(\omega A)^2} + \frac{x^2}{A^2} = 1$$

6. The trajectory of a projectile in a vertical plane is $y = \alpha x - \beta x^2$, where α and β are constants and x & y are respectively the horizontal and vertical distances of the projectile from the point of projection. The angle of projection θ and the maximum height attained H are respectively given by :-

(1) $\tan^{-1}\alpha, \frac{\alpha^2}{4\beta}$ (2) $\tan^{-1}\beta, \frac{\alpha^2}{2\beta}$

(3) $\tan^{-1}\alpha, \frac{4\alpha^2}{\beta}$ (4) $\tan^{-1}\left(\frac{\beta}{\alpha}\right), \frac{\alpha^2}{\beta}$

Official Ans. by NTA (1)

Sol. $y = \alpha x - \beta x^2$

comparing with trajectory equation

$$y = x\tan\theta - \frac{1}{2}\frac{gx^2}{u^2\cos^2\theta}$$

$\tan\theta = \alpha \Rightarrow \theta = \tan^{-1}\alpha$

$$\beta = \frac{1}{2}\frac{g}{u^2\cos^2\theta}$$

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

Maximum height : H

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

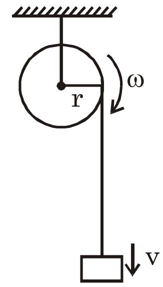
$$H = \frac{\tan^2\theta}{4\beta} = \frac{\alpha^2}{4\beta}$$

7. A cord is wound round the circumference of wheel of radius r. The axis of the wheel is horizontal and the moment of inertia about it is I. A weight mg is attached to the cord at the end. The weight falls from rest. After falling through a distance 'h', the square of angular velocity of wheel will be :-

(1) $\frac{2mgh}{I+2mr^2}$ (2) $\frac{2mgh}{I+mr^2}$

(3) 2gh (4) $\frac{2gh}{I+mr^2}$

Sol. $mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$



$v = \omega r$

$$mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}m\omega^2r^2$$

$$\frac{2mgh}{\left(I+mr^2\right)} = \omega^2$$

8. The internal energy (U), pressure (P) and volume (V) of an ideal gas are related as U = 3PV + 4. The gas is :-

(1) Diatomic only
(2) Polyatomic only
(3) Either monoatomic or diatomic
(4) Monoatomic only

Official Ans. by NTA (2)

Sol. U = 3PV + 4

$$\frac{nf}{2}RT = 3PV + 4$$

$$\frac{f}{2}PV = 3PV + 4$$

$$f = 6 + \frac{8}{PV}$$

Since degree of freedom is more than 6 therefore gas is polyatomic

9. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : For a simple microscope, the angular size of the object equals the angular size of the image.

Reason R : Magnification is achieved as the small object can be kept much closer to the eye than 25 cm and hence it subtends a large angle.

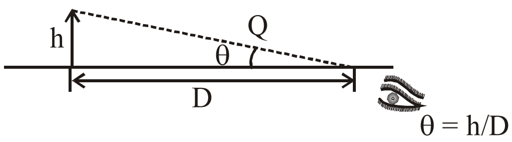
In the light of the above statements, choose the most appropriate answer from the options given below :

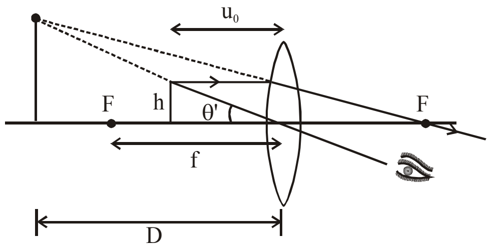
(1) A is true but R is false
(2) Both A and R are true but R is NOT the correct explanation of A.
(3) Both A and R are true and R is the correct explanation of A
(4) A is false but R is true

Official Ans. by NTA (3)

Ans. (2)

Sol.





$\theta' = \frac{h}{u_0}$; θ' is same for both object and image

$m = \frac{\theta'}{\theta} = \frac{D}{\mu_0}$

$u_0 < D$

Hence m > 1

10. Given below are two statements :

Statement I : An electric dipole is placed at the centre of a hollow sphere. The flux of electric field through the sphere is zero but the electric field is not zero anywhere in the sphere.

Statement II : If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at any point on the spherical surface of radius r (< R) is zero but the electric flux passing through this closed spherical surface of radius r is not zero.

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

(1) Both Statement I and Statement II are true

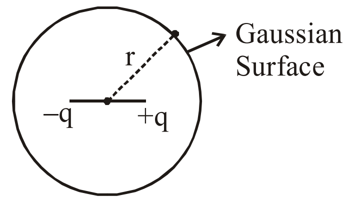
(2) Statement I is true but Statement II is false

(3) Both Statement I and Statement II are false

(4) Statement I is false but Statement II is true.

Official Ans. by NTA (2)

Sol.

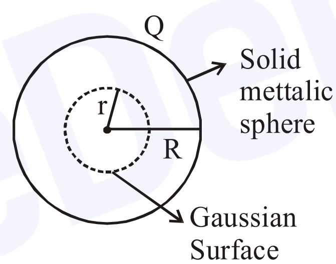


$\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\varepsilon_0} = 0 = \phi$

Flux of $\vec{E}$ through sphere is zero.

But $\oint \vec{E}.\vec{ds} = 0 \Rightarrow \{\vec{E}.\vec{ds} \neq 0\}$ for small section ds only

Statement-2



As change encloses within gaussian surface is equal to zero.

$\phi = \oint \vec{E}.\vec{ds} = 0$

Option(2) statement-1 correct statement-2 false.

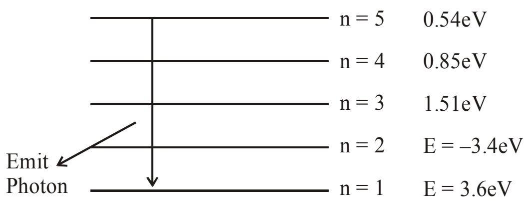
11. The recoil speed of a hydrogen atom after it emits a photon in going from n = 5 state to n = 1 state will be :-

(1) 4.17 m/s (2) 2.19 m/s

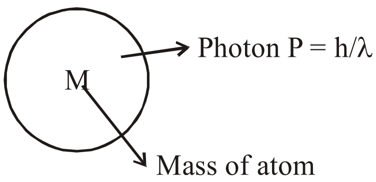
(3) 3.25 m/s (4) 4.34 m/s

Official Ans. by NTA (1)

Sol.



(ΔE) Releases when photon going from n = 5 to n = ΔE = (13.6 – 0.54) eV = 13.06 eV.



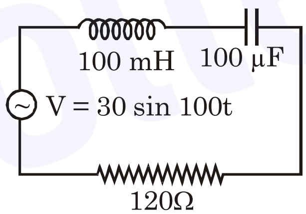
$P_i = P_f$ (By linear momentum conservation)

$$0 = \frac{h}{\lambda} - Mv = V_{Recoil} = \frac{h}{\lambda M} \qquad ....(i)$$

$$\& \ \Delta E = \frac{hc}{\lambda} = \frac{hc}{\lambda M} \times M \Rightarrow McV_{Recoil}$$

$$V_{Recoil} = \frac{\Delta E}{Mc} = \frac{13.06 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27} \times 3 \times 10^{8}} = 4.17 \text{ m / sec}$$

12. Find the peak current and resonant frequency of the following circuit (as shown in figure).

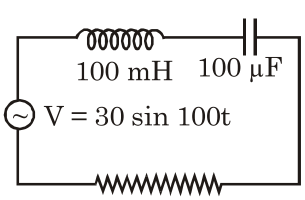


(1) 0.2 A and 50 Hz (2) 0.2 A and 100 Hz

(3) 2 A and 100 Hz (4) 2A and 50 Hz

Official Ans. by NTA (1)

Sol.



as given $z = \sqrt{(x_L - x_C)^2 + R^2}$

$x_L = \omega_L = 100 \times 100 \times 10^{-3} = 10\Omega$

$$x_C = \frac{1}{\omega_C} = \frac{1}{100 \times 100 \times 10^{-6}} = 10\Omega$$

$$z = \sqrt{(10-100)^2 + R^2} = \sqrt{90^2 + 120^2}$$

= 30 × 5= 150Ω

$$i_{peak} = \frac{\Delta v}{z} = \frac{30}{150} = \frac{1}{5} \text{amp} = 0.2\text{amp}$$

& For resonant frequency

$$\Rightarrow \omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC} \Rightarrow \omega = \frac{1}{\sqrt{LC}}$$

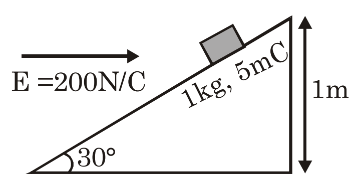
$$\& \ f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow \frac{1}{2\pi\sqrt{100 \times 10^{-3} \times 100 \times 10^{-6}}}$$

$$= \frac{100\sqrt{10}}{2\pi} = \frac{100\pi}{2\pi} = 50\text{Hz}$$

as $\sqrt{10} \approx \pi$

Answer (1)

13. An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field 200 $\frac{N}{C}$ as shown in the figure. A body of mass 1kg and charge 5 mC is allowed to slide down from rest at a height of 1m. If the coefficient of friction is 0.2, find the time taken by the body to reach the bottom.[g = 9.8 m/s^2, sin 30° = $\frac{1}{2}$; cos 30° = $\frac{\sqrt{3}}{2}$]

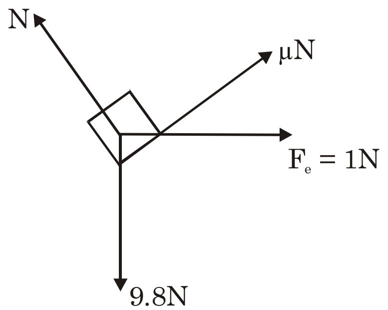


(1) 0.92 s (2) 0.46 s

(3) 2.3 s (4) 1.3 s

Official Ans. by NTA (4)

Sol. FBD



here N = 9.8 cos 30 + 1 sin 30

≈ 9N

so $a = \dfrac{9.8\sin 30 - 1\cos 30 - \mu N}{1}$

a = 2.233 m/s²

By $S = ut + \frac{1}{2}at^2$

$= \frac{1}{2}(2.233)t^2$

sin30°

t ≈ 1.3 sec

14. Two masses A and B, each of mass M are fixed together by a massless spring. A force acts on the mass B as shown in figure. If the mass A starts moving away from mass B with acceleration 'a', then the acceleration of mass B wil be :-

(1) $\dfrac{Ma - F}{M}$ (2) $\dfrac{MF}{F + Ma}$

(3) $\dfrac{F + Ma}{M}$ (4) $\dfrac{F - Ma}{M}$

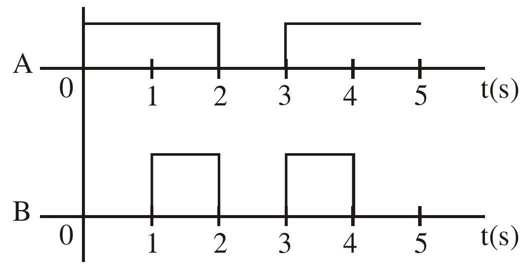
Official Ans. by NTA (4)

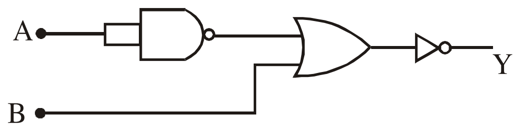
Sol. $a_{cm} = \dfrac{m_1a_1 + m_2a_2}{m_1 + m_2}$

$\dfrac{F}{2M} = \dfrac{Ma + Ma_B}{2M}$

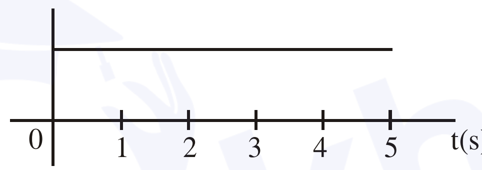
$F - Ma$

15. Draw the output signal Y in the given combination of gates :-

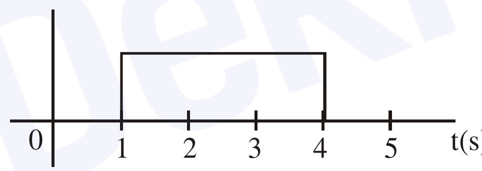




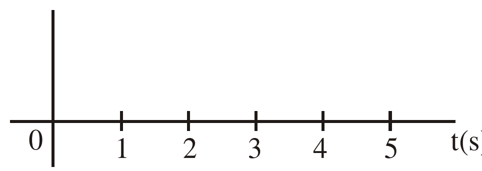
(1)



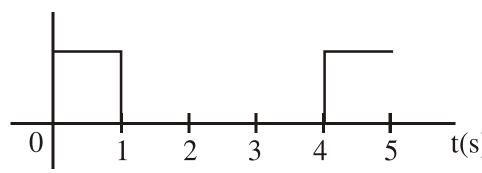
(2)



(3)



(4)



Official Ans. by NTA (4)

Sol. According to gates

by Demorgan's law

$\overline{\overline{A} + B} = A \cdot \overline{B}$

By observation.

16. A radioactive sample is undergoing α decay. At any time t_1, its activity is A and another time t_2, the activity is $\frac{A}{5}$. What is the average life time for the sample ?

(1) $\frac{\ell n5}{t_2 - t_1}$ (2) $\frac{t_1 - t_2}{\ell n5}$

(3) $\frac{t_2 - t_1}{\ell n5}$ (4) $\frac{\ell n(t_2 + t_1)}{2}$

Official Ans. by NTA (3)

Sol. Let initial activity be A_0

$A = A_0 e^{-\lambda t_1}$ .....(i)

$\frac{A}{5} = A_0 e^{-\lambda t_2}$ .....(ii)

(i) $\div$ (ii)

$5 = e^{\lambda(t_2 - t_1)}$

$\lambda = \frac{\ell n5}{t_2 - t_1} = \frac{1}{\tau}$

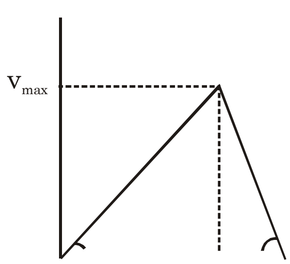
$\tau = \frac{t_2 - t_1}{\ell n5}$

17. A scooter accelerates from rest for time t_1 at constant rate a_1 and then retards at constant rate a_2 for time t_2 and comes to rest. The correct value of $\frac{t_1}{t_2}$ will be :-

(1) $\frac{a_1 + a_2}{a_2}$ (2) $\frac{a_2}{a_1}$ (3) $\frac{a_1}{a_2}$ (4) $\frac{a_1 + a_2}{a_1}$

Official Ans. by NTA (2)

Sol. Draw vt curve



$\tan\theta_1 = a_1 = \frac{v_{max}}{t_1}$

& $\tan\theta_2 = a_2 = \frac{v_{max}}{t_2}$

$\div$ above

$\frac{t_1}{t_2} = \frac{a_2}{a_1}$

18. Given below are two statements :

Statement I : A second's pendulum has a time period of 1 second.

Statement II : It takes precisely one second to move between the two extreme positions.

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

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

(2) Statement I is false but Statement II is true

(3) Statement I is true but Statement II is false

(4) Both Statement I and Statement II are true.

Official Ans. by NTA (2)

Sol. Second pendulum has a time period of 2 sec so statement 1 is false but from one extreme to other it takes only half the time period so statement 2 is true.

19. A wire of 1Ω has a length of 1m. It is stetched till its length increases by 25%. The percentage change in resistance to the neartest integer is :-

(1) 56% (2) 25% (3) 12.5% (4) 76%

Official Ans. by NTA (1)

Sol. $R_0 = 1\Omega$ $R_1 = ?$

$\ell_0 = 1m$ $\ell_1 = 1.25m$

$A_0 = A$

As volume of wire remains constant so

$A_0\ell_0 = A_1\ell_1 \Rightarrow A_1 = \frac{\ell_0 A_0}{\ell_1}$

Now

Resistance (R) = $\frac{\rho\ell}{A}$

$\frac{R_0}{\ } = \frac{\ell_0 / A_0}{\ }$

$$\frac{1}{R_1} = \frac{\ell_0}{A_0}\left(\frac{\ell_0 A_0}{\ell_1 \times \ell_1}\right) \quad R_1 = \frac{\ell_1^2}{\ell_0^2} = 1.5625\Omega$$

So % change in resistance

$$= \frac{R_1 - R_0}{R_0} \times 100\%$$

$$= \frac{1.5625 - 1}{1} \times 100\%$$

= 56.25%

20. The incident ray, reflected ray and the outward drawn normal are denoted by the unit vectors $\vec{a}$, $\vec{b}$ and $\vec{c}$ respectively. Then choose the correct relation for these vectors.

(1) $\vec{b} = \vec{a} + 2\vec{c}$ (2) $\vec{b} = 2\vec{a} + \vec{c}$

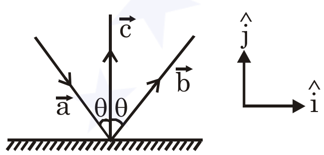
(3) $\vec{b} = \vec{a} - 2(\vec{a}.\vec{c})\vec{c}$ (4) $\vec{b} = \vec{a} - \vec{c}$

Official Ans. by NTA (3)

Sol. $\vec{a} = \sin\theta\hat{i} - \cos\theta\hat{j}$

$\vec{b} = \sin\theta\hat{i} + \cos\theta\hat{j}$

$\vec{c} = \hat{j}$



$\vec{a} - 2(\vec{a}.\vec{c})\vec{c} = \sin\theta\hat{i} + \cos\theta\hat{j}$

SECTION-B

1. The volume V of a given mass of monoatomic gas changes with temperature T according to the relation $V = KT^{2/3}$. The workdone when temperature changes by 90 K will be xR. The value of x is [R = universal gas constant]

Official Ans. by NTA (60)

Sol. We know that work done is

$$W = \int PdV \quad \text{... (1)}$$

$$\Rightarrow P = \frac{nRT}{V} \quad \text{... (2)}$$

$$\Rightarrow W = \int \frac{nRT}{V} dv \quad \text{... (3)}$$

and $V = KT^{2./3}$ ... (4)

$$\Rightarrow W = \int \frac{nRT}{{}^{2/3}} \cdot dv \quad \text{... (5)}$$

$\Rightarrow$ from (4) : $dv = \frac{2}{3}KT^{-1/3}dT$

$$\Rightarrow W = \int_{T_1}^{T_2} \frac{nRT}{KT^{2/3}} \frac{2}{3} K \frac{1}{T^{1/3}} dT$$

$$\Rightarrow W = \frac{2}{3} nR \times (T_2 - T_1) \quad \text{... (6)}$$

$\Rightarrow T_2 - T_1 = 90$ K ... (7)

$$\Rightarrow W = \frac{2}{3} nR \times 90$$

$\Rightarrow$ W = 60 nR

Assuming 1 mole of gas

n = 1

So W = 60R

2. If the highest frequency modulating a carrier is 5 kHz, then the number of AM broadcast stations accommodated in a 90 kHz bandwidth are ....

Official Ans. by NTA (9)

Sol. B. W. (Bandwidth) = 2 × maximum frequency at modulating signal

= 2 × 5kHz

= 10 kHz

∴ No of stations accommodate

$$= \frac{90}{10} = 9$$

3. Two stream of photons, possessing energies equal to twice and ten times the work function of metal are incident on the metal surface successively. The value of ratio of maximum velocities of the photoelectrons emitted in the two respective cases is x : y. The value of x is ....

Official Ans. by NTA (1)

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

$$\frac{1}{2}mv^2 = h\nu - \phi$$

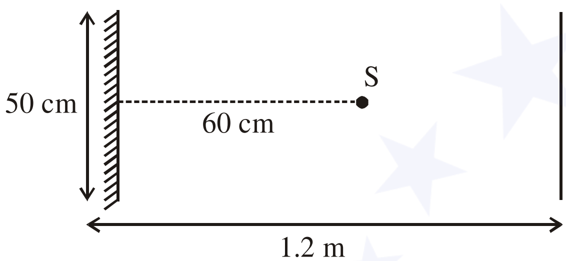
$$v = \sqrt{\frac{2(h\nu - \phi)}{m}}$$

Given $h\nu_1 = 2\phi$

$$\therefore \frac{v_1}{v_2} = \sqrt{\frac{h\nu_1 - \phi}{h\nu_2 - \phi}}$$

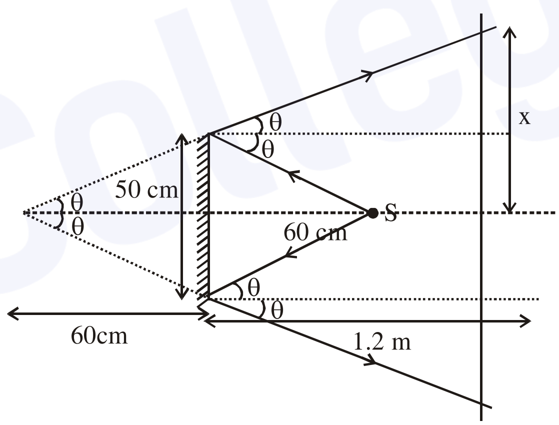
$$\frac{v_1}{v_2} = \sqrt{\frac{2\phi - \phi}{10\phi - \phi}} = \frac{1}{3}$$

4. A point source of light S, placed at a distance 60 cm infront of the centre of a plane mirror of width 50 cm, hangs vertically on a wall. A man walks infront of the mirror along a line parallel to the mirror at a distance 1.2 m from it (see in the figure). The distance between the extreme points where he can see the image of the light source in the mirror is .... cm.



Official Ans. by NTA (150)

Sol.



$$\tan\theta = \frac{25}{60} = \frac{x}{180}$$

x = 75 cm

so distance between extreme point = 2x = 2 ×

5. A particle executes S.H.M. with amplitude 'a' and time period V. The displacement of the particle when its speed is half of maximum speed is $\frac{\sqrt{x}a}{2}$. The value of x is ....

Official Ans. by NTA (3)

Sol. $V = \omega\sqrt{A^2 - x^2}$ $\qquad V_{max} = A\omega$

$$\frac{A\omega}{2} = \omega\sqrt{A^2 - x^2}$$

$$\frac{A^2}{4} = A^2 - x^2$$

$$x^2 = \frac{3A^2}{4}$$

$$x = \frac{\sqrt{3}}{2}A$$

6. 27 similar drops of mercury are maintained at 10 V each. All these spherical drops combine into a single big drop. The potential energy of the bigger drop is .... times that of a smaller drop.

Official Ans. by NTA (243)

Sol. $(27)\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$

R = 3r

Potential energy of smaller drop :

$$U_1 = \frac{3}{5}\frac{kq^2}{r}$$

Potential energy of bigger drop :

$$U = \frac{3}{5}\frac{kQ^2}{R}$$

$$U = \frac{3}{5}\frac{k(27q)^2}{R}$$

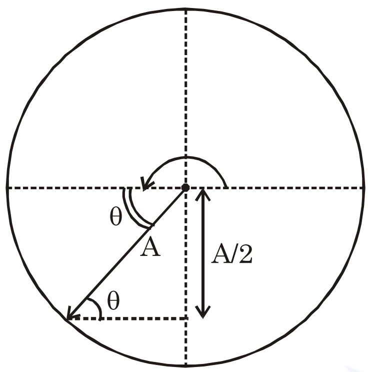
$$U = \frac{3}{5}k\frac{(27)(27)q^2}{3r}$$

$$U = \frac{(27)(27)}{3}\left(\frac{3}{5}\frac{kq^2}{r}\right)$$

7. Time period of a simple pendulum is T. The time taken to complete 5/8 oscillations starting from mean position is $\frac{\alpha}{\beta}T$. The value of α is ....

Official Ans. by NTA (7)

Sol. $\frac{5}{8}$th of oscillation $= \left(\frac{1}{2}+\frac{1}{8}\right)^{th}$ of oscillation



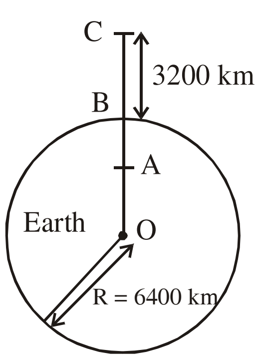
$\pi + \theta = \omega t$

$$\pi + \frac{\pi}{6} = \left(\frac{2\pi}{T}\right)t$$

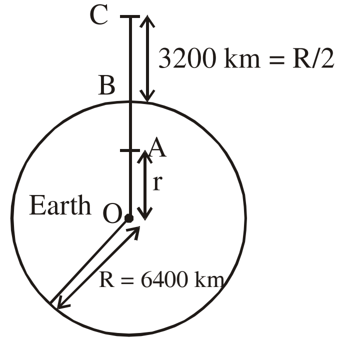
$$\frac{7\pi}{6} = \left(\frac{2\pi}{T}\right)t$$

$$t = \frac{7T}{12}$$

8. In the reported figure of earth, the value of acceleration due to gravity is same at point A and C but it is smaller than that of its value at point B (surface of the earth). The value of OA : AB will be x : y. The value of x is ....



Sol. $g_A = \frac{GM(r)}{R^3}$



$$g_C = \frac{GM}{\left(R+\frac{R}{2}\right)^2}$$

$g_A = g_C$

$$\frac{r}{R^3} = \frac{1}{\frac{9}{4}R^2} \Rightarrow r = \frac{4R}{9}$$

so $OA = \frac{4R}{9}$; $AB = R - r = \frac{5R}{9}$

OA : AB = 4 : 5

9. 1 mole of rigid diatomic gas performs a work of Q/5 when heat Q is supplied to it. The molar heat capacity of the gas during this transformation is $\frac{xR}{8}$, The value of x is ....

[K = universal gas constant]

Official Ans. by NTA (25)

Sol. $Q = \Delta U + W$

$$Q = \Delta U + \frac{Q}{5}$$

$$\Delta U = \frac{4Q}{5}$$

$$nC_v\Delta T = \frac{4}{5}nC\Delta T$$

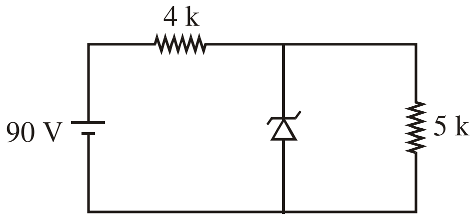
$$\frac{5}{4}C_V = C$$

$$C = \frac{5}{4}\left(\frac{f}{2}\right)R = \frac{5}{4}\left(\frac{5}{2}\right)R$$

$$C = \frac{25}{8}R$$

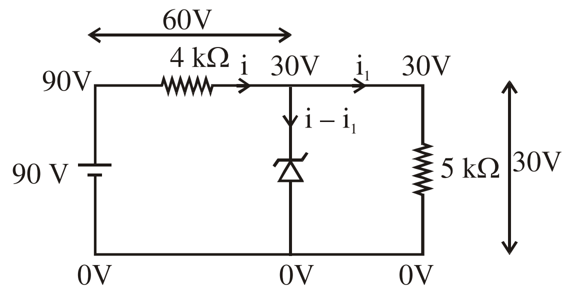
x = 25

10. The zener diode has a $V_z = 30$ V. The current passing through the diode for the following circuit is .... mA.



Official Ans. by NTA (9)

Sol.



$$i = \frac{60}{4000} A$$

$$i_1 = \frac{30}{5000} A$$

$$i - i_1 = \frac{60}{4000} - \frac{30}{5000} = \frac{9}{1000} A$$

current from zener diode

$i_z = i - i_1 = 9mA$