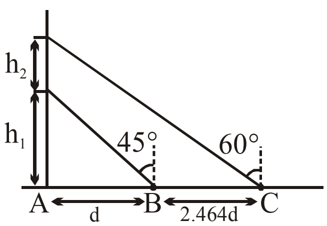
FINAL JEE–MAIN EXAMINATION – SEPTEMBER, 2020

(Held On Saturday 05th SEPTEMBER, 2020) TIME : 9 AM to 12 PM

PHYSICS — TEST PAPER WITH ANSWER & SOLUTION

1. A balloon is moving up in air vertically above a point A on the ground. When it is at a height h_1, a girl standing at a distance d (point B) from A (see figure) sees it at an angle 45° with respect to the vertical. When the balloon climbs up a further height h_2, it is seen at an angle 60° with respect to the vertical if the girl moves further by a distance 2.464 d (point C). Then the height h_2 is (given tan 30° = 0.5774) :

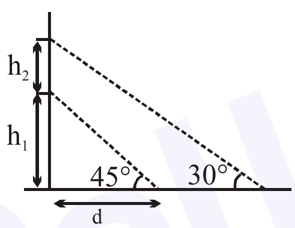


(1) d (2) 0.732d

(3) 1.464d (4) 0.464d

Official Ans. by NTA (1)

Sol.



$$\frac{h_1}{d} = \tan 45° \Rightarrow h_1 = d \ \dots (1)$$

$$\frac{h_1 + h_2}{d + 2.464\,d} = \tan 30°$$

$$\Rightarrow (h_1 + h_2) \times \sqrt{3} = 3.46\ d$$

$$(h_1 + h_2) = \frac{3.46\,d}{\sqrt{3}}$$

$$\Rightarrow d + h_2 = \frac{3.46\,d}{\sqrt{3}}$$

2. In a resonance tube experiment when the tube is filled with water up to height of 17.0 cm from bottom, it resonates with a given tuning fork. When the water level is raised the next resonance with the same tuning fork occurs at a height of 24.5 cm. If the velocity of sound in air is 330 m/s, the tuning fork frequency is:

(1) 1100 Hz (2) 3300 Hz

(3) 2200 Hz (4) 550 Hz

Official Ans. by NTA (3)

Sol. $\Rightarrow \lambda = 2\,(l_2 - l_1) \Rightarrow 2 \times (24.5 - 17)$

$\Rightarrow 2 \times 7.5 = 15$ cm

& $v = f\lambda \ \Rightarrow 330 = \lambda \times 15 \times 10^{-2}$

$$\lambda = \frac{330}{15} \times 100 \Rightarrow \frac{1100 \times 100}{5}$$

$\Rightarrow$ 2200 Hz

3. A helicopter reises from rest on the ground vertically upwards with a constant acceleration g. A food packet is dropped from the helicopter when it is a height h. The time taken by the packet to reach the ground is close to [g is the acceleration due to gravity] :

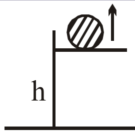
(1) $t = \sqrt{\dfrac{2h}{3g}}$

(2) $t = 1.8\sqrt{\dfrac{h}{g}}$

(3) $t = 3.4\sqrt{\left(\dfrac{h}{g}\right)}$

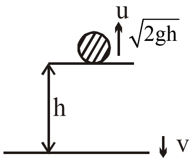
(4) $t = \dfrac{2}{3}\sqrt{\left(\dfrac{h}{g}\right)}$

Sol.



$u^2 = 0 + 2gh$

$\Rightarrow u = \sqrt{2gh}$



$v^2 = u^2 + 2as$

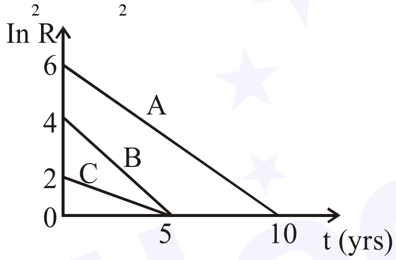
$v^2 = 2gh + 2gh$

$v = \sqrt{4gh}$

$$\Rightarrow \sqrt{4gh} = \sqrt{2gh} + gt$$

$$\Rightarrow t = \sqrt{\frac{4h}{g}} - \sqrt{\frac{2h}{g}} \Rightarrow 3.4\sqrt{\frac{h}{g}}$$

4. Activities of three radioactive substances A, B and C are represented by the curves A, B and C, in the figure. Then their half-lives $T_{\frac{1}{2}}(A) : T_{\frac{1}{2}}(B) : T_{\frac{1}{2}}(C)$ are in the ratio :



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

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

Official Ans. by NTA (3)

Sol. $R = R_0\, e^{-\lambda t}$

$\ln R = \ln R_0 - \lambda t$

$$\lambda_A = \frac{6}{10} \Rightarrow T_A = \frac{10}{6}\ \ln 2$$

$$\lambda_B = \frac{6}{5} \Rightarrow T_B = \frac{5\ln 2}{6}$$

$$\lambda_C = \frac{2}{5} \Rightarrow T_C = \frac{5\ln 2}{2}$$

$$\frac{10}{6} : \frac{5}{6} : \frac{15}{6} :: 2 : 1 : 3$$

5. A hollow spherical shell at outer radius R floats just submerged under the water surface. The inner radius of the shell is r. If the specific gravity of the shell material is $\frac{27}{8}$ w.r.t. water, the value of r is :

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

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

Official Ans. by NTA (2)

Sol. $\frac{4}{3}\pi\left(R^3 - r^3\right)\ \rho_m\ g = \frac{4}{3}\pi R^3 \rho_w g$

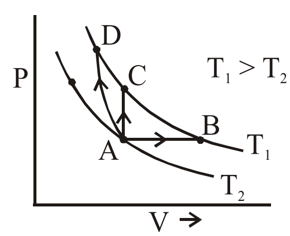
$$1 - \left(\frac{r}{R}\right)^3 = \frac{8}{27}$$

$$\Rightarrow \frac{r}{R} = \left(\frac{19}{27}\right)^{1/3} = \frac{19^{1/3}}{3}$$

$$= 0.88 \simeq \frac{8}{9}$$

6. Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are labelled as $A \to B$, $A \to C$ and $A \to D$. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the workdone as W_{AB}, W_{AC} and W_{AD}.

The correct relation between these parameters are :



(1) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} > 0$

(2) $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$

(3) $E_{AB} = E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$

(4) $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$

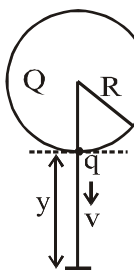
Sol. $\Delta U = nC_v\,\Delta T$ = same

AB $\rightarrow$ volume is increasing $\Rightarrow W > 0$

AD $\rightarrow$ volume is decreasing $\Rightarrow W < 0$

AC $\rightarrow$ volume is constant $\Rightarrow W = 0$

7. A solid sphere of radius R carries a charge (Q + q) distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q. If it acquires a speed v when it has f through a vertical height y (see figure), then : (assume the remaining portion to be spherical).



(1) $v^2 = 2y\left[\dfrac{qQ}{4\pi\epsilon_0 R(R+y)m} + g\right]$

(2) $v^2 = y\left[\dfrac{qQ}{4\pi\epsilon_0 R^2 ym} + g\right]$

(3) $v^2 = 2y\left[\dfrac{qQR}{4\pi\epsilon_0 (R+y)^3 m} + g\right]$

(4) $v^2 = y\left[\dfrac{qQ}{4\pi\epsilon_0 R(R+y)m} + g\right]$

Official Ans. by NTA (1)

Sol. $\dfrac{kQq}{R} + mgy$

$= \dfrac{kQq}{R+y} + \dfrac{1}{2}mv^2$

$\dfrac{2kQqy}{}$

8. With increasing biasing voltage of a photodiode, the photocurrent magnitude :

(1) increases initially and saturates finally

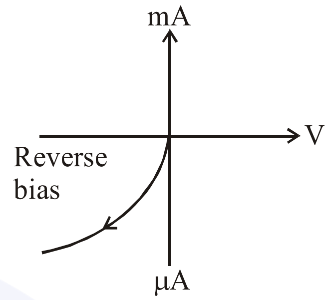
(2) increases initially and after attaining certain value, it decreases

(3) increases linearly

(4) remains constant

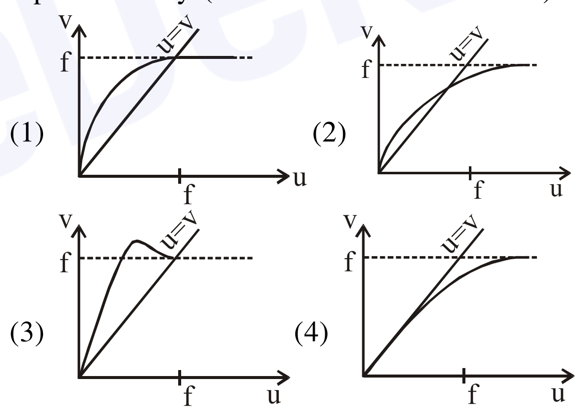
Official Ans. by NTA (1)

Sol. I-V characteristic of a photodiode is as follows:



On increasing the potential difference the current first increases and then attains a saturation.

9. For a concave lens of focal length f, the relation between object and image distance u and v, respectively, from its pole can best be represented by (u = v is the reference line):



Official Ans. by NTA (4)

Sol. $v = \dfrac{uf}{u+f}$

Case-I

If $v = u$

$\Rightarrow f + u = f$

$\Rightarrow u = 0$

Case-II

If $u = \infty$

then $v = f$

10. An electrical power line, having a total resistance of 2Ω, delivers 1 kW at 220 V. The efficiency of the transmission line is approximately:

(1) 72% (2) 96% (3) 91% (4) 85%

Official Ans. by NTA (2)

Sol. $vi = 10^3$

$i = \frac{1000}{220}$

$\text{loss} = i^2R = \left(\frac{50}{11}\right)^2 \times 2$

$\text{efficiency} = \frac{1000}{1000+i^2R} \times 100 = 96\%$

11. Assume that the displacement(s) of air is proportional to the pressure difference (Δp) created by a sound wave. Displacement(s) further depends on the speed of sound (v), density of air (ρ) and the frequency (f). If Δp~10Pa, v~300 m/s, p~1 kg/m³ and f~1000Hz, then s will be the order of (take multiplicative constant to be 1)

(1) 10 mm (2) $\frac{3}{100}$ mm

(3) 1 mm (4) $\frac{1}{10}$ mm

Official Ans. by NTA (2)

Sol. $\Delta p = BkS_0$

$= \rho v^2 \times \frac{\omega}{v} \times S_0$

$\Rightarrow S_0 = \frac{\Delta p}{\rho v \omega}$

$\approx \frac{10}{1\times300\times1000} m$

$= \frac{1}{30} mm \approx \frac{3}{100} mm$

12. A bullet of mass 5g, travelling with a speed of 210 m/s, strikes a fixed wooden target. One half of its kinetic energy is converted into heat in the bullet while the other half is converted into heat in the wood. The rise of temperature of the bullet if the specific heat of its material is 0.030 cal/(g–°C) (1 cal = 4.2 × 10⁷ ergs) close to :

(1) 83.3°C (2) 87.5°C

Sol. $\frac{1}{2}mv^2 \times \frac{1}{2} = ms\Delta T$

$\Delta T = \frac{v^2}{4\times5} = \frac{210^2}{4\times30\times4.200}$

$= 87.5°C$

13. Number of molecules in a volume of 4 cm³ of a perfect monoatomic gas at some temperature T and at a pressure of 2 cm of mercury is close to ? (Given, mean kinetic energy of a molecule (at T) is 4 × 10⁻¹⁴ erg, g = 980 cm/s², density of mercury = 13.6 g/cm³)

(1) 5.8 × 10¹⁸ (2) 5.8 × 10¹⁶

(3) 4.0 × 10¹⁸ (4) 4.0 × 10¹⁶

Official Ans. by NTA (3)

Sol. $n = \frac{PV}{RT}, \frac{3}{2}kT = 4\times10^{-14}$

$N = \frac{PV}{RT} \times Na$

$= \frac{2\times13.6\times980\times4}{\frac{8}{3}\times10^{-14}} = 3.99 \times 10^{18}$

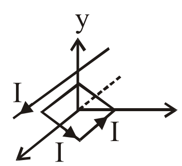
14. A square loop of side 2a, and carrying current I, is kept in XZ plane with its centre at origin. A long wire carrying the same current I is placed parallel to the z-axis and passing through the point (0, b, 0), (b > > a). The magnitude of the torque on the loop about z-axis is given by:

(1) $\frac{2\mu_0 I^2 a^2}{\pi b}$ (2) $\frac{\mu_0 I^2 a^3}{2\pi b^2}$

(3) $\frac{\mu_0 I^2 a^2}{2\pi b}$ (4) $\frac{2\mu_0 I^2 a^3}{\pi b^2}$

Official Ans. by NTA (1)

Sol.



$\vec{\tau} = \vec{M} \times \vec{B}$

$= 4a^2 I \times \frac{\mu_0 I}{}$

15. A physical quantity z depends on four observables a, b, c and d, as $z = \frac{a^2 b^{\frac{2}{3}}}{\sqrt{c}\, d^3}$. The percentage of error in the measurement of a, b, c and d 2%, 1.5%, 4% and 2.5% respectively. The percentage of error in z is:

(1) 12.25% (2) 14.5%
(3) 16.5% (4) 13.5%

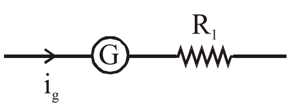
Official Ans. by NTA (2)

Sol. $\frac{\Delta Z}{Z} = \frac{2\Delta a}{a} + \frac{2}{3}\frac{\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c} + \frac{3\Delta d}{d} = 14.5\%$

16. A galvanometer of resistance G is converted into a voltmeter of range 0 – 1V by connecting a resistance R_1 in series with it. The additional resistance that should be connected in series with R_1 to increase the range of the voltmeter to 0 – 2V will be :

(1) R_1 (2) $R_1 + G$
(3) $R_1 - G$ (4) G

Official Ans. by NTA (2)

Sol.


$\Rightarrow 1 = i_g(G + R_1)$ ... (1)

$\Rightarrow 2 = i_g(R_1 + R_2 + G)$ ...(2)

(1) % (2)

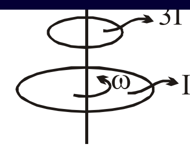
$\Rightarrow \frac{1}{2} = \frac{G + R_1}{G + R_1 + R_2}$

$G + R_1 + R_2 = 2G + 2h_1$

$(R_2 = G + R_1)$

17. A wheel is rotating freely with an angular speed ω on a shaft. The moment of inertia of the wheel is I and the moment of inertia of the shaft is negligible. Another wheel of momet of inertia 3I initially at rest is suddenly coupled to the same shaft. The resultant fractional loss in the kinetic energy of the system is :

(1) 0 (2) $\frac{1}{4}$ (3) $\frac{3}{4}$ (4) $\frac{5}{6}$

Sol.


By anglar momentum conservation

$\omega I + 3I \times 0 = 4I\omega' \Rightarrow \omega' = \frac{\omega}{4}$

$(KE)_i = \frac{1}{2} I\omega^2$

$(KE)_f = \frac{1}{2} \times (4I) \times \left(\frac{\omega}{4}\right)^2 = \frac{I\omega^2}{8}$

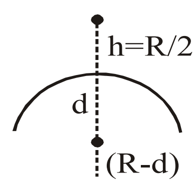
$\Delta KE = \frac{3}{8} I\omega^2$

fractional loss $= \frac{\Delta KE}{KE_1} = \frac{\frac{3}{8} I\omega^2}{\frac{1}{2} I\omega^2} = \frac{3}{4}$

18. The value of the acceleration due to gravity is g_1 at a height $h = \frac{R}{2}$ (R = radius of the earth) from the surface of the earth. It is again equal to g_1 at a depth d below the surface of the earth. The ratio $\left(\frac{d}{R}\right)$ equals :

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

Official Ans. by NTA (4)

Sol.


$g_1 = \frac{GM}{\left(R + \frac{R}{2}\right)^2}$ ... (1)

$g_2 = \frac{GM(R - d)}{R^3}$ ... (2)

$g_1 = g_2$

$\frac{GM}{\left(\frac{3R}{2}\right)^2} = \frac{GM(R-d)}{R^3}$

$\Rightarrow \frac{4}{9} = \frac{(R-d)}{R}$

$4R = 9R - 9d$

d 5

19. An electron is constrained to move along the y-axis with a speed of 0.1 c (c is the speed of light) in the presence of electromagnetic wave, whose electric field is

$\vec{E} = 30\hat{j}\ \sin(1.5\times10^{7}t - 5\times10^{-2}x)V/m$.

The maximum magnetic force experienced by the electron will be :

(given $c = 3 \times 10^{8}\ ms^{-1}$ and electron charge $= 1.6 \times 10^{-19}$ C)

(1) 1.6×10^{-19} N (2) 4.8×10^{-19} N

(3) 3.2×10^{-18} N (4) 2.4×10^{-18} N

Official Ans. by NTA (2)

Sol. $\Rightarrow E = \vec{E} = 30\hat{j}\sin(1.5\times10^{7}t - 5\times10^{-2}x)V/m$

$\Rightarrow B \Rightarrow E/V \Rightarrow \frac{30}{1.5\times10^{7}}\times5\times10^{-2}$

$\Rightarrow 10^{-7}$ Tesla

$\Rightarrow F_{mag} = q\left(\vec{V}\times\vec{B}\right) = |qVB|$

$= 1.6 \times 10^{-19} \times 0.1 \times 3 \times 10^{8} \times 10^{-7}$

$= 4.8 \times 10^{-19}$ N

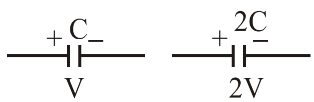
20. Two capacitors of capacitances C and 2C are charged to potential differences V and 2V, respectively. These are then connected in parallel in such a manner that the positive terminal of one is connected to the negative terminal of the other. The final energy of this configuration is:

(1) $\frac{9}{2}CV^{2}$ (2) $\frac{25}{6}CV^{2}$

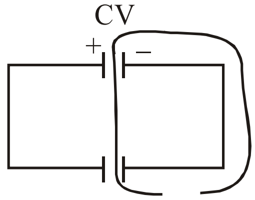
(3) zero (4) $\frac{3}{2}CV^{2}$

Official Ans. by NTA (4)

Sol.



$Q_1 = CV$ $Q_2 = 2C \times 2V = 4CV$



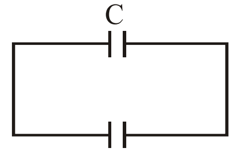
$\Rightarrow$ By conservation of charge

$q_i = q_f$

$Q_1 + Q_2 = q_1 + q_2$

$4CV - CV = (C + 2C)\ V_C$

$V_C = \frac{3CV}{3C} \Rightarrow V$



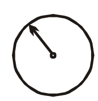
$\Rightarrow \frac{1}{2}\times(3C)\times V_C^2$

$= \frac{1}{2} \times 3C \times V^2 = \frac{3}{2}CV^2$

21. Two concentric circular coils, C_1 and C_2, are placed in the XY plane. C_1 has 500 turns, and a radius of 1 cm. C_2 has 200 turns and radius of 20 cm. C_2 carries a time dependent current $I(t) = (5t^2 - 2t + 3)$ A where t is in s. The emf induced in C_1 (in mV), at the instant t = 1s is $\frac{4}{x}$. The value of x is ____.

Official Ans. by NTA (5.00)

Sol.



$B = \frac{\mu_0 NI}{2R}$

$\phi = \frac{\mu_0 NN'I}{2R}\pi r^2$

$\varepsilon = \frac{d\phi}{dt} = \frac{2\pi\times10^{-7}\times10^{5}\times\pi\times10^{-4}}{0.2}$

22. A force $\vec{F}=\left(\hat{i}+2\hat{j}+3\hat{k}\right)N$ acts at a point $\left(4\hat{i}+3\hat{j}-\hat{k}\right)m$. Then the magnitude of torque about the point $\left(\hat{i}+2\hat{j}+\hat{k}\right)m$ will be $\sqrt{x}$ N-m. The value of x is _____.

Official Ans. by NTA (195)

Sol. $\vec{\tau}=\left(\vec{r}_2-\vec{r}_1\right)\times\vec{F}$

$=[(4\hat{i}+3\hat{j}-\hat{k})-(\hat{i}+2\hat{j}+\hat{k})]\times\vec{F}$

$=\left(3\hat{i}+\hat{j}-2\hat{k}\right)\times\left(\hat{i}+2\hat{j}+3\hat{k}\right)$

$$\tau=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 3 & 1 & -2\\ 1 & 2 & 3\end{vmatrix}$$

$=7\hat{i}-11\hat{j}+5\hat{k}$

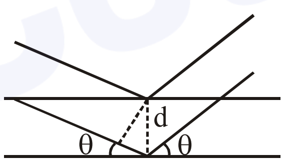
$|\vec{\tau}|=\sqrt{195}$

23. A beam of electrons of energy E scatters from a target having atomic spacing of 1Å. The first maximum intensity occurs at θ = 60°. Then E (in eV) is ______.

(Planck constant h = 6.64 × 10^{-34} Js, 1eV = 1.6 × 10^{-19} J, electron mass m = 9.1 × 10^{-31} kg)

Official Ans. by NTA (50.00 to 51.00)

Sol.



$$2d\sin\theta=\lambda=\frac{h}{\sqrt{2mE}}$$

$$2\times10^{-10}\times\frac{\sqrt{3}}{2}=\frac{6.6\times10^{-34}}{\sqrt{2mE}}$$

$$E=\frac{1}{2}\times\frac{6.64^2\times10^{-48}}{\quad^{-31}\qquad\qquad^{-19}}=50.47$$

24. A particle of mass 200 MeV/c² collides with a hydrogen atom at rest. Soon after the collision the particle comes to rest, and the atom recoils and goes to its first excited state. The initial kinetic energy of the particle (in eV) is $\frac{N}{4}$. The value of N is :

(Given the mass of the hydrogen atom to be 1 GeV/c²) ________.

Official Ans. by NTA (51.00)

Sol. $mV_0 = MV = p$

$$10.2=\frac{p^2}{2m}-\frac{p^2}{2M}=\frac{p^2}{2m}\left(1-\frac{m}{M}\right)$$

$$=\frac{p^2}{2m}(1-0.2)$$

$$\Rightarrow\frac{p^2}{2m}=K=\frac{10.2}{0.8}$$

25. A compound microscope consists of an objective lens of focal length 1cm and an eye piece of focal length 5 cm with a separation of 10 cm.

The distance between an object and the objective lens, at which the strain on the eye is minimum is $\frac{n}{40}$ cm. The value of n is ____.

Official Ans. by NTA (50.00)

Sol. Final image at ∞

⇒ obj. for eye piece at 5cm

⇒ image for objective at 5 cm

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

$$\frac{1}{5}+\frac{1}{x}=1$$

$$\frac{1}{x}=1-\frac{1}{5}=\frac{4}{5}\Rightarrow x=\frac{5}{4}$$