PART –A (PHYSICS)

***Questions*: 1:-** 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.

(A) $\frac{2}{3}$R **(B)** $\frac{4}{9}$R

(C) $\frac{1}{3}$R **(D)** $\frac{8}{9}$R

***Ans*:- (D)**

As it just floats B = mg

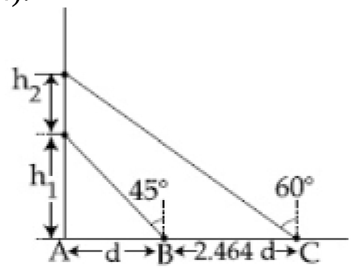
$$\left(\frac{4\pi R^3}{3}\right)(\rho_\ell)(g) = \left(\frac{4\pi R^3}{3} - \frac{4\pi r^3}{3}\right)(\rho_s)(g)$$

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

On solving we get,

$$r = \frac{8}{9}R \text{ (approx)}$$

***Questions*: 2:-** 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 the angle 45^0 with respect to the vertical. When the balloon climbs up a future height h_2, it is seen at the angle 60^0 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 = 0.5774):



(A) 0.464 d **(B)** 0.732 d

(C) 1.464 d **(D)** d

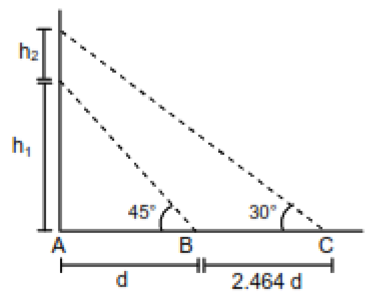
***Ans*:- (D)**

$$\frac{h_1}{d} = 1$$

$$\frac{h_1 + h_2}{3.464d} = \frac{1}{\sqrt{3}}$$

$$d + h_2 = \frac{3.464d}{\sqrt{3}}$$

$$h_2 = 2d - d = d$$

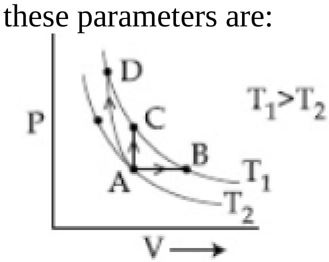


***Questions*: 3:-** A physical quantity z depends on four observables a, c, c and d, as $z = \frac{a^2\, b^{\frac{2}{3}}}{\sqrt{c}\, d^3}$. The percentages of error in the measurement of a, b, c and d are 2%, 1.5%, 4% and 2.5% respectively. The percentage of error in z is:

(A) 13.5% **(B)** 16.5%
(C) 12.25% **(D)** 14.5%

***Ans*:- (D)**

***Questions*: 4:-** Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are labeled as A → B, A → C and A → D. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the work done by W_{AB}, W_{AC} and W_{AD}. The correct relation between these parameters are:



(A) $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$
(B) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} = 0$, $W_{AC} = 0$, $W_{AD} > 0$
(C) $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$
(D) $E_{AB} = E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$

***Ans*:- (No Option)**

***Questions*: 5:-** A wheel is rotating freely with an angular speed □ 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 moment 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:

(A) $\frac{3}{4}$ **(B)** $\frac{5}{6}$
(C) $\frac{1}{4}$ **(D)** 0

***Ans*:- (A)**

As $Torque_{net} = 0$

Hence, L = constant

$I\omega = (3I + I)\omega'$

$$\omega' = \frac{\omega}{4}$$

$$\text{Loss in K.E.} = \frac{1}{2}I\omega^2 - \frac{1}{2}(I + 3I)\frac{\omega^2}{16}$$

$$= \frac{1}{2}I\omega^2\left(1 - \frac{1}{4}\right)$$

$$\text{Fractional loss} = \frac{\frac{1}{2}I\omega^2\frac{3}{4}}{\frac{1}{2}I\omega^2} = \frac{3}{4}$$

***Questions*: 6:-** In a resonance tube experiment when the tube is filled with water up to a 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:

(A) 1100 Hz **(B)** 2200 Hz

(C) 3300 Hz **(D)** 550 Hz

***Ans*:- (B)**

$$f = \frac{V(n)}{4\left(1 - \frac{17}{100}\right)} \text{ (as closed from end)}$$

$$f = \frac{(n-2)(v)}{4\left(1 - \frac{24.5}{100}\right)}$$

$$\frac{nV(100)}{4(83)} = \frac{(n-2)(v)(100)}{(4)(75.5)}$$

75.5 n = 83 (n – 2)

75.5 n = 83 (M – 2)

7.5 n = 166

n = 22 (approx)

$$f = \frac{(330)(22)(100)}{4(83)} = 2200 \text{ Hz}$$

***Questions*: 7:-** 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 $E = 30J\sin(1.5 \times 10^7 t - 5 \times 10^{-2} x)\ V/m$. The maximum magnetic force experienced by the electron will be: (given $c = 3 \times 10^8\ ms^{-1}$ and electron charge $= 1.6 \times 10^{-19} C$)

(A) 3.2×10^{-18} N **(B)** 1.5×10^{-19} N

(C) 2.4×10^{-18} N **(D)** 4.8×10^{-19} N

Ans:- **(D)**

$$\frac{E_0}{B_0} = C$$

$$B_0 = \frac{E_0}{C}$$

Force, $F_{max} = QVB$

***Questions*: 8:-** With increasing biasing voltage of a photodiode, the photocurrent magnitude:

(A) Remains constant

(B) Increases initially and after attaining

(C) Increases linearly

(D) Increases initially and saturates finally

Ans:- **(D)** Photodiode operate in reverse bias. The photocurrent increases initially and saturates finally.

***Questions*: 9:-** A bullet of mass 5 g, traveling 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 – ^{0}C) (1cal 4.2 x 10^7 ergs) close to:

(A) 83.3^o C **(B)** 38.4^o C

(C) 87.5^o C **(D)** 119.2^o C

Ans:- **(C)**

$$\frac{1}{4}m(210)^2 = m(0.03) \times (4.2) \times 1000 \times \Delta T \quad ; \quad Q = mS\Delta t$$

$$\Delta T = \frac{(210)(210)}{(4)(4.2)(0.03)(1000)} = 87.5°C$$

***Questions*: 10:-** 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:

(A) $\frac{7}{9}$ **(B)** $\frac{1}{3}$

(C) $\frac{5}{9}$ **(D)** $\frac{4}{9}$

Ans:- **(C)**

$$g' = g\left(\frac{R}{R+h}\right)^2 \quad \text{above}$$

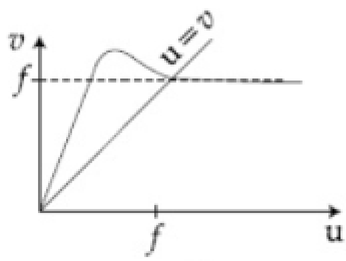
$$g' = g\left(\frac{2}{3}\right)^2 \qquad h = \frac{R}{2}$$

$$g' = g\left(1 - \frac{d}{R}\right) \quad \text{above}$$

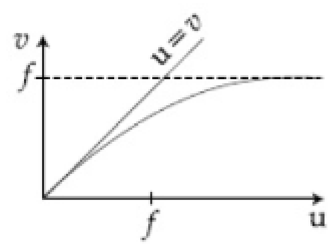
$$1 - \frac{d}{R} = \frac{4}{9} \qquad \frac{d}{R} = \frac{5}{9}$$

***Questions*: 11:-** For a concave lens of focal length f, the relation between object and image distances u and is ν, respectively, from its pole can best be represented by (u - ν is the reference line):

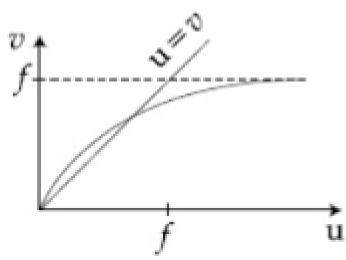
(A)



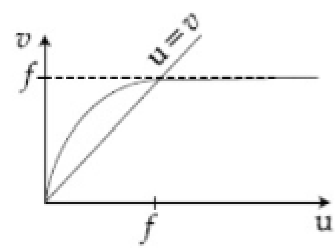
(B)



(C)



(D)



***Ans*:- (B)**

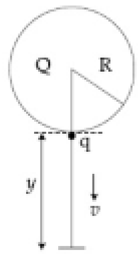
V is always less than u.

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

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{F}$$

$$V = \frac{uF}{u+F} = \frac{u}{\left(\frac{u}{F}+1\right)}$$

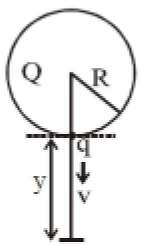
***Questions*: 12:-** A solid sphere of radius R carries a charge Q + q distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q. If it acquires a speed υ when it has fallen through a vertical height h (see figure), then: (assume the remaining portion to be spherical)



(A) $v^2 = y\left[\dfrac{qQ}{4\pi \in_0 R^2ym} + g\right]$ (B) $v^2 = 2y\left[\dfrac{qQ}{4\pi \in_0 R(R+y)m} + g\right]$

(C) $v^2 = y\left[\dfrac{qQ}{4\pi \in_0 R(R+y)m} + g\right]$ (D) $v^2 = 2y\left[\dfrac{QqR}{4\pi \in_0 (R+y)^3 m} + g\right]$

Ans:- **(B)**

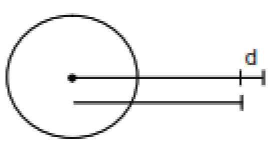


$dw_{ef} = Eqdx$

$$\int du_{et} = \int \frac{kQ}{x^2}dxq$$

$$= kQq\left(-\frac{1}{2}\right)_R^{R+y}$$

$$W_{ef} = \frac{kQq(y)}{(R)(R+y)}$$



$W_{all} = \Delta k$

$$W_{mg} + W_{ef} = \frac{1}{2}mv^2$$

$$V^2 = \frac{2}{m}\left(\frac{kQqy}{(R)(R+y)} + mg\,y\right)$$

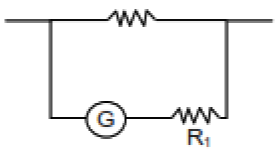
$$V^2 = 2y\left(\frac{kQq}{m(R)(R+y)} + g\right)\ ;\ k = \frac{1}{4\pi\varepsilon_0}$$

***Questions*: 13:-** A galvanometer of resistance G is converted into a voltmeter of range 0 – IV 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:

(A) R_1 + G **(B)** R_1

(C) G **(D)** R_1 – G

Ans:- **(A)**



$V = I_G(G + R_1)$

$1 = I_G(G + R_1)$ ...(1)

$2 = I_G(G + R_1 + R_2)$

$2 = 1 + I_G R_2$

$I_G R_2 = 1$

$R_2 = G + R_1$

***Questions*: 14:-** Number of molecules in a volume of 4 cm^3 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/s^2, density of mercury = 13.6 g/cm^3)

(A) 5.8×10^{18} **(B)** 4.0×10^{16}
(C) 5.8×10^{16} **(D)** 4.0×10^{18}

***Ans*:- (D)**

Use the equation to find 'N':

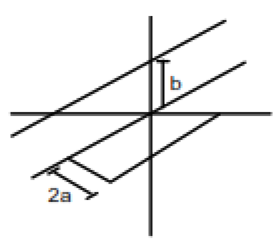
$$P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}mu^2\right)$$

***Questions*: 15:-** 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:

(A) $\frac{2\mu_0 I^2 a^3}{\pi b^2}$ **(B)** $\frac{\mu_0 I^2 a^2}{2\pi b}$
(C) $\frac{\mu_0 I^2 a^3}{2\pi b^2}$ **(D)** $\frac{2\mu_0 I^2 a^2}{\pi b}$

***Ans*:- (D)**

$$\vec{B}_1 = \frac{\mu_0 I}{2\pi(\ell)}$$

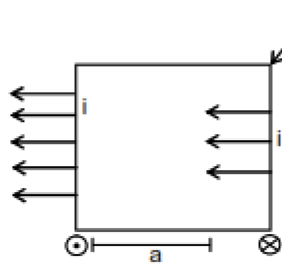


$$|\vec{\tau}| = |\vec{r} \times \vec{F}|$$

$\tau = 2aF$

$$\tau = 2(a)(I)(2a)\left(\frac{\mu_0 I}{2\pi b}\right)$$

$$\tau = \frac{2\mu_0 I^2 a^2}{\pi b}$$



B on the also equal to B_1 as

$$B = \frac{\mu_0 I}{2\pi\sqrt{b^2 + \frac{\mu_0^2}{4}}}$$

b >>> a

***Questions*: 16:-** Assume that the displacement (s) of air is proportional to the pressure difference ($\wedge$ p) created by a sound wave. Displacement (s) further depends on the speed of sound (v), density of air (ρ) and the frequency (f). If $\wedge p \sim 10\text{Pa}, \upsilon \sim 300\ \text{m/s}, \rho \sim \pi 1\ \ 1\text{g/m}^3$ and f ~ 1000 Hz, then s will be of the order of (take the multiplicative constant to be 1)

(A) $\frac{1}{10}$ mm **(B)** 10 mm

(C) $\frac{3}{100}$ mm **(D)** 1mm

***Ans*:- (C)**

$$\text{disp} = \left(\frac{\text{kg}}{\text{ms}^2}\right)\left(\frac{\text{s}}{\text{m}}\right)(\text{s})\left(\frac{\text{m}^3}{\text{kg}}\right)$$

$$\text{disp} = (1)\ (16)\ \left(\frac{1}{300}\right)\ \left(\frac{1}{1000}\right)\ (1)$$

$$\text{disp in mm} = \frac{1000}{300 \times 100} = 0.03333$$

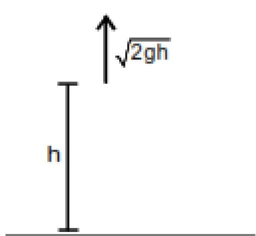
$$\Rightarrow \quad \frac{3}{100}$$

***Questions*: 17:-** A helicopter rises from rest on the ground vertically upwards with a constant acceleration g. A food packet is dropped from the helicopter when it is at a height h. The time taken by the packet to reach the ground is close to [g is the acceleration due to gravity]:

(A) $t = 1.8\sqrt{\frac{h}{g}}$ **(B)** $t = \sqrt{\frac{2h}{3g}}$

(C) $t = 3.4\sqrt{\left(\frac{h}{g}\right)}$ **(D)** $t = \frac{2}{3}\sqrt{\left(\frac{h}{g}\right)}$

***Ans*:- (C)**



$$V^2 = 2gh$$

$$V = \sqrt{2gh}$$

$$h = -\sqrt{2gh} + \frac{gt^2}{2}$$

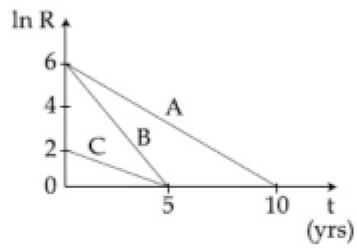
$$gt^2 - 2\sqrt{2gh}\,t - 2h = 0$$

$$t = \frac{2\sqrt{2gh} \pm \sqrt{8gh + 8gh}}{2g}$$

$$t = \frac{2\sqrt{2gh} + 4\sqrt{gh}}{2g} \quad \text{as cannot be negative.}$$

$$\therefore \quad t = (2 + \sqrt{2})\sqrt{\frac{h}{g}} \quad \Rightarrow \quad 3.4\sqrt{\frac{h}{g}}$$

***Questions*: 18:-** 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 radio:



(A) 3: 2: 1 **(B)** 2: 1: 3
(C) 4: 3: 1 **(D)** 2: 1: 1

Ans:- **(B)**

$\ln|R| = \ln|R_o| - \lambda t$

and $T_{1/2} \propto \frac{1}{\lambda}$

where 'N' is slope

$T_{1/2}(A) : T_{1/2}(B) : T_{1/2}(C) = \frac{10}{6} : \frac{5}{6} : \frac{5}{2}$

$= 2 : 1 : 3$

***Questions*: 19:-** An electrical power line, having a total resistance of 2Ω, delivers 1 kW at 220 V. The efficiency of the transmission line is approximately:

(A) 96% **(B)** 72%
(C) 91% **(D)** 85%

Ans:- **(A)**

Power delivered = 1000 W

Voltage = 220 V

Transmission 'I' = $\frac{1000}{220}$

Power loss = I^2R

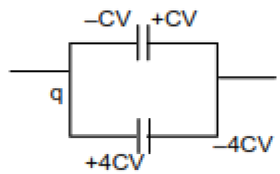
Efficiency = $\frac{1000 \times 100}{1000 + I^2R}$

***Questions*: 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:

(A) $\frac{3}{2}CV^2$ **(B)** $\frac{9}{2}CV^2$
(C) $\frac{25}{6}CV^2$ **(D)** zero

Ans:- **(A)**

$$\frac{4CV - q}{2\ell} = \frac{-CV + q}{c} \quad \text{(as same point)}$$



$$4cV - q = -2cV + 2q$$

$$q = 2cV$$

$$\text{Energy} = \frac{(2cv)^2}{4c} + \frac{(cV)^2}{2c} \Rightarrow \frac{3cV^2}{2}$$