PART – A (PHYSICS)

SECTION - A

(One Options Correct Type)

***Questions*: 1:-** A current of 10 A exists in a wire of cross-sectional area of $5mm^2$ with a drift velocity of 2×10^{-3} ms^{-1}. The number of free electrons in each cubic meter of the wire …………..

(A) 2×10^{25}
(B) 1×10^{23}
(C) 2×10^{6}
(D) 625×10^{25}

***Ans*:- D**

$i = neAV_d$

$$\Rightarrow n = \frac{i}{eAV_d} = \frac{10}{1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 2 \times 10^{-3}} = 625 \times 10^{25}$$

***Questions*: 2:-** An electron of mass m and a photon have same energy E. The ratio of wavelength of electron to that of photon is: (c being the velocity of light)

(A) $\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$
(B) $\left(\frac{E}{2m}\right)^{1/2}$
(C) $c(2mE)^{1/2}$
(D) $\frac{1}{c}\left(\frac{2m}{E}\right)^{1/2}$

***Ans*:- A**

$$\lambda_e = \frac{h}{mv} = \frac{h}{\sqrt{2mE}} \text{ and } \lambda_p = \frac{hc}{E}$$

$$\Rightarrow \frac{\lambda_e^2}{\lambda_p^2} = \frac{\frac{h^2}{2Em}}{\frac{h^2c^2}{E^2}} = \frac{E}{2mc^2} \Rightarrow \frac{\lambda_e}{\lambda_p} = \frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$$

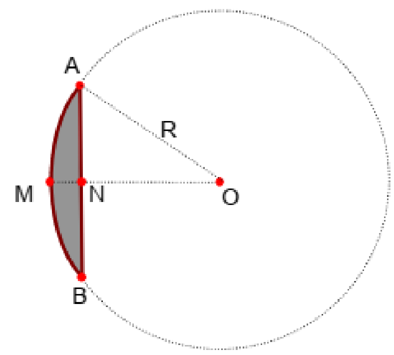
***Questions*: 3:-** The thickness at the centre of a plano-convex lens is 3 mm and the diameter is 6cm. If the speed of light in the material of the lens is 2×10^{8} ms^{-1}.The focal length of the lens is ………..

(A) 15 cm
(B) 0.30 cm
(C) 30 cm
(D) 1.5 cm

***Ans*:- C**

$$\mu = \frac{c}{v_m} = \frac{3\times10^8}{2\times10^8} = 1.5$$

Here MN = 3mm = 0.3 cm ,
AN = BN =6 cm



With the help of right angled triangle ANO ,we can write

$$(AO)^2 = (AN)^2 + (ON)^2$$

$$\Rightarrow R^2 = (3)^2 + (R-0.3)^2$$

$$\Rightarrow R^2 = 9 + R^2 + 0.09 - 0.6R$$

$$\Rightarrow 0.6R = 9.09 \Rightarrow R = \frac{9.09}{0.6} = 15.15\text{ cm} \approx 15\text{ cm}$$

With the help of Lens Maker's formula, we can write

$$\frac{1}{f} = \left(\frac{\mu-\mu_m}{\mu_m}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) = \left(\frac{1.5-1}{1}\right)\left(\frac{1}{15}-\frac{1}{\infty}\right) = \frac{1}{30} \Rightarrow f = 30\text{ cm}$$

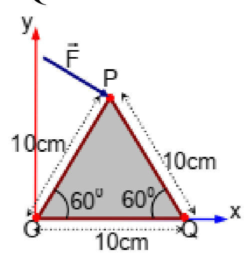
***Questions*: 4:-** The vernier-scale used for measurement has a positive zero error of 0.2 mm. If while taking a measurement it was noted that '0' on the vernier- scale lies between 8.5 cm and 8.6 cm, Vernier coincidence is 6, then the correct value of measurement is …………….. cm. (least count = 0.01
cm)

(A) 8.36 cm (B) 8.58 cm
(C) 8.54 cm (D) 8.56 cm

***Ans*:- C**

Positive zero error = 0.02cm
Reading 8.5 + 6 x 0.01 = 8.56cm
Actual reading = 8.56 - 0.02 = 8.54cm

***Questions*: 5:-** A triangular plate is shown. A force $\bar{F} = 4\hat{\imath} - 3\hat{\jmath}$ is applied at point P. The torque at point P with respect to point 'O' and 'Q' are:



(A) $15+20\sqrt{3}, 15-20\sqrt{3}$ (B) $-15-20\sqrt{3}, 15-20\sqrt{3}$
(C) $-15+20\sqrt{3}, 15+20\sqrt{3}$ (D) $15-20\sqrt{3}, 15+20\sqrt{3}$

***Ans*:- B**

For Torque about point-O

$$\vec{r}_{PO} = 5\hat{i} + 5\sqrt{3}\hat{j}$$

$$\vec{\tau}_O = \vec{r}_{PO} \times \vec{F} = \left(5\hat{i} + 5\sqrt{3}\,\hat{j}\right) \times \left(4\hat{i} - 3\hat{j}\right) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & 5\sqrt{3} & 0 \\ 4 & -3 & 0 \end{vmatrix} = \left(-15 - 20\sqrt{3}\right)\hat{k}$$

For Torque about point-Q

$$\vec{r}_{PQ} = -5\hat{i} + 5\sqrt{3}\,\hat{j}$$

$$\vec{\tau}_Q = \vec{r}_{PQ} \times \vec{F} = \left(-5\hat{i} + 5\sqrt{3}\,\hat{j}\right) \times \left(4\hat{i} - 3\hat{j}\right) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -5 & 5\sqrt{3} & 0 \\ 4 & -3 & 0 \end{vmatrix} = \left(+15 - 20\sqrt{3}\right)\hat{k}$$

***Questions*: 6:-** A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β to come to rest. If the total time elapsed is t seconds, the total distance traveled is:

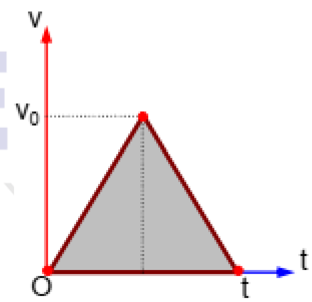
(A) $\frac{4\alpha\beta}{(\alpha+\beta)}t^2$ (B) $\frac{\alpha\beta}{4(\alpha+\beta)}t^2$

(C) $\frac{2\alpha\beta}{(\alpha+\beta)}t^2$ (D) $\frac{\alpha\beta}{2(\alpha+\beta)}t^2$

***Ans*:-** D

$t_1 + t_2 = t$

$$\frac{v_0}{t_1} = \alpha \text{ , and } \frac{v_0}{t_2} = \beta$$



$$\Rightarrow \frac{v_0}{\alpha} + \frac{v_0}{\beta} = t_1 + t_2 = t \Rightarrow v_0 = \frac{t}{\frac{1}{\alpha} + \frac{1}{\beta}} = \frac{\alpha\beta t}{\alpha+\beta}$$

Distance traveled = Area under speed –time graph $= \frac{1}{2} \times t \times \frac{\alpha\beta t}{\alpha+\beta} = \frac{\alpha\beta}{2(\alpha+\beta)}t^2$

***Questions*: 7:-** A boy is rolling a 0.5 kg ball on the frictionless floor with the speed of $20ms^{-1}$. The ball gets deflected by an obstacle on the way. After deflection it moves with 5% of its initial kinetic energy. What is the speed of the ball now?

(A) $14.41ms^{-1}$ (B) $19.0ms^{-1}$

(C) $1.00ms^{-1}$ (D) $4.47ms^{-1}$

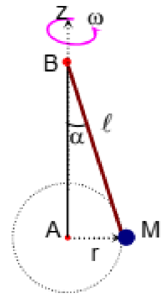
***Ans*:- D**

$$K_i = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right)\left(\frac{v}{r}\right)^2 = \frac{7}{10}mv^2 = 140\,J$$

$$K_f = 0.05K_i = \frac{7}{10}mv_f^2 \Rightarrow 7 = \frac{7}{10} \times \frac{1}{2} \times v_f^2 \Rightarrow v_f^2 = 20$$

$$\Rightarrow v_f = \sqrt{20} \approx 4.47\ ms^{-1}$$

***Questions*: 8:-** A mass M hangs on a massless rod of length ℓ which rotates at a constant angular frequency. The mass M moves with steady speed in a circular path of constant radius. Assume that the system is in steady circular motion with constant angular velocity ω. The angular momentum of M about point A is L_A which lies in the positive z direction and the angular momentum of M about point B is L_B. The correct statement for this system is:



(A) L_A is constant, both in magnitude and direction
(B) L_B is constant in direction with varying magnitude
(C) L_A and L_B are both constant in magnitude and direction
(D) L_B is constant, both in magnitude and direction

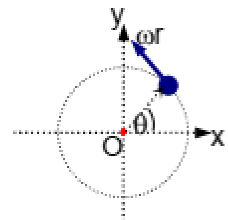
Ans:- **A**

$\vec{L}_A = Mvr\,\hat{k} = M\omega r^2\,\hat{k}$

$\vec{L}_B = \left(r\cos\theta\,\hat{i} + \sin\theta\,\hat{j} - \ell\cos\alpha\,\hat{k}\right) \times (M\omega r)\left(-\sin\theta\,\hat{i} + \cos\theta\,\hat{j}\right)$

Where $\theta = \omega t$

Magnitude $\vec{L}_B$ is constant and direction changes with time



***Questions*: 9:-** Which level of the single ionized carbon has the same energy as the ground state energy of hydrogen atom?

(A) 6 (B) 8
(C) 4 (D) 1

Ans:- **A**

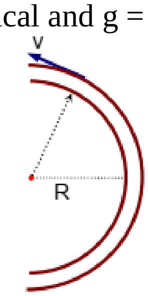
As we know that

$E_{Ground}(H-atom) = -13.6\,eV$

According to Question, we can write

$E_{Carbon} = E_{Ground}(H-atom) \Rightarrow -13.6\,eV = -13.6 \times \frac{6^2}{n^2} \Rightarrow n = 6$

***Questions*: 10:-** A modern grand - prix racing car of mass m is traveling on a flat track in a circular arc of radius R with a speed υ. If the coefficient of static between the tyres and the track is μ_s, then the magnitude of negative lift F_L acting downwards on the car is:
(Assume forces on the four tyres are identical and g = acceleration due to gravity)



(A) $m\left(\frac{\upsilon^2}{\mu_s R}-g\right)$

(B) $-m\left(g+\frac{\upsilon^2}{\mu_s R}\right)$

(C) $m\left(g-\frac{\upsilon^2}{\mu_s R}\right)$

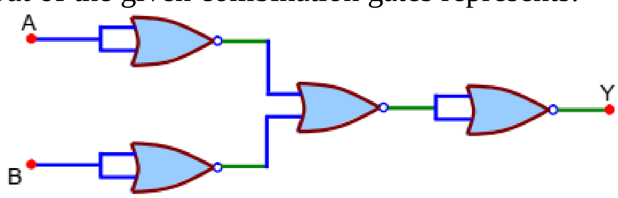
(D) $m\left(\frac{\upsilon^2}{\mu_s R}+g\right)$

***Ans*:- A**

$N = mg - F_L$

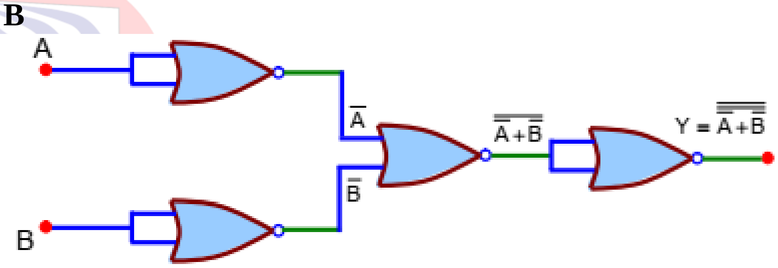
$$f_s = \frac{mv^2}{R} \le \mu_s N = \mu_s(mg-F_L) \Rightarrow |-F_L| = m\left(\frac{v^2}{\mu_s R}-g\right)$$

***Questions*: 11:-** The output of the given combination gates represents:



(A) NOR Gate
(B) NAND Gate
(C) XOR Gate
(D) AND Gate

***Ans*:- B**



$$Y = \overline{\overline{\bar{A}+\bar{B}}} = \bar{A}+\bar{B} = \overline{AB} \Rightarrow \text{NAND Gate}$$

***Questions*: 12:-** A polyatomic ideal gas has 24 vibrational modes. What is the value of γ?

(A) 1.30
(B) 1.03
(C) 10.03
(D) 1.37

***Ans*:- B**

Since each vibrational mode has two degree of freedom , so

$$f = f_{Translational} + f_{Rotational} + f_{Vibrational} = 3+3+48 = 54$$

$$\gamma = 1+\frac{2}{f} = 1+\frac{2}{54} = \frac{28}{27} \approx 1.03$$

***Questions*: 13:-** A solenoid of 1000 turns per meter has a core with relative permeability 500. Insulated windings of the solenoid carry an electric current of 5 A. The magnetic flux density produced by the solenoid is: (permeability of free space $4\pi \times 10^{-7}$ H/m)

(A) $2 \times 10^{-3}\ \pi T$
(B) πT
(C) $10^{-4}\ \pi T$
(D) $\frac{\pi}{5}$ T

***Ans*:- B**

$B = \mu ni = 500 \times 4\pi \times 10^{-7} \times 1000 \times 5 = \pi$ Tesla

***Questions*: 14:-** A Carnot's engine working between 400 K and 800 K has a work output of 1200J per cycle. The amount of heat energy supplied to the engine from the source in each cycle is:

(A) 3200 J
(B) 2400 J
(C) 1800 J
(D) 1600 J

***Ans*:- B**

$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{400}{800} = \frac{1}{2} \Rightarrow \eta = \frac{W}{Q} = \frac{1}{2} \Rightarrow Q = 2W = 2400\,J.$

***Questions*: 15:-** When two soap bubbles of radii a and b (b > a) coalesce, the radius of curvature of common surface is:

(A) $\frac{ab}{a+b}$
(B) $\frac{ab}{a-b}$
(C) $\frac{b-a}{ab}$
(D) $\frac{a+b}{ab}$

***Ans*:- B**

$P_1 - P_0 = \frac{4T}{a}$

$P_2 - P_0 = \frac{4T}{b}$

$\Rightarrow P_1 - P_2 = 4T\left(\frac{1}{a} - \frac{1}{b}\right)$

$P_1 - P_2 = \frac{4T}{r} = 4T\left(\frac{1}{a} - \frac{1}{b}\right) \Rightarrow r = \frac{ab}{b-a}$

***Questions*: 16:-** For what value of displacement the kinetic energy and potential energy of a simple harmonic oscillation become equal?

(A) x = 0
(B) $x = \pm A$
(C) $x = \pm\frac{A}{\sqrt{2}}$
(D) $x = \frac{A}{2}$

***Ans*:- C**

As we know that

$K = \frac{1}{2}mA^2\omega^2\cos^2\omega t = \frac{1}{2}m\omega^2\left(A^2 - x^2\right)$ and $U = \frac{1}{2}mA^2\omega^2\sin^2\omega t = \frac{1}{2}m\omega^2x^2$

According to Question, we can write

$K = U \Rightarrow \frac{1}{2}m\omega^2\left(A^2 - x^2\right) = \frac{1}{2}m\omega^2x^2 \Rightarrow A^2 - x^2 = x^2 \Rightarrow x = \pm\frac{A}{\sqrt{2}}$

***Questions*: 17:-** An AC current is given by $I = I_1 \sin \omega t + I_2 \cos \omega t$. A hot wire ammeter will give a reading:

(A) $\frac{I_1 + I_2}{2\sqrt{2}}$
(B) $\sqrt{\frac{I_1^2 + I_2^2}{2}}$

(C) $\dfrac{I_1 + I_2}{\sqrt{2}}$ (D) $\sqrt{\dfrac{I_1^2 - I_2^2}{2}}$

***Ans*:- B**

A hot wire ammeter reads rms value of current, so

$$I = I_1 \sin\omega t + I_2 \cos\omega t = \sqrt{I_1^2 + I_2^2}\sin(\omega t + \phi) = I_0 \sin(\omega t + \phi) \quad \text{, where } I_0 = \sqrt{I_1^2 + I_2^2}$$

$$\Rightarrow I_{rms} = \frac{I_0}{\sqrt{2}} = \sqrt{\frac{I_1^2 + I_2^2}{2}}$$

***Questions*: 18:-** Two ideal polyatomic gages at temperatures T_1 and T_2 are mixed so that there is no loss of energy. If F_1 and F_2 ,m_1 and m_2 n_1 and n_2 be the degrees of freedom, masses, number of molecules of the first and second gas respectively, the temperature of mixture of these two gases is:

(A) $\dfrac{n_1T_1 + n_2T_2}{n_1 + n_2}$ (B) $\dfrac{n_1F_1T_1 + n_2F_2T_2}{n_1F_1 + n_2F_2}$

(C) $\dfrac{n_1F_1T_1 + n_2F_2T_2}{F_1 + F_2}$ (D) $\dfrac{n_1F_1T_1 + n_2F_2T_2}{n_1 + n_2}$

***Ans*:- B**

$$U_1 = \left(\frac{n_1}{N_A}\right)\left(\frac{F_1R}{2}\right)T_1 \text{ and } U_2 = \left(\frac{n_2}{N_A}\right)\left(\frac{F_2R}{2}\right)T_2$$

$$U = U_1 + U_2 \Rightarrow \frac{(n_1 + n_2)}{N_A}\frac{(FR)}{2}T = \left(\frac{n_1}{N_A}\right)\left(\frac{F_1R}{2}\right)T_1 + \left(\frac{n_2}{N_A}\right)\left(\frac{F_2R}{2}\right)T_2 \quad \ldots(1)$$

$$F = \frac{n_1F_1 + n_2F_2}{n_1 + n_2} \quad \ldots\ldots\ldots\ldots(2)$$

With the help of equations (1) and (2), we can write

$$\Rightarrow T = \frac{n_1F_1T_1 + n_2F_2T_2}{n_1F_1 + n_2F_2}$$

***Questions*: 19:-** Two identical metal of thermal conductivities K_1 and K_2 respectively are connected in series. The effective thermal conductivity of the combination is:

(A) $\dfrac{K_1 + K_2}{K_1K_2}$ (B) $\dfrac{K_1 + K_2}{2K_1K_2}$

(C) $\dfrac{2K_1K_2}{K_1 + K_2}$ (D) $\dfrac{K_1K_2}{K_1 + K_2}$

***Ans*:- C**

$$R_{eq} = R_1 + R_2 = \frac{\ell}{K_1A} + \frac{\ell}{K_2A} = \frac{\ell}{A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right) = \frac{2\ell}{KA}$$

$$\Rightarrow K = \frac{2K_1K_2}{K_1 + K_2}$$

***Questions*: 20:-** If an electron is moving in the n^{th} orbit of the hydrogen atom, then its velocity (υ_n) for the n^{th} orbit is given as:

(A) $\upsilon_n \alpha \dfrac{1}{n}$ (B) $\upsilon_n \alpha n^2$

(C) $\upsilon_n \alpha\, n$

(D) $\upsilon_n\, \alpha \frac{1}{n^2}$

Ans:- **A**

$v_n\, \alpha \frac{1}{n}$