JEE-MAIN-2021 (18th March-First Shift)

PART – A (PHYSICS)

SECTION - A

***Questions*: 1:-** An oil drop of radius 2 mm with a density 3gcm^{-3} is held stationary under a constant electric field $3.55 \times 10^5\ Vm^{-1}$ in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess? Consider g = 9.81 m/s^2.

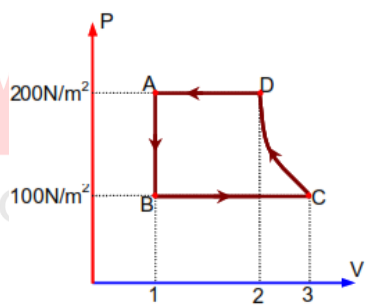
(A) 1.73 x 10^{10}
(B) 4.8 x 10^{11}
(C) 1.73 x 10^{12}
(D) 17.3 x 10^{10}

***Ans*:-A**

$$qE = mg \Rightarrow neE = \frac{4}{3}\pi r^3.\rho g$$

$$\Rightarrow n = \frac{4\pi r^3 \rho g}{3eE} = \frac{4\times 3.14\times\left(2\times10^{-3}\right)^3\times3\times10^3\times9.81}{3\times1.6\times10^{-19}\times3.55\times10^5} = 1.73\times10^{10}$$

***Questions*: 2:-** The P-V diagram of a diatomic ideal gas system going under cyclic process as shown in figure. The work done during an adiabatic process CD is (use γ =14)



(A) -500J
(B) 400J
(C) -400J
(D) 200J

***Ans*:-A**

For adiabatic process CD,

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{100\times4 - 200\times3}{1.4-1} = -500J$$

***Questions*: 3:-** In Young's double slit arrangement, slits are separated by a gap of 0.5 mm, and the screen is placed at a distance of 0.5 m from them. The distance between the first and the third bright fringe formed when the slits are illuminated by a monochromatic light of 5890 Å is :

(A) 1178 10^{-6} m
(B) 1178 x 10^{-12} m
(C) 1178 x 10^{-9} m
(D) 5890 x 10^{-7} m

***Ans*:- A**

Fringe width, $\beta = \frac{\lambda D}{d} = \frac{5890\times10^{-10}\times0.5}{0.5\times10^{-3}} = 589\times10^{-6}m$

Distance between first and third bright fright $= 2\beta = 1178\times10^{-6}m.$

***Questions*: 4:-** Match List – I with List – II.

List – I	List – II
(a) 10 km height over earth's surface	(i) Thermosphere
(b) 70 km height over earth's surface	(ii) Mesosphere
(c) 180 km height over earth's surface	(iii) Stratosphere
(d) 270 km height over earth's surface	(iv) Troposphere

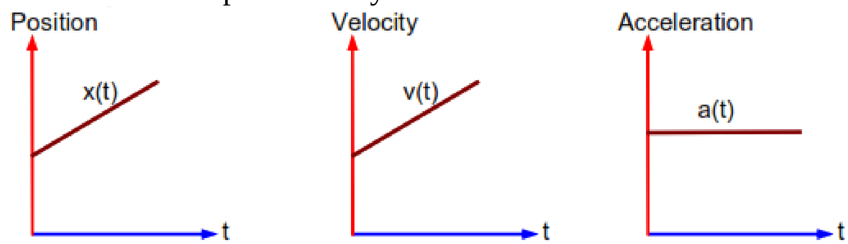
(A) (a) –(ii), (b) –(i), (c) –(iv), (d) –(iii) (B) (a) –(iv), (b) –(iii), (c) –(ii), (d) –(i)

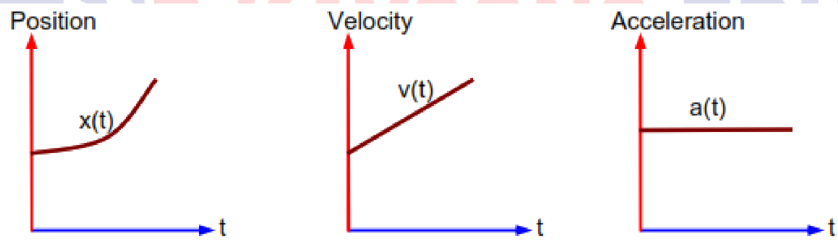
(C) (a) –(iii), (b) –(ii), (c) –(i), (d) –(iv) (D) (a) –(i), (b) –(iv), (c) –(iii), (d) –(ii)

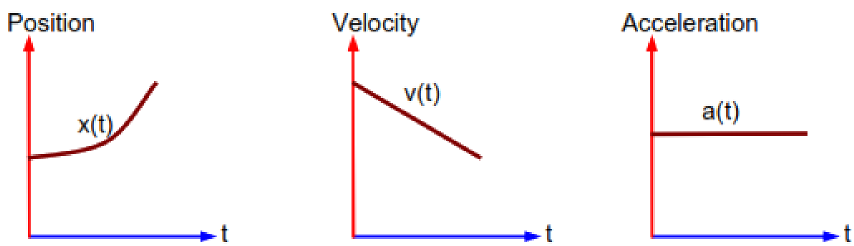
***Ans*: B**

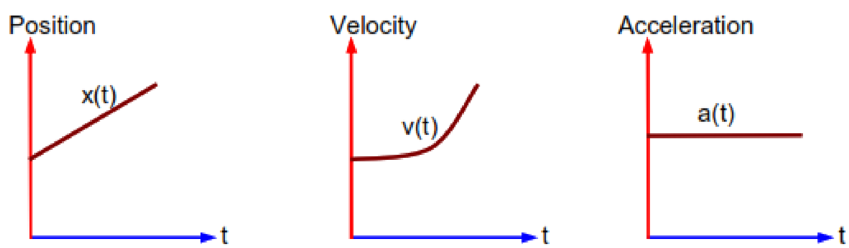
Layers of atmosphere are in order of (from bottom) troposphere, stratosphere, mesosphere, thermosphere.

***Questions*: 5:-** The position, velocity and acceleration of a particle moving with a constant acceleration can be represented by:

(A) 

(B) 

(C) 

(D) 

Ans:- **B**

For constant acceleration, a,

$x = ut + \frac{1}{2}at^2 \Rightarrow x - t$ graph is parabola.

$v = u + at \Rightarrow v - t$ graph is straight line with positive slope.

***Questions*: 6:-** In the experiment of Ohm's law, a potential difference of 5.0V is applied across the end of a conductor of length 10.0 cm and diameter of 5.00 mm. The measured current in the conductor is 2.00 A. The maximum permissible percentage error in the resistivity of the conductor is:

(A) 3.9
(B) 8.4
(C) 3.0
(D) 7.5

Ans:-**A**

From ohm's Law, $V = IR = I\frac{\rho\ell}{\pi\frac{d^2}{4}} \Rightarrow \rho = \frac{\pi d^2 V}{4\ell I}$

Relative error in resistively,

$$\frac{\Delta\rho}{\rho} = 2.\frac{\Delta d}{d} + \frac{\Delta V}{V} + \frac{\Delta\ell}{\ell} + \frac{\Delta I}{I} = 2\times\frac{0.01}{5.00} + \frac{0.1}{5.0} + \frac{0.1}{10.0} + \frac{0.01}{2000} = 0.039$$

Percentage error $= \frac{\Delta\delta}{\delta}\times 100 = 3.9\%$

***Questions*: 7:-** A thin circular ring of mass M and radius r is rotating about its axis with an angular speed ω . Two particles having mass m each are now attached at diametrically opposite points. The angular speed of the ring will become:

(A) $\omega\frac{M-2m}{M+2m}$
(B) $\omega\frac{M+2m}{M}$
(C) $\omega\frac{M}{M+m}$
(D) $\omega\frac{M}{M+2m}$

Ans:- **D**

Using conservation of Angular momentum along axis of rotation, we can write

$Mr^2\omega = (Mr^2 + 2mr^2)\omega_n \Rightarrow \omega_n = \frac{M\omega}{M+2m}$

***Questions*: 8:-** Your friend is having eye sight problem. She is not able to see clearly a distant uniform window mesh and it appears to her non-uniform and distorted. The doctor diagnosed the problems as:

(A) Myopia with Astigmatism
(B) Myopia and hypermetropia
(C) Astigmatism
(D) Presbyopia with Astigmatism

Ans:- **A**

An eye with defect of myopia can not see distant objects clearly, while that of stigmatism sees objects non- uniform and distorted.

***Questions*: 9:-** A constant power delivering machine has towed a box, which was initially at rest, along a horizontal straight line. The distance moved by the box in time 't' is proportional to:

(A)$t^{1/2}$
(B) t
(C) $t^{3/2}$
(D) $t^{2/3}$

Ans:-C

$$\Rightarrow m\frac{dv}{dt}.v = P \Rightarrow \int_0^v vdv = \frac{P}{m}\int_0^t dt \Rightarrow v = \left(\sqrt{\frac{2P}{m}}\right)t^{1/2}$$

$$\Rightarrow \int_0^x dx = \left(\sqrt{\frac{2P}{m}}\right)\int_0^t t^{1/2}dt \Rightarrow x = \left(\sqrt{\frac{2P}{m}}\right)\left(\frac{2}{3}t^{3/2}\right) \Rightarrow x \ \alpha \ t^{3/2}$$

***Questions*: 10:-** What will be the average value energy along one degree of freedom for an ideal gas in thermal equilibrium at a temperature T? (k_B is Boltzmann constant)

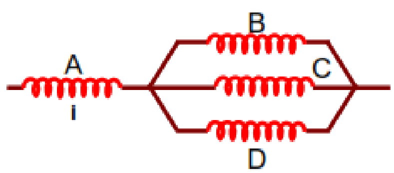
(A) k_B T (B) $\frac{2}{3}k_B T$

(C) $\frac{3}{2}k_B T$ (D) $\frac{1}{2}k_B T$

***Ans*:- D**

According to principle of equi-partition of Energy , the average energy per molecules associated with each degree of freedom is $\frac{1}{2}k_B T$.

***Questions*: 11:-** Four identical long solenoids A, B, C and D are connected to each other as shown in the figure. If the magnetic field at the centre of A is 3T,the field at the centre of C would be: (Assume that the magnetic field is confined within the volume of respective solenoid).



(A) 9 T (B) 6 T

(C) 12 T (D) 1 T

***Ans*:-D**

Magnetic field at centre of a solenoid is proportional to the current through it.
Current through C will be one -third of the current through A . So

Magnetic field at the centre of C $= \frac{3}{3} = 1$T.

***Questions*: 12:-** A plane electromagnetic wave of frequency 100 MHz is traveling in vacuum along the x-direction. At a particular point in space and time, $\vec{B} = 2.0 \times 10^{-8}\hat{k}T$. (where, $\hat{k}$ is unit vector along z-direction) What is $\vec{E}$ at this point ? (speed of light c = 3 x 10^8 m/s)

(A) 0.6 $\hat{j}$ V/m (B) 6.0 $\hat{j}$ V/m

(C) 0.6 $\hat{k}$ V/m (D) 6.0 $\hat{k}$ V/m

***Ans*:- B**

Direction of $\vec{E}$ is perpendicular to the direction of propagation and that of $\vec{B}$.

$E = cB = 3\times10^8 \times 2\times10^{-8} = 6 \quad V/m$

***Questions*:13:-**

A radioactive sample disintegrates via two independent decay processes having half lives $T^{(1)}_{1/2}$ and $T^{(2)}_{1/2}$ respectively. The effective half-life, $T_{1/2}$ of the nuclei is :

(A) None of the above

(B) $T_{1/2} = T^{(1)}_{1/2} + T^{(2)}_{1/2}$

(C) $T_{1/2} = \dfrac{T^{(1)}_{1/2} + T^{(2)}_{1/2}}{T^{(1)}_{1/2} - T^{(2)}_{1/2}}$

(D) $T_{1/2} = \dfrac{T^{(1)}_{1/2} T^{(1)}_{1/2}}{T^{(1)}_{1/2} + T^{(2)}_{1/2}}$

***Ans*:-D**

From Radioactive Decay Law,

$$-\frac{dN}{dt} = \lambda_1 N + \lambda_2 N = \lambda_{eff} N$$

$$\Rightarrow \lambda_{eff} = \lambda_1 + \lambda_2 \Rightarrow \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{T^{(1)}_{1/2}} + \frac{\ln 2}{T^{(2)}_{1/2}} \Rightarrow T_{1/2} = \frac{T^{(1)}_{1/2} T^{(2)}_{1/2}}{T^{(1)}_{1/2} + T^{(2)}_{1/2}}$$

***Questions*: 14:-** The time period of satellite in a circular orbit of radius R is T. The period of another satellite in a circular orbit of radius 9R is:

(A) 12 T

(B) 9 T

(C) 27 T

(D) 3 T

***Ans*:- C**

$$T^2 = \alpha R^3$$

$$\Rightarrow \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{R_2}{R_1}\right)^3 \Rightarrow T_2 = 9^{\frac{3}{2}} T = 27T$$

***Questions*: 15:-** Imagine that the electron in a hydrogen atom is replaced by a muon (μ) The mass of muon particle is 207 times that of an electron and charge is equal to the charge is of an electron. The ionization potential of this hydrogen atom will be:

(A) 13.6 eV

(B) 2815.2 eV

(C) 331.2 eV

(D) 27.2 eV

***Ans*:- B**

$$E \,\alpha\, m \Rightarrow \frac{E}{13.6} = 207 \Rightarrow E = 207 \times 13.6\,eV = 2815.2\,eV$$

***Questions*: 16:-** A loop of flexible wire of irregular shape carrying current is placed in an external magnetic field. Identify the effect of the field on the wire.

(A) Wire gets stretched to become straight.

(B) Loop assumes circular shape with its plane parallel to the field.

(C) Shape of the loop remains unchanged.

(D) Loop assumes circular shape with its plane normal to the field.

***Ans*:- D**

In external magnetic field, a magnetic force acts on every small part of the loop in direction perpendicular to the wire. Thus, loop assumes a shape (circular) in which it covers maximum area.

***Questions*: 17:-** A particle is traveling 4 times as fast as an electron. Assuming the ratio of de-Broglie wavelength of a particle to that of electron is 2:1, the mass of the particle is:

(A) 1/16 times the mass of e^- (B) 8 times the mass of e^-

(C) 1/8 times the mass of e^- (D) 16 times the mass of e^-

***Ans*:- C**

$$\frac{\lambda}{\lambda_e} = \frac{m_e v_e}{mv} \Rightarrow m = \frac{v_e}{v}.\frac{\lambda_e}{\lambda} m_e = \frac{1}{4} \times \frac{1}{2} m_e = \frac{1}{8} m_e$$

***Questions*: 18:-** In a series LCR resonance circuit, if we change the resistance only, from a lower to higher value:

(A) The quality factor will increase

(B) The resonance frequency will increase

(C) The quality factor and the resonance frequency will remain constant

(D) The band width of resonance circuit will increase

***Ans*:- D**

Resonance frequency is independent of R.

Quality factor $= \frac{\omega L}{R} \Rightarrow$ Quality factor decreases with increase in R.

Bandwidth of resonance circuit $= \frac{R}{L} \Rightarrow$ increases with increase in R.

***Questions*: 19:-** The time period of a simple pendulum is given by $T = 2\pi\frac{\sqrt{\ell}}{g}$.The measured value of the length of pendulum is 10cm known to a 1 mm accuracy. The time for 200 oscillations of the pendulum is found to be 100 second using a clock of 1s resolution. The percentage accuracy in the determination of ‘g’ using this pendulum is ‘x’. The value of ‘x’ to the nearest integer is,

(A) 4% (B) 3%

(C) 2% (D) 5%

***Ans*:- B**

$\ell = 10.0 \pm 0.1\text{cm}.$

$$T = \frac{100 \pm 1}{200} = 0.5 \pm 0.005$$

$$T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow g = \frac{4\pi^2 \ell}{T^2}$$

$$\frac{\Delta g}{g} = \frac{\Delta \ell}{\ell} + 2\frac{\Delta T}{T} = \frac{0.1}{10.0} + 2 \times \frac{0.005}{0.5} = 0.03$$

Percentage error $= \frac{\Delta g}{g} \times 100 = 3\%$

***Questions*: 20:-** An AC source rated 220 V, 50Hz is connected to a resistor. The time taken by the current to change from its maximum to the rms value is:

(A) 25ms (B) 2.5ms

(C) 0.25ms (D) 2.5 s

***Ans*:- B**

$\omega = 2\pi f = 100\pi \ \text{rad/s}$

$i_{rms} = \frac{i}{\sqrt{2}}$

While current changes from its maximum to its rms value, its phase changes by $\frac{\pi}{4}$ rad.

$t = \frac{\pi/4}{\omega} = \frac{\pi}{4 \times 100\pi} = 2.5 \times 10^{-3}\ \text{s} = 2.5\,\text{ms.}$