PHYSICS

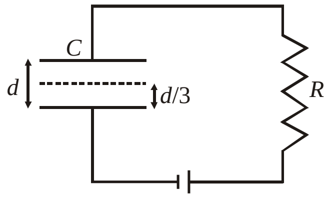
PART II

SECTION- I

Straight objective Type

This section contains 9 multiple choice questions numbered 23 to 31. Each question has 4 choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

23. A parallel plate capacitor C with plates of unit area and separation d is filled with a liquid of dielectric constant $K = 2$. The level of liquid is $\frac{d}{3}$ initially. Suppose the liquid level decreases at a constant speed V, the time constant as a function of time t is



(A) $\dfrac{6\varepsilon_0 R}{5d + 3Vt}$

(B) $\dfrac{(15d + 9Vt)\varepsilon_0 R}{2d^2 - 3dVt - 9V^2t^2}$

(C) $\dfrac{6\varepsilon_0 R}{5d - 3Vt}$

(D) $\dfrac{(15d - 9Vt)\varepsilon_0 R}{2d^2 + 3dVt - 9V^2t^2}$

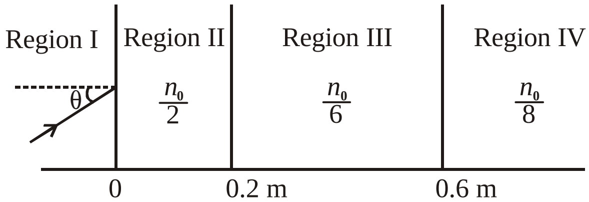
Sol. Ans [A]

Let x is thickness of dielectric

$$\Rightarrow \quad C = \frac{\varepsilon_0 A}{d - x + \frac{x}{K}}$$

$$\text{Time constant} = \frac{\varepsilon_0 AR}{d - x + \frac{x}{K}} = \frac{\varepsilon_0 R}{2d - \left(\frac{d}{3} - Vt\right) + \frac{\frac{d}{3} - Vt}{2}} = \frac{6\varepsilon_0 R}{5d + 3Vt}$$

24. A light beam is travelling from Region I to Region IV (Refer Figure). The refractive index in Regions I, II, III and IV are $n_0, \frac{n_0}{2}, \frac{n_0}{6}$ and $\frac{n_0}{8}$, respectively. The angle of incidence q for which the beam just misses entering Region IV is



(A) $\sin^{-1}\left(\frac{3}{4}\right)$ (B) $\sin^{-1}\left(\frac{1}{8}\right)$ (C) $\sin^{-1}\left(\frac{1}{4}\right)$ (D) $\sin^{-1}\left(\frac{1}{3}\right)$

Sol. Ans [B]

For parallel refracting surfaces

$\mu \sin i$ = constant

$\Rightarrow \quad n_0 \sin\theta = \frac{n_0}{8}\sin 90$

$\Rightarrow \quad \theta = \sin^{-1}\frac{1}{8}$

25. A vibrating string of certain length l under a tension T resonates with a mode corresponding to the first overtone (third harmonic) of an air column of length 75 cm inside a tube closed at one end. The string also generates 4 beats per second when excited along with a tuning fork of frequency n. Now when the tension of the string is slightly increased the number of beats reduces to 2 per second. Assuming the velocity of sound in air to be 340 m/s, the frequency n of the tuning fork in Hz is

(A) 344 (B) 336 (C) 117.3 (D) 109.3

Sol. Ans [A]

As tension increases, frequency of vibrating string also increases.

Given, for increase in tension, beat frequency decreases.

$\Rightarrow$ Frequency of tuning fork = $4 + \frac{3\times 340}{4\times 0.75} = 344$ Hz

26. A radioactive simple S_1 having an activity of 5 μ Ci has twice the number of nuclei as another sample S_2 which has an activity of 10 μ Ci. The half lifes of S_1 and S_2 can be

(A) 20 years and 5 years, respectively (B) 20 years and 10 years, respectively

(C) 10 years each (D) 5 years each

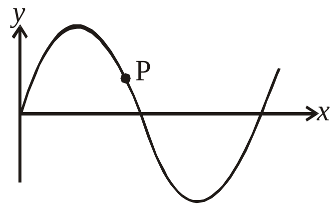
Sol. Ans [A]

$5 = \lambda_1 \times 2N_0$

$10 = \lambda_2 \times N_0$

$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{1}{4}$ or $\frac{T_1}{T_2} = 4$

27. A transverse sinusoidal wave moves along a string in a positive *x*-direction at a speed of 10 cm/s. The wavelength of the wave is 0.5 m and its amplitude is 10 cm. At a particular time *t*, the snap-shot of the wave is shown in figure. The velocity of point *P* when its displacement is 5 cm is



(A) $\frac{\sqrt{3}\pi}{50}\hat{j}$ m/s (B) $-\frac{\sqrt{3}\pi}{50}\hat{j}$ m/s (C) $\frac{\sqrt{3}\pi}{50}\hat{i}$ m/s (D) $-\frac{\sqrt{3}\pi}{50}\hat{i}$ m/s

Sol. Ans [A]

$$0.1 = \frac{0.5}{T} \Rightarrow T = 5\,\text{sec}.$$

$$\omega = \left(\frac{2\pi}{5}\right)$$

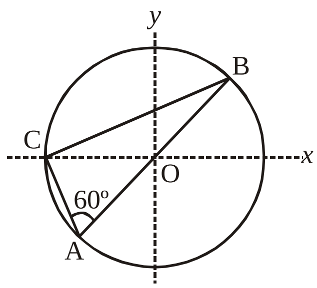
Particle velocity, $v_p = \frac{2\pi}{5}\left(\sqrt{(10)^2 - (5)^2}\right) \times 10^{-2} = \frac{\sqrt{3}\pi}{50}$ m/sec

Also particle velocity = –wave velocity × slope of wave form

∵ Slope at *P* is negative

⇒ Particle velocity along positive *y* axis.

28. Consider a system of three charges $\frac{q}{3}, \frac{q}{3}$ and $-\frac{2q}{3}$ placed at points *A*, *B* and *C*, respectively, as shown in figure. Take *O* to be the centre of the circle of radius *R* and angle *CAB* = 60º



(A) The electric field at point O is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative *x*-axis

(B) The potential energy of the system is zero

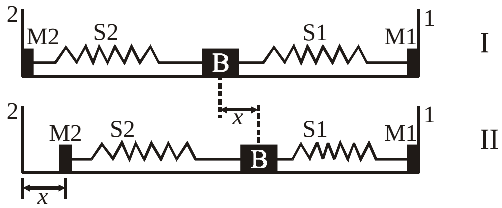
(C) The magnitude of the force between the charges at *C* and *B* is $\frac{q^2}{54\pi\varepsilon_0 R^2}$

(D) The potential at point O is $\frac{q}{12\pi\varepsilon_0 R}$

Sol. Ans [B]

$$V_{\text{at O}} = \frac{Kq/3}{R} + \frac{Kq/3}{R} + \frac{K(-2Kq/3)}{R} = 0$$

29. A block (B) is attached to two unstretched springs S_1 and S_2 with spring constants k and $4k$, respectively (see figure I). The other ends are attached to identical supports M_1 and M_2 not attached to the walls. The springs and supports have negligible mass. There is no friction anywhere. The block B is displaced towards wall 1 by a small distance x (figure II) and released. The block returns and moves a maximum distance y towards wall 2. Displacements x and y are measured with respect to the equilibrium position of the block B. The ratio $\frac{y}{x}$ is

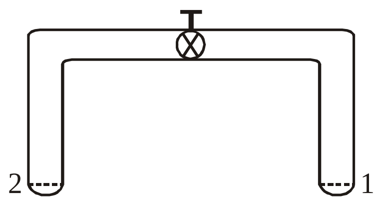


(A) 4 (B) 2 (C) $\frac{1}{2}$ (D) $\frac{1}{4}$

Sol. Ans [C]

$$\frac{1}{3}K(x)^2 = \frac{1}{2}\times 4K(y)^2 \quad \Rightarrow \quad \frac{y}{x} = \frac{1}{2}$$

30. A glass tube of uniform internal radius (r) has a valve separating the two identical ends. Initially, the valve is in a tightly closed position. End 1 has a hemispherical soap bubble of radius r. End 2 has sub-hemispherical soap bubble as shown in figure. Just after opening the valve,



(A) air from end 1 flows towards end 2. No change in the volume of the soap bubbles
(B) air from end 1 flows towards end 2. Volume of the soap bubble at end 1 decreases
(C) no change occurs
(D) air from end 2 flows towards end 1. Volume of the soap bubble at end 1 increases

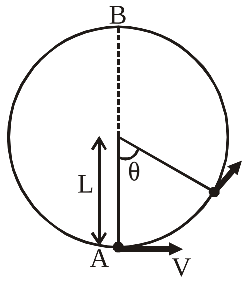
Sol. Ans [B]

Radius of bubble at 1 is less than radius of bubble at end 2 (i.e. $R_1 < R_2$)

$\because \quad \Delta P = \frac{4T}{R}$

$\Rightarrow$ Pressure inside bubble at 1 is more.

31. A bob of mass M is suspended by a massless string of length L. The horizontal velocity V at position A is just sufficient to make it reach the point B. The angle θ at which the speed of the bob is half of that at A, satisfies



(A) $\theta = \frac{\pi}{4}$

(B) $\frac{\pi}{4} < \theta < \frac{\pi}{2}$

(C) $\frac{\pi}{2} < \theta < \frac{3\pi}{4}$

(D) $\frac{3\pi}{4} < \theta < \pi$

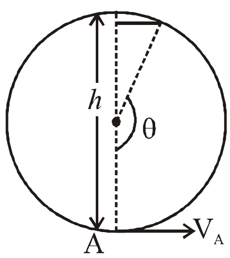
Sol. **Ans [D]**

$$\frac{1}{2}m\left(\sqrt{5gR}\right)^2 = mgh + \frac{1}{2}m\left(\frac{\sqrt{5gR}}{2}\right)^2$$

Solving, $h = \frac{15R}{8} = 1.875\ R$

For $\theta = \frac{3\pi}{4},\ h = 1.707\ R$

$\Rightarrow \quad \theta > \frac{3\pi}{4}$



SECTION- II

ASSERTION–REASON TYPE

This section contains 4 multiple choice questions numbered 32 to 35. Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which ONLY ONE is correct.

32. **STATEMENT-1:** For an observer looking out through the window of a fast moving train, the nearby objects appear to move in the opposite direction to the train, while the distant objects appear to the stationary.

and

STATEMENT-2: If the observer and the object are moving at velocities $\vec{V}_1$ and $\vec{V}_2$ respectively with reference to a laboratory frame, the velocity of the object with respect to the observer is $\vec{V}_2 - \vec{V}_1$.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

Sol. **Ans [B]**

33. STATEMENT-1: For particle purposes, the earth is used as a reference at zero potential in electrical circuits.

and

STATEMENT-2: The electrical potential of a sphere of radius *R* with charge *Q* uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

Sol. Ans [B]

Charge on earth is very large so small increment in charge does not change its potential. So potential of earth is taken to be positive.

34. STATEMENT-1: The sensitivity of a moving coil galvanometer is increased by placing a suitable magnetic material as a core inside the coil.

and

STATEMENT-2: Soft iron has a high magnetic permeability and cannot be easily magnetized or demagnetized.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

Sol. Ans [C]

Placing magnetic material increases magnetic material increases magnetic moment of coil, hence magnetic field associated with coil sensitivity $\frac{\theta}{C} = \left(\frac{NAB}{C}\right)$.

35. STATEMENT-1 : It is easier to pull a heavy object than to push it on a level ground.

and

STATEMENT-2: The magnitude of frictional force depends on the nature of the two surfaces in contact.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

Sol. Ans [D]

In case of pushing normal reaction between block and floor is more than that is in case of pulling and, $f = \mu N$.

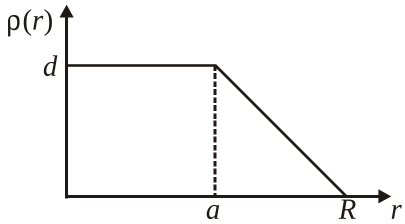
SECTION- III

LINKED COMPREHENSION TYPE

This section contains 2 Paragraphs. Based upon each paragraph, 3 multiple choice questions have to be answered. Each question has 4 choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

Paragraph for Question Nos. 36 to 38

The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density $\rho(r)$ [charge per unit volume] is dependent only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction.



36. The electric field at $r = R$ is

(A) independent of a

(B) directly proportional to a

(C) directly proportional to a^2

(D) inversely proportional to a

Sol. Ans [A]

Electric field at $r = R$ depends upon total charge enclosed.

$$\Rightarrow \quad E.\int ds = \frac{ze}{\varepsilon_0}$$

$$\Rightarrow \quad E = \frac{ze}{4\pi\varepsilon_0 R^2}$$ i.e., it independent of a

37. For $a = 0$, the value of d (maximum value of ρ as shown in the figure) is

(A) $\frac{3Ze}{4\pi R^3}$

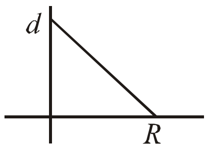
(B) $\frac{3Ze}{\pi R^3}$

(C) $\frac{4Ze}{3\pi R^3}$

(D) $\frac{Ze}{3\pi R^3}$

Sol. Ans [B]

For $a = 0$, graph $\rho(r)$ versus r is $d' = -\frac{d}{R}r + d$



Total charge enclosed = $\int \rho(r)\, dV = 4\pi \int_0^R \left(-\frac{d}{R} r + d\right) r^2\, dr = \frac{\pi d R^3}{3}$

$\Rightarrow \quad ze = \frac{\pi d R^3}{3}$

$\Rightarrow \quad d = \frac{3ze}{\pi R^3}$

38. The electric field within the nucleus is generally observed to be linearly dependent on r. This implies

(A) $a = 0$ (B) $a = \frac{R}{2}$ (C) $a = R$ (D) $a = \frac{2R}{3}$

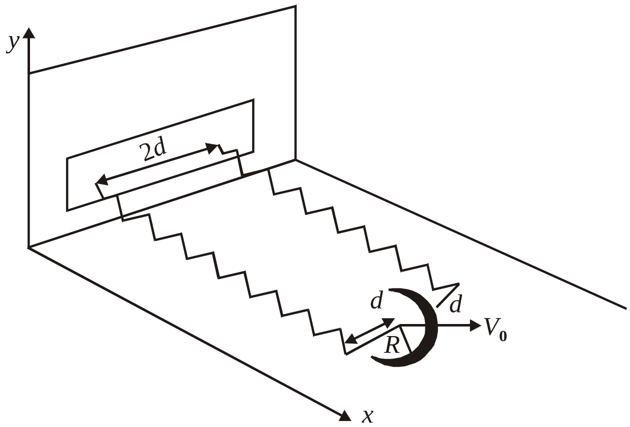
Sol. Ans [C]

Electric field varies linearly when charge density is constant and for that, $E = \frac{\rho r}{3\varepsilon_0}$.

Paragraph for Question Nos. 39 to 41

A uniform thin cylindrical disk of mass M and radius R is attached to two identical massless springs of spring constant k which are fixed to the wall as shown in the figure. The springs are attached to the axle is massless and both the springs and the axle are in a horizontal plane. The unstretched length of each spring is L. The disk is initially at its equilibrium position with its centre of mass (CM) at a distance L from the wall. The disk rolls without slipping with velocity $\vec{V}_0 = V_0 \hat{i}$. The coefficient of friction is μ.

Figure :



39. The net external force acting on the disk when its centre of mass is at displacement x with respect to its equilibrium position is

(A) $-kx$ (B) $-2kx$ (C) $-\frac{2kx}{3}$ (D) $-\frac{4kx}{3}$

Sol. Ans [D]

$\frac{1}{2}kx^2 + \frac{1}{2}kx^2 + \frac{1}{2}MV^2\left(1 + \frac{1}{2}\right) = \text{constant}$

Differentiating w.r.t. time

$$2kx\left(\frac{dx}{dt}\right)+\frac{3}{2}MV\frac{dV}{dt}=0$$

$$\frac{dV}{dt}=-\frac{4kx}{3M}$$

$$\frac{MdV}{dt}=-\frac{4kx}{3}$$

40. The centre of mass of the disk undergoes simple harmonic motion with angular frequency ω equal to

(A) $\sqrt{\frac{k}{M}}$ (B) $\sqrt{\frac{2k}{M}}$ (C) $\sqrt{\frac{2k}{3M}}$ (D) $\sqrt{\frac{4k}{3M}}$

Sol. Ans [D]

$$\frac{4kx}{3M}=\omega^2 x$$

$$\omega=\sqrt{\frac{4k}{3M}}$$

41. The maximum value of V_0 for which the disk will roll without slipping is

(A) $\mu g\sqrt{\frac{M}{k}}$ (B) $\mu g\sqrt{\frac{M}{2k}}$ (C) $\mu g\sqrt{\frac{3M}{k}}$ (D) $\mu g\sqrt{\frac{5M}{2k}}$

Sol. Ans [C]

For any displacement x from the mean position.

$\therefore$ $2kx - f = \frac{4kx}{3}$ (from part I)

$\therefore$ $f=\frac{2kx}{3}$, x for which friction is limiting.

$$\frac{2kx}{3}=\mu mg \quad \Rightarrow \quad x=\frac{3\mu mg}{2}$$

For V_0 to be maximum, this x should be amplitude of SHM

Now, conserving the mechanical energy,

$$\frac{3}{4}mV_0^2=kA^2=k\left(\frac{3\mu mg}{2}\right)^2$$

$$\Rightarrow \quad V_0=\mu g\sqrt{\frac{3m}{k}}$$

SECTION- IV

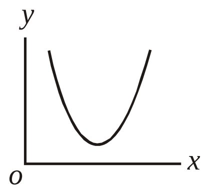
MATRIX-MATCH TYPE

This section contains 3 questions. Each question contains statements given in two columns which have to be matched. Statement (A, B, C, D) in Column I have to be matched with statements (p, q, r, s) in Column II.

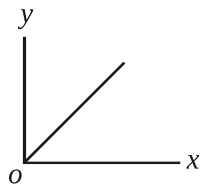
42. **Column I** gives a list of possible set of parameters measured in some experiments. The variations of the parameters in the form of graphs are shown in **Column II**. Match the set of parameters give in **Column I** with the graphs given in **Column II**. Indicate your answer by darkening the appropriate bubble of the 4 × 4 matrix given in the ORS.

Column I | **Column II**

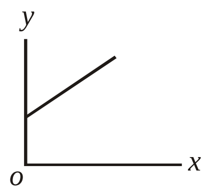
(A) Potential energy of a simple pendulum (y axis) as a function of displacement (x-axis)

(p)


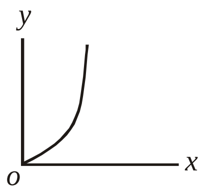
(B) Displacement (y axis) as a function of time (x axis) for a one dimensional motion at zero or constant acceleration when the body is moving along the positive x-direction

(q)


(C) Range of a projectile (y axis) as a function of its velocity (x axis) when projected at a fixed angle

(r)


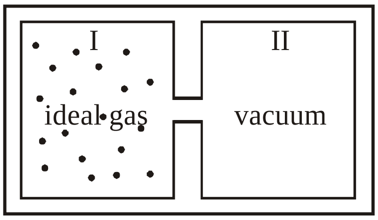
(D) The square of the time period (y axis) of a simple pendulum as a function of its length (x axis)

(s)


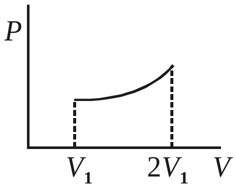
Sol. **Ans** (A) – p, s (B) q, r, s (C) s (D) q

43. **Column I** contains a list of processes involving expansion of an ideal gas. Match this with **Column II** describing the thermodynamic change during this process. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

Column I	Column II
(A) An insulated container has two chambers separated by a valve. Chamber I contains an ideal gas and the Chamber II has vacuum. The valve is opened.	(p) The temperature of the gas decreases.

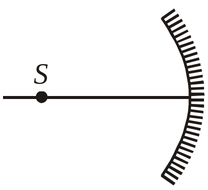


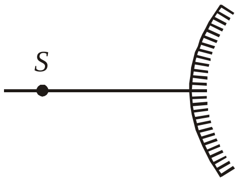
(B) An ideal monoatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^2}$, where V is the volume of the gas	(q) The temperature of the gas increases or remains constant
(C) An ideal monoatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^{4/3}}$, where V is its volume	(r) The gas loses heat
(D) An ideal monoatomic gas expands such that its pressure P and volume V follows the behaviour shown in the graph	(s) The gas gains heat



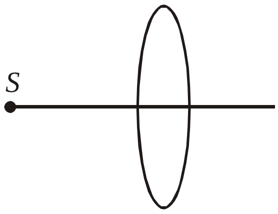
Sol. (A) q (B) p, r (C) p, r (D) s, q

44. An optical component and an object S placed along its optic axis are given in **Column I**. The distance between the object and the component can be varied. The properties of images are given in **Column II**. Match all the properties of images from **Column II** with the appropriate components given in **Column I**. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

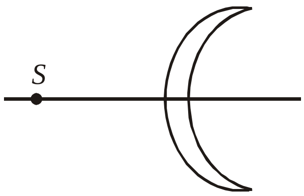
Column I	Column II
(A) 	(p) Real image

(B) 

(q) Virtual image

(C) 

(r) Magnified image

(D) 

(s) Image at infinity

Sol. **Ans** (A) p, q, r, s (B) q (C) p, q, r, s (D) p, q, r, s