

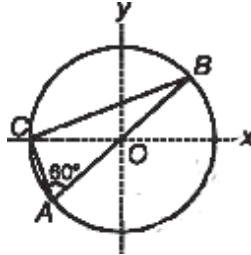
PHYSICS

SECTION-I

Straight Objective Type

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

- Q.1** 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 the figure. Take O to be the centre of the circle of radius R and angle CAB = 60°



- (A) The electric field at point O is $\frac{q}{8\pi\epsilon_0 R^2}$ 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 $\frac{q^2}{54\pi\epsilon_0 R^2}$
 (D) The potential at point O is $\frac{q}{12\pi\epsilon_0 R}$

Sol. (C)

Force between C and B is

$$\frac{1}{4\pi\epsilon_0} \left(\frac{2q}{3}\right) \left(\frac{q}{3}\right) \times \frac{1}{(R\sqrt{3})^2} = \frac{q^2}{54\pi\epsilon_0 R^2}$$

- Q.2** A radioactive sample S_1 having an activity of 5μ Ci has twice the number of nuclei as another sample S_2 which has an activity of 10μ Ci. The half lives 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. (A)

For S_1 , activity $\lambda_1 N_1 = 5\mu$ Ci

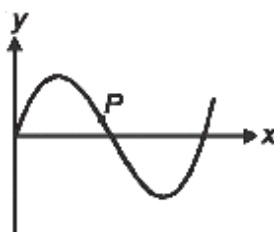
For S_2 , activity $\lambda_2 N_2 = 10\mu$ Ci

also $N_1 = 2N_2$

$$\Rightarrow \lambda_1 = \frac{\lambda_2}{4}$$

$$\Rightarrow T_1 = 4T_2$$

Q.3 A Transverse sinusoidal wave moves along a string in the 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. (A)

The wave equation can be written as

$$y = (0.1\text{m}) \sin (4\pi - 0.4\pi t) \hat{j} \quad \dots\dots(1)$$

As $A = 10 \text{ cm}$, $v = \frac{\omega}{k} = 10 \text{ cm/s}$ and $k = \frac{2\pi}{\lambda} = 4\pi \quad \dots\dots(2)$

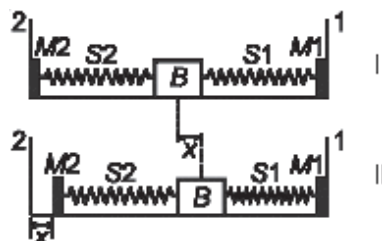
Now $\frac{dy}{dt} = 0.1 \times 0.4 \pi \cos (0.4\pi t - 4x) \hat{j}$

From (1), put $y = 5\text{cm}$ and $t = 0$, calculate x

From (2), velocity can be calculated

Q.4 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 : Figure



(A) 4

(B) 4

(C) $\frac{1}{2}$

(D) $\frac{1}{4}$

Sol. (C)

Using conservation of energy,

$$\frac{1}{2} kx^2 = \frac{1}{2} 4ky^2$$

$$\Rightarrow 2y = x$$

Sol. (A)

$$f_{\text{string}} = \frac{3 \times 340}{4 \times \left(\frac{75}{100}\right)} = 344 \text{ Hz}$$

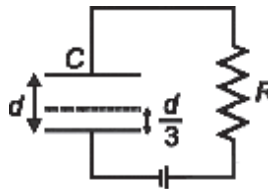
Now, $f_{\text{string}} - n = 4$

On increasing T , f_{string} increases and difference between the string frequency and tuning fork decreases. So,

$$f_{\text{string}} < n$$

$$\Rightarrow n = 344 \text{ Hz}$$

Q.8 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, the time constant as a function of time is



(A) $\frac{6\epsilon_0 R}{5d + 3vt}$

(B) $\frac{(15d + 9vt)\epsilon_0 R}{2d^2 - 3dvt - 9v^2t^2}$

(C) $\frac{6\epsilon_0 R}{5d - 3vt}$

(D) $\frac{(15d - 9vt)\epsilon_0 R}{2d^2 + 3dvt - 9v^2t^2}$

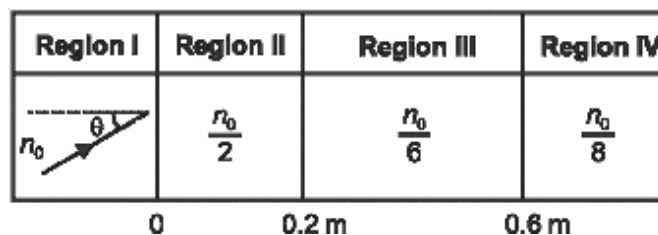
Sol. (A)

Time constant $T = RC$

$$\text{Now, } C = \frac{\epsilon_0 R}{\frac{2d}{3} + x + \frac{(d/3) - x}{k}}$$

where $x = vt$.

Q.9 A light beam is traveling 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 θ 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. (B)

For total internal reflection, at IV θ depends only on I and IV

$$\Rightarrow \sin \theta = \frac{\mu_{IV}}{\mu_I} = \frac{1}{8}$$

SECTION-II

Assertion-Reason Type

The section contains 4 reasoning type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

Q.10 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 be stationary.

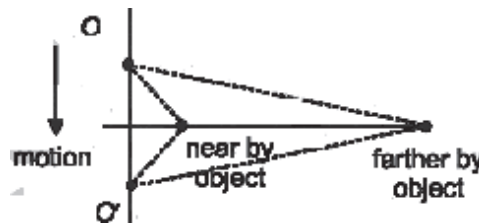
and

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. (B)

The angular position of farther objects change less. So They appear stationary. O and O' represent initial and final position of an observer in motion



Q.11 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. (B)

During Pull, normal reaction decreases so friction decreases

Q.12 STATEMENT-1 : For practical 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 and with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\epsilon_0 R}$

- (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. (B)

Earth is assumed to have zero potential, although it does have a negative potential. When potential at infinity is regarded as zero, the potential of a sphere with uniform charge of the

surface is $\frac{Q}{4\pi\epsilon_0 R}$

Q.13 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. (C)

By a suitable magnetic material field strength increases. Sensitivity is directly proportional to field as

$\frac{\theta}{1} = \frac{NBA}{C}$. Soft iron can be easily magnetised

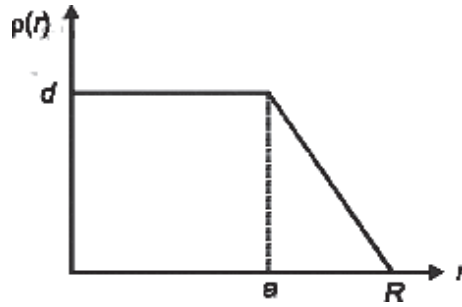
SECTION-III

Linked Comprehension Type

This section contains 2 paragraphs. Based upon each paragraph, 3 multiple choice question 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 14 to 16

The nuclear charge (Ze) is non- uniformly distributed with in 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



- Q.14** 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. (A)

The electric field at R (at the surface) is

$$E = \frac{Ze}{4\pi\epsilon_0 R^2}$$

It is independent of a

- Q.15** 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. (B)

When $a = 0$, $\rho = d \left(1 - \frac{r}{R}\right)$

Now, $Ze = \int_0^R \rho \times 4\pi r^2 dr = 4\pi d \int_0^R \left(r^2 - \frac{r^3}{R}\right) dr$

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

- Q.16** The electric field within the nucleus is generally observed to be linearly dependent on r . This implies

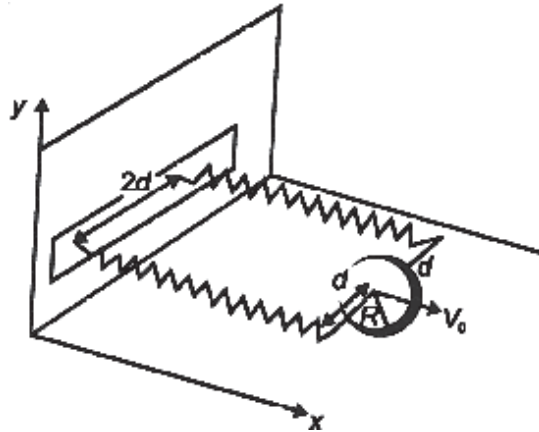
- (A) $a = 0$ (B) $a = \frac{R}{2}$ (C) $a = R$ (D) $a = \frac{2R}{3}$

Sol. (C)

When $E \propto r \Rightarrow$ charge density is uniform (like the case of a uniformly charged sphere).
 So, $a = R$

Paragraph for Question Nos. 17 to 20

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 of the disk symmetrically on either side at a distance d from its centre. 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 .



Q.17 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. (D)

$$F - f_r = Ma$$

$$f_r R = I \alpha \Rightarrow f_r = \frac{Ia}{R^2}$$

Solving these two,

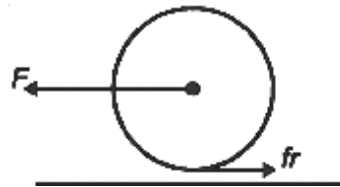
$$a = \frac{F}{M + \frac{I}{R^2}}$$

$$\text{Also, } F = -2kx \Rightarrow a = \frac{-2kx}{M + \frac{I}{R^2}}$$

$$f_r = \frac{I}{R^2} \times \left(\frac{-2kx}{M + \frac{I}{R^2}} \right)$$

$$\text{for disc } I = \frac{1}{2} MR^2$$

$$\Rightarrow f_r = -\frac{4kx}{3}$$



Q.18 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. (D)

$$a = - \frac{2kx}{m + \frac{I}{r^2}}$$

with $a = - \omega^2 x$

$$\Rightarrow \omega = \sqrt{\frac{2k}{m + \frac{I}{r^2}}} = \sqrt{\frac{4k}{3M}}$$

Q.19 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. (C)

$$fr = \frac{Ia}{R^2} \leq \mu Mg$$

and $\frac{IV_0\omega}{R^2} \leq \mu Mg$ ($\because a_{\max} = v_0 \omega$)

$$\frac{MR^2}{2} \frac{V_0\omega}{R^2} \leq \mu Mg$$

$$V_0 \leq 2\mu g \sqrt{\frac{3M}{4k}}$$

$$\leq \mu g \sqrt{\frac{3M}{k}}$$

SECTION-IV

Matrix-Match Type

This section contains 3 questions. Each question contains statements given in two columns, which have to be matched. Statements in **Column I** are labelled as (A), (B), (C) and (D), whereas statements in **Column II** are labelled as p,q,r and s. The answers to these questions have to be appropriately bubbled as illustrated in the following example.

If the correct matches are A-p, B-q, B-r, C-p, C-q and D-s, then the correctly bubbled matrix will look like the following

	p	q	r	s
A	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

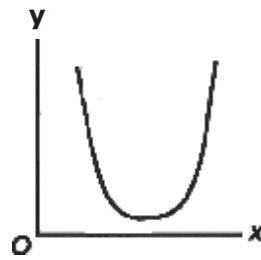
Q.20 Column I gives a list of possible set of parameters measured in some experiments. The variations of the parameters in the form of graphs are shown in column II. Match the set of parameters given in column I with the graphs given in Column II. Indicate your answer by darkening the appropriate bubble of the 4 x 4 matrix given in the ORS.

Column-I

Column - II

(A) Potential energy of a simple pendulum

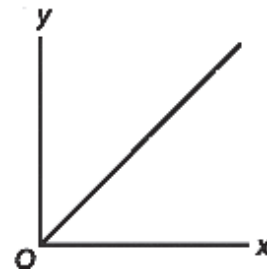
(p)



(y axis) as a function of displacement
(x axis)

(B) Displacement (y axis) as a function of

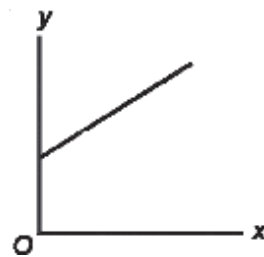
(q)



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

(C) Range of a projectile (y axis) as a

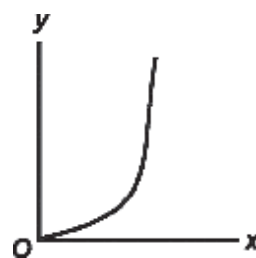
(r)



function of its velocity(x axis) when projected at a fixed angle

(D) The square of the time period(y axis)

(s)



of a simple pendulum as a function of its length (x axis)

Sol. A-p,s ; B-q,r,s ; C-s, D-q

(A) → p,s

Potential energy of a simple pendulum varies curvilinearly with displacement and is minimum at a certain value

(B) → q, r, s

q and r correspond to zero acceleration, while S corresponds to accelerated motion p is not possible as velocity is negative corresponding to initial portion of the graph.

(C) → s

$$R = \frac{u^2 \sin 2\theta}{g} \Rightarrow R \propto u^2$$

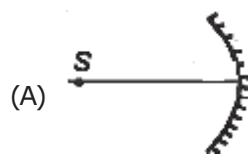
(D) \rightarrow q

$$T = 2\pi \sqrt{\frac{l}{g}} \Rightarrow T^2 \propto l$$

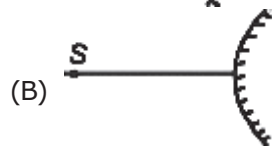
Q.21 An optical component and an object S placed along its optic axis are given in column I. The distance between the object and the component can be varied. The properties of images are given in column II. Match all the Properties of images from column II with the appropriate components given in column I. Indicate your answer

Column I

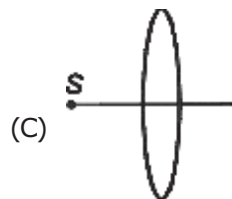
Column II



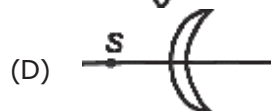
(p) Real image



(q) Virtual image



(r) Magnified image



(s) Image at infinity

Sol. A-p,q,r,s ; B-q ; C-p,r,s ; D-p,q,r,s

In all cases, u is negative

(A) \rightarrow p,q,r,s

$$\text{Magnification for mirror, } M = \frac{f}{f - u}$$

f is negative. Depending on value of u, m can be positive or negative and |m| can be > 1 or < 1 .

(B) \rightarrow q

$$m = \frac{f}{f - u}$$

f is positive $0 < m < 1$, for any value of u

(C) p,q,r,s

$$m = \frac{f}{f + u}$$

f is positive m can be positive or negative and |m| can be > 1 or < 1 depending on u

(D) \rightarrow p,q,r,s

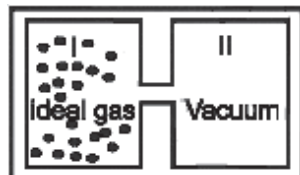
$$m = \frac{f}{f + u}$$

f is positive m can be positive or negative and |m| can be > 1 or < 1 depending on u.

Q.22 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 x 4 matrix given in the ORS

Column I

(A) An insulated container has two chambers by a valve. Chamber I contains an ideal gas and the chamber II has vacuum. The valve is opened.



(B) An ideal monoatomic gas expands to twice its original volume such

that its pressure $p \propto \frac{1}{\sqrt{V}}$, where V

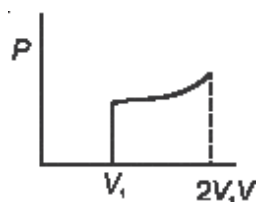
is the volume of the gas

(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

(D) An ideal monoatomic gas expands such that its pressure P and volume V follows the behaviour shown in the graph

**Column II**

(p) The temperature of the gas decreases

(q) The temperature of the gas increases or remains constant

(r) The gas loses heat

(s) The gas gains heat

Sol. A=q ; B-p,r ; C-p,s D-q,s

(A) in free expansion $W = \Delta U = Q = 0$

(B), (C) & (D)

$PV^n = \text{const.}$ if	$n < \gamma$	$Q > 0$
	$n > \gamma$	$Q < 0$
	$n = \gamma$	$Q = 0$
	$n = 1$	$T = \text{constant}$
	$n > 1$	$T \text{ decreases}$
	$n < 1$	$T \text{ increases}$