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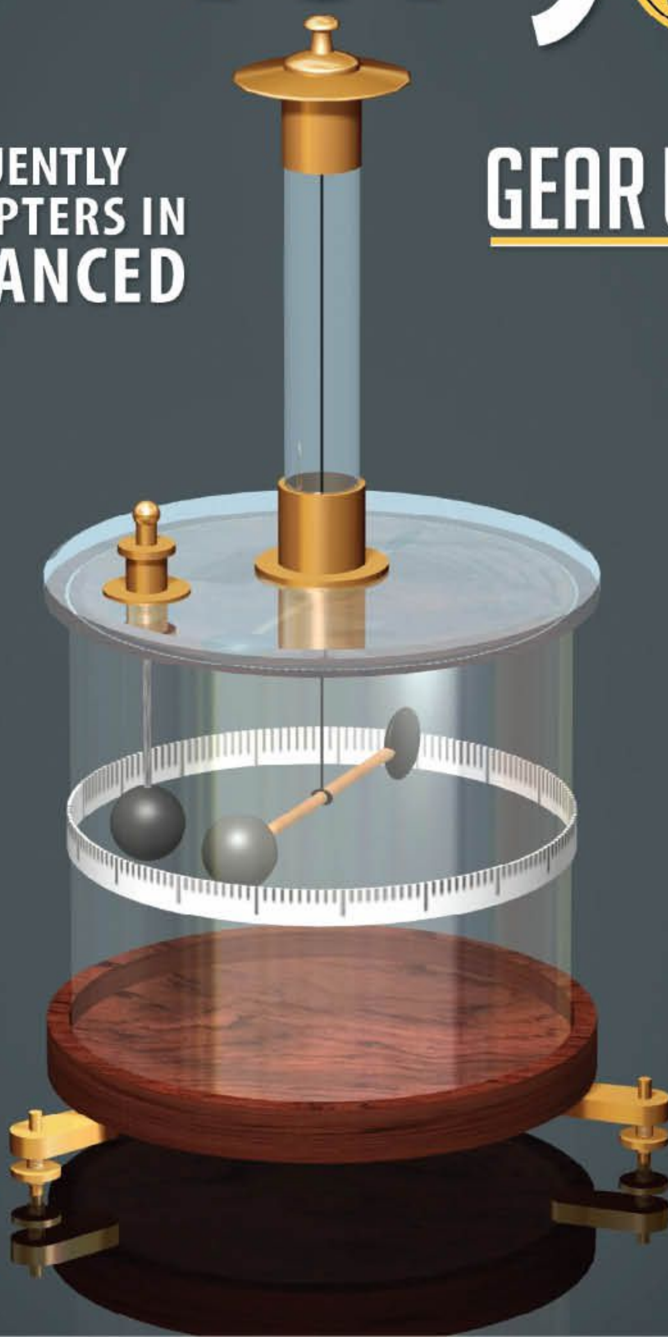

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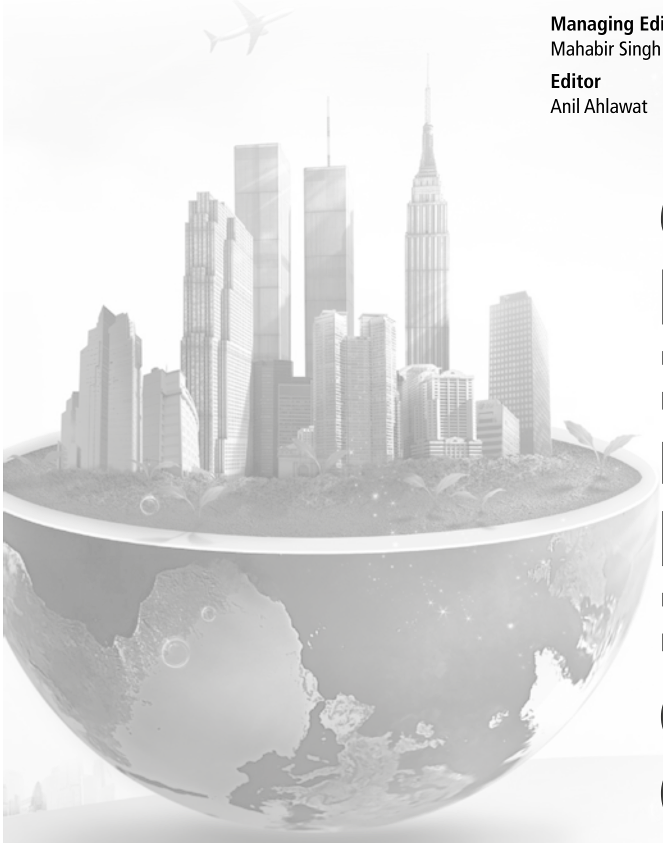

CONTENTS

TO OUR READERS

We are happy that intelligent students, teachers and other professionals continue to patronise Mathematics Today, Chemistry Today, Physics For You and Biology Today.
To them, we are addressing this open letter in view of increase in the cost of production and postage in the last seven years. All round spiralling prices have pushed production costs so high, that many in out fraternity find it impossible to continue business. We are compelled to raise the price to ₹ 40 from July 2018 issue.
We understand the pressure of cost on the student-teacher community in general but, we are hoping our readers will understand our problems and that we have no option but to comply with this unavoidable move.
We on our part, will keep up our efforts to improve the magazines in all its aspects.

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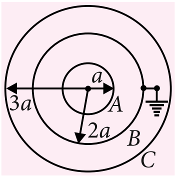
PHYSICS MUSING

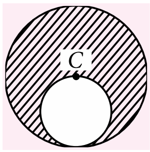
Physics Musing was started in August 2013 issue of Physics For You. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / NEET / AIIMS / JIPMER with additional study material.
In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / NEET. The detailed solutions of these problems will be published in next issue of Physics For You.
The readers who have solved five or more problems may send their detailed solutions with their names and complete address. The names of those who send atleast five correct solutions will be published in the next issue.
We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

PROBLEM Set 58

1. Figure shows a system of three concentric metal shells A, B and C with radii a, $2a$ and $3a$ respectively. Shell B is earthed and shell C is given a charge Q. Now if shell C is connected to shell A, then determine the final charge on the shell B.

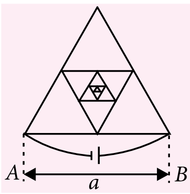


2. A solid sphere of radius R is uniformly charged with charge density ρ in its volume. A spherical cavity of radius $\frac{R}{2}$ is made in the sphere as shown in the figure. Find the electric potential at the centre of the sphere.

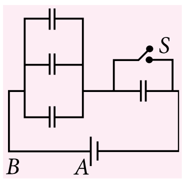


3. The potential inside a charged ball depends only on the distance from its centre as $V = ar^2 + b$, where a and b are constants. Find the space charge distribution $\rho(r)$ inside the ball.

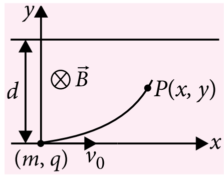
4. Determine the resistance R_{AB} between points A and B of the frame made of thin homogeneous wire (as shown in figure), assuming that the number of successively embedded equilateral triangles (with sides decreasing by half) tends to infinity. Side AB is equal to a, and the resistance per unit length of the wire is ρ.



5. Four capacitors of capacitance 10 μF and a battery of 200 V are arranged as shown. How much charge will flow through AB after the switch S is closed?

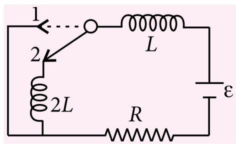


6. A non-uniform magnetic field $\vec{B} = B_0\left(1 + \frac{y}{d}\right)(-\hat{k})$ is present in region of space in between $y = 0$ and $y = d$. The lines are shown in the diagram. A particle of mass m and positive charge q is moving. Given an initial velocity $\vec{v} = v_0\,\hat{i}$. Find the components of velocity of the particle when it leaves the field.

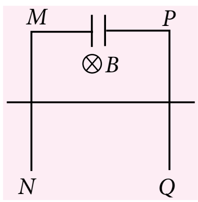


7. A positive charge particle of charge q and mass m is released at origin. There are uniform magnetic field and electric field in the space given by $\vec{E} = E_0\,\hat{j}$ and $\vec{B} = B_0\,\hat{k}$, where E_0 and B_0 are constants. Find the y co-ordinate of the particle at time t.

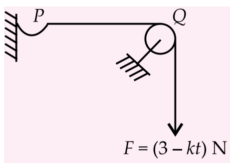
8. In the circuit shown, the switch S is shifted to position 2 from position 1 at t = 0, having been in position 1 for a long time. Find the current in the circuit as a function of time.



9. In the figure shown a conducting rod of length l, resistance R and mass m can move vertically downward due to gravity. Other parts are kept fixed. B = constant = B_0. MN and PQ are vertical, smooth, conducting rails. The capacitance of the capacitor is C. The rod is released from rest. Find the maximum current in the circuit.



10. In the given figure, a string of linear mass density 3×10^{-2} kg m^{-1} and length L = 1 m, is stretched by a force $F = (3 - kt)$ N, where k is a constant and t is time in second. At the time t = 0, a pulse is generated at the end P of the string. Find the value of k (in N s^{-1}) if the value of force becomes zero as the pulse reaches point Q.



By Akhil Tewari, Author Rank up Physics for JEE Main & Advanced, Professor, IITians PACE, Mumbai.

PRACTICE PAPER

NEET

Exam on
6^{th} May 2018

1. A projectile is projected with velocity kv_e in vertically upward direction from the ground into the space (v_e is escape velocity and $k < 1$). If air resistance is considered to be negligible then the maximum height from the centre of earth to which it can go, will be (R = radius of earth)

(a) $\frac{R}{k^2+1}$ (b) $\frac{R}{k^2-1}$ (c) $\frac{R}{1-k^2}$ (d) $\frac{R}{k+1}$

2. What is the wavelength of the most energetic photon emitted in the Balmer series of the Hydrogen atom?

(a) 645 nm (b) 580 nm
(c) 435 nm (d) 365 nm

3. A bomb is thrown at a speed 20 m s^{-1} at an angle 45°. At the highest point, it explodes into two parts of equal mass, the one part comes to rest. Find the distance from the origin to the point where the other part strikes the ground.

(a) 60 m (b) 30 m
(c) 15 m (d) 45 m

4. Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0\left(\frac{5}{4} - \frac{r}{R}\right)$ for $r \le R$, and $\rho(r) = 0$ for $r > R$, where r is the distance from the origin. The electric field at a distance r ($r < R$) from the origin is given by

(a) $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$ (b) $\frac{4\pi\rho_0 r}{3\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$

(c) $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ (d) $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

5. For a prism of refractive index $\sqrt{\frac{7}{3}}$ and prism angle 60°, find the minimum possible angle of incidence, so that the light ray grazes the second surface.

(a) 30° (b) 60° (c) 90° (d) 45°

6. A solid sphere of mass m and radius R rolls without slipping on a horizontal surface such that $v_{c.m.} = v_0$. Then,

(a) the kinetic energy of rotation is $\frac{1}{5}mv_0^2$

(b) the total kinetic energy is $\frac{7}{10}mv_0^2$

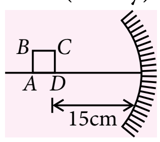
(c) the mechanical energy (assume the ground as reference) is $mgR + \frac{7}{10}mv_0^2$

(d) all of these.

7. The de Broglie wavelength of an electron moving with a velocity v is equal to the wavelength of a photon. The ratio of the kinetic energies of electron and photon is (Here c is the speed of light)

(a) $v : 4c$ (b) $v : 2c$ (c) $c : v$ (d) $2v : c$

8. A square $ABCD$ of side 1mm is kept at distance 15 cm infront of the concave mirror as shown in the figure. The focal length of the mirror is 10 cm. The length of the perimeter of its image will be (nearly)



(a) 8 mm
(b) 2 mm
(c) 12 mm
(d) 6 mm

9. A radioactive sample S_1 having an activity of 5 μCi has twice the number of nuclei as another sample S_2 which has an activity of 10 μCi. 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.

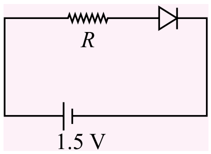
10. A pulley in the form of solid disc of mass 5 kg and radius 1 m is rotating at an angular speed of 120 rpm when the motor is turned off. Neglecting the friction at the axle, calculate the force that must by applied tangentially to the pulley to bring it to rest in 4 revolutions.

(a) 2.5 πN (b) 5.0 πN (c) 2.0 πN (d) 10 πN

11. The position of a particle at time t is given by the relation $x(t)=\frac{v_0}{A}(1-e^{-At})$, where v_0 is constant and $A>0$. The dimensions of v_0 and A are respectively

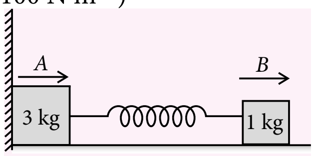
(a) $[M^0LT^0]$ and $[T^{-1}]$ (b) $[M^0LT^{-1}]$ and $[LT^{-2}]$
(c) $[M^0LT^{-1}]$ and $[T]$ (d) $[M^0LT^{-1}]$ and $[T^{-1}]$

12. The diode used in the circuit shown in the figure has a constant voltage drop of 0.5 V at all currents and a maximum power rating of 100 mW. What should be the value of the resistance R, connected in series with the diode for obtaining maximum current ?



(a) 1.5 Ω (b) 5 Ω (c) 6.67 Ω (d) 200 Ω

13. Initially spring is in its natural length. The block of mass 3 kg is in contact with rigid wall. The block of mass 1 kg is pushed through a distance 4 cm towards the wall and then released. The velocity of the center of mass when the block of mass 3 kg breaks off the wall is (k = 100 N m^{-1})

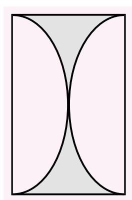


(a) 0.1 m s^{-1} (b) 0.2 m s^{-1}
(c) 0.3 m s^{-1} (d) 0.4 m s^{-1}

14. Radiation from a hydrogen discharge tube is incident on the cathode of a photocell. The work function of the cathode surface is 3.2 eV. If limit line of Balmer series is used, then to reduce the photocurrent to zero, the voltage (in volts) of the anode relative to the cathode must be made

(a) – 0.2 V (b) +3.2 V (c) – 10.4 V (d) –13.6 V

15. Two plano-convex lenses each of focal length 10 cm and refractive index $\frac{3}{2}$ are placed as shown in the figure. In the space left, water $\left(\mu=\frac{4}{3}\right)$ is filled. The whole arrangement is in air. The optical power of the system is(in dioptre)



(a) 6.67 (b) –6.67
(c) 33.3 (d) 20

16. A concrete sphere of radius R has a cavity of radius r which is packed with sawdust. The specific gravities of concrete and sawdust are respectively 2.4 and 0.3 for this sphere to float with its entire volume submerged under water. Ratio of mass of concrete to mass of sawdust will be
(density of water = 1 g cm^{-3})

(a) 8 :1 (b) 4 : 1 (c) 3 :2 (d) 5 : 3

17. The resistance of a wire at room temperature 30°C is found to be 10 Ω. Now to increase the resistance by 10%, the temperature of the wire must be
(The temperature coefficient of resistance of the material of the wire is 0.002 per °C.)

(a) 36°C (b) 83°C (c) 63°C (d) 33°C

18. In Young's experiment, two coherent sources are placed 0.90 mm apart and fringes are observed 1 m away. If it produces second dark fringe at a distance of 1 mm from central fringe, the wavelength of monochromatic light used would be

(a) 60×10^{-4} cm (b) 10×10^{-4} cm
(c) 10×10^{-5} cm (d) 6×10^{-5} cm

19. If β, R_L and r are the a.c. current gain, load resistance and the input resistance of a transistor respectively in CE configuration, the voltage and the power gains respectively are

(a) $\beta\frac{R_L}{r}$ and $\beta^2\frac{R_L}{r}$ (b) $\beta\frac{r}{R_L}$ and $\beta^2\frac{r}{R_L}$

(c) $\beta\frac{R_L}{r}$ and $\beta\left(\frac{R_L}{r}\right)^2$ (d) $\beta\frac{r}{R_L}$ and $\beta\left(\frac{r}{R_L}\right)^2$

20. Two particles begin to fall freely from the same height but the second falls t_0 second after the first. Find the time (after the dropping of first) when separation between the particles is h_0.

(a) $\frac{t_0}{2}+\frac{2h_0}{gt_0}$ (b) $t_0+\frac{h_0}{gt_0}$

(c) $\frac{t_0}{2}+\frac{h_0}{gt_0}$ (d) $2t_0-\frac{h_0}{gt_0}$

21. Three point masses are at the corners of an equilateral triangle of side a. Their separations do not change when the system rotates about the centre of the triangle. For this, the time period of rotation must be proportional to

(i) $a^{3/2}$ (ii) a (iii) $m^{1/2}$ (iv) $m^{-1/2}$

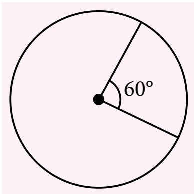
(a) (ii), (iv) (b) (ii), (iii)
(c) (i), (iii) (d) (i), (iv)

22. An electric bulb illuminates a plane surface. The intensity of illumination on the surface at a point 2 m away from the bulb is 5×10^{-4} phot lumen cm^{-2}. The line joining the bulb to the point makes an angle

60° with the normal to the surface. The intensity of the bulb in candela is

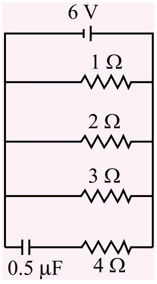
(a) $40\sqrt{3}$ (b) 40
(c) 20 (d) 40×10^{-4}

23. From a circular disc of mass M and radius R, a sector of 60° is removed. The moment of inertia of the remaining portion of disc about an axis passing through the centre and perpendicular to plane of disc is



(a) $\frac{5}{6}MR^2$ (b) $\frac{5}{3}MR^2$
(c) $\frac{5}{12}MR^2$ (d) $\frac{5}{24}MR^2$

24. In the given circuit diagram the current through the battery and the charge on the capacitor respectively in steady state are



(a) 1 A and 3 μC
(b) 17 A and 0 μC
(c) $\frac{6}{7}$ A and $\frac{12}{7}$ μC
(d) 11 A and 3 μC

25. Consider the following types of electromagnetic waves: (1) radio waves, (2) green light, (3) gamma rays, (4) microwaves and (5) X-rays. Which of the following sequences arranges these in the correct order of increasing wavelengths?

(a) (1) (5) (3) (4) (2) (b) (3) (5) (4) (2) (1)
(c) (5) (3) (2) (4) (1) (d) (3) (5) (2) (4) (1)

26. A current of 5 A is flowing at 220 V in the primary coil of a transformer. If the voltage produced in the secondary coil is 2200 V and 50% of power is lost, then the current in the secondary will be

(a) 0.25 A (b) 0.5 A (c) 2.5 A (d) 5 A

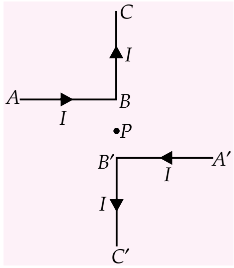
27. A ball A is projected with speed 20 m s^{-1} at an angle of 30° with the horizontal from the ground. Another ball B is released simultaneously from a point on the vertical line along the maximum height of the projectile. Both the balls collide at the maximum height of the first ball. The initial height of ball B is (Take g = 10 m s^{-2})

(a) 5 m (b) 10 m (c) 15 m (d) 20 m

28. The power radiated by a black body is P, and it radiates maximum energy around the wavelength λ_0. If the temperature of the black body is now changed so that it radiates maximum energy around a wavelength $\frac{3\lambda_0}{4}$, the power radiated by it will increase by a factor of

(a) $\frac{4}{3}$ (b) $\frac{16}{9}$ (c) $\frac{64}{27}$ (d) $\frac{256}{81}$

29. Current through ABC and $A'B'C'$ is I. What is the magnetic field at P ?
(Given : $BP = PB' = r$ and $C'B'PBC$ are collinear)



(a) $B = \frac{1}{4\pi}\frac{2I}{r}$

(b) $B = \frac{\mu_0}{4\pi}\left(\frac{2I}{r}\right)$

(c) $B = \frac{\mu_0}{4\pi}\left(\frac{I}{r}\right)$

(d) zero

30. A block of mass 3 kg is pulled up on a smooth incline of angle 37° with the horizontal. If the block moves with an acceleration 2 m s^{-2}, what is the average power delivered in the 5.0 s after the motion starts? (Take g = 10 m s^{-2})

(a) 120 W (b) 110 W
(c) 100 W (d) 150 W

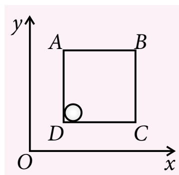
31. A gas undergoes a process in which its pressure P and volume V are related as VP^n = constant. The bulk modulus for the gas in this process is

(a) nP (b) $P^{1/n}$ (c) $\frac{P}{n}$ (d) P^n

32. A magnet takes a minute to make 30 oscillations in a magnetic field. If the field strength is doubled, then the time period of oscillation (in s) is

(a) $\sqrt{2}$ (b) $2\sqrt{2}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\sqrt{3}$

33. A solid sphere of mass 2 kg is resting inside a cube as shown in the figure. The cube is moving with a velocity $\vec{v} = (5t\,\hat{i} + 2t\,\hat{j})$ m s^{-1}. Here t is the time in second. All the surfaces are smooth. The sphere is at rest with respect to the cube. What is the total force exerted by the sphere on the cube ?
Take g = 10 m s^{-2}.



(a) $\sqrt{29}$ N
(b) $\sqrt{516}$ N
(c) 26 N
(d) $\sqrt{89}$ N

34. Two different coils have self-inductance $L_1 = 8$ mH, $L_2 = 2$ mH. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same rate. At a certain instant of time, the power given to the two coils is the same. At that time the current, the induced voltage and the energy stored in the first coil are I_1, V_1, and W_1 respectively. Corresponding values for the second coil at the same instant are I_2, V_2, and W_2 respectively. Then, W_2/W_1 is

(a) 8 (b) $\frac{1}{8}$

(c) 4 (d) $\frac{1}{4}$

35. The velocities of a body executing S.H.M. at displacements a and b are b and a respectively. The amplitude of S.H.M. will be

(a) $\sqrt{a^2+b^2}$ (b) $\sqrt{a^2-b^2}$

(c) $(a + b)$ (d) $(a - b)$

36. Mark the incorrect statement about the friction between two bodies.

(a) Static friction is always greater than the kinetic friction.

(b) Coefficient of static friction is always greater than the coefficient of kinetic friction.

(c) Limiting friction is always greater than the kinetic friction

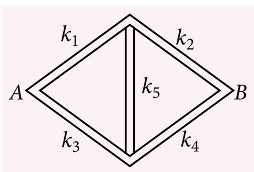
(d) Limiting friction is never less than static friction.

37. A particle of mass m and charge q moves with a constant velocity v along the positive x-direction. It enters a region containing a uniform magnetic field $\vec{B}$ directed along the negative z direction, extending from $x = a$ to $x = b$. The minimum value of v required so that the particle can just enter the region $x > b$ is

(a) qbB/m (b) $q(b - a)B/m$

(c) qaB/m (d) $q(b + a)B/2m$

38. Five rods of the same dimensions are arranged as shown. They have thermal conductivities k_1, k_2, k_3, k_4 and k_5. When points A and B are maintained at different temperatures, no heat flows through the central rod. It follows that



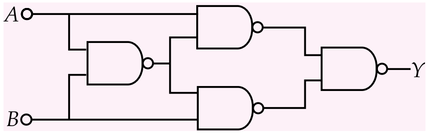
(a) $k_1 = k_4$ and $k_2 = k_3$

(b) $k_1/k_4 = k_2/k_3$

(c) $k_1k_4 = k_2k_3$

(d) $k_1k_2 = k_3k_4$

39. Truth table for system of four NAND gates as shown in figure is



(a)

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

(b)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(c)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

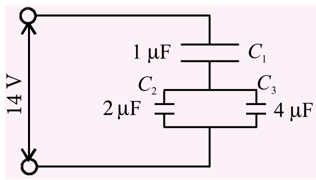
(d)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

40. Two springs X and $Y(k_x = 2k_y)$ are stretched by applying forces of equal magnitudes at the four ends. If the energy stored in X is U, that in Y is

(a) $\frac{U}{2}$ (b) $2U$ (c) U (d) $\frac{U}{4}$

41. Three capacitors C_1, C_2, and C_3 are connected as shown in the figure. A potential difference of 14 V is applied to the input terminals. What is the charge on C_3 (in μC) ?



(a) 8 (b) 4 (c) 2 (d) 10

42. A train has to negotiate a curve of radius 2000 m. By how much should the outer rail be raised with respect to inner rail for a speed 72 km h^{-1}. The distance between the rails is 1 m. (Take $g = 10$ m s^{-2})

(a) 0.5 cm (b) 2 cm (c) 5 cm (d) 10 cm

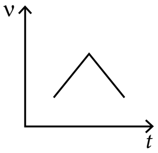
43. An aeroplane is flying horizontally with a velocity of 360 km h^{-1}. The distance between the tips of the wings of the aeroplane is 50 m. The vertical component of the earth's magnetic field is 4×10^{-4} Wb m^{-2}. The induced emf is

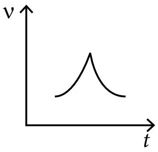
(a) 200 V (b) 20 V (c) 2 V (d) 0.2 V

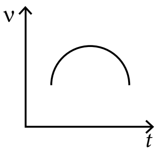
44. The rate of steady volume flow of water through a capillary tube of length l and radius r under a pressure difference of P is V. This tube is connected with another tube of the same length but half the radius is series. Then the rate of steady volume flow through them is (the pressure difference across the combination is P)

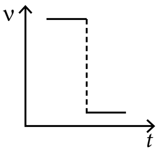
(a) $\frac{V}{16}$ (b) $\frac{V}{17}$ (c) $\frac{16V}{17}$ (d) $\frac{17V}{16}$

45. A railway engine whistling at a constant frequency moves with a constant speed. It goes past a stationary observer standing beside the railway track. The frequency (ν) of the sound heard by the observer is plotted against time (t). Which of the following best represents the resulting curve?

(a)


(b)


(c)


(d)


SOLUTIONS

1. (c) : Using energy conservation principle,

$$\frac{1}{2}m(kv_e)^2 - \frac{GMm}{R} = -\frac{GMm}{R+h}$$

$$\frac{1}{2}mk^2 \cdot 2gR = GMm\left(\frac{1}{R} - \frac{1}{R+h}\right)$$

$$k^2 \cdot mgR = mgR^2\left(\frac{h}{R(R+h)}\right) \qquad \left(\because \frac{GM}{R^2} = g\right)$$

$$k^2 = \frac{h}{R+h} \quad \text{or} \quad (R+h)\,k^2 = h \;\therefore\; h = \frac{k^2R}{1-k^2}$$

Height from center of earth,

$$r = R + h = R + \frac{k^2R}{1-k^2} = \frac{R}{1-k^2}$$

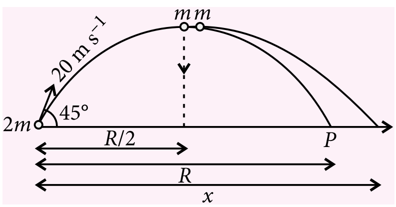
2. (d) : For Balmer series,

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]; \text{ where } n = 3, 4, 5 \qquad \text{...(i)}$$

By putting $n = \infty$ in equation (i), we obtain the series limit of the Balmer series

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] \quad \text{or} \quad \lambda = 364.5 \text{ nm}$$

3. (a) :

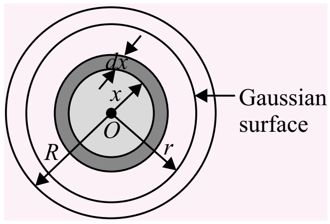


Range of bomb, $R = \frac{u^2}{g}\sin 2\theta = \frac{(20)^2}{10}\sin 90° = 40\,\text{m}$

The center of mass will hit the ground at P, *i.e.*,

$$\frac{m \times \frac{R}{2} + mx}{m+m} = R \text{ or } \frac{20+x}{2} = 40 \Rightarrow x = 60\,\text{m}$$

4. (c) : Consider a thin spherical shell of radius x and thickness dx as shown in the figure.



Volume of the shell,

$$dV = 4\pi x^2 dx$$

Let us draw a Gaussian surface of radius $r(r < R)$ as shown in the figure above.

Total charge enclosed inside the Gaussian surface is

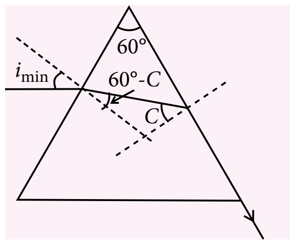
$$Q_{in} = \int_0^r \rho\, dV = \int_0^r \rho_0\left(\frac{5}{4} - \frac{x}{R}\right)4\pi x^2 dx$$

$$= 4\pi\rho_0\int_0^r\left(\frac{5}{4}x^2 - \frac{x^3}{R}\right)dx = \pi\rho_0\left[\frac{5}{3}r^3 - \frac{r^4}{R}\right]$$

According to Gauss's law,

$$E4\pi r^2 = \frac{Q_{in}}{\varepsilon_0} = \frac{\pi\rho_0}{\varepsilon_0}\left[\frac{5}{3}r^3 - \frac{r^4}{R}\right]; \therefore\; E = \frac{\rho_0 r}{4\varepsilon_0}\left[\frac{5}{3} - \frac{r}{R}\right]$$

5. (a) : For minimum angle of incidence case, the angles will be as shown in figure. For light ray to be reflected from the second surface,



$$\sin C = \frac{1}{\mu} = \sqrt{\frac{3}{7}} \text{ and}$$

$$\cos C = \sqrt{1 - \sin^2\mu} = \sqrt{1 - \frac{3}{7}} \qquad \text{...(i)}$$

Applying snell's law,

$$1 \times \sin i_{min} = \sqrt{\frac{7}{3}}\sin(60° - C)$$

$$= \sqrt{\frac{7}{3}}(\sin 60° \cos C - \cos 60° \sin C)$$

$$= \sqrt{\frac{7}{3}}\left(\sin 60°\sqrt{1 - \frac{3}{7}} - \cos 60\sqrt{\frac{3}{7}}\right) = \frac{1}{2} \qquad \text{(Using (i))}$$

$$\therefore\; i_{min} = \sin^{-1}\left(\frac{1}{2}\right) = 30°$$

6. **(d) :** For sphere, $\frac{k^2}{R^2} = \frac{2}{5}$

Rotational kinetic energy,

$$K_R = \frac{k^2}{R^2} \times \frac{1}{2} m v_{\text{c.m.}}^2 = \frac{2}{5} \times \frac{1}{2} m v_0^2 = \frac{1}{5} m v_0^2$$

Total kinetic energy,

$$K = \left(1 + \frac{k^2}{R^2}\right) \frac{1}{2} m v_{\text{c.m.}}^2 = \left(1 + \frac{2}{5}\right) \times \frac{1}{2} m v_0^2 = \frac{7}{10} m v_0^2$$

Potential energy (w.r.t ground), $U = mgR$

Total mechanical energy, $E = K + U = \frac{7}{10} m v_0^2 + mgR$

7. **(b)**

8. **(c) :** Using mirror formula,

$$v = \frac{uf}{u - f} = \frac{(-15)\times(-10)}{-15+10} = -30 \text{ cm},$$

$m = -\frac{v}{u} = -2$ $\therefore$ $A'B' = C'D' = 2 \times AB = 2 \times 1 = 2$ mm

Now for longitudinal magnification,

$$\frac{B'C'}{BC} = \frac{A'D'}{AD} = \frac{v^2}{u^2} = 4 \Rightarrow B'C' = A'D' = 4 \text{ mm}$$

$\therefore$ Perimeter length = 2 + 2 + 4 + 4 = 12 mm

9. **(a) :** Let λ_1 and λ_2 be the decay constants and N_1 and N_2 be the number of active nuclei present for the two samples S_1 and S_2 respectively. Then

$\lambda_1 N_1 = 5\ \mu\text{Ci}$, $\lambda_2 N_2 = 10\ \mu\text{Ci}$, $\lambda_2 N_2 = 2\lambda_1 N_1$

Also, $N_1 = 2N_2$

Then $\lambda_2 N_2 = 2\lambda_1 (2N_2)$ or $\lambda_2 = 4\lambda_1 \Rightarrow (T_{1/2})_1 = 4(T_{1/2})_2$.

10. **(a) :** $\omega_0 = 2\pi N = \frac{2\pi \times 120}{60} = 4\pi \text{ rad s}^{-1}$

θ = 4 revolution = 8 π rad

$\omega^2 = \omega_0^2 - 2\alpha\theta \Rightarrow 0 = (4\pi)^2 - 2\alpha(8\pi)$

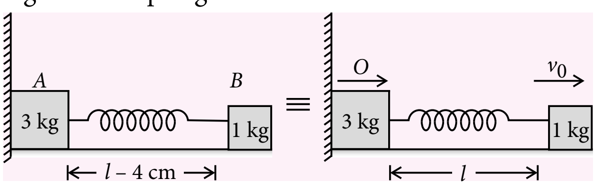
$\Rightarrow \alpha = \pi \text{ rad s}^{-2}$ (angular retardation)

$$I = \frac{1}{2} mR^2 = \frac{1}{2} \times 5 \times (1)^2 = 2.5 \text{ kg m}^2$$

$\tau = FR = I\alpha$ or $F \times 1 = 2.5\pi \Rightarrow F = 2.5\pi$ N

11. **(d)** 12. **(b)**

13. **(a) :** When block A is breaks off the wall, spring regains its natural length, speed of A is v_0, l is the natural length of the spring.



By the energy conservation,

$$\frac{1}{2} k \left(\frac{4}{100}\right)^2 = \frac{1}{2} \times 1 \times v_0^2 \Rightarrow 100 \left(\frac{4}{100}\right)^2 = v_0^2$$

$\Rightarrow v_0 = 0.4 \text{ m s}^{-1}$

$$v_{\text{c.m.}} = \frac{1 \times v_0 + 3 \times 0}{1+3} = \frac{0.4}{4} = 0.1 \text{ m s}^{-1}$$

14. **(a) :** The last line of Balmer series has energy $h\upsilon = 3.4$ eV

$\therefore$ $eV_0 = h\upsilon - W = 3.4 \text{ eV} - 3.2 \text{ eV} = 0.2$ eV

$\therefore$ Stopping potential = – 0.2 V

15. **(a) :** Focal length of plano-convex lens is 10 cm.

$$\frac{1}{10} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-R}\right) \text{ or } \frac{1}{10} = \frac{1}{2} \times \frac{1}{R} \Rightarrow R = 5 \text{ cm}$$

Let focal length of water lens is f_w.

$$\frac{1}{f_w} = \left(\frac{4}{3} - 1\right)\left(\frac{1}{-5} - \frac{1}{5}\right) = \frac{-2}{15} \text{cm}^{-1} = \frac{-40}{3} \text{m}^{-1}$$

Optical power of system,

$$P = \frac{1}{f} + \frac{1}{f} + \frac{1}{f_w} = \frac{1}{0.1} + \frac{1}{0.1} + \left(-\frac{40}{3}\right) = 6.67 \text{ D}$$

16. **(b)**

17. **(b) :** $R_T = R_0(1 + \alpha T)$, where R_0 is the resistance of wire at 0°C.

Initially, $R_0(1 + 30\alpha) = 10\ \Omega$

Finally, $R_0(1 + \alpha T) = 11\ \Omega$

$$\therefore \frac{11}{10} = \frac{1+\alpha T}{1+30\alpha}$$

or $10 + (10 \times 0.002 \times T) = 11 + 330 \times 0.002$

($\because \alpha = 0.002\ °\text{C}^{-1}$)

or $0.02T = 1 + 0.66 = 1.66$ or $T = \frac{1.66}{0.02} = 83°\text{C}$

18. **(d) :** For dark fringe, $x = (2n-1)\frac{\lambda D}{2d}$

$$\therefore \lambda = \frac{2xd}{(2n-1)D} = \frac{2 \times 10^{-3} \times 0.9 \times 10^{-3}}{(2\times 2 - 1) \times 1}$$

$\lambda = 0.6 \times 10^{-6} \text{ m} = 6 \times 10^{-5}$ cm

19. **(a)**

20. **(c) :** If the first particle falls for time t, the second

MPP CLASS XI ANSWER KEY

1.	(d)	2.	(c)	3.	(b)	4.	(a)	5.	(b)
6.	(b)	7.	(b)	8.	(c)	9.	(a)	10.	(d)
11.	(c)	12.	(d)	13.	(d)	14.	(d)	15.	(a)
16.	(a)	17.	(d)	18.	(c)	19.	(b)	20.	(b,c)
21.	(a,b,c)	22.	(a,b,d)	23.	(a,c)	24.	(5)	25.	(3)
26.	(6)	27.	(b)	28.	(d)	29.	(c)	30.	(b)

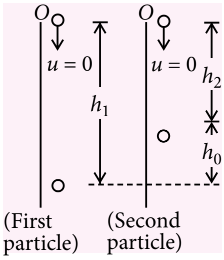
particle falls for time $(t - t_0)$

First particle : $h_1 = \frac{1}{2}gt^2$

Second particle : $h_2 = \frac{1}{2}g(t-t_0)^2$

$h_1 - h_2 = \frac{1}{2}gt^2 - \frac{1}{2}g(t-t_0)^2$

$h_0 = \frac{1}{2}g[t^2 - (t-t_0)^2]$



$$2t - t_0 = \frac{2h_0}{gt_0} \Rightarrow 2t = t_0 + \frac{2h_0}{gt_0} \Rightarrow t = \frac{t_0}{2} + \frac{h_0}{gt_0}$$

21. (d) : $F = \frac{Gm^2}{a^2}, r = \frac{a}{\sqrt{3}}$

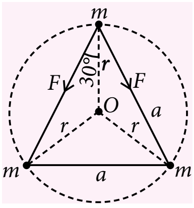
Resultant force on $m = 2F\cos 30° = \sqrt{3}F$

At the system rotates about centre of mass,

$\sqrt{3}F = m\omega^2 r$

$\sqrt{3}\frac{Gm^2}{a^2} = m\omega^2 \frac{a}{\sqrt{3}}$

$\omega = \sqrt{\frac{3Gm}{a^3}}$



$\therefore\ T = \frac{2\pi}{\omega} = \frac{2\pi a^{3/2}}{\sqrt{3Gm}};\ \therefore\ T \propto a^{3/2}, T \propto m^{-1/2}$

22. (b) : The intensity of illumination at a surface is given by $E = \frac{I\cos\theta}{r^2}$

$E = 5 \times 10^{-4}$ lumen cm^{-2} $= 5 \times 10^{-4} \times 10^4$ lumen m^{-2}
$= 5$ lumen cm^{-2}

or $I = \frac{Er^2}{\cos\theta} = \frac{5 \times (2)^2}{\cos 60°} = 40$ candela

23. (c) : Mass of the removed portion $= M \times \frac{60°}{360} = \frac{M}{6}$

Its moment of inertia, $I_1 = \frac{1}{2}\frac{M}{6}R^2$

Moment of inertia of the complete disc, $I_2 = \frac{1}{2}MR^2$

Moment of inertia of the remaining portion

$= I_2 - I_1 = \frac{5}{12}MR^2$

24. (d)

25. (d) : In the order of increasing wavelengths, the rays are γ-rays, X-rays, green light, microwaves, radiowaves, *i.e.*, (3) (5) (2) (4) (1).

26. (a) : Given the power output is 50% of the input power, *i.e.*, $I_sV_s = (1/2)\ I_pV_p$

Also given $I_p = 5$ A, $V_p = 220$ V and $V_s = 2200$ V

$\therefore\ I_s = \frac{1}{2}\frac{I_pV_p}{V_s} = \frac{1}{2} \times \frac{5\text{ A} \times 220\text{ V}}{2200\text{ V}}$ or $I_s = 0.25$ A

27. (b) : Time taken by A to reach at highest point,

$t = \frac{20\sin 30°}{g} = 1\text{ s}\ ;\ h_{max} = \frac{(20)^2\sin^2 30°}{2g} = 5\text{ m}$

$h = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times (1)^2 = 5\text{ m}$

Initial height of ball $B = h + H_{max} = 10$ m

28. (d) : Let T_0 = initial temperature of the black body.

$\therefore\ \lambda_0 T_0 = b$(constant)

Power radiated $= P_0 = c.\ T_0^4$

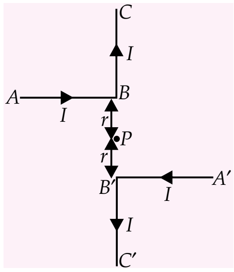
Let T = new temperature of black body.

$\therefore\ \frac{3\lambda_0}{4}T = b = \lambda_0 T_0$ or $T = \frac{4T_0}{3}$

Power radiated $= c \cdot T^4 = (cT_0^4)\left(\frac{4}{3}\right)^4 = P_0\left(\frac{256}{81}\right)$

29. (b) : The magnetic field at point P due to current I in AB is

$\vec{B}_{AB} = \frac{\mu_0}{4\pi}\frac{I}{r} \otimes$



The magnetic field at point P due to current I in BC is

$B_{BC} = 0$

(As the point P is along the BC)

The magnetic field at point P due to current I in $A'B'$ is

$\vec{B}_{A'B'} = \frac{\mu_0}{4\pi}\frac{I}{r} \otimes$

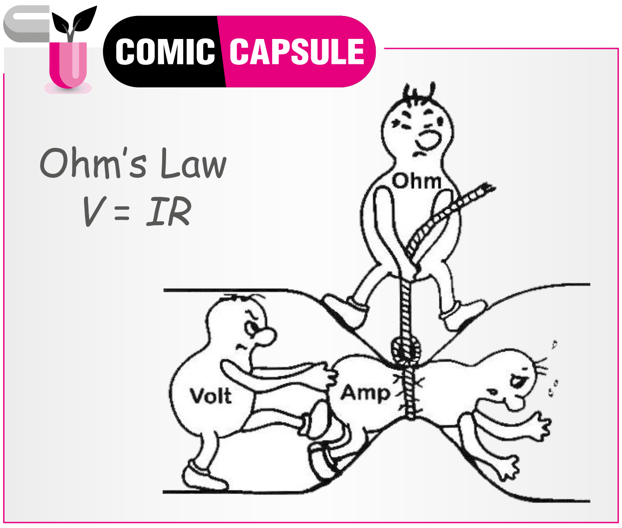
The magnetic field at point P due to current I in $B'C'$ is

$B_{B'C'} = 0$ (As the point P is along the BC)

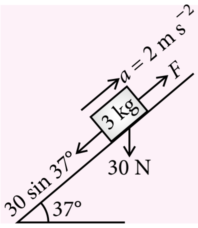
$\therefore$ The net magnetic field at P is

$B = B_{AB} + B_{BC} + B_{A'B'} + B_{B'C'}$

$= \frac{\mu_0 I}{4\pi r} + 0 + \frac{\mu_0 I}{4\pi r} + 0 = 2\left(\frac{\mu_0 I}{4\pi r}\right) = \frac{\mu_0}{4\pi}\left(\frac{2I}{r}\right)$



30. (a) : Let F be a pulling force.



$F - 30\sin 37° = 3a$

$F - 30 \times \frac{3}{5} = 3 \times 2 \Rightarrow F = 24$ N

After 5 s, velocity

$v = u + at = 0 + 2 \times 5 = 10$ m s^{-1}

The power delivered by F at $t = 5$ s

$P = Fv = 24 \times 10 = 240$ W

Displacement of block in 5 s

$$s = \frac{1}{2}at^2 = \frac{1}{2}\times 2\times 5^2 = 25\text{ m}$$

Work done by pulling force in 5 s

$W = Fs = 24 \times 25 = 600$ J

The average power delivered by pulling force

$$\bar{P} = \frac{W}{t} = \frac{600}{5} = 120\text{ W}$$

31. (c) **32. (a)**

33. (c) : $\vec{v} = (5t\hat{i} + 2t\hat{j})$ m s^{-1} ; $\vec{a} = \frac{d\vec{v}}{dt} = (5\hat{i} + 2\hat{j})$ m s^{-2}

$\vec{F}_1 = m\vec{a} = 2(5\hat{i} + 2\hat{j}) = (10\hat{i} + 4\hat{j})$ N ; $\vec{W} = m\vec{g} = 20\,\hat{j}$ N

$F = \sqrt{(10)^2 + (4)^2 + (-20)^2} = 26$ N

34. (c) : Here, $L_1 = 8$ mH and $L_2 = 2$ mH

Induced voltage in the coil is

$$V = -L\frac{dI}{dt} \qquad \left(\text{Since } \frac{dI}{dt} \text{ is a constant,}\right)$$

$\therefore\ V \propto L$

Thus, $\frac{V_2}{V_1} = \frac{L_2}{L_1} = \frac{2}{8} = \frac{1}{4}$

Power given to the two coils is same

$\therefore\ V_1I_1 = V_2I_2$ or $\frac{I_2}{I_1} = \frac{V_1}{V_2} = 4$

Energy stored in a coil, $W = \frac{1}{2}LI^2$

$$\therefore\ \frac{W_2}{W_1} = \left(\frac{L_2}{L_1}\right)\left(\frac{I_2}{I_1}\right)^2 = \left(\frac{2}{8}\right)(4)^2 = 4$$

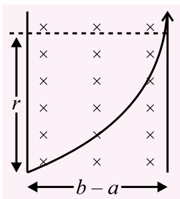
35. (a) : Velocity of harmonic oscillator $v = \omega\sqrt{a^2 - x^2}$

Here $b = \omega\sqrt{A^2 - a^2}$, $a = \omega\sqrt{A^2 - b^2}$

$$\therefore\ \frac{b}{a} = \left(\frac{A^2 - a^2}{A^2 - b^2}\right)^{1/2} \Rightarrow A = \sqrt{a^2 + b^2}$$

36. (a)

37. (b) : For just entering,



$$r = \frac{mv}{qB} = b - a$$

$$v = \frac{q(b-a)B}{m}$$

38. (c) : This is analogous to a balanced Wheatstone bridge.

$R_1 = \frac{l}{k_1A}$, and $R_1R_4 = R_2R_3$ for balance.

39. (d)

40. (b) : $k_x = 2k_0$, $k_y = k_0$

$$F = k_xx = k_yy;\ x = \frac{F}{2k_0}, y = \frac{F}{k_0}$$

$$U = \frac{1}{2}k_xx^2 = \frac{1}{2}\times 2k_0\left(\frac{F}{2k_0}\right)^2 = \frac{F^2}{4k_0}$$

$$U' = \frac{1}{2}k_yy^2 = \frac{1}{2}\times k_0\left(\frac{F}{k_0}\right)^2 = \frac{F^2}{2k_0} = 2U$$

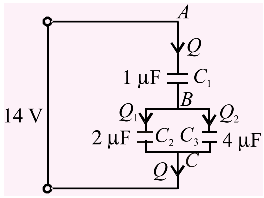
41. (a) : The capacitors C_2 and C_3 are connected in parallel, the equivalent capacitance C' is given by

$C' = C_2 + C_3 = 2$ μF + 4 μF = 6 μF

The capacitors C_1 and C' are connected in series and equivalent capacitance C'' is given by

$$\frac{1}{C''} = \frac{1}{C'} + \frac{1}{C_1} = \frac{1}{6\,\mu\text{F}} + \frac{1}{1\,\mu\text{F}} \text{ or } C'' = \frac{6}{7}\,\mu\text{F}$$

Total charge of the given circuit is



$Q = C''V$

$Q = \frac{6}{7}\times 14\,\mu\text{C} = 12\,\mu\text{C}$

$Q = Q_1 + Q_2$

$12 = 2V' + 4V' = 6V'$

or $V' = 2$ V

(where V' is the potential difference across BC)

$\therefore\ Q_2 = C_3V' = 4 \times 2 = 8$ μC

42. (b)

43. (c)

44. (b) : Resistances for flowing in first and second tube are, $R_1 = \frac{8\eta l}{\pi r^4} = R$ and $R_2 = \frac{8\eta l}{\pi(r/2)^4} = 16R$

Pressure difference, $P = VR_1 = VR$

$P = V'R_{eq} = V'(R_1 + R_2) = V'(R + 16R) = 17V'R$

So, $VR = 17V'R$ or $V' = \frac{V}{17}$

45. (d) : When the engine approaches the observer with constant velocity, the observer hears a frequency which is constant, and higher than the actual frequency. When the engine goes past the observer and recedes from him, he hears a frequency which is constant, and lower than the actual frequency.

◈◈

07 Most frequently asked chapters in JEE ADVANCED

- Units, Measurements and Errors
- Rotational Motion
- Heat and Thermodynamics
- Electrostatics
- Magnetism
- Electromagnetic Induction
- Optics

Questions from last 3 years (2017-2015) are covered here to give you an idea to score high in exam.

Units, Measurements and Errors

1. A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta T = 0.01$ seconds and he measures the depth of the well to be $L = 20$ metres. Take the acceleration due to gravity $g = 10$ m s^{-2} and the velocity of sound is 300 m s^{-1}. Then the fractional error in the measurement, $\delta L/L$, is closest to
(a) 5% (b) 1% (c) 3% (d) 0.2%
(2017)

2. Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the instantaneous density ρ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho}\frac{d\rho}{dt}\right)$ is constant. The velocity v of any point on the surface of the expanding sphere is proportional to
(a) R (b) $\frac{1}{R}$ (c) $R^{2/3}$ (d) R^3
(2017)

3. A length-scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression(s) for l is(are) dimensionally correct?
(a) $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$ (b) $l = \sqrt{\left(\frac{\varepsilon k_B T}{nq^2}\right)}$
(c) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{2/3} k_B T}\right)}$ (d) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$
(2016)

4. In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The value of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56 s, 0.57 s, 0.54 s and 0.59 s. The least count of the watch used for the measurement of time period is 0.01 s. Which of the following statement(s) is(are) true?
(a) The error in the measurement of r is 10%
(b) The error in the measurement of T is 3.57%
(c) The error in the measurement of T is 2%
(d) The error in the determined value of g is 11%
(2016)

5. Planck's constant h, speed of light c and gravitational constant G are used to form a unit of length L and a unit of mass M. Then the correct option(s) is(are)
(a) $M \propto \sqrt{c}$ (b) $M \propto \sqrt{G}$
(c) $L \propto \sqrt{h}$ (d) $L \propto \sqrt{G}$ *(2015)*

6. In terms of potential difference V, electric current I, permittivity ε_0, permeability μ_0 and speed of light c, the dimensionally correct equation(s) is(are)

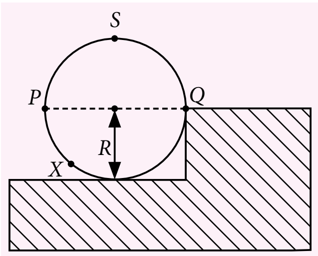
(a) $\mu_0 I^2 = \varepsilon_0 V^2$ (b) $\varepsilon_0 I = \mu_0 V$

(c) $I = \varepsilon_0 c V$ (d) $\mu_0 c I = \varepsilon_0 V$ *(2015)*

7. The energy of a system as a function of time t is given as $E(t) = A^2 \exp(-\alpha t)$, where $\alpha = 0.2\ \text{s}^{-1}$. The measurement of A has an error of 1.25%. If the error in the measurement of time is 1.50%, the percentage error in the value of $E(t)$ at $t = 5$ s is *(2015)*

Rotational Motion

8. A wheel of radius R and mass M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque τ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct?



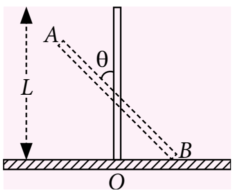
(a) If the force is applied at point P tangentially then τ decreases continuously as the wheel climbs.

(b) If the force is applied tangentially at point S then $\tau \neq 0$ but the wheel never climbs the step.

(c) If the force is applied normal to the circumference at point P then τ is zero.

(d) If the force is applied normal to the circumference at point X then τ is constant. *(2017)*

9. A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is θ. Which of the following statements about its motion is/are correct?



(a) When the bar makes an angle θ with the vertical, the displacement of its midpoint from the initial position is proportional to $(1 - \cos\theta)$.

(b) The midpoint of the bar will fall vertically downward.

(c) Instantaneous torque about the point in contact with the floor is proportional to $\sin\theta$.

(d) The trajectory of the point A is a parabola. *(2017)*

Paragraph for Questions 10 and 11

One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is r. The finger rotates with an angular velocity ω_0. The rotating ring rolls without slipping on the outside of a smaller circle described by the point where the ring and the finger is in contact (figure 2). The coefficient of friction between the ring and the finger is μ and the acceleration due to gravity is g.

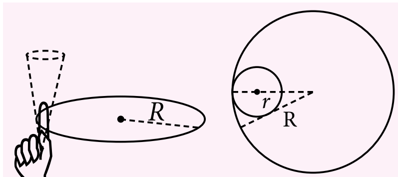


figure 1 figure 2

10. The minimum value of ω_0 below which the ring will drop down is

(a) $\sqrt{\dfrac{3g}{2\mu(R-r)}}$ (b) $\sqrt{\dfrac{g}{\mu(R-r)}}$

(c) $\sqrt{\dfrac{g}{2\mu(R-r)}}$ (d) $\sqrt{\dfrac{2g}{\mu(R-r)}}$

11. The total kinetic energy of the ring is

(a) $M\omega_0^2(R-r)^2$ (b) $\frac{1}{2}M\omega_0^2(R-r)^2$

(c) $\frac{3}{2}M\omega_0^2(R-r)^2$ (d) $M\omega_0^2 R^2$ *(2017)*

12. A uniform wooden stick of mass 1.6 kg and length l rests in an inclined manner on a smooth, vertical wall of height $h(< l)$ such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of 30° with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio h/l and the frictional force f at the bottom of the stick are (g = 10 m s^{-2})

(a) $\frac{h}{l}=\frac{\sqrt{3}}{16},\ f=\frac{16\sqrt{3}}{3}$ N

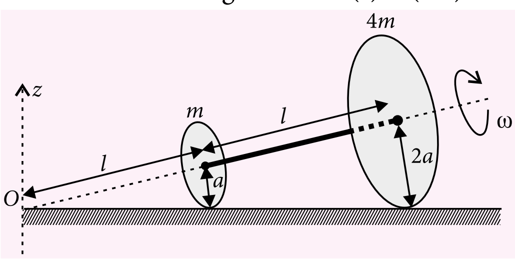
(b) $\frac{h}{l}=\frac{3}{16},\ f=\frac{16\sqrt{3}}{3}$ N

(c) $\frac{h}{l}=\frac{3\sqrt{3}}{16},\ f=\frac{8\sqrt{3}}{3}$ N

(d) $\frac{h}{l}=\frac{3\sqrt{3}}{16},\ f=\frac{16\sqrt{3}}{3}$ N *(2016)*

13. The position vector $\vec{r}$ of a particle of mass m is given by the following equation
$\vec{r}(t)=\alpha t^3\,\hat{i}+\beta t^2\,\hat{j}$,
where α = 10/3 m s^{-3}, β = 5 m s^{-2} and m = 0.1 kg. At t = 1 s, which of the following statement(s) is (are) true about the particle?
(a) The velocity $\vec{v}$ is given by $\vec{v}=(10\hat{i}+10\hat{j})$ m s^{-1}
(b) The angular momentum $\vec{L}$ with respect to the origin is given by $\vec{L}=-(5/3)\hat{k}$ N m s
(c) The force $\vec{F}$ is given by $\vec{F}=(\hat{i}+2\hat{j})$ N
(d) The torque $\vec{\tau}$ with respect to the origin is given by $\vec{\tau}=-(20/3)\hat{k}$ N m *(2016)*

14. Two thin circular discs of mass m and $4m$, having radii of a and $2a$, respectively, are rigidly fixed by a massless, rigid rod of length $l=\sqrt{24}a$ through their centers. This assembly is laid on a firm and flat surface, and set rolling without slipping on the surface so that the angular speed about the axis of the rod is ω. The angular momentum of the entire assembly about the point O is $\vec{L}$ (see the figure). Which of the following statement(s) is (are) true?



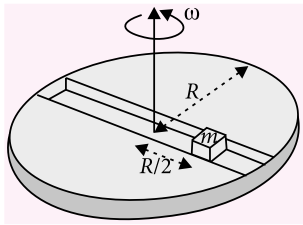
(a) The magnitude of angular momentum of the assembly about its center of mass is $17ma^2\omega/2$
(b) The center of mass of the assembly rotates about the z-axis with an angular speed of $\omega/5$
(c) The magnitude of the z-component of $\vec{L}$ is $55ma^2\omega$
(d) The magnitude of angular momentum of center of mass of the assembly about the point O is $81ma^2\omega$ *(2016)*

Paragraph for Questions 15 and 16

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{rot}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{in}$ experienced by the particle in an inertial frame of reference is

$$\vec{F}_{rot}=\vec{F}_{in}+2m(\vec{v}_{rot}\times\vec{\omega})+m(\vec{\omega}\times\vec{r})\times\vec{\omega},$$

where $\vec{v}_{rot}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc.



Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the center of the disc, the x-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis ($\vec{\omega}=\omega\hat{k}$). A small block of mass m is gently placed in the slot at $\vec{r}=(R/2)\hat{i}$ at t = 0 and is constrained to move only along the slot.

15. The distance r of the block at time t is

(a) $\frac{R}{4}(e^{2\omega t}+e^{-2\omega t})$ (b) $\frac{R}{4}(e^{\omega t}+e^{-\omega t})$

(c) $\frac{R}{2}\cos 2\omega t$ (d) $\frac{R}{2}\cos\omega t$

16. The net reaction of the disc on the block is

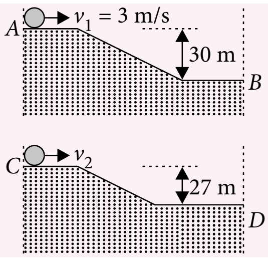
(a) $-m\omega^2 R\cos\omega t\,\hat{j}-mg\,\hat{k}$

(b) $\frac{1}{2}m\omega^2 R(e^{2\omega t}-e^{-2\omega t})\hat{j}+mg\,\hat{k}$

(c) $m\omega^2 R\sin\omega t\,\hat{j}-mg\,\hat{k}$

(d) $\frac{1}{2}m\omega^2 R(e^{\omega t}-e^{-\omega t})\hat{j}+mg\,\hat{k}$ *(2016)*

17. Two identical uniform discs roll without slipping on two different surfaces *AB* and *CD* (see figure) starting at *A* and *C* with linear speeds v_1 and v_2, respectively, and always remain in contact with the surfaces. If they reach *B* and *D* with the same linear speed and $v_1 = 3\ \text{ms}^{-1}$, then v_2 in ms^{-1} is ($g = 10\ \text{ms}^{-2}$) *(2015)*



18. The densities of two solid spheres *A* and *B* of the same radii *R* vary with radial distance *r* as

$$\rho_A(r) = k\left(\frac{r}{R}\right) \text{ and } \rho_B(r) = k\left(\frac{r}{R}\right)^5, \text{ respectively,}$$

where *k* is a constant. The moments of inertia of the individual spheres about axes passing through their centres are I_A and I_B respectively. If $\frac{I_B}{I_A} = \frac{n}{10}$, the value of *n* is *(2015)*

Heat and Thermodynamics

19. A human body has a surface area of approximately 1 m^2. The normal body temperature is 10 K above the surrounding room temperature T_0. Take the room temperature to be $T_0 = 300$ K. For $T_0 = 300$ K, the value of $\sigma T_0^4 = 460\ \text{W m}^{-2}$ (where σ is the Stefan Boltzmann constant). Which of the following options is/are correct?

(a) If the body temperature rises significantly then the peak in the spectrum of electromagnetic radiation emitted by the body would shift to longer wavelengths

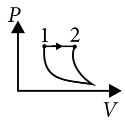
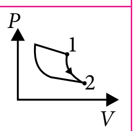
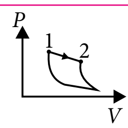
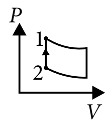
(b) If the surrounding temperature reduces by a small amount $\Delta T_0 << T_0$, then to maintain the same body temperature the same (living) human being needs to radiate $\Delta W = 4\sigma T_0^3 \Delta T_0$ more energy per unit time

(c) The amount of energy radiated by the body in 1 second is close to 60 Joules

(d) Reducing the exposed surface area of the body (e.g. by curling up) allows humans to maintain the same body temperature while reducing the energy lost by radiation. *(2017)*

Answer Q. 20, Q. 21 and Q. 22 by appropriately matching the information given in the three columns of the following table.

An ideal gas is undergoing a cyclic thermodynamic process in different ways as shown in the corresponding *P* – *V* diagrams in column 3 of the table. Consider only the path from state 1 to state 2. *W* denotes the corresponding work done on the system. The equations and plots in the table have standard notations as used in thermodynamic processes. Here γ is the ratio of heat capacities at constant pressure and constant volume. The number of moles in the gas is *n*.

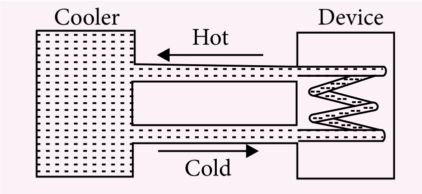
Column 1	Column 2	Column 3
(I) $W_{1\to 2} = \frac{1}{\gamma - 1}(P_2V_2 - P_1V_1)$	(i) Isothermal	(P) 
(II) $W_{1\to 2} = -PV_2 + PV_1$	(ii) Isochoric	(Q) 
(III) $W_{1\to 2} = 0$	(iii) Isobaric	(R) 
(IV) $W_{1\to 2} = -nRT\ln\left(\frac{V_2}{V_1}\right)$	(iv) Adiabatic	(S) 

20. Which one of the following options correctly represents a thermodynamic process that is used as a correction in the determination of the speed of sound in an ideal gas?
(a) (IV) (ii) (R) (b) (I) (ii) (Q)
(c) (I) (iv) (Q) (d) (III) (iv) (R)

21. Which of the following options is the only correct representation of a process in which $\Delta U = \Delta Q - P\Delta V$?
(a) (II) (iii) (S) (b) (II) (iii) (P)
(c) (III) (iii) (P) (d) (II) (iv) (R)

22. Which one of the following options is the correct combination?
(a) (II) (iv) (P) (b) (III) (ii) (S)
(c) (II) (iv) (R) (d) (IV) (ii) (S) *(2017)*

23. A water cooler of storage capacity 120 litres can cool water at a constant rate of *P* watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3 kW of heat (thermal load). The temperature of water fed into the device cannot exceed 30 °C and the entire stored 120 litres of water is initially cooled to 10°C. The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is



(Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and the density of water is 1000 kg m^{-3})
(a) 1600 (b) 2067 (c) 2533 (d) 3933 *(2016)*

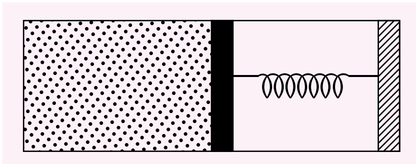
24. The ends Q and R of two thin wires, PQ and RS, are soldered (joined) together. Initially each of the wires has a length of 1 m at 10 °C. Now the end P is maintained at 10 °C, while the end S is heated and maintained at 400 °C. The system is thermally insulated from its surroundings. If the thermal conductivity of wire PQ is twice that of the wire RS and the coefficient of linear thermal expansion of PQ is 1.2×10^{-5} K^{-1}, the change in length of the wire PQ is
(a) 0.78 mm (b) 0.90 mm
(c) 1.56 mm (d) 2.34 mm *(2016)*

25. A gas is enclosed in a cylinder with a movable frictionless piston. Its initial thermodynamic state at pressure $P_i = 10^5$ Pa and volume $V_i = 10^{-3}$ m^3 changes to a final state at $P_f = (1/32) \times 10^5$ Pa and $V_f = 8 \times 10^{-3}$ m^3 in an adiabatic quasi-static process, such that P^3V^5 = constant. Consider another thermodynamic process that brings the system from the same initial state to the same final state in two steps : an isobaric expansion at P_i followed by an isochoric (isovolumetric) process at volume V_f. The amount of heat supplied to the system in the two-step process is approximately
(a) 112 J (b) 294 J (c) 588 J (d) 813 J *(2016)*

26. A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated (P) by the metal. The sensor has a scale that displays $\log_2(P/P_0)$, where P_0 is a constant. When the metal surface is at a temperature of 487 °C, the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to 2767 °C? *(2016)*

27. A container of fixed volume has a mixture of one mole of hydrogen and one mole of helium in equilibrium at temperature T. Assuming the gases are ideal, the correct statement(s) is(are)
(a) The average energy per mole of the gas mixture is $2RT$.
(b) The ratio of speed of sound in the gas mixture to that in helium gas is $\sqrt{6/5}$.
(c) The ratio of the rms speed of helium atoms to that of hydrogen molecules is 1/2.
(d) The ratio of the rms speed of helium atoms to that of hydrogen molecules is $1/\sqrt{2}$. *(2015)*

28. An ideal monoatomic gas is confined in a horizontal cylinder by a spring loaded piston (as shown in the figure). Initially the gas is at temperature T_1, pressure P_1 and volume V_1 and the spring is in its relaxed state. The gas is then heated very slowly to temperature T_2, pressure P_2 and volume V_2. During this process the piston moves out by a distance x. Ignoring the friction between the piston and the cylinder, the correct statement(s) is(are)

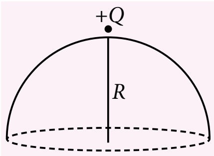


(a) If $V_2 = 2V_1$ and $T_2 = 3T_1$, then the energy stored in the spring is $\frac{1}{4}P_1V_1$
(b) If $V_2 = 2V_1$ and $T_2 = 3T_1$, then the change in internal energy is $3P_1V_1$
(c) If $V_2 = 3V_1$ and $T_2 = 4T_1$, then the work done by the gas is $\frac{7}{3}P_1V_1$
(d) If $V_2 = 3V_1$ and $T_2 = 4T_1$, then the heat supplied to the gas is $\frac{17}{6}P_1V_1$ *(2015)*

29. Two spherical stars A and B emit blackbody radiation. The radius of A is 400 times that of B and A emits 10^4 times the power emitted from B. The ratio $\left(\frac{\lambda_A}{\lambda_B}\right)$ of their wavelengths λ_A and λ_B at which the peaks occur in their respective radiation curves is *(2015)*

Electrostatics

30. A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct?



(a) The circumference of the flat surface is an equipotential.
(b) The component of the electric field normal to the flat surface is constant over the surface.
(c) Total flux through the curved and the flat surfaces is $\frac{Q}{\varepsilon_0}$.
(d) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$.

(2017)

Paragraph for Questions 31 and 32

Consider a simple RC circuit as shown in figure 1.

Process 1 : In the circuit the switch S is closed at $t = 0$ and the capacitor is fully charged to voltage V_0 (*i.e.*, charging continues for time $T >> RC$). In the process some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2 : In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time $T >> RC$. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time $T >> RC$. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in Process 1.

These two processes are depicted in figure 2.

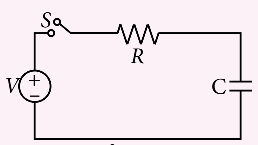


figure 1

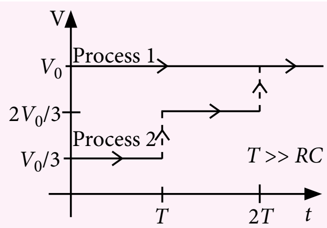


figure 2

31. In Process 2, total energy dissipated across the resistance E_D is

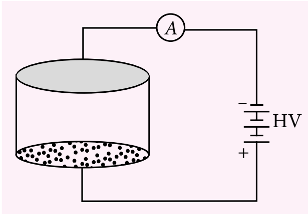
(a) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$ (b) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$
(c) $E_D = 3CV_0^2$ (d) $E_D = \frac{1}{2}CV_0^2$

32. In Process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by

(a) $E_C = E_D$ (b) $E_C = E_D \ln 2$
(c) $E_C = 2E_D$ (d) $E_C = (1/2)E_D$ *(2017)*

Paragraph for Questions 33 and 34

Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius $r << h$. Now a high voltage source (HV) is connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$. Due to their conducting surface, the balls will get charged, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collisions between the balls and the interaction between them is negligible. (Ignore gravity)



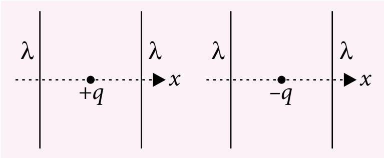
33. Which one of the following statements is correct?

(a) The balls will bounce back to the bottom plate carrying the opposite charge they went up with
(b) The balls will stick to the top plate and remain there
(c) The balls will execute simple harmonic motion between the two plates
(d) The balls will bounce back to the bottom plate carrying the same charge they went up with

34. The average current in the steady state registered by the ammeter in the circuit will be

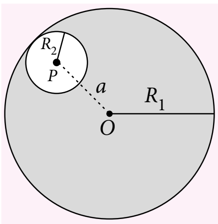
(a) proportional to $V_0^{1/2}$
(b) zero (c) proportional to V_0^2
(d) proportional to the potential V_0 *(2016)*

35. The figures below depict two situations in which two infinitely long static line charges of constant positive line charge density λ are kept parallel to each other. In their resulting electric field, point charges q and $-q$ are kept in equilibrium between them. The point charges are confined to move in the x direction only. If they are given a small displacement about their equilibrium positions, then the correct statement(s) is(are)



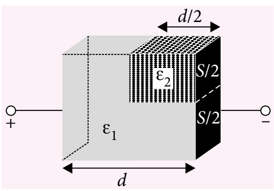
(a) Both charges execute simple harmonic motion.
(b) Both charges will continue moving in the direction of their displacement.
(c) Charge $+q$ executes simple harmonic motion while charge $-q$ continues moving in the direction of its displacement.
(d) Charge $-q$ executes simple harmonic motion while charge $+q$ continues moving in the direction of its displacement. *(2015)*

36. Consider a uniform spherical charge distribution of radius R_1 centred at the origin O. In this distribution, a spherical cavity of radius R_2, centred at P with distance $OP = a = R_1 - R_2$ (see figure) is made. If the electric field inside the cavity at position $\vec{r}$ is $\vec{E}(\vec{r})$, then the correct statement(s) is(are)



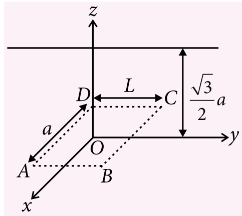
(a) $\vec{E}$ is uniform, its magnitude is independent of R_2 but its direction depends on $\vec{r}$
(b) $\vec{E}$ is uniform, its magnitude depends on R_2 and its direction depends on $\vec{r}$
(c) $\vec{E}$ is uniform, its magnitude is independent of a but its direction depends on $\vec{a}$
(d) $\vec{E}$ is uniform and both its magnitude and direction depend on $\vec{a}$ *(2015)*

37. A parallel plate capacitor having plates of area S and plate separation d, has capacitance C_1 in air. When two dielectrics of different relative permittivities ($\varepsilon_1 = 2$ and $\varepsilon_2 = 4$) are introduced between the two plates as shown in figure, the capacitance becomes C_2. The ratio $\dfrac{C_2}{C_1}$ is



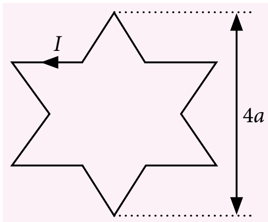
(a) 6/5 (b) 5/3 (c) 7/5 (d) 7/3 *(2015)*

38. An infinitely long uniform line charge distribution of charge per unit length λ lies parallel to the y-axis in the y-z plane at $z = \dfrac{\sqrt{3}}{2}a$ (see figure). If the magnitude of the flux of the electric field through the rectangular surface $ABCD$ lying in the x-y plane with its centre at the origin is $\dfrac{\lambda L}{n\varepsilon_0}$ (ε_0 = permittivity of free space), then the value of n is *(2015)*



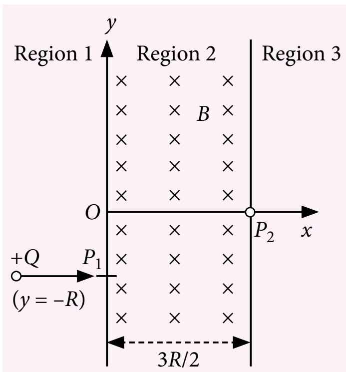
Magnetism

39. A symmetric star shaped conducting wire loop is carrying a steady state current I as shown in the figure. The distance between the diametrically opposite vertices of the star is $4a$. The magnitude of the magnetic field at the center of the loop is



(a) $\dfrac{\mu_0 I}{4\pi a}3[2-\sqrt{3}]$ (b) $\dfrac{\mu_0 I}{4\pi a}6[\sqrt{3}-1]$
(c) $\dfrac{\mu_0 I}{4\pi a}3[\sqrt{3}-1]$ (d) $\dfrac{\mu_0 I}{4\pi a}6[\sqrt{3}+1]$ *(2017)*

40. A uniform magnetic field B exists in the region between $x = 0$ and $x = \dfrac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge $+Q$ and momentum p directed along x-axis enters region 2 from region 1 at point $P_1(y = -R)$. Which of the following option(s) is/are correct?



(a) For $B > \frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1.

(b) For $B = \frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x-axis.

(c) For a fixed B, particles of same charge Q and same velocity v, the distance between the point P_1 and the point of re-entry into region 1 is inversely proportional to the mass of the particle.

(d) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the change in its linear momentum between point P_1 and the farthest point from y-axis is $p/\sqrt{2}$. *(2017)*

Answer Q. 41, Q. 42 and Q. 43 by appropriately matching the information given in the three columns of the following table.

A charged particle (electron or proton) is introduced at the origin $(x=0, y=0, z=0)$ with a given initial velocity $\vec{v}$. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity $\vec{v}$, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns 1, 2 and 3, respectively. The quantities E_0, B_0 are positive in magnitude.

Column 1	Column 2	Column 3
(I) Electron with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(i) $\vec{E} = E_0\hat{z}$	(P) $\vec{B} = -B_0\hat{x}$
(II) Electron with $\vec{v} = \frac{E_0}{B_0}\hat{y}$	(ii) $\vec{E} = -E_0\hat{y}$	(Q) $\vec{B} = B_0\hat{x}$
(III) Proton with $\vec{v} = 0$	(iii) $\vec{E} = -E_0\hat{x}$	(R) $\vec{B} = B_0\hat{y}$
(IV) Proton with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(iv) $\vec{E} = E_0\hat{x}$	(S) $\vec{B} = B_0\hat{z}$

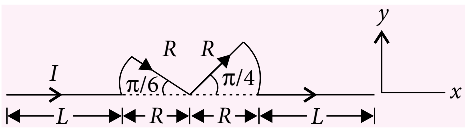
41. In which case would the particle move in a straight line along the negative direction of y-axis (*i.e.*, move along $-\hat{y}$)?
(a) (IV) (ii) (S) (b) (II) (iii) (Q)
(c) (III) (ii) (R) (d) (III) (ii) (P)

42. In which case will the particle move in a straight line with constant velocity?
(a) (II) (iii) (S) (b) (III) (iii) (P)
(c) (IV) (i) (S) (d) (III) (ii) (R)

43. In which case will the particle describe a helical path with axis along the positive z direction?
(a) (II) (ii) (R) (b) (III) (iii) (P)
(c) (IV) (i) (S) (d) (IV) (ii) (R) *(2017)*

44. Consider two identical galvanometers and two identical resistors with resistance R. If the internal resistance of the galvanometers $R_C < R/2$, which of the following statement(s) about any one of the galvanometers is(are) true?
(a) The maximum voltage range is obtained when all the components are connected in series
(b) The maximum voltage range is obtained when the two resistors and one galvanometer are connected in series, and the second galvanometer is connected in parallel to the first galvanometer
(c) The maximum current range is obtained when all the components are connected in parallel
(d) The maximum current range is obtained when the two galvanometers are connected in series and the combination is connected in parallel with both the resistors *(2016)*

45. A conductor (shown in the figure) carrying constant current I is kept in the x-y plane in a uniform magnetic field $\vec{B}$. If F is the magnitude of the total magnetic force acting on the conductor, then the correct statement(s) is(are)

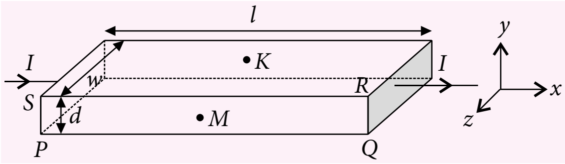


(a) If $\vec{B}$ is along $\hat{z}$, $F \propto (L + R)$
(b) If $\vec{B}$ is along $\hat{x}$, $F = 0$
(c) If $\vec{B}$ is along $\hat{y}$, $F \propto (L + R)$
(d) If $\vec{B}$ is along $\hat{z}$, $F = 0$ *(2015)*

Paragraph for Questions 46 and 47

In a thin rectangular metallic strip a constant current I flows along the positive x-direction, as shown in the figure. The length, width and thickness of the strip are l, w and d, respectively.

A uniform magnetic field $\vec{B}$ is applied on the strip along the positive y-direction. Due to this, the charge carriers experience a net deflection along the z-direction. This results in accumulation of charge carriers on the surface $PQRS$ and appearance of equal and opposite charges on the face opposite to $PQRS$. A potential difference along the z-direction is thus developed. Charge accumulation continues until the magnetic force is balanced by the electric force. The current is assumed to be uniformly distributed on the cross section of the strip and carried by electrons.



46. Consider two different metallic strips (1 and 2) of the same material. Their lengths are the same, widths are w_1 and w_2 and thicknesses are d_1 and d_2, respectively. Two points K and M are symmetrically located on the opposite faces parallel to the x-y plane (see figure). V_1 and V_2 are the potential differences between K and M in strips 1 and 2, respectively. Then, for a given current I flowing through them in a given magnetic field strength B, the correct statement(s) is(are)

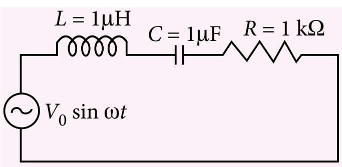
(a) If $w_1 = w_2$ and $d_1 = 2d_2$, then $V_2 = 2V_1$
(b) If $w_1 = w_2$ and $d_1 = 2d_2$, then $V_2 = V_1$
(c) If $w_1 = 2w_2$ and $d_1 = d_2$, then $V_2 = 2V_1$
(d) If $w_1 = 2w_2$ and $d_1 = d_2$, then $V_2 = V_1$

47. Consider two different metallic strips (1 and 2) of same dimensions (length l, width w and thickness d) with carrier densities n_1 and n_2, respectively. Strip 1 is placed in magnetic field B_1 and strip 2 is placed in magnetic field B_2, both along positive y-directions. Then V_1 and V_2 are the potential differences developed between K and M in strips 1 and 2, respectively. Assuming that the current I is the same for both the strips, the correct option(s) is(are)

(a) If $B_1 = B_2$ and $n_1 = 2n_2$, then $V_2 = 2V_1$
(b) If $B_1 = B_2$ and $n_1 = 2n_2$, then $V_2 = V_1$
(c) If $B_1 = 2B_2$ and $n_1 = n_2$, then $V_2 = 0.5\ V_1$
(d) If $B_1 = 2B_2$ and $n_1 = n_2$, then $V_2 = V_1$ *(2015)*

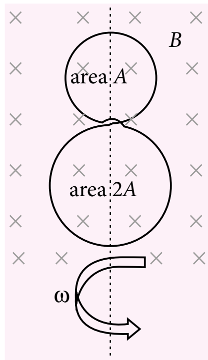
Electromagnetic Induction

48. In the circuit shown, $L = 1\ \mu$H, $C = 1\ \mu$F and $R = 1$ kΩ. They are connected in series with an a.c. source $V = V_0 \sin \omega t$ as shown. Which of the following options is/are correct?



(a) At $\omega \sim 0$ the current flowing through the circuit becomes nearly zero.
(b) The frequency at which the current will be in phase with the voltage is independent of R.
(c) The current will be in phase with the voltage if $\omega = 10^4$ rad s^{-1}.
(d) At $\omega \gg 10^6$ rad s^{-1}, the circuit behaves like a capacitor. *(2017)*

49. A circular insulated copper wire loop is twisted to form two loops of area A and $2A$ as shown in the figure. At the point of crossing the wires remain electrically insulated from each other. The entire loop lies in the plane (of the paper). A uniform magnetic field $\vec{B}$ points into the plane of the paper. At $t = 0$, the loop starts rotating about the common diameter as axis with a constant angular velocity ω in the magnetic field. Which of the following options is/are correct?



(a) The emf induced in the loop is proportional to the sum of the areas of the two loops
(b) The rate of change of the flux is maximum when the plane of the loops is perpendicular to plane of the paper
(c) The net emf induced due to both the loops is proportional to cos ωt
(d) The amplitude of the maximum net emf induced due to both the loops is equal to the amplitude of maximum emf induced in the smaller loop alone *(2017)*

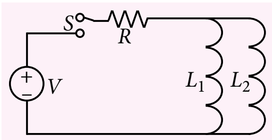
50. The instantaneous voltages at three terminals marked X, Y and Z are given by $V_X = V_0 \sin \omega t$,

$$V_Y = V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) \text{ and } V_Z = V_0 \sin\left(\omega t + \frac{4\pi}{3}\right)$$

An ideal voltmeter is configured to read rms value of the potential difference between its terminals. It is connected between points X and Y and then between Y and Z. The reading(s) of the voltmeter will be

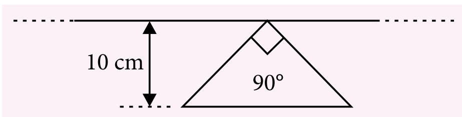
(a) independent of the choice of the two terminals
(b) $V_{XY}^{rms} = V_0$
(c) $V_{YZ}^{rms} = V_0\sqrt{\frac{1}{2}}$
(d) $V_{XY}^{rms} = V_0\sqrt{\frac{3}{2}}$ *(2017)*

51. A source of constant voltage V is connected to a resistance R and two ideal inductors L_1 and L_2 through a switch S as shown. There is no mutual inductance between the two inductors. The switch S is initially open. At $t = 0$, the switch is closed and current begins to flow. Which of the following options is/are correct?



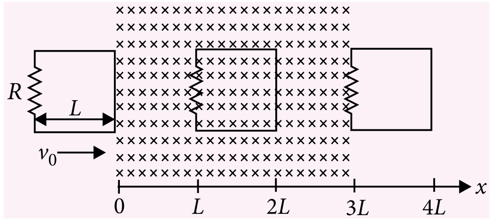
(a) At $t = 0$, the current through the resistance R is V/R.
(b) The ratio of the currents through L_1 and L_2 is fixed at all times ($t > 0$).
(c) After a long time, the current through L_2 will be $\frac{V}{R}\frac{L_1}{L_1+L_2}$.
(d) After a long time, the current through L_1 will be $\frac{V}{R}\frac{L_2}{L_1+L_2}$. *(2017)*

52. A conducting loop in the shape of a right angled isosceles triangle of height 10 cm is kept such that the 90° vertex is very close to an infinitely long conducting wire (see the figure). The wire is electrically insulated from the loop. The hypotenuse of the triangle is parallel to the wire. The current in the triangular loop is in counterclockwise direction and increased at a constant rate of 10 A s^{-1}. Which of the following statement(s) is(are) true?

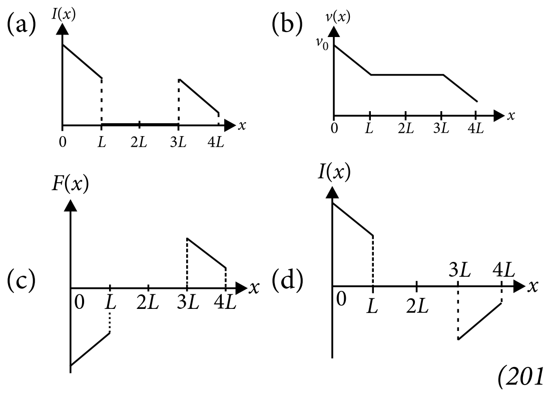


(a) The induced current in the wire is in opposite direction to the current along the hypotenuse
(b) The magnitude of induced emf in the wire is $\left(\frac{\mu_0}{\pi}\right)$ volt
(c) There is a repulsive force between the wire and the loop
(d) If the loop is rotated at a constant angular speed about the wire, an additional emf of $\left(\frac{\mu_0}{\pi}\right)$ volt is induced in the wire *(2016)*

53. A rigid wire loop of square shape having side of length L and resistance R is moving along the x-axis with a constant velocity v_0 in the plane of the paper. At $t = 0$, the right edge of the loop enters a region of length $3L$ where there is a uniform magnetic field B_0 into the plane of the paper, as shown in the figure. For sufficiently large v_0, the loop eventually crosses the region. Let x be the location of the right edge of the loop. Let $v(x)$, $I(x)$ and $F(x)$ represent the velocity of the loop, current in the loop, and force on the loop, respectively, as a function of x. Counter-clockwise current is taken as positive.

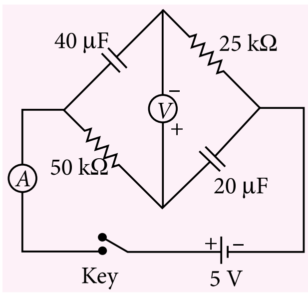


Which of the following schematic plot(s) is(are) correct? (Ignore gravity)



(2016)

54. In the circuit shown below, the key is pressed at time $t = 0$. Which of the following statement(s) is(are) true?



(a) The voltmeter displays –5 V as soon as the key is pressed, and displays +5 V after a long time
(b) The voltmeter will display 0 V at time $t = \ln 2$ seconds
(c) The current in the ammeter becomes $1/e$ of the initial value after 1 second
(d) The current in the ammeter becomes zero after a long time *(2016)*

55. Two inductors L_1 (inductance 1 mH, internal resistance 3 Ω) and L_2 (inductance 2 mH, internal resistance 4 Ω), and a resistance R (resistance 12 Ω) are all connected in parallel across a 5 V battery. The circuit is switched on at time $t = 0$. The ratio of the maximum to the minimum current (I_{max}/I_{min}) drawn from the battery is *(2016)*

Optics

56. For an isosceles prism of angle A and refractive index μ, it is found that the angle of minimum deviation $\delta_m = A$. Which of the following options is/are correct?

(a) For the angle of incidence $i_1 = A$, the ray inside the prism is parallel to the base of the prism

(b) At minimum deviation, the incident angle i_1 and the refracting angle r_1 at the first refracting surface are related by $r_1 = (i_1/2)$

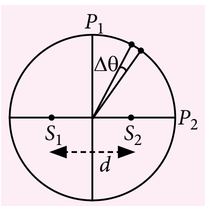
(c) For this prism, the emergent ray at the second surface will be tangential to the surface when the angle of incidence at the first surface is

$$i_1 = \sin^{-1}\left[\sin A\sqrt{4\cos^2\frac{A}{2}-1}-\cos A\right]$$

(d) For this prism, the refractive index μ and the angle of prism A are related as $A = \frac{1}{2}\cos^{-1}\left(\frac{\mu}{2}\right)$

(2017)

57. Two coherent monochromatic point sources S_1 and S_2 of wavelength λ = 600 nm are placed symmetrically on either side of the center of the circle as shown. The sources are separated by a distance d = 1.8 mm. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta\theta$. Which of the following options is/are correct?



(a) The angular separation between two consecutive bright spots decreases as we move from P_1 to P_2 along the first quadrant.

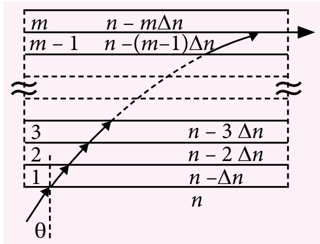
(b) At P_2 the order of the fringe will be maximum.

(c) A dark spot will be formed at the point P_2.

(d) The total number of fringes produced between P_1 and P_2 in the first quadrant is close to 3000.

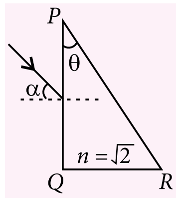
(2017)

58. A monochromatic light is travelling in a medium of refractive index n = 1.6. It enters a stack of glass layers from the bottom side at an angle θ = 30°. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $n_m = n - m\Delta n$, where n_m is the refractive index of the m^{th} slab and Δn = 0.1 (see the figure). The ray is refracted out parallel to the interface between the $(m - 1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m?



(2017)

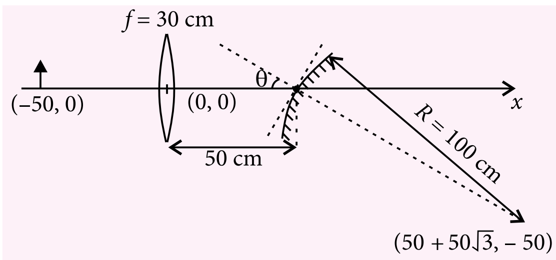
59. A parallel beam of light is incident from air at an angle α on the side PQ of a right angled triangular prism of refractive index $n = \sqrt{2}$. Light undergoes total internal reflection in the prism at the face PR when α has a minimum value of 45°. The angle θ of the prism is



(a) 15° (b) 22.5° (c) 30° (d) 45°

(2016)

60. A small object is placed 50 cm to the left of a thin convex lens of focal length 30 cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 50 cm. The mirror is tilted such that the axis of the mirror is at an angle θ = 30° to the axis of the lens, as shown in the figure.



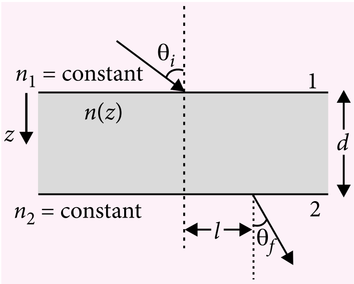
If the origin of the coordinate system is taken to be at the centre of lens, the coordinates (in cm) of the point (x, y) at which the image is formed are

(a) $(25, 25\sqrt{3})$ (b) $(0, 0)$

(c) $(125/3, 25/\sqrt{3})$ (d) $(50 - 25\sqrt{3}, 25)$

(2016)

61. A transparent slab of thickness d has a refractive index $n(z)$ that increases with z. Hence z is the vertical distance inside the slab, measured from the top. The slab is placed between two media with uniform refractive indices n_1 and n_2 ($> n_1$), as shown in the figure. A ray of light is incident with angle θ_i from medium 1 and emerges in medium 2 with refraction angle θ_f with a lateral displacement l.



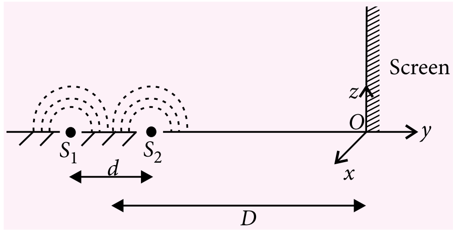
Which of the following statement(s) is (are) true?

(a) l is independent of n_2
(b) $n_1 \sin\theta_i = n_2 \sin\theta_f$
(c) l is dependent on $n(z)$
(d) $n_1 \sin\theta_i = (n_2 - n_1)\sin\theta_f$ *(2016)*

62. A plano-convex lens is made of material of refractive index n. When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image is observed at a distance of 10 cm away from the lens. Which of the following statement(s) is(are) true?

(a) The refractive index of the lens is 2.5
(b) The radius of curvature of the convex surface is 45 cm
(c) The faint image is erect and real
(d) The focal length of the lens is 20 cm *(2016)*

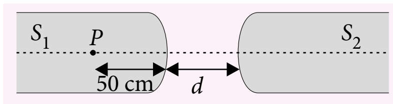
63. While conducting the Young's double slit experiment, a student replaced the two slits with a large opaque plate in the x-y plane containing two small holes that act as two coherent point sources (S_1, S_2) emitting light of wavelength 600 nm. The student mistakenly placed the screen parallel to the x-z plane (for $z > 0$) at a distance D = 3 m from the mid-point of S_1S_2, as shown schematically in the figure. The distance between the sources d = 0.6003 mm. The origin O is at the intersection of the screen and the line joining S_1S_2. Which of the following is (are) true of the intensity pattern on the screen?



(a) Hyperbolic bright and dark bands with foci symmetrically placed about O in the x-direction
(b) Straight bright and dark bands parallel to the x-axis
(c) Semi circular bright and dark bands centered at point O
(d) The region very close to the point O will be dark *(2016)*

64. Two identical glass rods S_1 and S_2 (refractive index = 1.5) have one convex end of radius of curvature 10 cm. They are placed with the curved surfaces at a distance d as shown in the figure, with their axes (shown by the dashed line) aligned. When a point source of light P is placed inside rod S_1 on its axis at a distance of 50 cm from the curved face, the light rays emanating from it are found to be parallel to the axis inside S_2. The distance d is

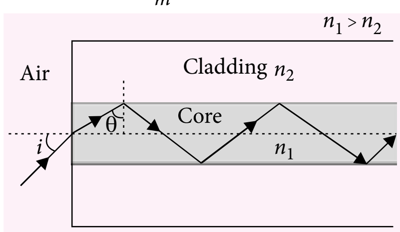
(a) 60 cm
(b) 70 cm
(c) 80 cm
(d) 90 cm



(2015)

Paragraph for Questions 65 and 66

Light guidance in an optical fiber can be understood by considering a structure comprising of thin solid glass cylinder of refractive index n_1 surrounded by a medium of lower refractive index n_2. The light guidance in the structure takes place due to successive total internal reflections at the interface of media n_1 and n_2 as shown in the figure. All rays with the angle of incidence i less than a particular value i_m are confined in the medium of refractive index n_1. The numerical aperture (NA) of the structure is defined as $\sin i_m$.



65. For two structures namely S_1 with $n_1 = \sqrt{45}/4$ and $n_2 = 3/2$, and S_2 with $n_1 = 8/5$ and $n_2 = 7/5$ and taking the refractive index of water to be 4/3 and that of air to be 1, the correct option(s) is(are)

(a) NA of S_1 immersed in water is the same as that of S_2 immersed in a liquid of refractive index $\frac{16}{3\sqrt{15}}$

(b) NA of S_1 immersed in liquid of refractive index $\frac{6}{\sqrt{15}}$ is the same as that of S_2 immersed in water

(c) NA of S_1 placed in air is the same as that of S_2 immersed in liquid of refractive index $\frac{4}{\sqrt{15}}$

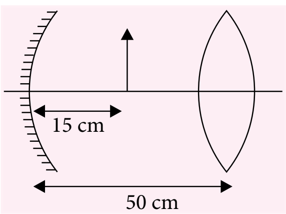
(d) NA of S_1 placed in air is the same as that of S_2 placed in water

66. If two structures of same cross-sectional area, but different numerical apertures NA_1 and NA_2 ($NA_2 < NA_1$) are joined longitudinally, the numerical aperture of the combined structure is

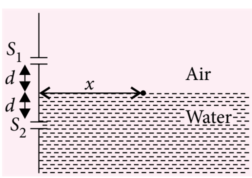
(a) $\frac{NA_1 NA_2}{NA_1 + NA_2}$ (b) $NA_1 + NA_2$

(c) NA_1 (d) NA_2 *(2015)*

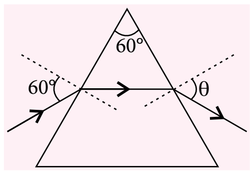
67. Consider a concave mirror and a convex lens (refractive index = 1.5) of focal length 10 cm each, separated by a distance of 50 cm in air (refractive index = 1) as shown in the figure. An object is placed at a distance of 15 cm from the mirror. Its erect image formed by this combination has magnification M_1. When the set-up is kept in a medium of refractive index 7/6, the magnification becomes M_2. The magnitude $\left|\frac{M_2}{M_1}\right|$ is *(2015)*



68. A Young's double slit interference arrangement with slits S_1 and S_2 is immersed in water (refractive index = 4/3) as shown in the figure. The positions of maxima on the surface of water are given by $x^2 = p^2m^2\lambda^2 - d^2$, where λ is the wavelength of light in air (refractive index = 1), $2d$ is the separation between the slits and m is an integer. The value of p is *(2015)*



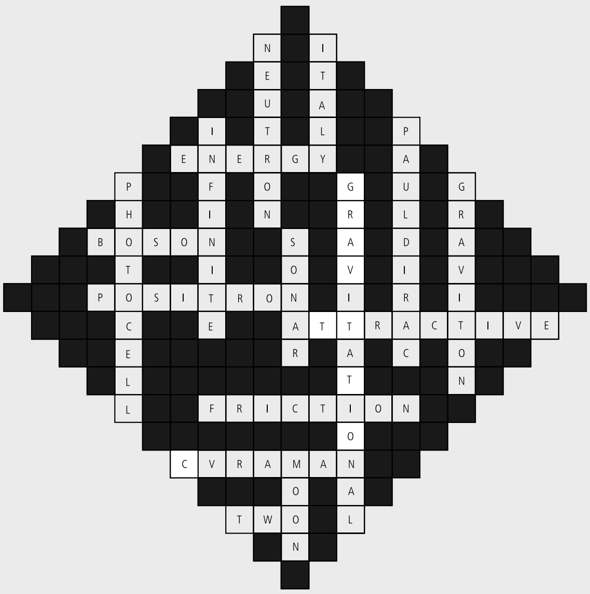
69. A monochromatic beam of light is incident at 60° on one face of an equilateral prism of refractive index n and emerges from the opposite face making an angle $\theta(n)$ with the normal (see the figure). For $n = \sqrt{3}$ the value of θ is 60° and $\frac{d\theta}{dn} = m$. The value of m is *(2015)*



ANSWER KEY

1.	(b)	2.	(a)	3.	(b,d)	4.	(a,b,d)	5.	(a,c,d)
6.	(a,c)	7.	(4)	8.	(a)	9.	(a,b,c)	10.	(b)
11.	(d)	12.	(d)	13.	(a,b,d)	14.	(a,b)	15.	(b)
16.	(d)	17.	(7)	18.	(6)	19.	(b,c,d)	20.	(c)
21.	(b)	22.	(b)	23.	(b)	24.	(a)	25.	(c)
26.	(9)	27.	(a,b,d)	28.	(a,b,c)	29.	(2)	30.	(a,d)
31.	(b)	32.	(a)	33.	(a)	34.	(c)	35.	(c)
36.	(d)	37.	(d)	38.	(6)	39.	(b)	40.	(a,b)
41.	(c)	42.	(a)	43.	(c)	44.	(a,c)	45.	(a,b,c)
46.	(a,d)	47.	(a,c)	48.	(a,b)	49.	(b,d)	50.	(a,d)
51.	(b,c,d)	52.	(b,c)	53.	(b,d)	54.	(a,b,c,d)	55.	(8)
56.	(a,b,c)	57.	(b,d)	58.	(8)	59.	(a)	60.	(a)
61.	(a,b,c)	62.	(a,d)	63.	(c,d)	64.	(b)	65.	(a,c)
66.	(d)	67.	(7)	68.	(3)	69.	(2)		

CROSSWORD SOLUTION APRIL 2018



Winners

1. Shubham Ramdas Shirke, Ulkangari, Aurangabad
2. Devjit Acharjee, Kolkata, West Bengal

JEE ADVANCED
PRACTICE PAPER 2018

Exam on 20th May

PAPER - I

Section 1 (Maximum Marks : 28)

- *This section contains SEVEN questions.*
- *Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four options is(are) correct.*
- *For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.*
- *For each question, marks will be awarded in one of the following categories :*

  Full Marks : +4 *If only the bubble(s) corresponding to all the correct option(s) is(are) darkened.*

  Partial Marks : +1 *For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened.*

  Zero Marks : 0 *If none of the bubbles is darkened.*

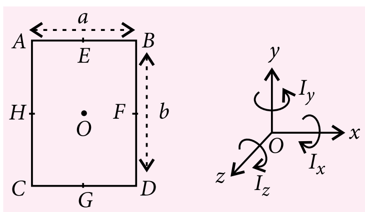
  Negative Marks : –2 *In all other cases.*
- *For example, if (a), (c) and (d) are all the correct options for a question, darkening all these three will get +4 marks; darkening only (a) and (d) will get +2 marks; and darkening (a) and (b) will get –2 marks, as a wrong option is also darkened.*

1. If the gravitational force between A and B (masses $2m$ and $3m$ respectively and separated by a distance $2d$) is 1 unit, the force between C and D (of masses $3m$ and $4m$ respectively with separation $3d$) will be between

(a) 0 and 0.5 (b) 0.5 and 1.0

(c) 1.0 and 1.5 (d) 1.5 and 2.0

2. The moment of inertia of a rectangular lamina $ABCD$ about O, along an axis perpendicular to the lamina, passing through the centre of mass O is $=\frac{a^2+b^2}{12}$. The moment of inertia



(a) about an axis perpendicular to the plane, passing through B is greater than that through O but smaller than that through H

(b) about an axis perpendicular to the plane, passing through B > through F > through O

(c) will be same if this had been a thick block

(d) I_z is always greater than I_x and I_y because $I_z = I_x + I_y$.

3. A boy of 40 kg is standing on a boat of mass 120 kg at a distance of 20 m from shore. He slowly moves in the direction of the shore on the boat by 8 m. Then

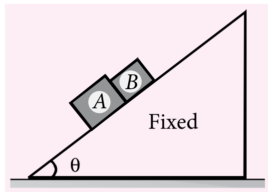
(a) the distance of the boy from the shore is now 14 m

(b) the boat moves back, thus disturbing the position of the centre of mass

(c) the centre of mass of the boat remains at same position but the boy has moved forward

(d) the centre of mass of the boat and the boy remains at the same place.

4. In the arrangement shown in figure all surfaces are smooth. Select the correct alternative(s).



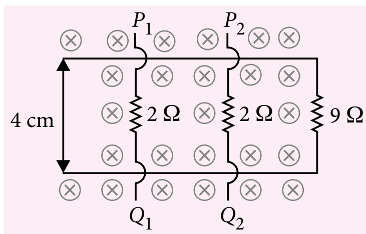
(a) For any value of θ acceleration of A and B are equal.

(b) Contact force between the two blocks is zero if $m_A/m_B = \tan\theta$.

(c) Contact force between the two is zero for any value of m_A or m_B.

(d) Normal reactions exerted by the wedge on the blocks are equal.

5. In figure shown, the wires P_1Q_1 are made to slide on the rails with same speed of 5 cm s^{-1}. In this region, a magnetic field of 1 T exists. The electric current in the 9 Ω resistance is



(a) zero if both wires slide toward left
(b) zero if both wires slide in opposite directions
(c) 0.2 mA if both wires move toward left
(d) 0.2 mA if both wires move in opposite directions

6. A uniform cylinder of length L and mass M having cross-sectional area A is suspended, with its length vertical, from a fixed point by a massless spring, such that it is half-submerged in a liquid of density ρ at equilibrium position. When the cylinder is given a small downward push and released, it starts oscillating vertically with small amplitude. If the force constant of the spring is k, the frequency of oscillation of the cylinder is

(a) $\frac{1}{2\pi}\left(\frac{k-A\rho g}{M}\right)^{1/2}$ (b) $\frac{1}{2\pi}\left(\frac{k+A\rho g}{M}\right)^{1/2}$

(c) $\frac{1}{2\pi}\left(\frac{k+\rho-gL}{M}\right)^{1/2}$ (d) $\frac{1}{2\pi}\left(\frac{k+A-gL}{A\rho g}\right)^{1/2}$

7. Oxygen gas is made to undergo a process in which its molar heat capacity C depends on its absolute temperature T as $C = \alpha T$. Work done by it when heated from an initial temperature T_0 to a final temperature $2T_0$, will be

(a) $4\alpha T_0^2$ (b) $(\alpha T_0 - R)\frac{3T_0}{2}$

(c) $(3\alpha T_0 - 5R)\frac{T_0}{2}$ (d) none of these

Section 2 (Maximum Marks : 15)

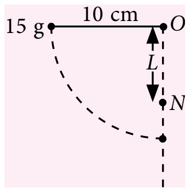
- *This section contains FIVE questions.*
- *The answer to each question is a SINGLE DIGIT INTEGER ranging from 0 to 9, both inclusive.*
- *For each question, darken the bubble corresponding to the correct integer in the ORS.*
- *For each question, marks will be awarded in one of the following categories :*

Full Marks : +3 *If only the bubble corresponding to the correct answer is darkened.*
Zero Marks : 0 *In all other cases.*

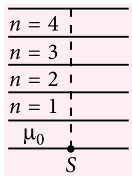
8. A steel tape is placed around the earth at the equator when the temperature is 0 °C. What will be the distance (in km) between the tape and the ground (assumed to be uniform) if the temperature of the tape rises to 30°C? (Neglect the expansion of the earth. Take $\alpha_{steel} = 11 \times 10^{-6}\ °C^{-1}$)

9. The electric potential between a proton and an electron is given by $V = V_0 \ln\left(\frac{r}{r_0}\right)$, where r_0 is a constant. Assuming Bohr's model to be applicable, the variation of r_n with n is given by $r_n \propto n^k$, n being the principal quantum number. Find the value of k.

10. A ball weighing 15 g is tied to a string 10 cm long. Initially the ball is held in position such that the string is horizontal. The ball is now released. A nail N is situated vertically below the support at a distance L. The minimum value of L (in cm) such that the string will be wound round the nail is



11. A point source S is placed at the bottom of different layers as shown in figure. The refractive index of bottom most layer is μ_0. The refractive index of any other upper layer is $\mu(n) = \mu_0 - \frac{\mu_0}{4n-18}$ where n = 1, 2, ... A ray of light starts from the source S as shown. Total internal reflection takes place at the upper surface of a layer having n (minimal value) equal to



12. A proton has kinetic energy E = 100 keV which is equal to that of a photon. The wavelength of photon is λ_2 and that of proton is λ_1. The ratio λ_2/λ_1 is given by $c\sqrt{2m_p}\ E^{-1/n}$. Find the value of n.

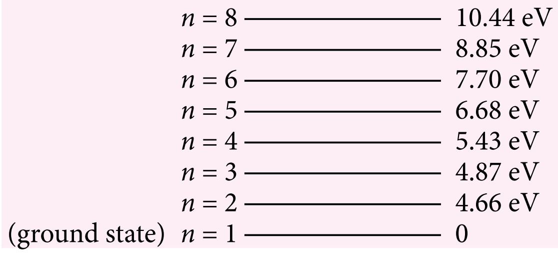
Section 3 (Maximum Marks : 18)

- *This section contains SIX questions of matching type.*
- *This section contains TWO tables (each having 3 columns and 4 rows).*
- *Based on each table, there are THREE questions.*
- *Each question has FOUR options (a), (b), (c), and (d). ONLY ONE of these four options is correct.*
- *For each question, darken the bubble corresponding to the correct option in the ORS.*
- *For each question, marks will be awarded in one of the following categories :*

Full Marks : +3 *If only the bubble corresponding to the correct option is darkened.*
Zero Marks : 0 *If none of the bubbles is darkened*
Negative Marks : –1 *In all other cases*

Answer Q.13, Q.14 and Q.15 by appropriately matching the information given in the three columns of the following table.

A mercury lamp is a convenient source for studying frequency dependence of photoelectric emission, since it gives a number of spectral lines ranging from the UV to the red end of the visible spectrum. The energy level diagram of mercury is shown in the figure. Assume ground state energy is 0 eV.



In our experiment with rubidium photocell, some lines from mercury source were used. The rubidium has work function of 2.01 eV. The given matrix has three columns in which column 1 contains wavelengths of line used, column 2 contains the transition states from which the spectral lines contained in column 1 had been obtained and column 3 lists the stopping voltages measured in our experiment.

Column 1	Column 2	Column 3
(I) 3626 Å	(i) $n = 5$ to $n = 3$	(P) 0.82 V
(II) 5714 Å	(ii) $n = 7$ to $n = 5$	(Q) 1.41 V
(III) 6850 Å	(iii) $n = 6$ to $n = 3$	(R) 0 V
(IV) 4381 Å	(iv) $n = 7$ to $n = 4$	(S) 0.16 V

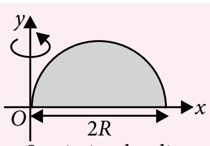
13. For which of the following combinations, the photoelectron has maximum velocity equals to 5.37×10^5 m s^{-1}?
(a) (I) (iv) (S) (b) (II) (i) (P)
(c) (IV) (ii) (S) (d) (IV) (iii) (P)

14. For which of the following combinations, photon emitted by mercury lamp will be fully absorbed by rubidium photocell?
(a) (III) (i) (R) (b) (II) (ii) (Q)
(c) (II) (i) (R) (d) (III) (iv) (S)

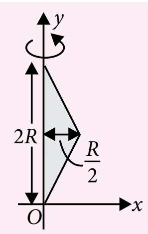
15. For which of the following combinations, photon striking the photocell has energy 5.472×10^{-19} J?
(a) (I) (iii) (P) (b) (IV) (iii) (P)
(c) (I) (iv) (Q) (d) (IV) (iv) (Q)

Answer Q. 16, Q.17 and Q. 18 by appropriately matching the information given in the three columns of the following table.

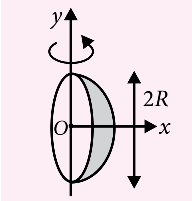
A student takes four different rigid objects having continuous mass distribution. He rotates the objects about y-axis as shown in the figure.



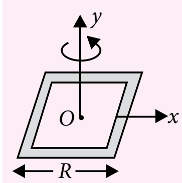
Semi-circular disc



Triangular plate



Hemispherical bowl



Square frame

The figure shows the position of bodies at $t = 0$.
All the four objects has mass m and dimensions of the objects are described in the figure.
The table shown below contains three columns in which column 1 describes the rigid body, column 2 gives the coordinates of centre of mass of the bodies at the given instant and column 3 contains the value of moment of inertia of bodies about y-axis. All the data in table is kept in random order

Column 1	Column 2	Column 3
(I) Semicircular disc of diameter $2R$	(i) $\left(\frac{R}{6}, R\right)$	(P) $\frac{2}{3}mR^2$
(II) Triangular plate of height $\frac{R}{2}$ and base $2R$	(ii) (0, 0)	(Q) $\frac{5}{4}mR^2$
(III) Hemispherical bowl of radius R	(iii) $\left(R, \frac{4R}{3\pi}\right)$	(R) $\frac{mR^2}{3}$
(IV) Square frame made of four identical rods of length R	(iv) $\left(\frac{R}{2}, 0\right)$	(S) $\frac{mR^2}{24}$

16. Which of the following combinations is correct, for the object whose axis of rotation passes through its centre of mass?
(a) (IV) (ii) (R) (b) (IV) (ii) (P)
(c) (II) (iv) (S) (d) (II) (i) (S)

17. If all the object have same rotational kinetic energy, then which of the following combinations will have maximum angular velocity?
(a) (I) (iii) (Q) (b) (III) (iv) (S)
(c) (II) (i) (S) (d) (IV) (ii) (R)

18. If a point of mass m is added to the origin (O) of each rigid point, then in which of following combination the centre of mass of new system will not lie on x-axis?
(a) (III) (iv) (P)
(b) (I) (iii) (Q)
(c) (IV) (iv) (R)
(d) (III) (i) (S)

PAPER - II

Section 1 (Maximum Marks : 21)

- *This section contains SEVEN questions.*
- *Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is correct.*
- *For each question, darken the bubble corresponding to the correct option in the ORS.*
- *For each question, marks will be awarded in one of the following categories :*

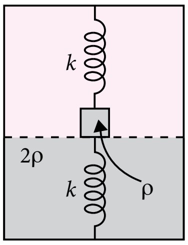
Full Marks : +3 *If only the bubble corresponding to the correct option is darkened.*
Zero Marks : 0 *If none of the bubbles is darkened.*
Negative Marks : –1 *In all other cases.*

1. A uniform ball of radius r rolls without slipping down from the top of a sphere of radius R. The angular velocity of the ball when it breaks from the sphere is

(a) $\sqrt{\frac{5g(R+r)}{17r^2}}$ (b) $\sqrt{\frac{10g(R+r)}{17r^2}}$

(c) $\sqrt{\frac{5g(R-r)}{10r^2}}$ (d) $\sqrt{\frac{10g(R+r)}{7r^2}}$

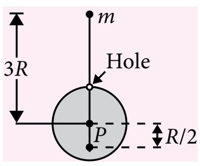
2. A cubic block of side a is connected with two similar vertical springs as shown. Initially, bottom surface of the block of density ρ touches the surface of the fluid of density 2ρ while floating. A weight is placed on the block so that it is immersed half in the fluid, find the weight.



(a) $a\left(\frac{k}{2}+a^2\rho g\right)$ (b) $a(k + a^2\rho g)$

(c) $a\left(k+\frac{a^2}{2}\rho g\right)$ (d) $\frac{a}{2}(k+a^2\rho g)$

3. A point mass m is released from rest at a distance of $3R$ from the centre of a thin-walled hollow sphere of radius R and mass M as shown in figure. The hollow sphere is fixed in position and the only force on the point mass is the gravitational attraction of the hollow sphere. There is a very small hole in the hollow sphere through which the point mass falls as shown. The velocity of a point mass when it passes through P at a distance $R/2$ from the centre of the sphere is



(a) $\sqrt{\frac{2GM}{3R}}$ (b) $\sqrt{\frac{5GM}{3R}}$

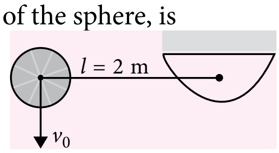
(c) $\sqrt{\frac{25GM}{24R}}$ (d) $\sqrt{\frac{4GM}{3R}}$

4. The deceleration experienced by a moving motor boat, after its engine is switched off is given by $dv/dt = -kv^3$, where k is constant. If v_0 is the magnitude of the velocity of the boat when engine is switched off, the magnitude of the velocity at a time t after the engine is switched off is

(a) $v_0/2$ (b) v

(c) v_0e^{-kt} (d) $\frac{v_0}{\sqrt{2v_0^2kt+1}}$

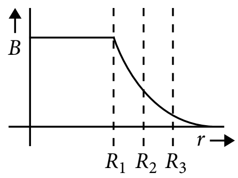
5. A small sphere is given vertical velocity of magnitude $v_0 = 5$ m s^{-1} and it swings in a vertical plane about the end of a massless string. The angle θ with the vertical at which string will break, knowing that it can withstand a maximum tension equal to twice the weight of the sphere, is

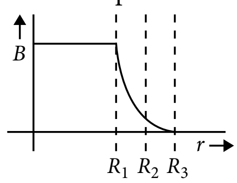


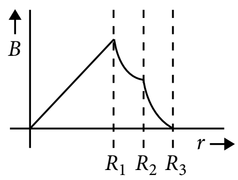
(a) $\cos^{-1}\left(\frac{2}{3}\right)$ (b) $\cos^{-1}\left(\frac{1}{4}\right)$

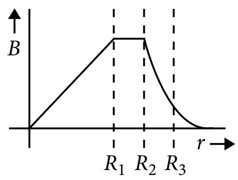
(c) 60° (d) 30°

6. A coaxial cable is made up of two conductors. The inner conductor is solid and is of radius R_1 and the outer conductor is hollow of inner radius R_2 and outer radius R_3. The space between the conductors is filled with air. The inner and outer conductors are carrying currents of equal magnitudes and in opposite directions. Then the variation of magnetic field with distance from the axis is best plotted as

(a) 

(b) 

(c) 

(d) 

7. When 100 V dc is applied across a solenoid, a current of 1.0 A flows in it. When 100 V ac is applied across the same coil, the current drops to 0.5 A. If the frequency of the ac source is 50 Hz, the impedance and inductance of the solenoid are
(a) 200 Ω and 0.55 H (b) 100 Ω and 0.86 H
(c) 200 Ω and 1.0 H (d) 100 Ω and 0.93 H

Section 2 (Maximum Marks : 28)

- *This section contains SEVEN questions.*
- *Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four options is(are) correct.*
- *For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.*
- *For each question, marks will be awarded in one of the following categories :*

Full Marks : +4 *If only the bubble(s) corresponding to all the correct option(s) is(are) darkened.*

Partial Marks: +1 *For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened.*

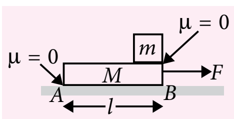
Zero Marks : 0 *If none of the bubbles is darkened.*

Negative Marks : –2 *In all other cases.*

- *For example, if (a), (c) and (d) are all the correct options for a question, darkening all these three will result in +4 marks; darkening only (a) and (d) will result in +2 marks; and darkening (a) and (b) will result in –2 marks, as a wrong option is also darkened.*

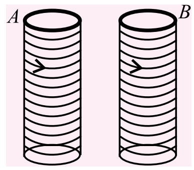
8. Two balls A and B thrown with speeds u and $u/2$, respectively. Both the balls cover the same horizontal distance before returning to the plane of projection. If the angle of projection of ball B is 15° with the horizontal, then the angle of projection of A is
(a) $\sin^{-1}\left(\frac{1}{8}\right)$ (b) $\frac{1}{2}\sin^{-1}\left(\frac{1}{8}\right)$
(c) $\frac{1}{3}\sin^{-1}\left(\frac{1}{8}\right)$ (d) $\frac{1}{4}\sin^{-1}\left(\frac{1}{8}\right)$

9. In shown figure, a small block is kept on slab of mass M. Then



(a) the acceleration of m with respect to ground is F/m.
(b) the acceleration of m with respect to ground is zero.
(c) the time taken by m to separate from M is $\sqrt{\frac{2lm}{F}}$.
(d) the time taken by m to separate from M is $\sqrt{\frac{2lM}{F}}$.

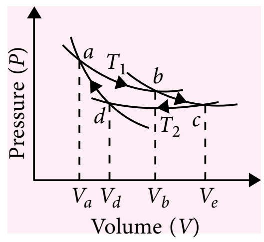
10. Two metallic rings A and B, identical in shape and size but having different resistivities ρ_A and ρ_B, are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights h_A and h_B, respectively, with $h_A > h_B$. The possible relation(s) between their resistivities and their masses m_A and m_B is(are)



(a) $\rho_A > \rho_B$ and $m_A = m_B$
(b) $\rho_A < \rho_B$ and $m_A = m_B$
(c) $\rho_A > \rho_B$ and $m_A > m_B$
(d) $\rho_A < \rho_B$ and $m_A < m_B$

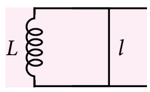
11. A choke coil of resistance 5 Ω and inductance 0.6 H is in series with a capacitor of capacitance of 10 μF. If a voltage of 200 V is applied and the frequency is adjusted to resonance, the current and voltage across the inductor are I_0 and V_0, and across the capacitor are I_1 and V_1.
(a) I_0 = 40 A (b) V_0 = 9.8 kV
(c) V_1 = 9.8 kV (d) V_1 = 19.6 kV

12. An ideal gas undergoes the cyclic process shown in a graph below.



(a) $T_1 = T_2$
(b) $T_1 > T_2$
(c) $V_aV_c = V_bV_d$
(d) $V_aV_b = V_cV_d$

13. Two parallel resistance rails are connected by an inductor of inductance L at one end as shown in figure. A magnetic field B exists in the space which is perpendicular to the plane of the rails. Now a conductor of length l and mass m is placed transverse on the rail and given an impulse J toward the rightward direction. Then choose the correct option(s).

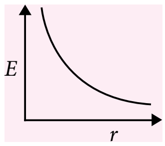


(a) Velocity of the conductor is half of the initial velocity after a displacement of the conductor $d = \sqrt{\frac{3J^2L}{4B^2l^2m}}$
(b) Current flowing through the inductor at the instant when velocity of the conductor is half of the initial velocity is $i = \sqrt{\frac{3J^2}{4Lm}}$

(c) Velocity of the conductor is half of the initial velocity after a displacement of the conductor $d = \sqrt{\frac{3J^2L}{B^2l^2m}}$

(d) Current flowing through the inductor at the instant when velocity of the conductor is half of the initial velocity is $i = \sqrt{\frac{3J^2}{mL}}$

14. Energy density E (energy per unit volume) of the medium at a distance r from a sound source varies according to the curve shown in figure. Which of the following are possible?



(a) The source may be a point isotropic source.

(b) If the source is a plane source then the medium particles have damped oscillations.

(c) If the source is a plane source then power of the source is decreasing with time.

(d) All of these

Section 3 (Maximum Marks : 12)

- *This section contains TWO paragraphs.*
- *Based on each paragraph, there are TWO questions.*
- *Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is correct. For each question, darken the bubble corresponding to the correct option in the ORS.*
- *For each question, marks will be awarded in one of the following categories :*

Full Marks : +3 *If only the bubble corresponding to the correct option is darkened.*

Zero Marks : 0 *In all other cases.*

PARAGRAPH 1

A 500 g teapot and an insulated thermos are in a 20 °C room. The teapot is filled with 1000 g of the boiling water. 12 tea bags are then placed into the teapot. The brewed tea is allowed to cool to 80 °C, then 250 g of the tea is poured from the teapot into the thermos. The teapot is then kept on an insulated warmer that transfers 500 cal min^{-1} to the tea. Assume that the specific heat of brewed tea is the same as that of pure water, and that the tea bags have a very small mass compared to that of the water, and a negligible effect on the temperature. The specific heat of teapot is 0.17 J $g^{-1}K^{-1}$ and that of water is 4.18 J $g^{-1}K^{-1}$. The entire procedure is done under atmospheric pressure. There are 4.18 J in one calorie.

15. After the tea is added to the thermos, the temperature of the liquid quickly falls from 80 °C to 75 °C as it reaches thermal equilibrium with the thermos flask. What is the heat capacity of the thermos?

(a) 9.5 J K^{-1} (b) 14 J K^{-1}
(c) 95 J K^{-1} (d) 878 J K^{-1}

16. If, after some of the tea has been transferred to the thermos (as described in the passage), the teapot with its contents (at a temperature of 80°C) was placed on the insulated warmer for 5 minutes, what would be the temperature at the end of this 5 minutes period (Assume that no significant heat transfer occurs with the surroundings)?

(a) 80.7 °C (b) 82.5 °C
(c) 83.2 °C (d) 95.2 °C

PARAGRAPH 2

It is assumed that an electron is revolving round the proton in a circular path. However, both are revolving round their centre of mass. This is a two body problem. The energy of the hydrogen atom or any one electron system is normally given as

$$E_n = -\frac{1}{2}m_e c^2 \alpha^2 \cdot \frac{Z^2}{n^2}.$$

where m_e is the rest mass of the electron, α is a Sommerfield fine structure constant.

$$\alpha = \frac{e^2}{4\pi\varepsilon_0} \cdot \frac{1}{hc} = \frac{1}{137}.$$

If both the particles are revolving about their centre of mass, m_e is replaced by the reduced mass μ where

$$\frac{1}{\mu} = \frac{1}{m_e} + \frac{1}{m_p} \text{ or, } \frac{1}{\mu} = \frac{1}{m_1} + \frac{1}{m_2}.$$

17. As the mass of the hydrogen nucleus is different from that of deuterium (D) and tritium (T) but having the same Z,

(a) the energy levels for H and D are not the same

(b) the energy levels are different and therefore different isotopes can be distinguished

(c) the energy levels are different but the difference is very small to be observed

(d) none of these.

18. If an electron is caught in the orbit of a positron (having a charge e^+, mass = m_e)

(a) the energy of the ground state is E_1 = –13.6 eV

(b) observed frequencies will be higher than that for H

(c) the energy of the ground state is $E_1 = -\frac{13.6 \text{ eV}}{2}$

(d) the frequencies of lines observed will only be thrice of that for H.

SOLUTIONS

PAPER - 1

1. (b): The gravitational force between A and B is

$$F = \frac{G(2m)(3m)}{(2d)^2} = \frac{6Gm^2}{4d^2} = \frac{3}{2}\frac{Gm^2}{d^2} \quad \text{... (i)}$$

The gravitational force between C and D is

$$F' = \frac{G(3m)(4m)}{(3d)^2} = \frac{12Gm^2}{9d^2} = \frac{4}{3}\frac{Gm^2}{d^2} \quad \text{... (ii)}$$

Divide (ii) by (i), we get

$$\frac{F'}{F} = \frac{8}{9} \quad \text{or} \quad F' = \frac{8}{9}F$$

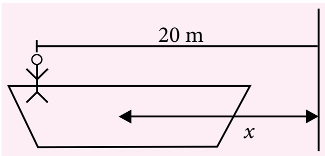
But $F = 1$ unit (given) ∴ $F' = \frac{8}{9} \times 1 \text{ unit} = 0.9 \text{ unit}$

2. (b, c, d) : (b) The parallel axes theorem gives that $I_B = I_0 + M(OB)^2$ is having the greatest value compared to O, F, G, H, E.

(c) For block also it is valid.

(d) For this rectangular lamina it is valid but not valid for a sphere, thin cylindrical rod etc. The perpendicular axes theorem is not always valid. It depends on the shape.

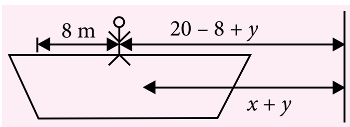
3. (a,d) : Let the centre of mass of boat is at x m from the shore. The given situation is shown in figure



Centre of mass of the system is at

$$r_{CM} = \frac{40 \times 20 + 120 \times x}{40 + 120} = \frac{800 + 120x}{160}$$

Now, boy starts moving towards the shore, so the boat will move backward, say, a distance y.



Now, $r'_{CM} = \frac{(12 + y)40 + 120(x + y)}{160}$

Since there is no external force acting on the system,

∴ $r_{CM} = r'_{CM}$

$$\frac{800 + 120x}{160} = \frac{(12 + y)40 + 12(x + y)}{160}$$

∴ $y = 2$ m

So, boy is now 14 m from the shore and centre of mass of system will remain at same place.

4. (a,c) : $a_A = a_B = g \sin\theta$

If the surface is smooth, contact force between the two is zero.

5. (b,c) : Each wire can be replaced by a battery whose emf is equal to $Blv = 1 \times 4 \times 10^{-2} \times 5 \times 10^{-2}$

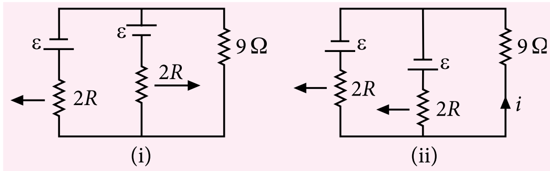
$= 20 \times 10^{-4}$ V

The polarity of the battery can be given by Fleming's right hand rule. When both wire move in opposite direction, the circuit diagram looks like as shown in figure (i).

The effective emf of the two batteries shown in the diagram is zero.

So, choice (b) is correct and choice (d) is wrong.

When both wires move towards left, the circuit diagram looks like as shown in figure (ii) shown.



Effective emf of two batteries shown is E (= 20×10^{-4} V) and internal resistance is 1 Ω.

Hence, current in the circuit is

$$i = \frac{20 \times 10^{-4}}{10} = 0.2 \text{ mA}$$

Hence, choice (c) is correct and choice (a) is wrong.

6. (b) : When the cylinder is given a small push downwards, say x, then two forces start acting on the cylinder trying to bring it to its mean position.

Restoring force = – (upthrust + spring force

$F = -(\rho Axg + kx)$

⇒ $Ma = -(\rho Ag + k)x$, where a is the acceleration of cylinder

$$\text{or} \quad a = \frac{(\rho Ag + k)}{M}x$$

on comparing with standard equation for SHM *i.e.* $a = -\omega^2 x$, where ω is the angular frequency we have

$$\omega = \left[\frac{\rho Ag + k}{M}\right]^{1/2} \Rightarrow \upsilon = \frac{1}{2\pi}\left[\frac{\rho Ag + k}{M}\right]^{1/2}$$

7. (c) : $C = C_V + W'$

where W' is the work done by the gas per mole per unit rise in temperature. So $W' = \alpha T - C_V = \alpha T - (5R/2)$

$$\Delta W = \int W' dT = \int_{T_0}^{2T_0}\left(\alpha T - \frac{5R}{2}\right)dT = (3\alpha T_0 - 5R)\frac{T_0}{2}$$

8. (2)

9. **(1) :** Given : $V = V_0 \ln\left(\frac{r}{r_0}\right)$

$\therefore$ Potential energy $U = eV$

or $U = eV_0 \ln\frac{r}{r_0}$ $\therefore$ $\frac{dU}{dr} = eV_0\left(\frac{r_0}{r}\right)\frac{1}{r_0}$

or $|\text{force}| = \frac{eV_0}{r}$

This force provides the necessary centripetal force.

$\therefore$ $\frac{mv^2}{r} = \frac{eV_0}{r}$ or $v = \sqrt{\frac{eV_0}{m}}$ ...(i)

By Bohr's postulate, $mvr = \frac{nh}{2\pi}$

or $v = \frac{nh}{2\pi mr}$ ...(ii)

From (i) and (ii),

$\frac{nh}{2\pi mr} = \sqrt{\frac{eV_0}{m}}$ or $r = \frac{nh}{2\pi m} \times \sqrt{\frac{m}{eV_0}}$

or $r = \left[\frac{h}{2\pi}\sqrt{\frac{1}{meV_0}}\right] \times n$ $\therefore$ $r_n \propto n$. $\therefore$ $k = 1$.

10. **(6) :** For string to be wound around the nail,

$v \geq \sqrt{5gr}$ $\Rightarrow$ $v \geq \sqrt{5g(10 - L)}$

Now $\frac{1}{2}mv^2 = mg(10)$ $\Rightarrow v^2 = 2g(10)$

$\sqrt{2g.10} \geq \sqrt{5g(10 - L)}$

$\Rightarrow$ $20g \geq 5g(10 - L)$ $\Rightarrow$ $20 \geq 50 - 5L$

$\Rightarrow$ $5L \geq 30$ $\Rightarrow$ $L \geq 6$

$L_{min} = 6$ cm.

11. **(4) :** Total internal reflection can happen only when $\mu\ (n) < \mu_0$

$\Rightarrow \mu_0 - \frac{\mu_0}{4n-18} < \mu_0 \Rightarrow \frac{-\mu_0}{4n-18} < 0$ or $\frac{\mu_0}{4n-18} > 0$

$\Rightarrow$ $4n - 18 > 0$ $\Rightarrow$ $n > \frac{18}{4} = 4.5$

The minimum integral value of n satisfying the inequality is $n = 5$.

Total internal reflection can happen when light is going from 4^{th} to the 5^{th} layer or on the upper layer of 4^{th} layer, since $\mu_5 < \mu_4$.

$\Rightarrow$ Required answer is $n = 4$.

12. (2) : For photon, $E = \frac{hc}{\lambda_2}$ or $\lambda_2 = \frac{hc}{E}$ ....(i)

For proton kinetic energy $K = \frac{1}{2} m_p v_p^2$

or $2m_p K = m_p^2 v_p^2$ or $2m_p K = p^2$

or $2m_p K = \left(\frac{h}{\lambda_1}\right)^2$, by de Broglie equation

K = K.E. = energy E.

or $\lambda_1 = \frac{h}{\sqrt{2m_p K}} = \frac{h}{\sqrt{2m_p E}}$ ....(ii)

From (i) and (ii),

$$\frac{\lambda_2}{\lambda_1} = \frac{hc}{E} \times \frac{\sqrt{2m_p E}}{h} \text{ or } \frac{\lambda_2}{\lambda_1} = \frac{c \times \sqrt{2\,m_p}}{\sqrt{E}} = c\sqrt{2m_p} \times E^{-1/2}$$

$\therefore$ $n = 2$

13. (d) **14. (a)** **15. (c)**

Let us start calculating from the given transitions (column 2)

(i) $n = 5$ to $n = 3$

Energy of photon emitted

$h\upsilon_1 = E_5 - E_3 = 6.68 - 4.87 = 1.81$ eV

Wavelength of emitted photon

$\lambda_1 = \left(\frac{12400}{1.81}\right)$ Å = 6850 Å

Since $h\upsilon_1 < \phi$ (ϕ = 2.01 eV)

Hence no electron will be emitted, all the energy of the photon is absorbed by the photocell. So stopping potential, $V_1 = 0$

$\therefore$ (III) (i) (R) is correct combination for Q. 14.

(ii) $n = 7$ to $n = 5$

Energy of emitted photon,

$h\upsilon_2 = E_7 - E_5 = 8.85 - 6.68 = 2.17$ eV

Wavelength of emitted photon,

$\lambda_2 = \frac{12400}{2.17}$ Å = 5714 Å

Maximum kinetic energy of emitted photoelectron

$= h\upsilon_2 - \phi = 2.17 - 2.01 = 0.16$ eV

So, stopping potential photon, $V_2 = 0.16$ V

(iii) $n = 6$ to $n = 3$

Energy of emitted

$h\upsilon_3 = E_6 - E_3 = 7.70 - 4.87 = 2.83$ eV

$\lambda_3 = \frac{12400}{2.83}$ Å = 4381 Å

$$V_3 = \frac{(h\upsilon_3 - \phi)}{e} = (2.83 - 2.01)\text{V} = 0.82\text{ V}$$

(iv) $n = 7$ to $n = 4$

$h\upsilon_4 = E_7 - E_4 = 8.85 - 5.43 = 3.42$ eV

$\lambda_4 = \frac{12400}{3.42}$ Å = 3626 Å

$V_4 = 1.41$ V

Now, for maximum velocity of emitted photoelectron, $v_{max} = 5.37 \times 10^5$ m s^{-1}.

$eV = \text{K.E}_{max} = \frac{1}{2} m v_{max}^2 = 1.31 \times 10^{-19}$ J = 0.82 eV

So, correct combination for Q.13 is (IV) (iii) (P)

If energy of photon striking electron is 5.472×10^{-19} J, then

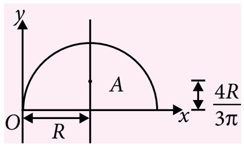
$h\upsilon$ = 3.42 eV which is same as case (iv)

So, correct combination for Q.15 is (I) (iv) (Q).

16. (a) **17. (c)** **18. (b)**

(I) For semicircular disc, centre of mass lies at point A.

Coordinates of centre of mass $\left(R, \frac{4R}{3\pi}\right)$.



Moment of inertia about axis passing through A, parallel to y-axis $= \frac{mR^2}{4}$

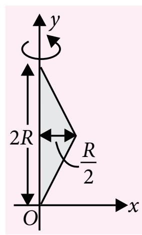
$\therefore$ Moment of inertia about y-axis

$$= \frac{mR^2}{4} + mR^2 = \frac{5}{4} mR^2$$

If a point mass m is placed at O then centre of mass will shift toward origin but will not lie on any of axis.

(I) (iii) (Q)

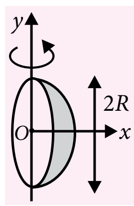
(II) Triangular plate has centre of mass at $B\left(\frac{R}{6}, R\right)$, *i.e.*, centroid.



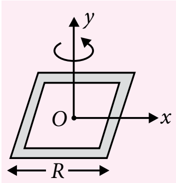
Moment of inertia about $O = \frac{mh^2}{6} = \frac{m(R/2)^2}{6} = \frac{mR^2}{24}$

(III) Hemispherical bowl has centre of mass lie at C on x-axis, $C\left(\frac{R}{2}, 0\right)$

Moment of inertia of bowl is $\frac{2}{3} mR^2$ about y-axis.



(IV) Square frame has centre of mass at origin *i.e.*, (0, 0).
Moment of inertia of one rod about y-axis



$$=\frac{m}{4}\left(\frac{R^2}{12}\right)+\frac{m}{4}\left(\frac{R}{2}\right)^2$$

$$=\frac{mR^2}{4}\left(\frac{1}{12}+\frac{1}{4}\right)=\frac{mR^2}{12}$$

Moment of inertia of frame about y-axis

$$=\frac{4\times mR^2}{12}=\frac{mR^2}{3}$$

For square frame axis of rotation passes through centre of mass.

∴ (IV) (ii) (R) is the correct combination for Q. 16.

If the bodies has same rotational kinetic energy

$$K=\frac{1}{2}I\omega^2 \Rightarrow \omega\propto\frac{1}{\sqrt{I}}$$

then angular velocity will be maximum if moment of inertia is least:

For triangular plate the angular velocity is maximum.

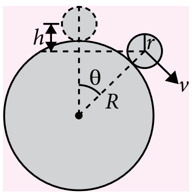
∴ (II) (i) (S) is the correct combination for Q. 17.

If a mass m is added to origin then the centre of mass will shift towards origin. In the case of semicircular disc and triangular plate the centre of mass will not lie on x-axis.

So, (I)(iii)(Q) is the correct combination for Q. 18.

PAPER - II

1. (b): $\frac{mv^2}{(R+r)}=mg\cos\theta,$ ...(i)



$$mgh=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$$

$$mg(R+r)(1-\cos\theta)=\frac{1}{2}mv^2+\frac{1}{5}mv^2$$

$$=\frac{7}{10}mv^2 \qquad \{\because\ h=(R+r)(1-\cos\theta)\} \quad ...(ii)$$

From eqn. (i) and (ii)

$$\frac{10}{7}mg\frac{(R+r)(1-\cos\theta)}{(R+r)}=mg\cos\theta$$

$$\frac{10}{7}(1-\cos\theta)=\cos\theta$$

Substituting in eqn. (i)

$$v=\sqrt{g(R+r)\cos\theta}=\sqrt{\frac{10}{17}g(R+r)}$$

$$\text{and } \omega=\frac{v}{r}=\sqrt{\frac{10g(R+r)}{17r^2}}$$

2. (b): Let W_0 be the weight placed on block

Initially, $W-2kx=0$ ...(i)

$$\text{Finally } W'-2k\left(x+\frac{a}{2}\right)-a\cdot a\cdot\frac{a}{2}(2\rho)\cdot g=0 \quad ...(ii)$$

Here, $W'=W+W_0$

∴ $W+W_0-2Kx-Ka-a^3\rho g=0$ [From eqn. (ii)]

From eqn. (i),

$W_0=ka+a^3\rho g=a(k+a^2\rho g).$

3. (d): Inside the spherical shell, V is constant, so speed of point mass is also constant.

From energy conservation,

$$\frac{-GMm}{3R}=\frac{mv^2}{2}-\frac{GMm}{R}$$

$$\frac{v^2}{2}=\frac{GM}{R}\left[1-\frac{1}{3}\right]=\frac{GM}{R}\times\frac{2}{3} \quad\text{or}\quad v=\sqrt{\frac{4GM}{3R}}$$

4. (d): Here $\frac{dv}{dt}=-kv^3$ or $\frac{dv}{v^3}=-kdt$ ...(i)

At $t=0$, the velocity of the boat is V_0.

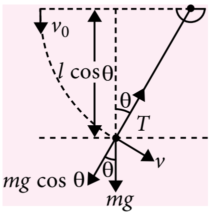
By integrating both side of eqn. (i).

$$\int_{v_0}^{v}\frac{dv}{v^3}=\int_0^t -k\,dt$$

$$\text{or}\quad\left[-\frac{1}{2v^2}\right]_{v_0}^{v}=-kt \quad\text{or}\quad -\frac{1}{2v^2}+\frac{1}{2v_0^2}=-kt$$

$$\text{or}\quad v^2=\frac{v_0^2}{1+2v_0^2kt} \quad\text{or}\quad v=\frac{v_0}{\sqrt{2v_0^2kt+1}}$$

5. (b): $v^2 = v_0^2 + 2gl\cos\theta$ ...(i)



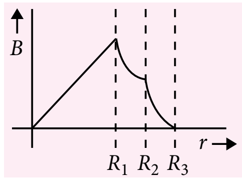
$$T = mg\cos\theta + \frac{mv^2}{l}$$

$\because$ $T = 2mg$ (Given)

$$2mg = mg\cos\theta + \frac{m}{l}(v_0^2 + 2gl\cos\theta)$$ {using (i)}

$$\therefore \cos\theta = \frac{1}{4} \Rightarrow \theta = \cos^{-1}\left(\frac{1}{4}\right)$$

6. (c): From Ampere's circuital law, the field at the axis is zero. From $x = 0$ to R_1, the field increases linearly as the current enclosed increases.



From $x = R_1$ to R_2 and from $x = R_2$ to R_3, the field decreases hyperbolically but with different slopes as the media are different. Hence, the required graph is (c).

7. (a): For dc : $R = \frac{\varepsilon}{I_{dc}} = \frac{100}{1} = 100\,\Omega$

For ac : $Z = [R^2 + (2\pi\upsilon L)^2]^{1/2}$

$$= \frac{\varepsilon_{ac}}{I_{ac}} = \frac{100}{0.5} = 200\,\Omega$$

or $200 = [(100)^2 + (100\pi L)^2]^{1/2}$

On solving, we get $L = 0.55$ H

8. (b): Since horizontal range for both balls are same

$$\frac{u^2\sin 2\theta}{g} = \frac{(u/2)^2\sin 30^\circ}{g} = \frac{u^2}{8g}$$

$$\therefore \sin 2\theta = \frac{1}{8} \text{ or } \theta = \frac{1}{2}\sin^{-1}\left(\frac{1}{8}\right)$$

9. (b,d) : Acceleration of slab of mass M, $a = \left(\frac{F}{M}\right)$

Using Newton's equation of motion,

$$l = \frac{1}{2}\frac{F}{M}t^2 \Rightarrow t = \sqrt{\frac{2Ml}{F}}$$

10. (b, d) : The magnetic flux is changing at the same rate for both the solenoids.

The induced emf, $\varepsilon = -\frac{d\phi}{dt}$ is the same for both the rings. However, the resistance of A has to be lower, if the masses of the rings A and B are the same, because the repulsion is more for ring A *i.e.*, $\mu_0 iA$ is more. The resistance is less, the current is more (b).

It is also possible that ρ_A is less than ρ_B and the mass of the ring m_A is also smaller.

$\therefore$ (d) is also correct.

11. (a,b,c) : The frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} = \frac{1}{2\pi}\sqrt{\frac{1}{0.6\times 10\times 10^{-6}}} = 65 \text{ Hz}$$

The current at resonance is $I_0 = \frac{200\text{ V}}{5\ \Omega} = 40\text{ A}$

Since coil and capacitor are connected in series, to current across them will be same, *i.e.*, 40 A.

The voltage across inductor, $V_0 = I_0\sqrt{R^2 + (\omega L)^2}$

$$= 40\sqrt{25^2 + (0.6\times 2\pi\times 65)^2} = 9.8\text{ kV}$$

Voltage across capacitor, $V_1 = \frac{I_0}{\omega C} = \frac{40\times 10^5}{2\pi\times 65} = 9.8\text{ kV}$

12. (b,c) : For adiabatic process '*bc*'.

$T_1V_b^{\gamma-1} = T_2V_c^{\gamma-1}$

For adiabatic process '*da*'

$T_2V_d^{\gamma-1} = T_1V_a^{\gamma-1}$

Multiplying eqns. (i) and (ii), we get

$T_1T_2(V_bV_d)^{\gamma-1} = T_1T_2(V_aV_c)^{\gamma-1}$

$V_bV_d = V_aV_c$

Since adiabatic expansion leads to cooling,

So, $T_1 > T_2$

13. (a,b) : $L\frac{di}{dt} = Bvl$

$$\therefore \int di = \frac{Bl}{L}\int v\,dt \Rightarrow i = \frac{Bl}{L}x \quad ...(i)$$

$$F = ma \text{ or, } -iBl = mv\frac{dv}{dx}$$

$$\text{or, } -\frac{B^2l^2x}{L} = mv\frac{dv}{dx} \text{ or, } -\frac{B^2l^2}{mL}\int_0^d x\,dx = \int_{v_0}^{v_0/2} v\,dv$$

$$\text{or } -\frac{B^2l^2d^2}{2mL} = \frac{-3v_0^2}{8},$$

$$\text{Since, } v_0 = \frac{J}{m} \Rightarrow d = \sqrt{\frac{3J^2L}{4B^2l^2m}}$$

$$\text{Put } x = d \text{ in eqn. (i), } i = \frac{Bl}{L}\sqrt{\frac{3J^2L}{4B^2l^2m}} = \sqrt{\frac{3J^2}{4Lm}}$$

14. (a,b) : Due to propagation of a wave the energy density at point is given by $E = I/v$
where I is intensity at that point and v is wave propagation velocity.
It means energy density E is directly proportional to intensity I.
If power emitted by a point source is P then intensity at a distance r from it is equal to

$$I = \frac{P}{4\pi r^2} \quad \text{or} \quad I \propto \frac{1}{r^2}$$

Hence, the shape of the curve between I and r will also be same as that given in figure of the question.
Hence, option (a) is correct.
If the source is a plane sound source then intensity at every point in front of the source will be same if damping does not take place. But if damping takes place then the amplitude of oscillation of medium particles decreases with distance. Hence, the intensity decreases with the distance from the source. In that case, the curve between I and r may have the same shape as shown in the figure given in the question. Hence, option (b) is also correct.
If the source is a plane source, intensity at every point of the source will be the same. But if power of the source is decreasing with time, intensity will also decrease with time. But at any in instant, intensity at every point in front of source will be same. Therefore, the energy density at every point in front of source will also be same, though it will decrease with time. Hence, option (c) is wrong.

15. (c) : 250 g × 4.18 × (80 – 75) = (ms)(75 – 20)
∴ (ms) = 95 J K^{-1}

16. (c) : As rate of heat transfer from warmer = 500 cal min^{-1}
∴ In 5 min heat transferred = 2500 cal
$2500 \times 4.18 = (750 \times 4.18 + 500 \times 0.17)\Delta\theta \Rightarrow \Delta\theta = 3.24$
Therefore, final temperature = 83.24 °C.

17. (c) : The correction for reduced mass is very small for hydrogen and its isotopes because even in hydrogen, the mass of the proton is about 1857 times the mass of the electron.

$$\therefore\ \mu = \frac{m_e \cdot m_p}{m_e + m_p} = \frac{m_e \cdot 1857 m_e}{1858 m_e} \simeq m_e.$$

It is only slightly less. $\mu = 0.999 m_e \simeq m_e$.
Unless very high resolving power instruments are used, one cannot distinguish between the spectra of H and D or H and T.

18. (c) : In the case of positronium, $\mu = \frac{m_e \cdot m_e}{m_e + m_e} = \frac{m_e}{2}$
as the positron has the same mass as the electron.

Therefore, $E_n = -\frac{1}{2} m_e c^2 \cdot \alpha^2 \frac{Z^2}{n^2}$. for normal H-atom.

For positronium,

$$E_n = -\frac{1}{2}\left(\frac{m_e}{2} c^2\right)\alpha^2 \cdot \frac{Z^2}{n^2} = -\frac{13.6}{2}\frac{1}{n^2}$$

$$\therefore\ E_1 = -\frac{13.6 \text{ eV}}{2}.$$

◇◇

BRAIN MAP

HEAT TRANSFER

Class XI **Class XII**

RADIOACTIVITY

BRAIN MAP

HEAT TRANSFER

Heat is a form of energy transferred between two or more systems or a system and its surroundings by virtue of temperature difference.

Radiation

Heat is transferred without heating the intervening medium.

Stefan-Boltzmann Law

The radiant energy emitted by a perfectly black body per unit area per unit time is directly proportional to fourth power of its absolute temperature.

Emissive power, $E \propto T^4 \Rightarrow E = \sigma T^4$

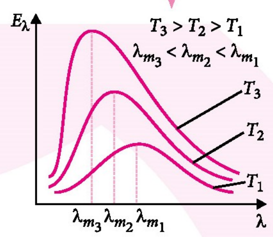
(σ = Stefan-Boltzmann constant)

Kirchhoff's Law

Ratio of emissive power to absorptive power at temperature, T for every object $E_1/A_1 = E_2/A_2 = \ldots = [E/A]_{\text{Perfectly black body}}$

Wien's Displacement Law

The product of wavelength corresponding to maximum intensity of radiation and temperature of body is constant. $\lambda_m T = b = 2.89 \times 10^{-3}$ m K

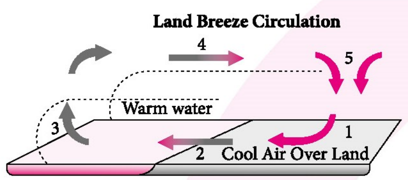


This law is of great importance in 'astrophysics' for analysis of radiations coming from a distant star, by finding λ_m the temperature of the star is determined.

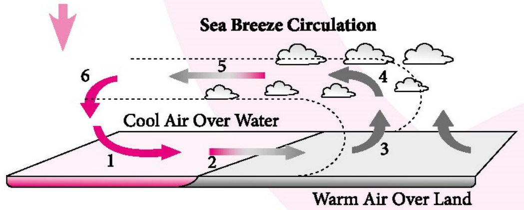
Convection

Heat is transmitted due to actual motion of heated particles.

Land breeze circulation



Formation of trade winds and sea breeze circulation



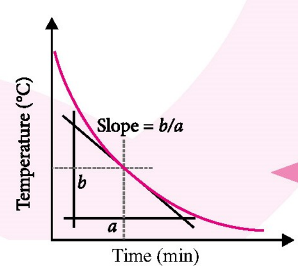
Newton's Law of Cooling

Rate of cooling of a body is proportional to the excess temperature of the body over the surroundings.

If T_2 be the instantaneous temperature of the hot body and T_1 be the temperature of surrounding

Rate of cooling

$$\frac{dT}{dt} = \frac{-k}{ms}(T_2 - T_1)$$



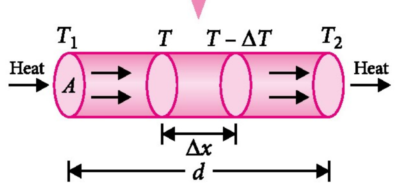
Conduction

Heat is transferred without any actual motion of particles of a substance.

Rate of heat flow

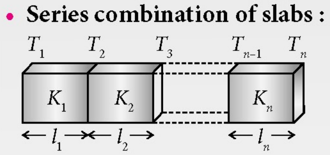
$$\frac{Q}{t} = \frac{KA(T_1 - T_2)}{d} \Rightarrow \frac{dQ}{dt} = KA\frac{dT}{dx}; (T_1 > T_2)$$

(K = Coefficient of thermal conductivity)



Equivalent thermal conductivity

- **Series combination of slabs :**



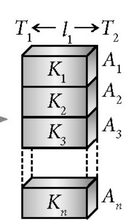
For n slabs of equal length,

$$K_{eq} = \frac{n}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \ldots \frac{1}{K_n}}$$

- **Parallel combination of slabs :**

For n slabs of equal area,

$$K_{eq} = \frac{K_1 + K_2 + K_3 + \ldots + K_n}{n}$$



Thermal resistance

It is defined as the ratio of temperature difference to the heat current.

$$R_T = \frac{\text{Temperature difference}}{\text{Rate of heat flow}}$$

For a slab of cross-section area A, thickness l and thermal conductivity K,

$$R_T = \frac{T_1 - T_2}{KA(T_1 - T_2)/l} = \frac{l}{KA}$$

Units : °C s cal^{-1} or K s kcal^{-1}

Dimensions : [M^{-1}L^{-2}T^{-3}K]

RADIOACTIVITY

Discovered in 1896 by Antoine Henri Becquerel. The spontaneous disintegration of nuclei of some nuclides with the emission of α or β particles and some accompanied by a γ-rays emission.

Law of Radioactive Decay

At any instant, the rate of decay of radioactive nuclei is proportional to the number of nuclei present at that instant.

$$\frac{dN}{dt} = -\lambda N \quad \text{or} \quad N(t) = N_0 e^{-\lambda t}$$

λ = decay constant
N_0 = initial no. of nuclei at $t = 0$
N = nuclei left undecayed at $t = t$

Activity

The number of disintegrations occurring in a radioactive substance per second.

$R = -dN/dt$.

Activity law : $R(t) = R_0 e^{-\lambda t}$

SI unit : becquerel (Bq).

1 Bq = 1 disintegration s^{-1}

1 Rutherford = 10^6 disintegration s^{-1}

1 curie = 3.7×10^{10} disintegration s^{-1}

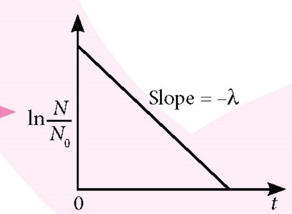
Mean-Life

Time for which radioactive material remains active.

$$\tau = \frac{1}{\lambda} = 1.44\ T_{1/2}$$

The number of undecayed nuclei present after n mean life is

$$N = (0.37)^n N_0 = \left(\frac{1}{e}\right)^n N_0.$$

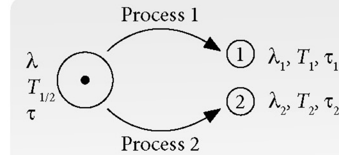


Half-Life

Time interval in which the number of radioactive nuclei reduce to half of initial.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

If a nuclide can decay simultaneously by two different process which have decay constant λ_1 and λ_2, half life T_1 and T_2 and mean lives τ_1 and τ_2 respectively then

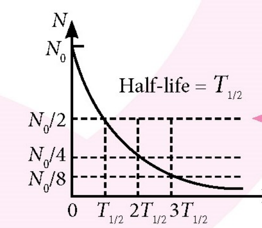


$$\lambda = \lambda_1 + \lambda_2, \quad T_{1/2} = \frac{T_1 T_2}{T_1 + T_2}$$

Fraction of nuclei left undecayed after n half lives is

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}} = \left(\frac{1}{2}\right)^n$$

$(\because\ t = nT_{1/2})$



Properties of α, β and γ-rays

	Decay Equation	Charge and Mass	Penetration Power	Speed
α-particle	${}_ZX^A \xrightarrow{\alpha\text{-decay}} {}_{Z-2}Y^{A-4} + {}_2He^4$	+2e and 4 times mass of proton	Low (Stopped by a piece of paper)	≈ 10^7 m s^{-1}
β-particle	${}_ZX^A \xrightarrow{\beta^-\text{-decay}} {}_{Z+1}Y^A + {}_{-1}e^0 + \bar{\upsilon}$ ${}_ZX^A \xrightarrow{\beta^+\text{-decay}} {}_{Z-1}Y^A + {}_{+1}e^0 + \upsilon$	$-e$ or $+e$ and equal to mass of electron	Moderate (100 times of α)	1% to 99% of speed of light
γ-rays	$({}_ZX^A)^* \xrightarrow{\gamma\text{-decay}} {}_ZX^A + \gamma$	Zero and massless	High (100 times of β)	speed of light

GEAR UP FOR AIIMS

EXAM ON 26th & 27th MAY 2018

1. In short wave communication, which of the following frequencies corresponding to waves will be reflected back by the ionospheric layer having electron density $10^{11}\ m^{-3}$?
(a) 2.85 MHz (b) 5.25 MHz
(c) 12 MHz (d) 18 MHz

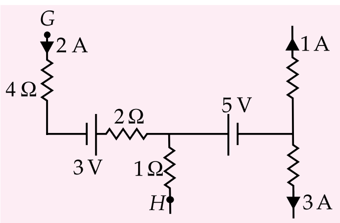
2. The velocity of a body moving in viscous medium is given by $v = \frac{P}{Q}(1 - e^{-Qt})$ where t is time; P and Q are constants. Then the dimensions of P are
(a) $[M^0LT^{-2}]$ (b) $[M^0L^2T^{-2}]$
(c) $[M^{-1}LT^{-2}]$ (d) $[M^0L^0T^{-2}]$

3. The velocity of a particle is $v = v_0 + gt + ft^2$. If its position is $x = 0$ at $t = 0$, then its displacement after unit time ($t = 1$ s) is
(a) $v_0 - g/2 + f$ (b) $v_0 + g/2 + 3f$
(c) $v_0 + g/2 + f/3$ (d) $v_0 + g + f$

4. If the atom $^{257}_{100}$Fm follows the Bohr model and the radius of fifth orbit of $^{257}_{100}$Fm is n times the Bohr radius, then find n.
(a) 100 (b) 200 (c) 4 (d) 1/4

5. A motorcycle moving with a velocity of 72 km h^{-1} on a flat road takes a turn on the road at a point where the radius of curvature of the road is 20 m. The acceleration due to gravity is 10 m s^{-2}. In order to avoid skidding, it must not bent with respect to the vertical by an angle greater than
(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(6)$
(c) $\tan^{-1}(4)$ (d) $\tan^{-1}(8)$

6. In the part of a circuit shown in figure, the potential difference between points G and H will be



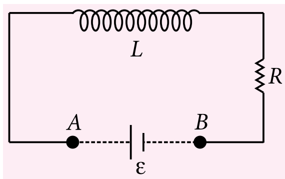
(a) 0 V (b) 12 V
(c) 7 V (d) 3 V

7. A pendulum consists of a wooden bob of mass m and length l. A bullet of mass m_1 is fired towards the pendulum with a speed v_1. The bullet emerges out of the bob with a speed $v_1/3$, and the bob just completes the vertical circle. The value of v_1 is
(a) $\left(\frac{m}{m_1}\right)\sqrt{5gl}$ (b) $\frac{m}{m_1}\sqrt{\frac{g}{l}}$
(c) $\frac{2}{3}\left(\frac{m_1}{m}\right)\sqrt{5gl}$ (d) $\frac{3}{2}\left(\frac{m}{m_1}\right)\sqrt{5gl}$

8. The equation of a projectile is $y = \sqrt{3}x - \frac{gx^2}{2}$. The angle of projection is given by
(a) $\tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (b) $\tan^{-1}(\sqrt{3})$
(c) $\frac{\pi}{2}$ (d) zero

9. The time dependence of a physical quantity P is given by $P = P_0 e^{-\alpha t^2}$ where α is a constant and t is time. Then constant α is having dimensions
(a) [T] (b) $[T^{-2}]$ (c) $[T^{-1}]$ (d) $[T^2]$

10. An inductor (L = 100 mH), a resistor (R = 100 Ω) and a battery (ε = 100 V) are initially connected in series as shown in figure. After sometime, the battery is disconnected by short circuiting the points A and B. The current in the circuit 1 ms after the short circuit is



(a) e A (b) 0.1 A (c) 1 A (d) $1/e$ A

11. A parallel plate capacitor has the space between its plates filled by two slabs of thickness $\frac{d}{2}$ each and dielectric constant K_1 and K_2. d is the plate separation of the capacitor. The capacity of the capacitor is

(a) $\frac{2\varepsilon_0 d}{A}\left(\frac{K_1+K_2}{K_1K_2}\right)$ (b) $\frac{2\varepsilon_0 A}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)$

(c) $\frac{2\varepsilon_0 A}{A}(K_1+K_2)$ (d) $\frac{2\varepsilon_0 A}{d}\left(\frac{K_1+K_2}{K_1K_2}\right)$

12. Two equal masses each of mass m are hung from a balance whose scale pans differ in vertical height by h. The error in weighing in terms of density of the earth ρ is

(a) $\pi G\rho mh$ (b) $\frac{1}{3}\pi G\rho mh$

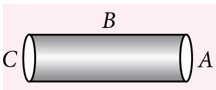
(c) $\frac{8}{3}\pi G\rho mh$ (d) $\frac{4}{3}\pi G\rho mh$

13. A rod of length l and mass m is capable of rotating freely about an axis passing through a hole at the end. The period of oscillations of this physical pendulum is

(a) $2\pi\sqrt{\frac{l}{3g}}$ (b) $2\pi\sqrt{\frac{2l}{3g}}$

(c) $2\pi\sqrt{\frac{l}{2g}}$ (d) $2\pi\sqrt{\frac{2l}{g}}$

14. A hollow cylinder has a charge q C within it. If ϕ is the electric flux in unit of V m associated with the curved surface B, the flux linked with the plane surface A in unit of V m will be



(a) $\frac{1}{2}\left(\frac{q}{\varepsilon_0}-\phi\right)$ (b) $\frac{q}{2\varepsilon_0}$

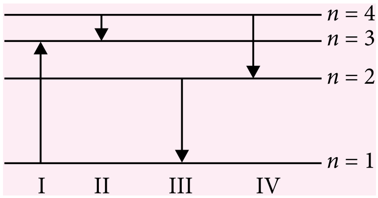
(c) $\frac{\phi}{3}$ (d) $\frac{q}{\varepsilon_0}-\phi$

15. When a man increases his speed by 2 m s^{-1}, he finds that his kinetic energy is doubled, the original speed of the man is

(a) $2(\sqrt{2}-1)$ m s^{-1} (b) $2(\sqrt{2}+1)$ m s^{-1}

(c) 4.5 m s^{-1} (d) None of these

16. Figure shows the energy levels for an electron in a certain atom. Which of the following transitions shown, represents the emission of a photon with the most energy?



(a) III (b) IV

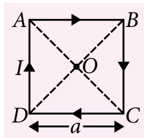
(c) I (d) II

17. $^{221}_{87}$Ra is a radioactive substance having half-life of 4 days. The probability that a nucleus undergoes decay in two half-lives is

(a) 1 (b) 1/2

(c) 3/4 (d) 1/4

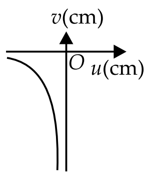
18. Magnetic field induction at the centre O of a square loop of side a carrying current I as shown in figure is

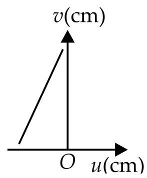


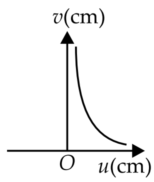
(a) $\frac{\mu_0 I}{\sqrt{2}\pi a}$ (b) $\frac{2\mu_0 I}{\pi a}$

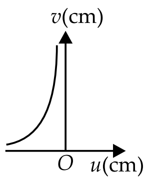
(c) $\frac{\mu_0 I}{2\pi a}$ (d) zero

19. A student measures the focal length of a convex lens by putting an object pin at a distance u from the lens and measuring the distance v of the image pin. The graph between u and v plotted by the student should look like

(a) 

(b) 

(c) 

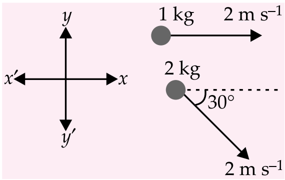
(d) 

20. When light of wavelength 300 nm falls on a photoelectric emitter, photoelectrons are liberated. For another emitter, however, light of 600 nm wavelength is sufficient for creating photo emission. What is the ratio of the work function of the two emitters?

(a) 1 : 1 (b) 2 : 1

(c) 4 : 1 (d) 1 : 4

21. Find the velocity of centre of mass of the system shown in the figure.



(a) $\left(\frac{2+2\sqrt{3}}{3}\right)\hat{i}-\frac{2}{3}\hat{j}$ (b) $\left(\frac{2-2\sqrt{3}}{3}\right)\hat{i}-\frac{1}{3}\hat{j}$

(c) $4\hat{i}$ (d) $2\hat{j}$

22. If the wavelength of first line of Balmer series is 6563 Å, then wavelength of first line of Lyman series and Rydberg's constant respectively will be

(a) 1215.4 Å, 1.1×10^7 m^{-1}

(b) 5863 Å, 2.0×10^7 m^{-1}

(c) 2316.4 Å, 0.1×10^7 m^{-1}

(d) 911.5 Å, 1.1×10^7 m^{-1}

23. Three rods each of length L and mass M are placed along X, Y and Z axes in such a way that one end of each rod is at the origin. The moment of inertia of the system about Z-axis is

(a) $\frac{ML^2}{3}$ (b) $\frac{2ML^2}{3}$

(c) $\frac{3ML^2}{2}$ (d) $\frac{2ML^2}{12}$

24. A gas undergoes a process in which its pressure P and volume V are related as VP^n = constant. The bulk modulus for the gas in this process is

(a) nP (b) $P^{1/n}$ (c) $\frac{P}{n}$ (d) P^n

25. In a photoemissive cell, with exciting wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be

(a) less than $v\left(\frac{4}{3}\right)^{1/2}$ (b) $v\left(\frac{4}{3}\right)^{1/2}$

(c) $v\left(\frac{3}{4}\right)^{1/2}$ (d) greater than $v\left(\frac{4}{3}\right)^{1/2}$

26. If one mole of a monatomic gas $\left(\gamma=\frac{5}{3}\right)$ is mixed with one mole of a diatomic gas $\left(\gamma=\frac{7}{5}\right)$, the value of γ for the mixture is

(a) 1.40 (b) 1.50

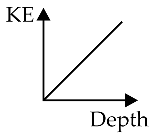
(c) 1.53 (d) 3.07

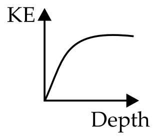
27. A coil is placed in a linearly time varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and radius of the wire is halved, the electrical power dissipated would be

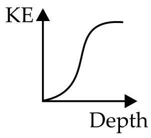
(a) halved (b) $\frac{1}{4}^{\text{th}}$

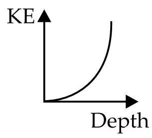
(c) doubled (d) quadrupled

28. Which one of the following diagrams correctly shows the change in kinetic energy of an iron sphere falling freely in a lake having sufficient depth to impart it a terminal velocity?

(a)


(b)


(c)


(d)


29. An electron of mass m and charge e moving with an initial velocity $\vec{v} = v_0\hat{i}$ is in an electric field $\vec{E} = E_0\hat{j}$. If $\lambda_0 = h/mv_0$, its de Broglie wavelength at time t is given by

(a) λ_0 (b) $\lambda_0\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}$

(c) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}}$ (d) $\frac{\lambda_0}{\left(1+\frac{e^2E_0^2t^2}{m^2v_0^2}\right)}$

30. In Young's double slit experiment $\frac{d}{D}=10^{-4}$ (d = distance between slits, D = distance of screen from the slits). At a point P on the screen the resulting intensity is equal to the intensity due to individual slit I_0. Then the distance of point P from the central maximum is (Take λ = 6000 Å)

(a) 2 mm (b) 1 mm

(c) 0.5 mm (d) 4 mm

31. Average density of the earth

(a) does not depend on g

(b) is a complex function of g

(c) is directly proportional to g

(d) is inversely proportional to g

32. A 12 V battery is applied in forward bias across a circuit having *p-n* junction and resistance R in series. A 0.6 V potential drop is across *p-n* junction and current is 2×10^{-3} A. The resistance R is
(a) $5.7 \times 10^{2}\ \Omega$ (b) $5.7 \times 10^{3}\ \Omega$
(c) $5.7 \times 10^{4}\ \Omega$ (d) $5.7 \times 10^{5}\ \Omega$

33. The phase difference between two points separated by 1 m in a wave of frequency 120 Hz is 90°. The wave velocity will be
(a) 720 m s^{-1} (b) 480 m s^{-1}
(c) 240 m s^{-1} (d) 180 m s^{-1}

34. In a hydrogen atom, an electron revolves with a frequency of 6.8×10^{9} MHz in an orbit of diameter 1.06 Å. The equivalent magnetic moment is
(a) 1.9×10^{-24} A m^2 (b) 9.6×10^{-24} A m^2
(c) 9.6×10^{24} A m^2 (d) 7.9×10^{24} A m^2

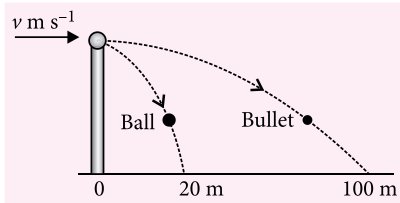
35. The composition of two simple harmonic motions of equal periods at right angle to each other and with a phase difference of π results in the displacement of the particle along
(a) circle (b) figure of eight
(c) straight line (d) ellipse

36. Assuming the sun to have a spherical outer surface of radius R, radiating like a black body at temperature t °C, the power received by a unit surface (normal to the incident rays) at a distance r from the centre of the sun is
(a) $\dfrac{4\pi R^2\sigma t^4}{r^2}$ (b) $\dfrac{R^2\sigma(t+273)^4}{4\pi r^2}$
(c) $\dfrac{16\pi R^2\sigma t^4}{r^2}$ (d) $\dfrac{R^2\sigma(t+273)^4}{r^2}$

37. Let T_1 and T_2 be the time periods of springs A and B when mass M is suspended from one end of each spring. If both springs are taken in series combination, the time period is T, then
(a) $T = T_1 + T_2$ (b) $\dfrac{1}{T} = \dfrac{1}{T_1} + \dfrac{1}{T_2}$
(c) $T^2 = T_1^2 + T_2^2$ (d) $\dfrac{1}{T^2} = \dfrac{1}{T_1^2} + \dfrac{1}{T_2^2}$

38. Angle of a prism is A and its one surface is silvered. Light rays falling at an angle of incidence of $2A$ on first surface return back through the same path after suffering reflection at the second silvered surface. Refractive index of the material is
(a) $2 \sin A$ (b) $2 \cos A$
(c) $(1/2) \cos A$ (d) $\tan A$

39. A ball of mass 0.2 kg rests on a vertical post of height 5 m. A bullet of mass 0.01 kg travelling with a velocity v m s^{-1} in a horizontal direction, hits the centre of the ball. After the collision, the ball and the bullet travel independently. The ball hits the ground at a distance of 20 m and the bullet at a distance of 100 m from the foot of the post.



The initial velocity v of the bullet is
(a) 250 m s^{-1} (b) $250\sqrt{2}$ m s^{-1}
(c) 400 m s^{-1} (d) 500 m s^{-1}

40. The angular velocity and the amplitude of a simple pendulum are ω and A respectively. At a displacement x from the mean position if its kinetic energy is T and potential energy is V, then the ratio of T to V is
(a) $\dfrac{(A^2 - x^2\omega^2)}{x^2\omega^2}$ (b) $\dfrac{x^2\omega^2}{(A^2 - x^2\omega^2)}$
(c) $\dfrac{(A^2 - x^2)}{x^2}$ (d) $\dfrac{x^2}{(A^2 - \omega^2)}$

Directions : In the following questions (41-60), a statement of assertion is followed by a statement of reason. Mark the correct choice as
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

41. **Assertion :** The frequency of a seconds pendulum in an elevator moving up with an acceleration half the acceleration due to gravity is 0.612 s^{-1}.
Reason : The frequency of a seconds pendulum does not depend upon acceleration due to gravity.

42. **Assertion :** It is not possible for a system, unaided by an external agency to transfer heat from a body at lower temperature to another body at a higher temperature.
Reason : It is not possible to violate the second law of thermodynamics.

43. Assertion : On going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.
Reason : Electric field is inversely proportional to square of distance from a point charge or an electric dipole.

44. Assertion: For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.
Reason : The net work done by a conservative force on an object moving along a closed loop is zero.

45. Assertion: For best contrast between maxima and minima in the interference pattern of Young's double slit experiment, the intensity of light emerging out of the two slits should be equal.
Reason : The intensity of interference pattern is proportional to square of amplitude.

46. Assertion : Maximum air flow due to convection does not occur at the north pole but it occurs at 30° N.
Reason : There is maximum temperature difference between equator and 30° N.

47. Assertion : If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason : In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.

48. Assertion : Work function of aluminium is 4.2 eV. Emission of electrons will not be possible if two photons, each of energy 2.5 eV, strike an electron of aluminium.
Reason : For photoelectric emission, the energy of each photon should be greater than the work function of aluminium.

49. Assertion : Velocity - time graph for an object in uniform motion along a straight path is a straight line parallel to the time axis.
Reason : In uniform motion of an object velocity increases as the square of time elapsed.

50. Assertion : Electrostatic crashes are heard on radio, when lightning flash occurs in the sky.
Reason : Electromagnetic waves having frequency of radio wave range interfere with radio waves.

51. Assertion : The horizontal range of the bullet is dependent on the angle of projectile with horizontal direction.
Reason : In order to hit a target, a man should point his rifle in the same level as that of target.

52. Assertion : An inductance and a resistance are connected in series in an A.C. circuit. In this circuit the current and the potential difference across the resistance lag behind potential difference across the inductance by an angle $\pi/2$.
Reason : In LR circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

53. Assertion : The driver in a vehicle moving with a constant speed on a straight road is in a non-inertial frame of reference.
Reason : A reference frame in which Newton's laws of motion are applicable is non-inertial.

54. Assertion : A charged particle moving in a uniform magnetic field penetrates a layer of lead and there by loses half of its kinetic energy. The radius of curvature of its path is now reduced to half of its initial value.
Reason : Kinetic energy is inversely proportional to radius of curvature.

55. Assertion : The linear momentum of an isolated system remains constant.
Reason : If there is no external torque on a body about its centre of mass, then the velocity of the centre of mass remains constant.

56. Assertion : The temperature dependence of resistance is usually given as $R = R_0(1 + \alpha\Delta T)$. The resistance of a wire changes from 100 Ω to 150 Ω when its temperature is increased from 27 °C to 227 °C. This implies that $\alpha = 2.5 \times 10^{-3}$ °C^{-1}.
Reason : $R = R_0(1 + \alpha\Delta T)$ is valid only when the change in the temperature ΔT is small and $\Delta R = (R - R_0) << R_0$.

57. Assertion : Generally the path of a projectile from the earth is parabolic but it is elliptical for projectiles going to a very large height.
Reason : The path of a projectile is independent of the gravitational force of earth.

58. Assertion : The magnetic poles of earth do not coincide with the geographic poles.
Reason : The angle between the orientation of a compass and true north-south direction is known as magnetic declination.

59. Assertion : The stream of water flowing at high speed from a garden hose pipe tends to spread like a fountain when held vertically up, but tends to narrow down when held vertically down.

Reason : In any steady flow of an incompressible fluid, the volume flow rate of the fluid remains constant.

60. Assertion : The ratio for time taken for light emission from an atom to that for release of nuclear energy in fission is 1 : 100.

Reason : Time taken for the light emission from an atom is of the order of 10^{-8} s.

SOLUTIONS

1. (a) : Here, $N_{max} = 10^{11}\ m^{-3}$

$\therefore$ frequency of wave reflected back by the ionospheric layer is

$$\upsilon_c = 9(N_{max})^{1/2} = 9 \times (10^{11})^{1/2} = 2.85\ \text{MHz}.$$

2. (a) : Here, $v = \frac{P}{Q}(1 - e^{-Qt})$

As Qt = number, $\therefore\ [Q] = \frac{1}{[t]} = T^{-1}$

Now, $\frac{P}{Q} = v,$

$\therefore\ [P] = [Q \times v] = T^{-1} \times LT^{-1} = [M^0LT^{-2}]$

3. (c) : Given: velocity, $v = v_0 + gt + ft^2$

As, $v = \frac{dx}{dt};\ \int_0^x dx = \int_0^t v dt = \int_0^t (v_0 + gt + ft^2) dt$

or $x = v_0 t + gt^2/2 + ft^3/3$

When t = 1 s, then $x = v_0 + g/2 + f/3$

4. (d)

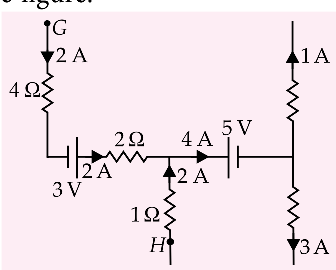
5. (a) : Using the condition for motorcycle not to skid

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

Here, r = 20 m, $v = 72\ \text{km h}^{-1} = 72 \times \frac{5}{18} = 20\ \text{m s}^{-1}$ and $g = 10\ \text{m s}^{-2}$

$\therefore\ \theta = \tan^{-1}\left(\frac{20 \times 20}{20 \times 10}\right)$ or $\theta = \tan^{-1}(2)$

6. (c) : The current distribution in a circuit is as shown in the figure.



Let V_G and V_H be the potentials at points G and H respectively.

$\therefore\ V_G - (2\ A)(4\ \Omega) + 3\ V - (2\ A)(2\ \Omega) + (2\ A)(1\ \Omega) = V_H$

$V_G - 8\ V + 3\ V - 4\ V + 2\ V = V_H$

$V_G - V_H = 7\ V$

7. (d) : For completing a vertical circle, velocity of the bob

$$v = \sqrt{5gl} \quad ...(i)$$

Using principle of conservation of linear momentum,

$$mv = m_1\left(v_1 - \frac{v_1}{3}\right) = m_1\left(\frac{2}{3}v_1\right)$$

or $v = \frac{2}{3}\frac{m_1}{m}v_1$ ...(ii)

From eqns. (i) and (ii),

$$\frac{2}{3}\frac{m_1}{m}v_1 = \sqrt{5gl} \text{ or } v_1 = \frac{3}{2}\frac{m}{m_1}\sqrt{5gl}$$

8. (b) : Here, the equation of projectile is

$$y = \sqrt{3}x - \frac{gx^2}{2}$$

Comparing the given equation with

$$y = x\tan\theta - \frac{gx^2}{2v^2\cos^2\theta},$$

we get, $\tan\theta = \sqrt{3} \Rightarrow \theta = \tan^{-1}(\sqrt{3})$

9. (b) : Here αt^2 is a dimensionless quantity.

Therefore, $[\alpha] = \left[\frac{1}{t^2}\right]$ and α has the dimension of $[T^{-2}]$.

10. (d) : Here, $L = 100\ \text{mH} = 100 \times 10^{-3}\ \text{H} = 0.1\ \text{H}$

$R = 100\ \Omega,\ \varepsilon = 100\ V$

$$I_0 = \frac{\varepsilon}{R} = \frac{100}{100} = 1\ A$$

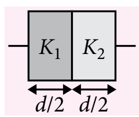
When the short circuiting is done the current in RL circuit decays. At any time t,

$$I = I_0 e^{\frac{-R}{L}t}$$

At $t = 1$ ms, $I = 1 \times e^{\frac{-100}{0.1} \times 10^{-3}} = e^{-1} = \frac{1}{e}$ A.

11. (b) : The capacities of two individual capacitors is $C_1 = \frac{K_1\varepsilon_0 A}{d/2} = \frac{2K_1\varepsilon_0 A}{d}$ and $C_2 = \frac{2K_2\varepsilon_0 A}{d}$

Now, C_1 and C_2 are in series,



$$\therefore\ \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{d}{2K_1\varepsilon_0 A} + \frac{d}{2K_2\varepsilon_0 A}$$

$$= \frac{d}{2\varepsilon_0 A}\left(\frac{K_1 + K_2}{K_1K_2}\right) \text{ or } C_s = \frac{2\varepsilon_0 A}{d}\left(\frac{K_1K_2}{K_1 + K_2}\right).$$

12. (c) : As $g_h = \frac{g}{\left[1+\frac{h}{R}\right]^2} = g\left[1-\frac{2h}{R}\right]$

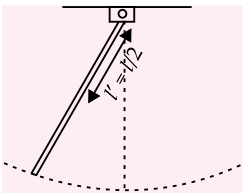
$\therefore$ error in weighing $= W_2 - W_1 = mg_2 - mg_1$

$= 2mg\left[\frac{h_1}{R} - \frac{h_2}{R}\right] = 2m\frac{GM}{R^2}\frac{h}{R}$

$\left(\because\ g = \frac{GM}{R^2} \text{ and } h_1 - h_2 = h\right)$

$= 2mG\cdot\frac{4}{3}\pi R^3\rho\frac{h}{R^3} = \frac{8\pi}{3}Gm\rho h.$

13. (b) : Here, length of rod = l, mass of rod = m



$\therefore$ Moment of inertia of rod about one end $I = \frac{1}{3}ml^2$.

Since rod is uniform hence, effective length of rod is, $l' = \frac{l}{2}$.

$\therefore$ Time period of oscillations,

$$T = 2\pi\sqrt{\frac{I}{mgl'}} = 2\pi\sqrt{\frac{\frac{1}{3}ml^2}{mg\frac{l}{2}}} = 2\pi\sqrt{\frac{2l}{3g}}$$

14. (a) : Using Gauss's law

$$\phi_{total} = \frac{q}{\varepsilon_0}$$

Let electric flux linked with surfaces A, B and C are ϕ_A, ϕ_B and ϕ_C respectively.

So, $\phi_{total} = \phi_A + \phi_B + \phi_C$

Since $\phi_C = \phi_A$,

$\therefore\ 2\phi_A + \phi_B = \frac{q}{\varepsilon_0}$ or $\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi_B\right)$

$\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$ $\qquad (\because\ \phi_B = \phi)$

15. (b) : Let, $v_1 = v$ m s^{-1}, then $v_2 = (v + 2)$ m s^{-1} and $K_2 = 2K_1$

Now, kinetic energy, $K = \frac{1}{2}mv^2 \Rightarrow K \propto v^2$

or $\frac{K_1}{K_2} = \left(\frac{v_1}{v_2}\right)^2$; $\therefore\ \frac{1}{2} = \frac{v^2}{(v+2)^2}$

or $v^2 + 4v + 4 = 2v^2$ or $v^2 - 4v - 4 = 0$

or $v = \frac{4\pm\sqrt{16+16}}{2}$ or $v = \frac{4\pm\sqrt{32}}{2} = 2\left(\sqrt{2}+1\right)$ m s^{-1}

16. (a)

17. (c) : As $\frac{N_0}{N} = 2^{t/T_{1/2}} = 2^2 = 4\ \ (\because\ t = 2T_{1/2})$

$\therefore\ N = \frac{N_0}{4}$

The sample that decays is $N_0 - \frac{N_0}{4} = \frac{3N_0}{4}$

$\therefore$ Required probability $= \frac{3N_0/4}{N_0} = \frac{3}{4}$

18. (d) : AB and DC, AD and BC are the two current carrying pairs. They are so situated that currents of each pair produce equal and opposite magnetic fields at the centre O of the loop. Hence, the resultant magnetic field induction at the centre O of the loop is zero.

19. (d) : From the lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$(constant)

Here u is always negative, v is positive.

Also, graph cannot be a straight line.

$\therefore$ choice (d) is correct.

20. (b) : Since work function of photoelectric emitter,

$W_0 = h\upsilon_0 = \frac{hc}{\lambda_0}\quad \therefore\quad W_0 \propto \frac{1}{\lambda_0}$

$\therefore\ \frac{W_{01}}{W_{02}} = \frac{\lambda_{02}}{\lambda_{01}} = \frac{600}{300} = 2:1$

21. (a) : Here, $m_1 = 1$ kg, $\vec{v}_1 = 2\hat{i}$ m s^{-1}

$m_2 = 2$ kg, $\vec{v}_2 = (2\cos30°\hat{i} - 2\sin30°\hat{j})$ m s^{-1}

$\therefore\ \vec{v}_{CM} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2}$

$= \frac{1\times 2\hat{i} + 2(2\cos30°\hat{i} - 2\sin30°\hat{j})}{1+2}$

$= \frac{2\hat{i} + 2\sqrt{3}\hat{i} - 2\hat{j}}{3} = \left(\frac{2+2\sqrt{3}}{3}\right)\hat{i} - \frac{2}{3}\hat{j}$

22. (a) : As for the first line of Balmer series,

$\frac{1}{\lambda_B} = \frac{5R}{36}$ ...(i)

and for the first line of Lyman series,

$\frac{1}{\lambda_L} = \frac{3R}{4}$ ...(ii)

From equations (i) and (ii), we get

$\lambda_L = \frac{5}{27}\lambda_B = \frac{5}{27}\times 6563\text{ Å} = 1215.4\text{ Å}$

Now,

$R = \frac{4}{3\lambda_L} = \frac{4}{3(1215.4\times10^{-10}\text{ m})} \approx 1.1\times10^7\ \text{m}^{-1}$

23. (b) : Moment of inertia of a rod about one end

$I_X = I_Y = \frac{ML^2}{3}$

Hence, moment of inertia of the system about Z-axis

$I = I_X + I_Y + I_Z$

$\therefore \quad I = \frac{ML^2}{3} + \frac{ML^2}{3} + 0 = \frac{2ML^2}{3}$

24. (c) : VP^n = constant

$\therefore \quad VP^n = (V + \Delta V)(P + \Delta P)^n$

$= VP^n\left(1+\frac{\Delta V}{V}\right)\left(1+n\frac{\Delta P}{P}\right)$

$\Rightarrow \quad 1 = 1 + \frac{\Delta V}{V} + n\frac{\Delta P}{P} + n\frac{\Delta V}{V}\frac{\Delta P}{P}$

or $\quad \frac{\Delta V}{V} = -n\frac{\Delta P}{P}$, $\left(\text{neglecting the product } n\frac{\Delta V}{V}\frac{\Delta P}{P}\right)$

Now, bulk modulus of the gas,

$K = \frac{-\Delta P}{\Delta V / V} = \frac{P}{n}$

25. (d) : From Einstein's photoelectric equation, we get

$\frac{hc}{\lambda} = \frac{1}{2}mv^2 + h\upsilon_0$ ...(i)

and $\quad \frac{hc}{3\lambda/4} = \frac{1}{2}mv'^2 + h\upsilon_0$

or $\quad \frac{1}{2}mv'^2 = \frac{4}{3}\left(\frac{hc}{\lambda}\right) - h\upsilon_0 = \frac{4}{3}\left(h\upsilon_0 + \frac{1}{2}mv^2\right) - h\upsilon_0$ (Using (i))

$= \frac{1}{3}h\upsilon_0 + \frac{4}{3}\left(\frac{1}{2}mv^2\right)$

or $\quad \frac{1}{2}mv'^2 > \frac{4}{3}\left(\frac{1}{2}mv^2\right)$ or $v'^2 > \frac{4}{3}v^2$

or $\quad v' > v\left(\frac{4}{3}\right)^{1/2}$

26. (d) : $\gamma_{mix} = \dfrac{\frac{n_1\gamma_1}{\gamma_1 - 1} + \frac{n_2\gamma_2}{\gamma_2 - 1}}{\frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}}$

$= \dfrac{\dfrac{1\times\frac{5}{3}}{\left[\frac{5}{3}-1\right]} + \dfrac{1\times\frac{7}{5}}{\left[\frac{7}{5}-1\right]}}{\left[\dfrac{1}{\frac{5}{3}-1}\right] + \left[\dfrac{1}{\frac{7}{5}-1}\right]} = \frac{3}{2} = 1.5$

27. (b) : Power dissipated, $P = \frac{\varepsilon^2}{R}$, where

induced emf $\varepsilon = -\left(\frac{d\phi}{dt}\right)$ and $\phi = NBA$

$\therefore \quad \varepsilon = -NA\left(\frac{dB}{dt}\right)$

Also $R \propto \frac{l}{a} \propto \frac{l}{r^2}$

$\therefore \quad P = \frac{\varepsilon^2}{R} \propto \frac{N^2A^2r^2}{l} \propto \frac{N^2r^6}{l}$

As r is halved and N is quadrupled,

$\therefore \quad P$ becomes one fourth.

28. (b) : The velocity of sphere goes on increasing till it attains its terminal velocity and then continues moving with it. Same is the case with its K.E. $\left(=\frac{1}{2}mv^2\right)$.

Hence (b) is correct.

29. (c)

30. (a) : We know that $I = 4I_0\cos^2\left(\frac{\phi}{2}\right)$

$I_0 = 4I_0\cos^2\left(\frac{\phi}{2}\right)$ ($\because$ $I = I_0$ (given))

or $\quad \cos\left(\frac{\phi}{2}\right) = \frac{1}{2}$ or $\frac{\phi}{2} = \frac{\pi}{3}$

or $\quad \phi = \frac{2\pi}{3} = \frac{2\pi}{\lambda}\cdot\Delta x$ or $\frac{1}{3} = \frac{1}{\lambda}\cdot\left(\frac{yd}{D}\right)$

$\therefore \quad y = \frac{\lambda}{3\left(\frac{d}{D}\right)} = \frac{6\times10^{-7}}{3\times10^{-4}} = 2\times10^{-3}$ m = 2 mm.

31. (c) : Acceleration due to gravity on earth's surface

$g = \frac{GM}{R^2} = \frac{G}{R^2}\times\frac{4}{3}\pi R^3\rho = \frac{4\pi GR\rho}{3}$

or $\quad \rho = \frac{3g}{4\pi GR} \quad \therefore \quad \rho \propto g.$

32. (b) : $R = \frac{V - V_D}{I} = \frac{12\,\text{V} - 0.6\,\text{V}}{2\times10^{-3}\,\text{A}} = 5.7\times10^3\,\Omega.$

33. (b) : Here, Δx = 1 m, ϕ = 90° = $\frac{\pi}{2}$ rad, υ = 120 Hz

As $\quad \phi = \frac{2\pi}{\lambda}\times\Delta x$ or $\frac{\pi}{2} = \frac{2\pi}{\lambda}\times1$

$\Rightarrow \quad \lambda$ = 4 m

$\therefore \quad$ Wave velocity, $v = \upsilon\lambda = 120\times4 = 480$ m s^{-1}

34. (b) : Here, $\upsilon = 6.8\times10^9$ MHz $= 6.8\times10^{15}$ Hz

$r = \frac{1.06}{2}$ Å = 0.53 Å = 0.53×10^{-10} m

$$M = IA = \left(\frac{e}{1/\upsilon}\right)\pi r^2 = e\upsilon\pi r^2$$

$= (1.6 \times 10^{-19})(6.8 \times 10^{15}) \times \frac{22}{7}(0.53\times10^{-10})^2$

$= 9.7 \times 10^{-24}$ A m^2

35. (c) : Here, two SHM's are having phase difference, $\phi = \pi$ rad.

$\therefore$ their equation of motion,

$x = A\sin\omega t$ ...(i)

and $y = B\sin(\omega t + \pi) = -B\sin\omega t$ ...(ii)

From equations (i) and (ii),

$$\frac{x}{A} = -\frac{y}{B} \text{ or } y = -\frac{B}{A}x$$

This is the equation of a straight line.

$\Rightarrow$ option (c) is correct.

36. (d) : From Stefan's law, energy radiated by the sun per second,

$E = \sigma AT^4 = \sigma \times 4\pi R^2 T^4$

Power received per unit area at distance r from the sun,

$$I = \frac{E}{4\pi r^2} = \frac{\sigma \times 4\pi R^2 \times T^4}{4\pi r^2} = \frac{\sigma R^2 (t+273)^4}{r^2}$$

37. (c) : Time period of spring A, $T_1 = 2\pi\sqrt{\frac{M}{k_1}}$

where k_1 is spring constant of spring A.

Time period of spring B, $T_2 = 2\pi\sqrt{\frac{M}{k_2}}$

where k_2 is spring constant of spring B.

For series combination, spring constant

$$k_s = \frac{k_1 k_2}{k_1 + k_2}$$

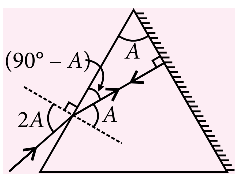
$\therefore$ $T = 2\pi\sqrt{\frac{M}{k_s}} = 2\pi\sqrt{\frac{M(k_1+k_2)}{k_1 k_2}}$

or $T^2 = \frac{4\pi^2 M}{k_1} + \frac{4\pi^2 M}{k_2} = T_1^2 + T_2^2$

38. (b) : Given : $i = 2A$

From figure, $r = A$

$\therefore$ $\mu = \frac{\sin i}{\sin r} = \frac{\sin 2A}{\sin A} = 2\cos A$



39. (d) : As $y = \frac{1}{2}gt^2$,

$\therefore$ $5 = \frac{1}{2}(10)t^2$ or $t = 1$ s

Further, as $(v_{ball})t = 20$ m,

$$v_{ball} = \frac{20\text{ m}}{1\text{ s}} = 20 \text{ m s}^{-1}$$

and as $(v_{bullet})t = 100$ m,

$$v_{bullet} = \frac{100\text{ m}}{1\text{ s}} = 100 \text{ m s}^{-1}$$

Applying the law of conservation of momentum,

$(0.01 \text{ kg})v = (0.01 \text{ kg})(100 \text{ m s}^{-1}) + (0.2 \text{ kg})(20 \text{ m s}^{-1})$

$\therefore$ $v = 500$ m s^{-1}

40. (c) : Kinetic energy of SHM,

$T = \frac{1}{2}m\omega^2(A^2 - x^2)$ ...(i)

and potential energy of SHM,

$V = \frac{1}{2}m\omega^2 x^2$ ...(ii)

Dividing equation (i) by equation (ii),

$$\frac{T}{V} = \frac{(A^2 - x^2)}{x^2}$$

41 (c) : Seconds pendulum is a simple pendulum whose time period of vibration is two seconds. Thus frequency $\upsilon = (1/2)$ s^{-1}. When elevator is moving upwards with acceleration $g/2$, the effective acceleration due to gravity is

$g' = g + a = g + g/2 = 3g/2$

As $\upsilon = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ so $\upsilon^2 \propto g$

$\therefore$ $\frac{\upsilon'^2}{\upsilon^2} = \frac{g'}{g} = \frac{3g/2}{g} = \frac{3}{2}$ or $\frac{\upsilon'}{\upsilon} = \sqrt{\frac{3}{2}} = 1.225$

or, $\upsilon' = 1.225\,\upsilon = 1.225 \times (1/2) = 0.612$ s^{-1}.

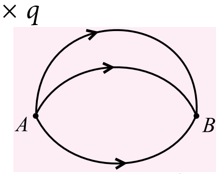
42. (a) : Second law of thermodynamics can be explained with the help of example of refrigerator, as we know that in refrigerator, the working substance extracts heat from colder body and rejects a large amount of heat to a hotter body with the help of an external agency *i.e.*, the electric supply of the refrigerator. No refrigerator can ever work without external supply of electric energy to it.

43. (d)

44. (b) : Work done = Potential difference × charge

$= (V_B - V_A) \times q$

V_A and V_B only depend on the initial and final positions and not on the path. Electrostatic force is a conservative force.



If the loop is completed, $V_A - V_A = 0$. No net work is done as the initial and final potentials are the same.

45. (b) : When intensity of light emerging from two slits is equal, the intensity at minima,

$$I_{\min} = \left(\sqrt{I_a} - \sqrt{I_b}\right)^2 = 0, \text{ or absolute dark.}$$

46. (a) : Maximum air flow due to convection does not occur at the north pole but it occurs at 30° N pole because there is a maximum temperature difference between equator and 30° N at poles.

47. (a) : If μ be the refractive index of glass with respect to air, then according to Snell's law for the refraction of light,

$\mu = \frac{\sin i}{\sin r}$ (At the point of incidence)

and, $\mu = \frac{\sin i'}{\sin r'}$ (At the point of emergence)

For minimum deviation $i = i'$, hence $r = r'$.

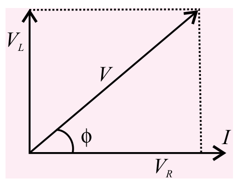
48. (a) : Photoelectric effect is a one to one process, *i.e.*, only one photon interacts with one electron.

49. (c) : In uniform motion the object moves with uniform velocity, the magnitude of its velocity at different instant *i.e.*, at $t = 0$, $t = 1$ s, $t = 2$ s, ... will always be constant. Thus, velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to time axis.

50. (a)

51. (c) : The man should point his rifle at a point higher than the target since the bullet suffers a vertically downward deflection $\left(y = \frac{1}{2}gt^2\right)$ due to gravity.

52. (b) : As both the inductance and resistance are joined in series, hence current through both will be same. But in case of resistance, both the current and potential vary simultaneously, hence they are in same phase. While in case of an inductance when current is zero, potential difference across it is maximum and when current reaches maximum (at $\omega t = \pi/2$), potential difference across it becomes zero *i.e.*, potential difference leads the current by $\pi/2$ or current lags behind the potential difference by $\pi/2$.



Phase angle in case of LR circuit is given as $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$.

53. (d) : A frame is non-inertial if the particle in the frame does not move with a constant velocity. Here the driver moves with a constant speed on a straight road. It is therefore an inertial frame. Newton's laws of motion are not applicable in case of non-inertial frame.

54. (d) : The radius of curvature of a charged particle in a magnetic field is given by, $r = \frac{mv}{qB} = \frac{\sqrt{2m\,\text{K.E.}}}{qB}$

i.e. $r \propto \sqrt{\text{K.E.}}$ When kinetic energy is halved, the radius is reduced to $\left(\frac{1}{\sqrt{2}}\right)$ times its initial value.

55. (c) : For the velocity of the centre of mass to remain constant, net external force on the system must be zero. Zero external torque on the body about its centre of mass does not guarantee zero external force on the system. An isolated system does not have any force acting on it, its linear momentum will not change.

56. (c) : $R = R_0(1 + \alpha\Delta T)$

Given, $\Delta T = 200$ °C, $R = 150\ \Omega$, $R_0 = 100\ \Omega$

$\therefore\quad 150 = 100\ (1 + \alpha \times 200) \Rightarrow \alpha = 2.5 \times 10^{-3}\ °C^{-1}$

The resistance of a wire changes from 100 Ω to 150 Ω when the temperature is increased from 27 °C to 227 °C.

It is true that α is small. But (150 – 100) Ω or 50 Ω is not very much less than 100 Ω *i.e.*, $R - R_0 << R_0$ is not true.

57. (c) : Upto ordinary heights, the change in the distance of a projectile from the centre of earth is negligible compared to the radius of earth. Hence the projectile moves under a nearly uniform gravitational force and the path is parabolic .But for the projectiles moving to a large height the gravitational force decreases quite rapidly (as $F \propto 1/r^2$). Under such a rapidly decreasing variable force, the path of the projectile becomes elliptical.

58. (b)

59. (a) : As the stream falls down, its speed will increase and cross-section area will decrease, it will become narrow.

Similarly as the stream will go up, speed will decrease and cross-section area will increase, it will become broader.

60. (a) : Time taken for the light emission from an atom ≈ 10^{-8} s.

Time taken for release of energy in fission ≈ 10^{-6} s

Required ratio $= \frac{10^{-8}}{10^{-6}} = \frac{1}{100} = 1:100$

◈◈

JEE MAIN

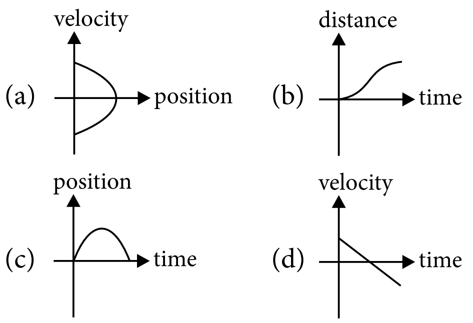
Exam held on 8^{th} April

SOLVED PAPER 2018

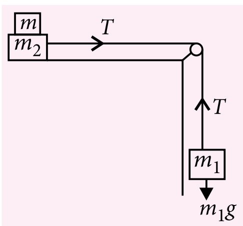
1. The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1%, the maximum error in determining the density is

(a) 2.5% (b) 3.5% (c) 4.5% (d) 6%

2. All the graphs below are intended to represent the same motion. One of them does it incorrectly. Pick it up.



3. Two masses $m_1 = 5$ kg and $m_2 = 10$ kg, connected by an inextensible string over a frictionless pulley, are moving as shown in the figure. The coefficient of friction of horizontal surface is 0.15. The minimum weight m that should be put on top of m_2 to stop the motion is



(a) 18.3 kg (b) 27.3 kg

(c) 43.3 kg (d) 10.3 kg

4. A particle is moving in a circular path of radius a under the action of an attractive potential $U = -\frac{k}{2r^2}$. Its total energy is

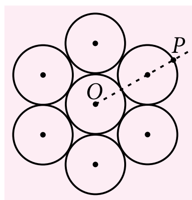
(a) $-\frac{k}{4a^2}$ (b) $\frac{k}{2a^2}$

(c) Zero (d) $-\frac{3}{2}\frac{k}{a^2}$

5. In a collinear collision, a particle with an initial speed v_0 strikes a stationary particle of the same mass. If the final total kinetic energy is 50% greater than the original kinetic energy, the magnitude of the relative velocity between the two particles, after collision, is

(a) $\frac{v_0}{4}$ (b) $\sqrt{2}v_0$ (c) $\frac{v_0}{2}$ (d) $\frac{v_0}{\sqrt{2}}$

6. Seven identical circular planar disks, each of mass M and radius R are welded symmetrically as shown. The moment of inertia of the arrangement about the axis normal to the plane and passing through the point P is



(a) $\frac{19}{2}MR^2$ (b) $\frac{55}{2}MR^2$

(c) $\frac{73}{2}MR^2$ (d) $\frac{181}{2}MR^2$

7. From a uniform circular disc of radius R and mass $9M$, a small disc of radius $\frac{R}{3}$ is removed as shown in the

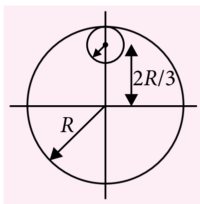


figure. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through centre of disc is

(a) $4MR^2$ (b) $\frac{40}{9}MR^2$

(c) $10MR^2$ (d) $\frac{37}{9}MR^2$

8. A particle is moving with a uniform speed in a circular orbit of radius R in a central force inversely proportional to the n^{th} power of R. If the period of rotation of the particle is T, then

(a) $T \propto R^{3/2}$ for any n (b) $T \propto R^{\frac{n}{2}+1}$

(c) $T \propto R^{(n+1)/2}$ (d) $T \propto R^{n/2}$

9. A solid sphere of radius r made of a soft material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area a floats on the surface of the liquid, covering entire cross section of cylindrical container. When a mass m is placed on the surface of the piston to compress the liquid, the fractional decrement in the radius of the sphere, $\left(\frac{dr}{r}\right)$, is

(a) $\frac{Ka}{mg}$ (b) $\frac{Ka}{3mg}$ (c) $\frac{mg}{3Ka}$ (d) $\frac{mg}{Ka}$

10. Two moles of an ideal monatomic gas occupies a volume V at 27°C. The gas expands adiabatically to a volume $2V$. Calculate (i) the final temperature of the gas and (ii) change in its internal energy.

(a) (i) 198 K (ii) 2.7 kJ
(b) (i) 195 K (ii) −2.7 kJ
(c) (i) 189 K (ii) −2.7 kJ
(d) (i) 195 K (ii) 2.7 kJ

11. The mass of a hydrogen molecule is 3.32×10^{-27} kg. If 10^{23} hydrogen molecules strike, per second, a fixed wall of area 2 cm^2 at an angle of 45° to the normal, and rebound elastically with a speed of 10^3 m s^{-1}, then the pressure on the wall is nearly

(a) 2.35×10^3 N m^{-2} (b) 4.70×10^3 N m^{-2}

(c) 2.35×10^2 N m^{-2} (d) 4.70×10^2 N m^{-2}

12. A silver atom in a solid oscillates in simple harmonic motion in some direction with a frequency of 10^{12} s^{-1}. What is the force constant of the bonds connecting one atom with the other? (Mole wt. of silver = 108 and Avogadro number = 6.02×10^{23} gm $mole^{-1}$)

(a) 6.4 N m^{-1} (b) 7.1 N m^{-1}

(c) 2.2 N m^{-1} (d) 5.5 N m^{-1}

13. A granite rod of 60 cm length is clamped at its middle point and is set into longitudinal vibrations. The density of granite is 2.7×10^3 kg m^{-3} and its Young's modulus is 9.27×10^{10} Pa. What will be the fundamental frequency of the longitudinal vibrations?

(a) 5 kHz (b) 2.5 kHz

(c) 10 kHz (d) 7.5 kHz

14. Three concentric metal shells A, B and C of respective radii, a, b and c ($a < b < c$) have surface charge densities $+\sigma$, $-\sigma$ and $+\sigma$ respectively. The potential of shell B is

(a) $\frac{\sigma}{\varepsilon_0}\left[\frac{a^2-b^2}{a}+c\right]$ (b) $\frac{\sigma}{\varepsilon_0}\left[\frac{a^2-b^2}{b}+c\right]$

(c) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2-c^2}{b}+a\right]$ (d) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2-c^2}{c}+a\right]$

15. A parallel plate capacitor of capacitance 90 pF is connected to a battery of emf 20 V. If a dielectric material of dielectric constant $K = \frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be

(a) 1.2 nC (b) 0.3 nC (c) 2.4 nC (d) 0.9 nC

16. In an a.c. circuit, the instantaneous e.m.f. and current are given by

$e = 100\sin 30t$; $i = 20\sin\left(30t - \frac{\pi}{4}\right)$

In one cycle of a.c., the average power consumed by the circuit and the wattless current are, respectively

(a) 50, 10 (b) $\frac{1000}{\sqrt{2}}, 10$

(c) $\frac{50}{\sqrt{2}}, 0$ (d) 50, 0

17. Two batteries with e.m.f. 12 V and 13 V are connected in parallel across a load resistor of 10 Ω. The internal resistances of the two batteries are 1 Ω and 2 Ω respectively. The voltage across the load lies between

(a) 11.6 V and 11.7 V (b) 11.5 V and 11.6 V

(c) 11.4 V and 11.5 V (d) 11.7 V and 11.8 V

18. An electron, a proton and an alpha particle having the same kinetic energy are moving in circular orbits of radii r_e, r_p, r_α respectively in a uniform magnetic field B. The relation between r_e, r_p, r_α is

(a) $r_e > r_p = r_\alpha$ (b) $r_e < r_p = r_\alpha$

(c) $r_e < r_p < r_\alpha$ (d) $r_e < r_\alpha < r_p$

19. The dipole moment of a circular loop carrying a current I, is m and the magnetic field at the centre of the loop is B_1. When the dipole moment is doubled by keeping the current constant, the magnetic field at the centre of the loop is B_2. The ratio $\frac{B_1}{B_2}$ is

(a) 2 (b) $\sqrt{3}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

20. For an *RLC* circuit driven with voltage of amplitude v_m and frequency $\omega_0 = \frac{1}{\sqrt{LC}}$ the current exhibits resonance. The quality factor, *Q* is given by

(a) $\frac{\omega_0 L}{R}$ (b) $\frac{\omega_0 R}{L}$ (c) $\frac{R}{(\omega_0 C)}$ (d) $\frac{CR}{\omega_0}$

21. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\upsilon\left(\frac{z}{c}-t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z-ct)]$ in medium, where the wave number *k* and frequency υ refer to their values in air. The medium is non-magnetic. If ε_{r_1} and ε_{r_2} refer to relative permittivities of air and medium respectively, which of the following options is correct?

(a) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 4$ (b) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 2$

(c) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$ (d) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{2}$

22. Unpolarized light of intensity *I* passes through an ideal polarizer *A*. Another identical polarizer *B* is placed behind *A*. The intensity of light beyond *B* is found to be $\frac{I}{2}$. Now another identical polarizer *C* is placed between *A* and *B*. The intensity beyond *B* is now found to be $\frac{I}{8}$. The angle between polarizer *A* and *C* is

(a) 0° (b) 30° (c) 45° (d) 60°

23. The angular width of the central maximum in a single slit diffraction pattern is 60°. The width of the slit is 1 μm. The slit is illuminated by monochromatic plane waves. If another slit of same width is made near it, Young's fringes can be observed on a screen placed at a distance 50 cm from the slits. If the observed fringe width is 1 cm, what is slit separation distance?
(*i.e.* distance between the centres of each slit.)

(a) 25 μm (b) 50 μm (c) 75 μm (d) 100 μm

24. An electron from various excited states of hydrogen atom emit radiation to come to the ground state. Let λ_n, λ_g be the de Broglie wavelength of the electron in the n^{th} state and the ground state respectively. Let Λ_n be the wavelength of the emitted photon in the transition from the n^{th} state to the ground state. For large *n*, (*A*, *B* are constants)

(a) $\Lambda_n \approx A + \frac{B}{\lambda_n^2}$ (b) $\Lambda_n \approx A + B\lambda_n$

(c) $\Lambda_n^2 \approx A + B\lambda_n^2$ (d) $\Lambda_n^2 \approx \lambda$

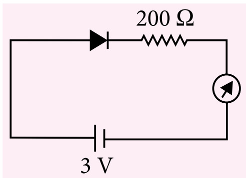
25. If the series limit frequency of the Lyman series is υ_L, then the series limit frequency of the Pfund series is

(a) 25 υ_L (b) 16 υ_L (c) $\upsilon_L/16$ (d) $\upsilon_L/25$

26. It is found that if a neutron suffers an elastic collinear collision with deuterium at rest, fractional loss of its energy is p_d; while for its similar collision with carbon nucleus at rest, fractional loss of energy is p_c. The values of p_d and p_c are respectively

(a) (0.89, 0.28) (b) (0.28, 0.89)
(c) (0, 0) (d) (0, 1)

27. The reading of the ammeter for a silicon diode in the given circuit is



(a) 0
(b) 15 mA
(c) 11.5 mA
(d) 13.5 mA

28. A telephonic communication service is working at carrier frequency of 10 GHz. Only 10% of it is utilized for transmission. How many telephonic channels can be transmitted simultaneously if each channel requires a bandwidth of 5 kHz?

(a) 2×10^3 (b) 2×10^4
(c) 2×10^5 (d) 2×10^6

29. In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance of 5 Ω, a balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell.

(a) 1 Ω (b) 1.5 Ω (c) 2 Ω (d) 2.5 Ω

30. On interchanging the resistances, the balance point of a meter bridge shifts to the left by 10 cm. The resistance of their series combinations is 1 kΩ. How much was the resistance on the left slot before the interchange?

(a) 990 Ω (b) 505 Ω
(c) 550 Ω (d) 910 Ω

SOLUTIONS

1. **(c) :** Density of a material is given by,

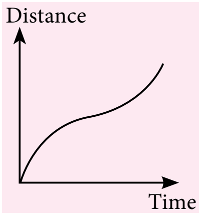
$$\rho = \frac{m}{V} = \frac{m}{l^3}$$

For maximum error in ρ, $\frac{d\rho}{\rho} = \frac{dm}{m} + 3\frac{dl}{l}$

$$\frac{d\rho}{\rho} \times 100 = \frac{dm}{m} \times 100 + 3\frac{dl}{l} \times 100$$

$$= 1.5 + (3 \times 1) = 4.5\%$$

2. **(b) :** In options (a), (c) and (d), given graphs represent uniformly decelerated motion of a particle in a straight line with positive initial velocity. Distance-time graph of such a motion is shown here.



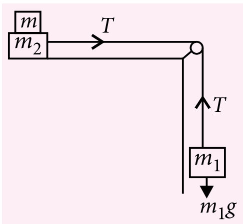
3. **(b) :** To stop the moving blocks, here frictional force between m_2 and surface is increased by placing some extra mass m on top of mass m_2.

Condition for stopping moving blocks,

$f \geq T$

or $\mu N \geq T$

or $\mu(m + m_2)g \geq m_1 g$



For minimum value of m,

$\mu(m + m_2)g = m_1 g$

or $m = \frac{m_1}{\mu} - m_2 = \frac{5}{0.15} - 10$

$= 33.33 - 10 = 23.33$ kg

From given options suitable answer will be 27.3 kg.

4. **(c) :** Here, $U = -\frac{k}{2r^2}$

Force acting on the particle, $F = -\frac{dU}{dr} = \frac{k}{r^3}$

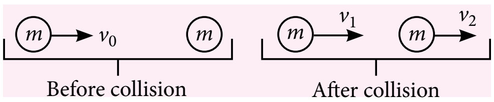
This force provides necessary centripetal force.

So, $\frac{mv^2}{r} = \frac{k}{r^3}$; $mv^2 = \frac{k}{r^2}$

∴ Kinetic energy of particle, $K = \frac{1}{2}mv^2 = \frac{k}{2r^2}$

Total energy of the particle $= U + K = -\frac{k}{2r^2} + \frac{k}{2r^2} = 0$

5. **(b) :**



Using conservation of linear momentum, $p_i = p_f$

$mv_0 = mv_1 + mv_2$ or $v_1 + v_2 = v_0$ ...(i)

According to the question,

$K_f = \frac{3}{2}K_i \Rightarrow \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 = \frac{3}{2} \times \frac{1}{2}mv_0^2$

$v_1^2 + v_2^2 = \frac{3}{2}v_0^2$ ...(ii)

From eqn (i), $(v_1 + v_2)^2 = v_0^2$

$v_1^2 + v_2^2 + 2v_1v_2 = v_0^2$

$2v_1v_2 = v_0^2 - \frac{3}{2}v_0^2$ (Using equation (ii))

$2v_1v_2 = -\frac{v_0^2}{2}$ or $4v_1v_2 = -v_0^2$

Now, $(v_1 - v_2)^2 = (v_1 + v_2)^2 - 4v_1v_2$

$= v_0^2 - (-v_0^2) = 2v_0^2$; ∴ $v_1 - v_2 = \sqrt{2}\,v_0$

6. **(d) :** Moment of inertia of one of the outer disc about an axis passing through point O and perpendicular to the plane

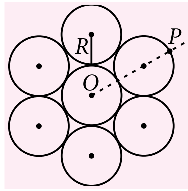
$$I_1 = \frac{1}{2}MR^2 + M(2R)^2 = \frac{9}{2}MR^2$$

Moment of inertia of the system about point O,

$I_O = \frac{1}{2}MR^2 + 6I_1$

$= \frac{1}{2}MR^2 + 6 \times \frac{9}{2}MR^2$

$= \frac{55}{2}MR^2$



Required moment of inertia of the system about point P,

$I_P = I_O + 7M(3R)^2$

$= \frac{55}{2}MR^2 + 63\,MR^2 = \frac{181}{2}MR^2$

7. **(a) :** Mass per unit area of disc $= \frac{9M}{\pi R^2}$

∴ Mass of removed portion $= \frac{9M}{\pi R^2} \times \pi\left(\frac{R}{3}\right)^2 = M$

Let moment of inertia of removed portion $= I_1$

∴ $I_1 = \frac{M}{2}\left(\frac{R}{3}\right)^2 + M\left(\frac{2R}{3}\right)^2 = \frac{MR^2}{2}$

Let I_2 = Moment of inertia of the whole disc $= \frac{9MR^2}{2}$

Moment of inertia of remaining disc, $I = I_2 - I_1$

or $I = \frac{9MR^2}{2} - \frac{MR^2}{2} = \frac{8MR^2}{2} = 4MR^2$

8. **(c) :** According to the question, central force is given by

$F_c \propto \frac{1}{R^n}$; $F_c = k\frac{1}{R^n}$

$m\omega^2 R = k\frac{1}{R^n}$; $m\frac{(2\pi)^2}{T^2} = k\frac{1}{R^{n+1}}$

or $T^2 \propto R^{n+1}$; ∴ $T \propto R^{(n+1)/2}$

9. **(c) :** Bulk modulus $= \frac{\text{Volumetric stress}}{\text{Volumetric strain}}$

$$K = \left|\frac{\Delta P}{\Delta V/V}\right| = \frac{F/a}{dV/V}$$

Here, $F = mg, \dfrac{dV}{V} = 3\dfrac{dr}{r}$

$\therefore\ K = \dfrac{mg/a}{3\dfrac{dr}{r}}$ or, $\dfrac{dr}{r} = \dfrac{mg}{3Ka}$

10. (c) : For a adiabatic process,

$PV^{\gamma} = \text{constant}$

$\dfrac{nRT}{V}V^{\gamma} = \text{constant}$ or $TV^{\gamma-1} = \text{constant}$

$\therefore\ T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$; $T_2 = T_1\left(\dfrac{V_1}{V_2}\right)^{\gamma-1}$

Here, $T_1 = 27°\text{C} = 300$ K, $V_1 = V$, $V_2 = 2V$

$\gamma = \dfrac{5}{3}$

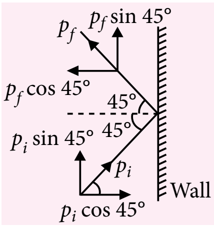
$\therefore\ T_2 = 300\left(\dfrac{V}{2V}\right)^{\left(\frac{5}{3}-1\right)} = 300\left(\dfrac{1}{2}\right)^{\frac{2}{3}} \approx 189$ K

Change in internal energy, $\Delta U = nC_V\Delta T$

$= n\left(\dfrac{f}{2}R\right)(T_2 - T_1) = 2\times\dfrac{3}{2}\times\dfrac{25}{3}(189-300)$

$= -25 \times 111 = -2775$ J $= -2.7$ kJ

11. (a) : As $p_i = p_f$



Net force on the wall,

$F = \dfrac{dp}{dt} = 2np_f\cos 45°$

$= 2nmv\cos 45°$

Here, n is the number of hydrogen molecules striking per second.

$\text{Pressure} = \dfrac{F}{A} = \dfrac{2nmv\cos 45°}{\text{Area}}$

$= \dfrac{2\times10^{23}\times3.32\times10^{-27}\times10^{3}\times(1/\sqrt{2})}{2\times10^{-4}}$

$= 2.35\times10^{3}$ N m^{-2}

12. (b) : Frequency of a particle executing SHM,

$\upsilon = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$; $k = 4\pi^2\times\upsilon^2\times m$

Here, $\upsilon = 10^{12}$ s^{-1}, $m = \dfrac{108}{6.02\times10^{23}}\times10^{-3}$ kg

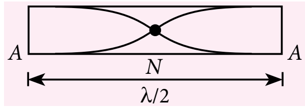
$k = ?$

$\therefore\ k = 4\times(3.14)^2\times(10^{12})^2\times\dfrac{108\times10^{-3}}{6.02\times10^{23}} = 7.1$ N m^{-1}

13. (a) : Velocity of wave, $v = \sqrt{\dfrac{Y}{\rho}} = \sqrt{\dfrac{9.27\times10^{10}}{2.7\times10^{3}}}$

$= \sqrt{3.433\times10^{7}} = 10^{3}\times\sqrt{34.33} = 5.86\times10^{3}$ m s^{-1}

Since rod is clamped at the middle, shape of fundamental wave is as follows



As, $\dfrac{\lambda}{2} = L$; $\lambda = 2L$

$L = 60$ cm $= 0.6$ m

$\therefore\ \lambda = 1.2$ m

So fundamental frequency,

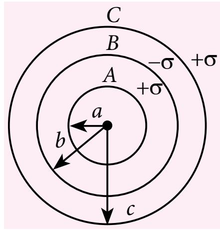
$\upsilon = \dfrac{v}{\lambda} = \dfrac{5.86\times10^{3}}{1.2} = 4.88\times10^{3}$ Hz $= 5$ kHz

14. (b) : The potential of the shell B,

$V_B = \dfrac{kq_A}{r_b} + \dfrac{kq_B}{r_b} + \dfrac{kq_C}{r_c}$

$= \dfrac{4\pi}{4\pi\varepsilon_0}\left[\dfrac{\sigma\times a^2}{b} - \dfrac{\sigma\times b^2}{b} + \dfrac{\sigma\times c^2}{c}\right]$

$= \dfrac{\sigma}{\varepsilon_0}\left[\dfrac{a^2-b^2}{b} + c\right]$



15. (a) : Induced charge on dielectric,

$Q_{\text{ind}} = Q\left(1 - \dfrac{1}{K}\right)$

Final charge on capacitor, $Q = KC_0V$

$= \dfrac{5}{3}\times90\times10^{-12}\times20 = 3\times10^{-9}\text{C} = 3$ nC

$\therefore\ Q_{\text{ind}} = 3\left(1-\dfrac{3}{5}\right) = 3\times\dfrac{2}{5} = 1.2$ nC

16. (b) : Average power, $P_{av} = e_{\text{rms}}\,i_{\text{rms}}\cos\phi$

$= \dfrac{e_0}{\sqrt{2}}\dfrac{i_0}{\sqrt{2}}\cos\phi$

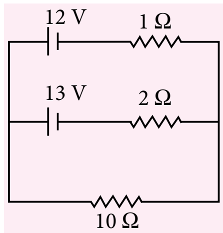
Here, $e_0 = 100$, $i_0 = 20$, $\phi = \pi/4$

$\therefore\ P_{av} = \dfrac{100}{\sqrt{2}}\times\dfrac{20}{\sqrt{2}}\cos 45° = \dfrac{1000}{\sqrt{2}}$ units

Wattless current, $i_w = i_{\text{rms}}\sin\phi = \dfrac{i_0}{\sqrt{2}}\sin 45° = 10$ units

17. (b) : Equivalent e.m.f. of parallel batteries

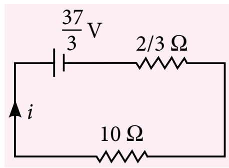
$\varepsilon = \dfrac{\dfrac{\varepsilon_1}{r_1}+\dfrac{\varepsilon_2}{r_2}}{\dfrac{1}{r_1}+\dfrac{1}{r_2}} = \dfrac{\dfrac{12}{1}+\dfrac{13}{2}}{\dfrac{1}{1}+\dfrac{1}{2}} = \dfrac{37}{3}$ V



Equivalent resistance of parallel batteries,

$r_{eq} = \dfrac{2\times1}{2+1} = \dfrac{2}{3}\Omega$

Now, its equivalent circuit is as drawn.



Current in the circuit,

$i = \dfrac{37/3}{10+(2/3)} = \dfrac{37}{32}$

Voltage across the load,

$V_{10\Omega} = i\times10 = \dfrac{37}{32}\times10 = \dfrac{370}{32} = 11.56$ V

18. (b) : Radius of circular path followed by a charged particle in a uniform magnetic field (B) is given by

$$r = \frac{mv}{qB} = \frac{p}{qB} = \frac{\sqrt{2mK}}{qB}$$

For electron, $r_e = \frac{\sqrt{2m_eK}}{eB}$; For proton, $r_p = \frac{\sqrt{2m_pK}}{eB}$

For α particle,

$$r_\alpha = \frac{\sqrt{2m_\alpha K}}{2eB} = \frac{\sqrt{2(4m_pK)}}{2eB} = \frac{\sqrt{2m_pK}}{eB}$$

As $m_p > m_e$, so, $r_\alpha = r_p > r_e$

19. (c) : Initially, dipole moment of circular loop is

$m = I.A = I.\pi R^2$ and magnetic field, $B_1 = \frac{\mu_0 I}{2R}$

Finally, dipole moment becomes double, keeping current constant, so radius of the loop becomes $\sqrt{2}R$.

$$B_2 = \frac{\mu_0 I}{2(\sqrt{2}R)} = \frac{B_1}{\sqrt{2}}; \quad \therefore \quad \frac{B_1}{B_2} = \sqrt{2}$$

20. (a)

21. (c) : In air, EM wave is $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\upsilon\left(\frac{z}{c} - t\right)\right]$

$$= E_{01}\,\hat{x}\cos[k(z - ct)] \qquad \left(\because\ k = \frac{2\pi}{\lambda_0} = \frac{2\pi\upsilon}{c}\right)$$

In medium, EM wave is $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z - ct)]$

$$= E_{02}\,\hat{x}\cos\left[2k\left(z - \frac{c}{2}t\right)\right]$$

During refraction, frequency remains unchanged, whereas wavelength gets changed

$\therefore \quad k' = 2k$ (From equations)

$$\frac{2\pi}{\lambda'} = 2\left(\frac{2\pi}{\lambda_0}\right) \text{ or } \lambda' = \frac{\lambda_0}{2}$$

Since, $v = \frac{c}{2}$; $\frac{1}{\sqrt{\mu_0\varepsilon_{r_2}}} = \frac{1}{2}\times\frac{1}{\sqrt{\mu_0\varepsilon_{r_1}}}$; $\therefore \frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$

22. (c) : Polarizers A and B are oriented with parallel pass axis. Suppose polarizer C is at angle θ with A then it also makes angle θ with B,

Using Malus' law,

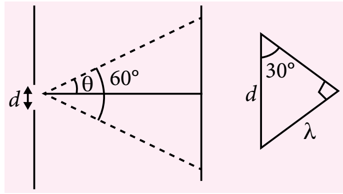
$$I_C = \left(\frac{I}{2}\cos^2\theta\right) \text{ and } I_B = I_C\cos^2\theta = \frac{I}{2}\cos^4\theta$$

$$\frac{I}{8} = \frac{I}{2}\cos^4\theta \qquad \left(\because\ I_B = \frac{I}{8}\right)$$

$$\cos^4\theta = \frac{1}{4} = \frac{1}{(\sqrt{2})^4}; \cos\theta = \frac{1}{\sqrt{2}} = \cos 45°$$

So, $\theta = 45°$

23. (a) : In a single slit diffraction, $a\sin\theta = \lambda$.



$$\lambda = \frac{a}{2} = \frac{1\times10^{-6}\text{ m}}{2} \qquad \therefore \quad \lambda = 5000\text{ Å}$$

In Young's double slit experiment

Fringe width, $\beta = \frac{\lambda D}{d}$ (d is slit separation)

$$10^{-2} = \frac{5000\times10^{-10}\times0.5}{d}$$

$d = 25\times10^{-6}$ m $= 25$ μm

24. (a) : Momentum of electron in different states

$$p_n = \frac{h}{\lambda_n}, p_g = \frac{h}{\lambda_g}$$

Kinetic energy, $K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

Total energy in an orbit of hydrogen atom,

$$E = -K = -\frac{h^2}{2m\lambda^2}$$

$$E_n - E_g = \frac{h^2}{2m}\left(\frac{1}{\lambda_g^2} - \frac{1}{\lambda_n^2}\right)$$

$$\frac{h^2}{2m}\left(\frac{\lambda_n^2 - \lambda_g^2}{\lambda_g^2\,\lambda_n^2}\right) = \frac{hc}{\Lambda_n}; \quad \Lambda_n = \frac{2mc}{h}\left(\frac{\lambda_g^2\,\lambda_n^2}{\lambda_n^2 - \lambda_g^2}\right)$$

$$\Lambda_n = \frac{2mc\lambda_g^2}{h}\left[1 - \frac{\lambda_g^2}{\lambda_n^2}\right]^{-1} = \frac{2mc\lambda_g^2}{h}\left[1 + \frac{\lambda_g^2}{\lambda_n^2}\right]$$

$(\because\ \lambda_g << \lambda_n)$

$$= \frac{2mc\lambda_g^2}{h} + \left(\frac{2mc\lambda_g^4}{h}\right)\frac{1}{\lambda_n^2} = A + \frac{B}{\lambda_n^2}$$

where A and B are

$$A = \frac{2mc\lambda_g^2}{h}, B = \frac{2mc\lambda_g^4}{h}$$

25. (d) : Frequency of emitted photon in a hydrogen atom is given by

$$\upsilon = Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For Lyman series, series limit condition is given by $n_2 = \infty, n_1 = 1$.

$$\therefore \upsilon_L = Rc\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = Rc \quad \text{...(i)}$$

For Pfund series, series limit condition is given by, $n_2 = \infty, n_1 = 5$

$$\therefore \upsilon_P = Rc\left(\frac{1}{5^2} - \frac{1}{\infty^2}\right) = \frac{Rc}{25} \quad \text{...(ii)}$$

From equation (i) and (ii),

$$\upsilon_P = \frac{\upsilon_L}{25}$$

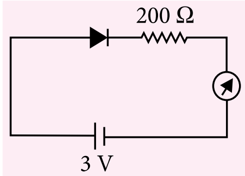
26. (a)

27. (c) : Current in the circuit,

$$I = \frac{V - V_{diode}}{R}$$

$$= \frac{3 - 0.7}{200} = \frac{2.3}{200}\text{A}$$

$$= \frac{2300}{200}\text{mA} = 11.5\text{ mA}$$



28. (c) : Frequency of carrier wave = 10×10^9 Hz

Available bandwidth = 10% of 10×10^9 Hz = 10^9 Hz

Bandwidth for each telephonic channel = 5 kHz

$= 5 \times 10^3$ Hz

$$\therefore \text{ Number of channels} = \frac{10^9}{5 \times 10^3} = 2 \times 10^5$$

29. (b) **30. (c)**

◈◈

For an MBBS seat, you need just 5% in physics, 20% in bio

Percentile Drives Cut-Offs To Absurd Low

With just 5% marks in physics, less than 10% in chemistry, and 20-odd per cent in the biology section of the National Eligibility-cum-Entrance Test (NEET), candidates have got admission to medical colleges in the past two years. This was made possible by the "percentile" system under NEET that was supposed to keep non-meritorious students out.

NEET 2017 : WHY 50th PERCENTILE IS 18%

Category	Marks range*	Qualifying percentile	Effective cut-off in % marks	No. of qualified candidates
General	697-131	50th	18.2	5,43,473
OBC/SC/ST	130-107	40th	14.9	67,999
Handicapped general	130-118	45th	16.4	67
Handicapped OBC/SC/ST	130-107	40th	14.9	200
Total	697-107	NA	14.9	6,11,739

*Out of a total of 720

Before NEET was made mandatory in 2016, the cut-offs for admission were 50% marks for the general category, and 40% for the reserved categories. From the 2016 admission year, these were changed to 50th and 40th percentile, respectively, opening the doors to candidates with just 18-20% marks in the NEET aggregate.

Here's how it happened. In 2015, you needed 50% marks for admission in the general category, so you would have had to score at least 360 out of 720 marks. But in 2016 you only needed to be in the 50th percentile, which meant scoring 145 out of 720, or barely 20%.

The reserved categories needed to be in the 40th percentile, which translated to 118 out of 720, or 16.3% marks. In 2017, this fell further to 131 marks (18.3%) for the general category, and 107 marks (14.8%) for the reserved seats.

This year's NEET exams, to be held next month, continue with the same percentile cut-offs, so students with less than 20% marks in the entrance exam may be admitted to MBBS courses again.

Percentile measures the proportion of candidates, not scores. Thus, 50th percentile means students with more marks than the bottom half, 90th percentile comprises students with more marks than the bottom 90%, and so on. It does not mean they have 90% marks.

The percentile system not only made low-scoring students eligible to study medicine, it actually got them seats in colleges. TOI found that in 2016, general category students with just 148 marks, or 20.6%, in NEET were admitted to a private college in Uttar Pradesh which is a deemed university. As many as 30 of the 100 students this institution admitted had less than 25% marks in NEET. A Puducherry college admitted 14 students with less than 21% marks, the lowest being 20.1%. Some students admitted in the reserved categories had even lower marks.

Some of the best-known private colleges in the country have admitted students with less than 40% marks in the general category and under 30% in the reserved categories.

The percentile system has played havoc with merit, making it easy for wealthy low-performers to buy seats. Thanks to the low cut-offs last year, 6.1 lakh of the 10.9 lakh NEET candidates qualified for admission, 5.4 lakh of them from the general category. With about 60,000 MBBS seats available across India, there were about 10 eligible students for every seat. A large number of affluent students with poor scores got in as many high-scoring middle class or poor students had to opt out because of the high fees.

"Whether it's an entrance examination or the Class XII exams, students are expected to get a minimum of 50% or 40%, depending on their category, to get into medicine. But with this flawed eligibility criteria of NEET, we saw students with low scores getting into medical colleges," said Dr Raj Bahadur, VC of Baba Farid University of Health Sciences in Punjab.

In his dissenting note on the parliamentary standing committee's report regarding the National Medical Commission Bill, Tamil Nadu MP K Kamaraj said NEET had allowed the admission of candidates with such low scores who would probably never have been admitted in pre-NEET days.

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Courtesy : The Times of India

Dr Nicholas B. Dirks

Pro Chancellor
SRM University, AP Amaravati

Dr Nicholas B. Dirks was named the 10th chancellor of the University of California, Berkeley on November 8, 2012, and served in that role between June 1, 2013 and July 1, 2017. An internationally renowned historian and anthropologist, he is a leader in higher education and well-known for his commitment to and advocacy for accessible, high-quality undergraduate education, to the globalization of the university, and to innovation and collaboration across the disciplines and between universities and outside partners.

While chancellor, Dirks launched an undergraduate initiative, which occasioned unprecedented cooperation among the deans of undergraduate colleges and the appointment of the first Vice Chancellor of Undergraduate Education. Dirks convened a group of faculty who developed a new set of courses in data science across the curriculum (and led to the appointment of the first Dean of Data Science). He oversaw the development of the first fully residential college dormitory, and launched an initiative in arts and design. He invested in major research collaborations in neuroscience and genomics, developed a close working relationship with UCSF, and helped negotiate Berkeley's participation in the $600 m Chan Zuckerberg Biohub.

Dirks established two important task forces in athletics, one to improve the academic performance and commitment of student athletes, the other to formulate a plan for long-term financial sustainability. He appointed the first campus lead to guide efforts to combat sexual violence and sexual harassment while changing campus level procedures and investing significant additional resources. Dirks established new global partnerships with Cambridge University and the National University of Singapore, while developing the Tsinghua Berkeley Shenzhen Institute and a joint climate institute with the Berkeley Lab and Tsinghua University. Dirks revamped the development operation (Fundraising 2.0) and presided over record breaking fundraising efforts, while spearheading efforts to promote more expansive alumni relations. Dirks took on unprecedented challenges around the financial health of the university, spearheading a campus wide discussion around strategic planning and beginning the process of bringing the budget back into long-term balance. Finally, Dirks maintained the unparalleled excellence of Berkeley as indicated in every major ranking, and did so while focusing on increasing accessibility for low income and underrepresented students.

Before coming to Berkeley, he was the executive vice president for the arts and sciences and dean of the faculty at Columbia University, where, in addition to his work on behalf of undergraduate programs, he improved and diversified the faculty, putting special emphasis on interdisciplinary and international initiatives. The Franz Boas Professor of Anthropology and History, Dirks joined Columbia in 1997 as chair of the anthropology department. Prior to his appointment at Columbia, he was a professor of history and anthropology at the University of Michigan for 10 years, before which he taught Asian history and civilization at the California Institute of Technology. He received his B.A. from Wesleyan University, and his M.A. and Ph.D. at the University of Chicago. He has published four major books, edited three more, and written numerous essays, articles, and papers.

Dirks has held numerous fellowships and scholarships and received several scholarly honors, including a Guggenheim Fellowship, a MacArthur Foundation residential fellowship at the Institute for Advanced Study at Princeton, and the Lionel Trilling Award for his book Castes of Mind. He is a fellow of the American Academy of Arts and Sciences, and has served on numerous national and international bodies while receiving honorary degrees in Beijing, China, and Madras, India. He is a Senior Fellow at the Council on Foreign Relations.

SLABS

Answers for questionnaire about SLABS by Dr Nicholas B. Driks

1. What is liberal arts and how is it different from a normal arts and science degree, like a B.Sc. Physics or B.A. History?

The Liberal Arts entails taking both a broad cross section of courses as well as course work that leads to a more specialized education and degree. In many cases, liberal arts curricula include a set of "core" or "foundation" courses (or, in other cases, a menu of such courses) in order to provide "structured" breadth, introducing students to core issues, texts, and perspectives that will benefit them no matter what the area of specialization. The Liberal Arts therefore assures that students not only have achieved mastery of a particular field but have a sophisticated and wide exposure to subjects with the additional value of "learning how to learn" across a wide range of fields. At a time of massive change in our society, economy, technology, etc., the liberal arts is therefore more important than ever.

2. Who do you view as some of the pioneers in the liberal arts fields and what are their major contributions?

The Liberal Arts represents the best of what colleges and universities in the United States drew from previous traditions of learning developed in the classical world, and then more recently in England and Germany, while developing a new, and now distinctive and world class, educational system. The Liberal Arts provides a foundation for education that has benefited Nobel laureates in science and economics, prize winners in the arts and humanities, and the work of influential publicly minded social scientists who are addressing critical questions and public policy needs with important background across history, culture, society, and economy.

3. Why do you believe liberal arts is important in India and what do you see as its potential?

The liberal arts will provide the basis not just for general learning but for creativity and innovation across many disciplines. If India is to continue to become one of the world's largest and most dynamic societies and economies, its citizens will require precisely the kind of education that the liberal arts affords.

4. What is unique about the program and degree that will be granted at SRM Amaravati?

SRM Amaravati is designing a cutting-edge curriculum that will have innovative and path-breaking "foundation" courses, a core set of majors in the arts, humanities, social sciences, sciences, journalism, and business, all in proximity to and collaboration with one of India's most prominent engineering faculties. Students will therefore have the opportunity not just to build robots, design new forms of artificial intelligence, and analyze new technological solutions for India's and global challenge while majoring in other fields, they will also be prepared to make a major contribution to the ethical and cultural dimensions, the historical and policy implications, and the social and economic opportunities that will emerge as a result.

5. What are the differences in student development that such an SRM Amaravati degree would grant and what are some of the opportunities that will open up to them?

Students graduating from SRM Amaravati will develop to be leaders in their fields as well as leaders in their professions in India and abroad. These are the students who will be sought after by major companies, by the Indian government, by world's leading universities, and across all other careers and walks of life.

6. Could you tell us about some of your best experiences with American universities and how these will manifest themselves at SRM Amaravati?

I did my Ph.D; work at the University of Chicago, and then have taught (and been a senior administrator at) the California Institute of Technology, the University of Michigan, Columbia University, and the University of California, Berkeley. I have learned about the best features of liberal arts training while also being part of a handful of the world's best leading research universities.

7. What role are you playing at SRM Amaravati and in what capacity will you remain associated going is forward?

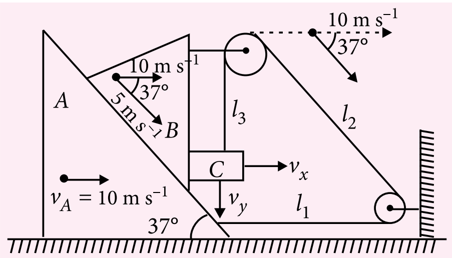
It is my honor to serve as the Honorary Pro-Chancellor of SRM Amaravati, and to be in a position to advise the university as a whole and the new School of Liberal Arts and Basic Sciences more specifically. I will remain in this capacity in the years ahead and will be a frequent visitor to SRM Amaravati, where I will also lead seminars and workshops for faculty and administrators as well as, on occasions, for students too.

☺☺

PHYSICS MUSING

SOLUTION SET-57

1.



Let v_x and v_y be the horizontal and vertical component of velocity of block C.

The component of relative velocity of B and C normal to the surface of contact is zero.

$\therefore$ $10 + 5\cos 37° - v_x = 0$; $v_x = 14$ m s^{-1}

Also, from the figure

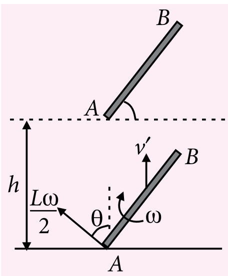
$$l_1 + l_2 + l_3 = \text{constant} \quad \therefore \quad \frac{dl_1}{dt} + \frac{dl_2}{dt} + \frac{dl_3}{dt} = 0$$

$$(-10) + (-5 - 10\cos 37°) + (-5\sin 37° + v_y) = 0$$

$\therefore$ $v_y = 26$ m s^{-1}

2. End A strikes the ground with velocity $\sqrt{2gh}$.

If velocity of COM of rod just after collision v' and angular velocity acquired by the rod is ω clockwise as shown then using equation for coefficient of restitution



velocity of approach

= velocity of separation

(at point A)

$$\sqrt{2gh} = v' + \frac{L}{2}\omega\cos\theta \quad \text{...(i)}$$

Angular momentum can be conserved about A just before collision and after collision as only impulsive force will be acting at A only.

$$\sqrt{2gh}M\frac{L}{2}\cos\theta = I_{cm}\omega - Mv'\frac{L}{2}\cos\theta \quad \text{...(ii)}$$

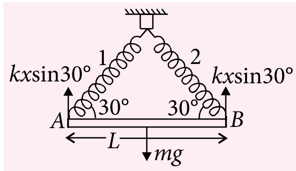
Putting value of $\omega = (\sqrt{2gh} - v')\dfrac{2}{L\cos\theta}$ from (i) in (ii) we get

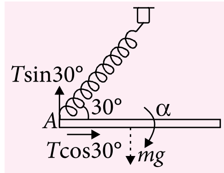
$$v' = \left(\frac{1 - 3\cos^2\theta}{1 + 3\cos^2}\right)\sqrt{2gh}$$

COM will of at maximum height when its velocity becomes zero during upward motion.

$$0 = v'^2 - 2gH;\ H = \frac{v'^2}{2g} = \left(\frac{1 - 3\cos^2\theta}{1 + 3\cos^2\theta}\right)^2 h$$

3.





Before cutting, $2k\,x\sin 30° = mg$

$kx = mg = T$ (say)

After cutting, torque about COM

$$(T\sin 30°)\times\frac{L}{2} = I\alpha \quad \Rightarrow \quad \frac{mgL}{4} = \frac{mL^2}{12}.\alpha$$

$$\Rightarrow \quad \alpha = \left(\frac{3g}{L}\right) \qquad \text{(clockwise)}$$

(b) Acceleration of point $A = a_A$ (say)

$$ma_x = T\cos 30° \Rightarrow a_x = \frac{mg\sqrt{3}}{2m} = \frac{\sqrt{3}g}{2} = a_{Ax}$$

$$mg - T\sin 30° = ma_y \Rightarrow mg - \frac{mg}{2} = ma_y; a_y = \frac{g}{2}$$

$$a_{Ay} = \left(-\frac{g}{2}\right) + \frac{\alpha L}{2} = -\frac{g}{2} + \frac{3g}{2} = g$$

$$\therefore \quad \vec{a}_A = \left(\frac{\sqrt{3}}{2}\hat{i} + \hat{j}\right)g$$

(c) $$a_{Bx} = \frac{\sqrt{3}}{2}g;\ a_{B_y} = \left(-\frac{g}{2}\right) - \frac{\alpha L}{2} = -2g$$

$$\therefore \quad \vec{a}_B = \left(\frac{\sqrt{3}}{2}\hat{i} - 2\hat{j}\right)g$$

4. $$\left(\frac{GM}{R^2}\right)m_s = m_s\omega^2 R$$

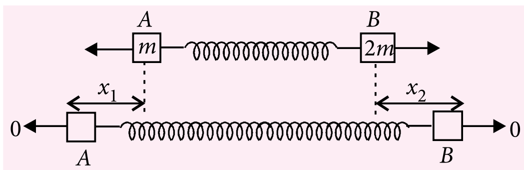
$$M = \frac{\omega^2 R^3}{G} = \frac{4\pi^2 R^3}{T^2 G} = 6 \times 10^{41} \text{ kg}$$

$$n = \frac{M}{m_s} = 3 \times 10^{11};\ \text{so } x = 11.$$

5. $$a_{cm} = \frac{2F - F}{3m} = \frac{F}{3m};\ V_{cm} = \frac{-mu + (2m)\cdot(2u)}{(m + 2m)} = u$$

Applying work energy theorem

$$\Delta K = W_{\text{Net}} = W_{sp} + W_{\text{ext}} + W_g + W_N$$



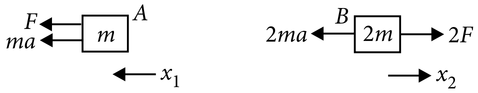
At the position of maximum extension :

$$\frac{1}{2}(3m)V_{cm}^2 - \left[\frac{1}{2}mu^2 + \frac{1}{2}(2m)(2u)^2\right]$$

$$= -\frac{k}{2}x_{max}^2 + W_{F_{ext}} + 0 + 0$$

$$\Rightarrow \frac{-6mu^2}{2} = \frac{-k\,x_{max}^2}{2} + W_{ext} \quad \text{...(i)}$$

Now the total work done by the external force



$$W_{ext} = (F + ma)x_1 + (2F - 2ma)x_2$$

$$\Rightarrow W_{ext} = \frac{4F}{3}(x_1 + x_2) = \frac{4F}{3}x_{max} \quad \text{...(ii)}$$

Substituting (ii) in (i) and solving we get

$$\frac{-6mu^2}{2} = \frac{-kx_{max}^2}{2} + \frac{4F}{3}x_{max}$$

$$\Rightarrow \quad x_{max} = \frac{4F \pm \sqrt{16F^2 + 54mu^2k}}{3k}$$

6. Collision is elastic so K.E. = constant

$$\frac{p_1^2}{2m_1} + \frac{p_2^2}{2m_2} = \frac{p'^2_1}{2m_1} + \frac{p'^2_2}{2m_2}$$

$$\Rightarrow \frac{p_1^2}{2m_1} = \frac{p'^2_1}{2m_1} + \frac{p'^2_2}{2m_2} \qquad (\because \quad p_2 = 0) \quad \text{...(i)}$$

Using linear momentum conservation law in 2D. (θ is angle of deviation)

$$\vec{p}'_1 + \vec{p}'_2 = \vec{p}_1$$

$$\Rightarrow |(\vec{p}'_2)|^2 = |(\vec{p}_1 - \vec{p}'_1)|^2 = p_1^2 + p'^2_1 - 2p_1p'_1\cos\theta$$

Substituting p'^2_2 from equation (i)

$$m_2\left[\frac{p_1^2}{m_1} - \frac{p'^2_1}{m_1}\right] = p_1^2 + p'^2_1 - 2p_1p'_1\cos\theta$$

$$\Rightarrow \quad p_1^2\left[1 - \frac{m_2}{m_1}\right] + p'^2_1\left[1 + \frac{m_2}{m_1}\right] - 2p_1p'_1\cos\theta = 0$$

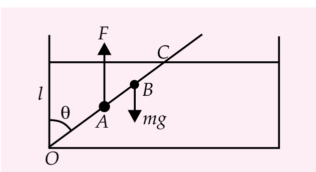
For real root of p'_1

$$4p_1^2\cos^2\theta \;\geq\; 4\left(1 - \frac{m_2}{m_1}\right)\left(1 + \frac{m_2}{m_1}\right)p_1^2$$

$$\left(\frac{m_2}{m_1}\right)^2 \geq 1 - \cos^2\theta = \sin^2\theta\,; (\sin\theta)_{max} = \frac{m_2}{m_1}$$

7. We have $OB = l$

The buoyant force F acts through the point A which is the middle point of the dipped part OC of the plank.



We have $OA = \frac{OC}{2} = \frac{l}{2\cos\theta}$.

Let the mass per unit length of the plank be ρ.

Its weight $mg = 2l\rho g$.

The mass of the part OC of the plank $= \left(\frac{l}{\cos\theta}\right)\rho$

The mass of water displaced $= \frac{1}{0.5}\frac{l}{\cos\theta}\rho = \frac{2l\rho}{\cos\theta}$

The buoyant force F is therefore, $F = \frac{2l\rho g}{\cos\theta}$

Now, for equilibrium, the torque of mg about O should balance the torque of F about O.

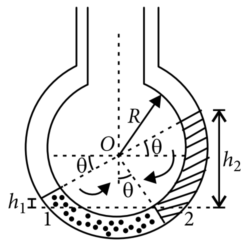
So, $mg(OB)\sin\theta = F(OA)\sin\theta$

or $(2l\rho)l = \left(\frac{2l\rho}{\cos\theta}\right)\left(\frac{l}{2\cos\theta}\right)$; or $\theta = 45°$

8. In equilibrium, pressure of same liquid at same level will be same. Therefore , $P_1 = P_2$

or $P + (1.5\,\rho g h_1) = P + (\rho g h_2)$

(P = pressure of gas in empty part of the tube)



$\therefore$ $1.5h_1 = h_2$

$1.5[R\cos\theta - R\sin\theta] = (R\cos\theta + R\sin\theta)$

$$\theta = \tan^{-1}\left(\frac{1}{5}\right)$$

9. $F_m = qvB$, and directed radially outward.

$$\therefore \; N - mg\sin\theta + qvB = \frac{mv^2}{R}$$

Hence at $\theta = \frac{\pi}{2}$

$$\therefore \; N_{max} = \frac{2mgR}{R} + mg - qB\sqrt{2gR} = 3mg - qB\sqrt{2gR}$$

10. By conservation of momentum of two protons system

$$mu = mv + mv \quad \text{or} \quad v = \frac{1}{2}u \quad \text{...(i)}$$

And by conservation of energy

$$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad \text{...(ii)}$$

$$\text{or} \quad \frac{1}{2}mu^2 - m\left(\frac{u}{2}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

From eqn (i) and (ii), $r = \frac{e^2}{\pi\varepsilon_0 mu^2}$

◆◆

PRACTICE PAPER BITSAT

Exam dates : 16^{th} to 31^{st} May 2018

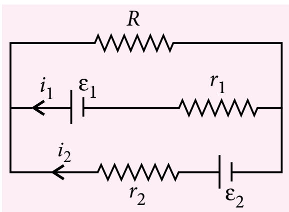
1. In Young's double slit experiment, the intensity at a point is $(1/4)^{th}$ of the maximum intensity. Angular position of this point is
(a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$
(c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

2. Two radioactive materials X_1 and X_2 have decay constants 5λ and λ respectively. If initially they have the same number of nuclei, then after what time the ratio of the number of nuclei of X_1 to that X_2 will be $1/e$?
(a) $\frac{1}{4\lambda}$ (b) e/λ (c) λ (d) $\frac{1}{2\lambda}$

3. A train approaching a railway platform with a speed of 20 m s^{-1} starts blowing the whistle. Speed of sound in air is 340 m s^{-1}. If the frequency of the emitted sound from the whistle is 640 Hz, the frequency of sound as heard by person standing on the platform is
(a) 600 Hz (b) 640 Hz
(c) 680 Hz (d) 720 Hz

4. A block of mass M is held against a rough vertical wall by pressing it with a finger. If the coefficient of friction between the block and the wall is μ and the acceleration due to gravity is g, calculate the minimum force required to be applied by the finger to hold the block against the wall ?
(a) μMg (b) Mg/μ (c) $\mu g/M$ (d) Mg

5. See the electrical circuit shown in this figure. Which of the following equations is a correct equation for it?



(a) $\varepsilon_2 - i_2r_2 - \varepsilon_1 - i_1r_1 = 0$
(b) $-\varepsilon_2 - (i_1 + i_2)R + i_2r_2 = 0$
(c) $\varepsilon_1 - (i_1 + i_2)R + i_1r_1 = 0$
(d) $\varepsilon_1 - (i_1 + i_2)R - i_1r_1 = 0$

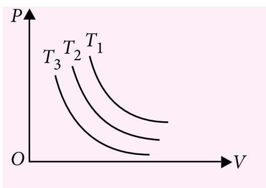
6. A solid cylinder of mass 20 kg and radius 20 cm rotates about its axis with an angular speed 100 rad s^{-1}. The angular momentum of the cylinder about its axis is
(a) 40 J s (b) 400 J s
(c) 20 J s (d) 200 J s

7. Two long and parallel straight wires A and B are carrying currents of 4 A and 7 A in the same direction are separated by a distance of 5 cm. The force acting on a 8 cm section of wire A is
(a) 3×10^{-6} N (b) 6×10^{-6} N
(c) 9×10^{-6} N (d) 12×10^{-6} N

8. A particle is projected at 60° to the horizontal with a kinetic energy K. The kinetic energy at the highest point is
(a) $K/2$ (b) K (c) zero (d) $K/4$

9. For a given lens, the magnification was found to be twice as larger as when the object was 0.15 m distant from it as when the distance was 0.2 m. The focal length of the lens is
(a) 1.5 m (b) 0.20 m
(c) 0.10 m (d) 0.05 m

10. The isothermal diagram of a gas at three different temperatures T_1, T_2 and T_3, is shown in the given figure. Then



(a) $T_1 < T_2 < T_3$
(b) $T_1 < T_2 > T_3$
(c) $T_1 > T_2 > T_3$
(d) $T_1 > T_2 < T_3$

11. An electric charge of 8.85×10^{-13} C is placed at the centre of a sphere of radius 1 m. The electric flux through the sphere is
(a) 0.2 N C^{-1} m^2 (b) 0.1 N C^{-1} m^2
(c) 0.3 N C^{-1} m^2 (d) 0.01 N C^{-1} m^2

12. Speeds of two identical cars are u and $4u$ at a specific instant. The ratio of the respective distances at which the two cars are stopped from that instant is
(a) 1 : 1 (b) 1 : 4
(c) 1 : 8 (d) 1 : 16

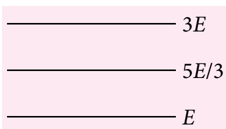
13. The primary and secondary coils of a transformer have 50 and 1500 turns respectively. If the magnetic flux ϕ linked with the primary coil is given by $\phi = \phi_0 + 4t$, where ϕ is in weber, t is time in second and ϕ_0 is a constant, the output voltage across the secondary coil is
(a) 90 V (b) 120 V
(c) 220 V (d) 30 V

14. Two pendulums differ in lengths by 22 cm. They oscillate at the same place so that one of them makes 30 oscillations and the other makes 36 oscillations during the same time. The lengths (in cm) of the pendulums are
(a) 72 and 50 (b) 60 and 38
(c) 50 and 28 (d) 80 and 58

15. A body moving with some initial velocity and having uniform acceleration attains a final velocity v m s^{-1} after travelling x m. If its final velocity is $v = \sqrt{180 - 7x}$, find the acceleration of the body.
(a) – 3.5 m s^{-2} (b) – 7 m s^{-2}
(c) – 15 m s^{-2} (d) – 30 m s^{-2}

16. A proton and an α-particle are accelerated through a potential difference of 100 V. The ratio of the wavelength associated with the proton to that associated with an α-particle is
(a) $\sqrt{2}:1$ (b) $2:1$
(c) $2\sqrt{2}:1$ (d) $\frac{1}{2\sqrt{2}}:1$

17. The figure shows the energy levels of certain atom. When the electron de-excites from $3E$ to E, an electromagnetic wave of wavelength λ is emitted. What is the wavelength of the electromagnetic wave emitted, when the electron de-excites from $\frac{5E}{3}$ to E?

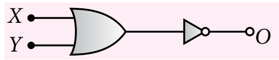


(a) 3λ (b) 2λ (c) 5λ (d) $\frac{3\lambda}{5}$

18. If P, Q, R are physical quantities, having different dimensions, which of the following combinations can never be a meaningful quantity?
(a) $\frac{(P-Q)}{R}$ (b) $PQ - R$
(c) $\frac{PQ}{R}$ (d) $\frac{(PR-Q^2)}{R}$

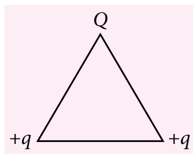
19. The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between
(a) $n = 3$ to $n = 1$ states (b) $n = 2$ to $n = 1$ states
(c) $n = 4$ to $n = 3$ states (d) $n = 3$ to $n = 2$ states

20. The following logic circuit represents



(a) NAND gate with output $O = \overline{X} + \overline{Y}$
(b) NOR gate with output $O = \overline{X + Y}$
(c) NAND gate with output $O = \overline{X.Y}$
(d) AND gate with output $O = X \,.\, Y$

21. Three charges are placed at the vertex of an equilateral triangle as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) $-q$ (b) $q/2$ (c) $-2q$ (d) $-q/2$

22. If three molecules have velocities 0.5 km s^{-1}, 1 km s^{-1} and 2 km s^{-1}, the ratio of the rms speed and average speed is
(a) 2.15 (b) 1.13 (c) 0.53 (d) 3.96

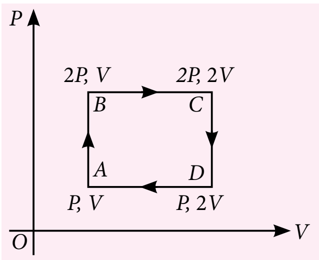
23. A hollow pipe of length 0.8 m is closed at one end. At its open end a 0.5 m long uniform string is vibrating in its second harmonic and it resonates with the fundamental frequency of the pipe. If the tension in the wire is 50 N and the speed of sound is 320 m s^{-1}, the mass of the string is
(a) 5 g (b) 10 g (c) 20 g (d) 40 g

24. A convex lens of refractive index 3/2 has a power of 2.5 D in air. If it is placed in a liquid of refractive index 2, then the new power of the lens is
(a) −1.25 D (b) −1.5 D
(c) 1.25 D (d) 1.5 D

25. Consider two rods of same length and different specific heats (c_1,c_2), thermal conductivities (K_1,K_2) and area of cross-sections (A_1,A_2) and both having temperatures (T_1, T_2) at their ends. If their rate of loss of heat due to conduction is equal, then
(a) $K_1A_1 = K_2A_2$ (b) $K_1A_1/c_1 = K_2A_2/c_2$
(c) $K_2A_1 = K_1A_2$ (d) $K_2A_1/c_2 = K_1A_2/c_1$

26. A circuit area 0.01 m^2 is kept inside a magnetic field which is normal to its plane. The magnetic field changes from 2 T to 1 T in 1 ms. If the resistance of the circuit is 2 Ω. The rate of heat evolved is
(a) 5 J s^{-1} (b) 50 J s^{-1} (c) 0.05 J s^{-1} (d) 0.5 J s^{-1}

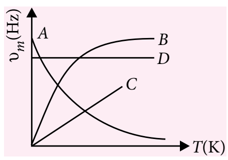
27. An ideal monatomic gas is taken around the cycle *ABCDA* as shown in the *P*-*V* diagram. The work done during the cycle is given by



(a) 1/2 *PV*
(b) *PV*
(c) 2*PV*
(d) 4 *PV*

28. The imaginary angular velocity of the earth for which the effective acceleration due to gravity at the equator shall be zero is equal to
(Take $g = 10$ m s^{-2} for the acceleration due to gravity if the earth were at rest and radius of earth equal to 6400 km.)
(a) 1.25×10^{-3} rad s^{-1} (b) 2.50×10^{-3} rad s^{-1}
(c) 3.75×10^{-3} rad s^{-1} (d) 5.0×10^{-3} rad s^{-1}

29. Which one of the following is υ_m - *T* graph for perfectly black body? υ_m is the frequency of radiation with maximum intensity. *T* is the absolute temperature.

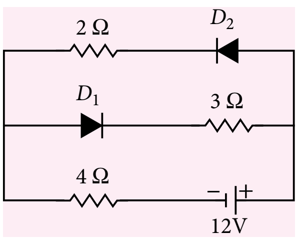


(a) *A*
(b) *B*
(c) *C*
(d) *D*

30. Two particles *X* and *Y* having equal charges, after being accelerated through the same potential difference enter a region of uniform magnetic field and describe circular paths of radii r_1 and r_2 respectively. The ratio of the mass of *X* to that of *Y* is

(a) $\left(\frac{r_1}{r_2}\right)^{1/2}$ (b) $\left(\frac{r_2}{r_1}\right)$ (c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\left(\frac{r_1}{r_2}\right)$

31. The circuit has two oppositely connected ideal diodes in parallel.
What is the current flowing in the circuit?



(a) 1.71 A
(b) 2.0 A
(c) 2.31 A
(d) 1.33 A

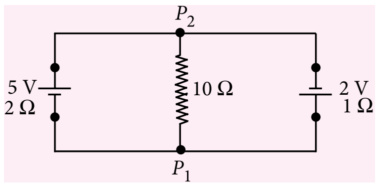
32. An electrical device draws 2 kW power from ac mains voltage 223 V(rms). The current differs lags in phase by $\phi = \tan^{-1}\left(-\frac{3}{4}\right)$ as compared to voltage. The resistance *R* in the circuit is
(a) 15 Ω (b) 20 Ω (c) 25 Ω (d) 30 Ω

33. An explosion blows a rock into three parts. Two parts go off at right angles to each other, first part of 1 kg moves with a velocity of 12 m s^{-1} and second part of 2 kg moves with a velocity of 8 m s^{-1}. If the third part flies off with a velocity of 4 m s^{-1}, its mass would be
(a) 3 kg (b) 5 kg (c) 7 kg (d) 17 kg

34. A beam of light of wavelength 600 nm from a distant source falls on a single slit 1.00 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between the first dark fringes on either side of the central bright fringe is
(a) 1.2 cm (b) 1.2 mm (c) 2.4 cm (d) 2.4 mm

35. The frequency of electromagnetic wave which is best suitable to observe a particle of radius 3×10^{-4} cm is of the order of
(a) 10^{15} Hz (b) 10^{10} Hz
(c) 10^{13} Hz (d) 10^{12} Hz

36. A 5 V battery with internal resistance 2 Ω and 2 V battery with internal resistance 1 Ω are connected to a 10 Ω resistor as shown in the figure.



The current in the 10 Ω resistor is
(a) 0.27 A P_1 to P_2 (b) 0.27 A P_2 to P_1
(c) 0.03 A P_1 to P_2 (d) 0.03 A P_2 to P_1

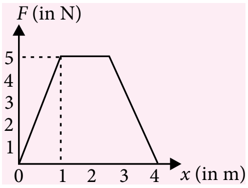
37. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. Then the elastic energy stored in the wire is
(a) 0.2 J (b) 10 J (c) 20 J (d) 0.1 J

38. The rise in the water level in a capillary tube of radius 0.07 cm when dipped vertically in a beaker containing water of surface tension 0.07 N m^{-1} is (Take $g = 10$ m s^{-2} and angle of contact of water with beaker = 0°)
(a) 2 cm (b) 4 cm (c) 1.5 cm (d) 3 cm

39. In the magnetic meridian of a certain place the horizontal component of earth's magnetic field is 0.25 G and dip angle is 60°. The magnetic field of the earth at this location is

(a) 0.50 G (b) 0.52 G (c) 0.54 G (d) 0.56 G

40. The force F acting on a particle moving in a straight line is shown in figure. What is the work done by the force on the particle in the 1st meter of the trajectory?

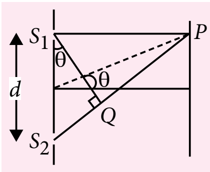


(a) 5 J (b) 10 J

(c) 15 J (d) 2.5 J

SOLUTIONS

1. (c) : Intensity at any point in Young's double slit experiment,



$$I = I_{max}\cos^2\left(\frac{\phi}{2}\right)$$

$$\therefore \quad \frac{I_{max}}{4} = I_{max}\cos^2\frac{\phi}{2}$$

or $\cos\frac{\phi}{2} = \frac{1}{2}$ or $\frac{\phi}{2} = \frac{\pi}{3}$

$\therefore \quad \phi = \frac{2\pi}{3} = \frac{2\pi\Delta x}{\lambda}$, where Δx is the path difference

or $\Delta x = \frac{\lambda}{3}$

Path difference, $\Delta x = S_2Q = d\sin\theta$

$\therefore \quad d\sin\theta = \frac{\lambda}{3}$ or $\sin\theta = \frac{\lambda}{3d}$ or $\theta = \sin^{-1}\left(\frac{\lambda}{3d}\right)$

2. (a) : $X_1 = N_0e^{-\lambda_1 t}$; $X_2 = N_0e^{-\lambda_2 t}$

$$\frac{X_1}{X_2} = e^{-1} = e^{(-\lambda_1+\lambda_2)t}\ ;\ e^{-1} = e^{-(\lambda_1-\lambda_2)t}$$

$$\therefore \quad t = \frac{1}{(\lambda_1-\lambda_2)} = \frac{1}{(5\lambda-\lambda)} = \frac{1}{4\lambda}$$

3. (c) : Here, speed of source (*i.e.* train), $v_s = 20$ m s^{-1}

Speed of sound in air, $v = 340$ m s^{-1}

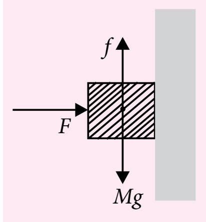
Frequency of the source, $\upsilon_0 = 640$ Hz

The frequency heard by the person standing on the platform is

$$\upsilon' = \upsilon_0\left[\frac{v}{v-v_s}\right]$$

$$= 640\left[\frac{340}{340-20}\right] = \frac{640\times340}{320} = 680\text{ Hz}$$

4. (b) : Let F = Minimum force applied by finger to hold the block



Mg = weight of block.

f = friction force on the block

Normal reaction, $N = F$

$\therefore \quad f = \mu N = \mu F$ ...(i)

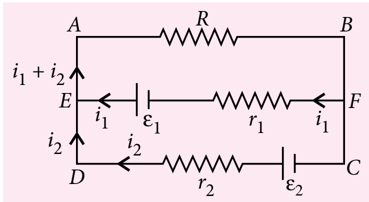
Also, $f = Mg$ ...(ii)

(As block does not move)

From equation (i) and (ii), $Mg = \mu F$

$$\Rightarrow \quad F = \frac{Mg}{\mu}$$

5. (d) :



Applying Kirchhoff's rule to the loop $ABFE$,

$\varepsilon_1 - (i_1 + i_2)R - i_1r_1 = 0$

For loop $EFCD$, $\varepsilon_2 - i_2r_2 - \varepsilon_1 + i_1r_1 = 0$

For loop $ABCD$, $(i_1 + i_2)R - \varepsilon_2 - i_2r_2 = 0$

$\therefore$ Only option (d) is correct.

6. (a) : Here, $M = 20$ kg

$R = 20$ cm $= 20 \times 10^{-2}$ m, $\omega = 100$ rad s^{-1}

Moment of inertia of the solid cylinder about its axis is

$$I = \frac{MR^2}{2} = \frac{(20\text{ kg})(20\times10^{-2}\text{ m})^2}{2} = 0.4\text{ kg m}^2$$

Angular momentum of the cylinder about its axis is

$L = I\omega = (0.4$ kg m$^2)$ $(100$ rad s$^{-1}) = 40$ J s

7. (c) : Here, $I_1 = 4$ A, $I_2 = 7$ A

$d = 5$ cm $= 5 \times 10^{-2}$ m, $l = 8$ cm $= 8 \times 10^{-2}$ m

$$\therefore \quad F = \frac{\mu_0}{4\pi}\frac{2I_1I_2l}{d} = \frac{10^{-7}\times2\times4\times7}{5\times10^{-2}}\times8\times10^{-2}$$

$= 89.6 \times 10^{-7}$ N $= 9 \times 10^{-6}$ N

8. (d) : Initial K.E., $K = \frac{1}{2}mv^2$

Velocity at the highest point = Horizontal component of $v = v\cos60° = \frac{v}{2}$

$\therefore$ K.E. at the highest point $= \frac{1}{2}m\left(\frac{v}{2}\right)^2 = \frac{K}{4}$

9. (c) : Here $m_1 = 2m_2$

$$\frac{f}{f-0.15} = 2\frac{f}{f-0.20} \qquad \left(\because\ m = \frac{f}{f+u}\right)$$

or $2f - 0.30 = f - 0.20$ or $f = 0.10$ m.

10. (c) : The given diagram shows that the curves move away from the origin as temperature increases.

11. (b): According to Gauss's law,
the electric flux through the sphere is

$$\phi = \frac{q_{in}}{\varepsilon_0} = \frac{8.85\times10^{-13}\,\text{C}}{8.85\times10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}} = 0.1\ \text{N C}^{-1}\ \text{m}^2$$

12. (d): For first car : $u = u$, $a = -a$, $v = 0$

As $v^2 - u^2 = 2as$

$\therefore \quad v^2 - u^2 = 2(-a)s_1$ or $s_1 = u^2/2a$

For second car : $u = 4u$, $a = -a$, $v = 0$

$$\therefore \quad s_2 = \frac{(4u)^2}{2a} = \frac{8u^2}{a}$$

Hence, $\frac{s_1}{s_2} = \frac{u^2}{2a}\cdot\frac{a}{8u^2} = \frac{1}{16} = 1:16$

13. (b): Flux linked with the primary coil,

$\phi = \phi_0 + 4t$

Voltage across primary, $V_p = \frac{d\phi}{dt} = 0 + 4\times1 = 4\,\text{V}$

Voltage across secondary,

$$V_s = \frac{N_s}{N_p}.V_p = \frac{1500}{50}\times4 = 120\ \text{V}$$

14. (a)

15. (a): $v = \sqrt{180-7x}$, where x is the distance.

$\therefore \quad v^2 = 180 - 7x$

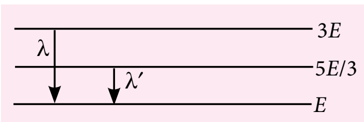
For a body travelling with uniform acceleration, $v^2 - u^2 = 2ax$ is valid. By inspection one can say $u^2 = 180$, $2ax = -7x$. $\therefore \quad a = -3.5\ \text{m s}^{-2}$

16. (c) : For a particle accelerated through potential difference V, $\lambda = \frac{h}{\sqrt{2mqV}}$

$$\lambda_p = \frac{h}{\sqrt{2meV}}\ ;\ \lambda_\alpha = \frac{h}{\sqrt{2\times4m\times2e\times V}} = \frac{1}{2\sqrt2}\lambda_p$$

$$\frac{\lambda_p}{\lambda_\alpha} = 2\sqrt2:1$$

17. (a) :



From figure,

$$\frac{hc}{\lambda} = 3E - E = 2E \quad ...(i) \qquad \frac{hc}{\lambda'} = \frac{5E}{3} - E = \frac{2}{3}E \quad ...(ii)$$

Divide (i) by (ii), we get

$$\frac{\lambda'}{\lambda} = 3 \ \text{or}\ \lambda' = 3\lambda$$

18. (a) : Physical quantities having different dimensions cannot be added or subtracted.

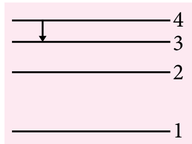
As P, Q and R are physical quantities having different dimensions, therefore they can neither be added nor be subtracted. Thus, (a) can never be a meaningful quantity.

19. (c) : $\frac{n(n-1)}{2} = 6$

$n^2 - n - 12 = 0$

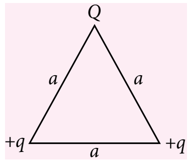
$(n-4)(n+3) = 0$ or $n = 4$

Maximum wavelength corresponds to lowest energy $(E_4 \to E_3)$.



20. (b): The given logic circuit represents a NOR gate with output $O = \overline{X+Y}$.

21. (d): Electrostatic potential energy of the system of charges is



$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Qq}{a} + \frac{Qq}{a} + \frac{q^2}{a}\right]$$

$$U = \frac{1}{4\pi\varepsilon_0 a}[2Qq + q^2]$$

Given, $U = 0 \Rightarrow 2Qq + q^2 = 0 \quad \Rightarrow \quad Q = -q/2$

22. (b)

23. (b): For hollow pipe, fundamental frequency is

$$f = \frac{v}{4l} = \frac{320}{4\times0.8}$$

For string in 2nd harmonic,

$$f = \frac{1}{l}\sqrt{\frac{T}{\mu}} = \frac{1}{l}\sqrt{\frac{Tl}{m}} = \frac{1}{0.5}\sqrt{\frac{50\times0.5}{m}}$$

Equating and solving, we get $m = 0.01$ kg $= 10$ g

24. (a) : $P \propto (\mu - 1)$

$$\therefore \quad \frac{P_l}{P_a} = \frac{({}^l\mu_g - 1)}{({}^a\mu_g - 1)} = \frac{\left(\frac{3/2}{2} - 1\right)}{\left(\frac{3}{2} - 1\right)} = -\frac{1}{4}\times\frac{2}{1} = -0.5$$

$P_l = -0.5\ P_a = -0.5 \times 2.5 = -\ 1.25$ D

25. (a) : Given : $\frac{Q_1}{t} = \frac{Q_2}{t}$

or $\frac{K_1A_1(T_1 - T_2)}{l} = \frac{K_2A_2(T_1 - T_2)}{l}$ or $K_1A_1 = K_2A_2$

COMIC CAPSULE

REMEMBER : WITH GREAT POWER COMES GREAT CURRENT SQUARED TIMES RESISTANCE.

OHM NEVER FORGOT HIS DYING UNCLE'S ADVICE.

26. (b) : Induced emf, $\varepsilon = \frac{-d\phi}{dt} = \frac{-d}{dt}(BA)$

$$\Rightarrow \quad \varepsilon = \frac{-A(B_2 - B_1)}{t} = \frac{-0.01(1-2)}{1\times10^{-3}}$$

$\varepsilon = 0.01 \times 10^3 = 10$ V

$V = IR$ or $I = \frac{10}{2}$ $\therefore$ $I = 5$ A.

Rate of heat evolved $= I^2R = (5)^2 \times 2 = 50$ J s^{-1}.

27. (b) : Work done = Area of the loop $ABCDA$

$= (2P - P)(2V - V) = PV$

28. (a) : The effective acceleration due to gravity at the equator is $g' = g - R\omega^2$

As per question, $g' = 0$

$$\therefore \quad \omega = \sqrt{\frac{g}{R}}$$

Substituting the given values, we get

$$\omega = \sqrt{\frac{10 \text{ m s}^{-2}}{6400\times10^3 \text{m}}} = \frac{1}{8}\times10^{-2} \text{rad s}^{-1} = 1.25\times10^{-3} \text{rad s}^{-1}$$

29. (c) : According to Wien's displacement law

$\lambda_m T = b$, where b is the Wien's constant.

In terms of frequency, $\frac{c}{\upsilon_m}T = b$ or $\upsilon_m = \frac{c}{b}T$

Hence, the (υ_m-T) graph is a straight line.

30. (c)

31. (b) : No current flows through diode D_1 because it is reverse biased. Only diode D_2 conducts because it is forward biased.

$$I = \frac{V}{R} = \frac{12}{2+4} = 2.0 \text{ A}$$

32. (b) : As, $P = \frac{V_{\text{rms}}^2}{Z}$; $Z = \frac{V_{\text{rms}}^2}{P} = \frac{(223)^2}{2000} \approx 25\ \Omega$

$$\tan\phi = \frac{X_C - X_L}{R} = -\frac{3}{4} \quad \therefore \quad X_C - X_L = -\frac{3}{4}R.$$

As, $Z^2 = R^2 + (X_C - X_L)^2$

$$\therefore \quad (25)^2 = R^2 + \left(-\frac{3}{4}R\right)^2$$

$$625 = R^2 + \frac{9}{16}R^2 = \frac{25\ R^2}{16}$$

$$R^2 = \frac{625\times16}{25} = 400 \quad \Rightarrow \quad R = 20\ \Omega$$

33. (b) : $\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = \vec{0}$ or $\vec{p}_3 = -(\vec{p}_1 + \vec{p}_2)$

$$\therefore \quad m_3 v_3 = \sqrt{p_1^2 + p_2^2} \qquad [\because \vec{p}_1 \perp \vec{p}_2]$$

$$\text{or} \quad m_3 = \frac{\sqrt{(1\times12)^2 + (2\times8)^2}}{4} = 5 \text{ kg}$$

34. (d) : Distance between the first dark fringes on either side of central maxima = Width of central maximum

$$= \frac{2D\lambda}{d} = \frac{2\times2\times600\times10^{-9}}{1.00\times10^{-3}} \text{ m}$$

$= 2.4 \times 10^{-3}$ m $= 2.4$ mm

35. (a) : Let λ be the radius of the particle then

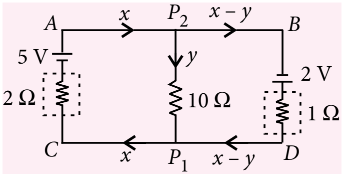
$\lambda = 3 \times 10^{-4} \times 10^{-2}$ m $= 3 \times 10^{-6}$ m

Frequency of electromagnetic wave,

$$\upsilon = \frac{c}{\lambda} = \frac{3\times10^8}{3\times10^{-6}} = 10^{14} \text{ Hz}$$

Thus to observe the particle, the frequency of wave should be more than 10^{14} Hz *i.e* 10^{15} Hz or smaller value of wavelength.

36. (d) : Applying Kirchhoff's law for the loops



AP_2P_1CA and $P_2BDP_1P_2$, one gets

$-10y - 2x + 5 = 0 \quad \Rightarrow \quad 2x + 10y = 5$ ...(i)

$+2 - 1(x - y) + 10y = 0$

$\Rightarrow \quad 2x - 22y = 4$ ...(ii)

From eqns. (i) and (ii),

$$\Rightarrow \quad y = \frac{1}{32} \text{ A} = 0.03 \text{ A from } P_2 \text{ to } P_1.$$

37. (d) : Elastic potential energy $= \frac{1}{2}\times F \times \Delta L$

$$= \frac{1}{2}\times 200 \times (1\times10^{-3}) = 0.1 \text{ J}$$

38. (a) : Rise of a liquid in a capillary tube,

$$\therefore \quad h = \frac{2\times(0.07 \text{ N m}^{-1})\times1}{(0.07\times10^{-2} \text{ m})(10^3 \text{ kg m}^{-3})(10 \text{ m s}^{-2})}$$

$= 2 \times 10^{-2}$ m $= 2$ cm

39. (a) : Here, $H_E = 0.25$ G and $\cos\delta = \frac{H_E}{B_E}$

$\therefore$ the magnetic field of earth at the given location is

$$B_E = \frac{H_E}{\cos 60°} = \frac{0.25}{1/2} = 0.50 \text{ G}$$

40. (d)

MPP CLASS XII ANSWER KEY

1.	(a)	2.	(c)	3.	(b)	4.	(a)	5.	(c)
6.	(d)	7.	(d)	8.	(a)	9.	(c)	10.	(c)
11.	(a)	12.	(d)	13.	(d)	14.	(b)	15.	(b)
16.	(d)	17.	(a)	18.	(d)	19.	(a)	20.	(a,b,c)
21.	(a,c,d)	22.	(b, c)	23.	(a,c,d)	24.	(2)	25.	(2)
26.	(4)	27.	(c)	28.	(b)	29.	(c)	30.	(a)

MPP | MONTHLY Practice Paper

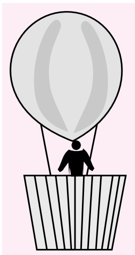
This specially designed column enables students to self analyse their extent of understanding of complete syllabus. Give yourself four marks for correct answer and deduct one mark for wrong answer.
Self check table given at the end will help you to check your readiness.

Total Marks : 120 | **Time Taken : 60 min**

NEET / AIIMS

Only One Option Correct Type

1. A man in a balloon, throws a stone downwards with a speed 5 m s^{-1} with respect to balloon. The balloon is moving upwards with a constant acceleration of 5 m s^{-2}. Then velocity of the stone relative to the man after 2 s is



(a) 10 m s^{-1} (b) 30 m s^{-1}
(c) 15 m s^{-1} (d) 35 m s^{-1}

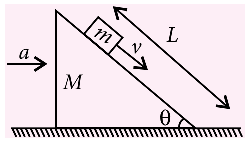
2. A straight rod of length L extends from $x = a$ to $x = L + a$. Find the gravitational force it exerts on a point mass m at $x = 0$ if the mass per unit length of the rod is $\mu = A + Bx^2$.

(a) $\dfrac{Gm}{(a+L)a}(B+AL^2)$ (b) $\dfrac{GmLB}{(a+L)a}$
(c) $\dfrac{G\cdot mL}{(a+L)a}(A+Ba(a+L))$
(d) None of these

3. A balloon is ascending vertically with an acceleration of 0.4 m s^{-2}. Two stones are dropped from it at an interval of 2 s. Find the distance between them 1.5 s after the second stone is released. (g = 10 m s^{-2})
(a) 42 m (b) 52 m (c) 35 m (d) 44 m

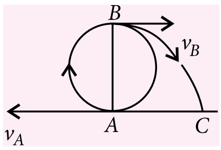
4. The pitch of a screw gauge is 1 mm and there are 50 divisions on its circular scale. When the two jaws of the screw gauge are in contact with each other, the zero of the circular scale lies 6 division above the line of graduation. When a wire is placed between the jaws, 3 main scale divisions are clearly visible while 31st division on the circular scale coincide with the reference line. The diameter of the wire (in mm) is
(a) 3.74 (b) 3.50 (c) 3.5 (d) 3.62

5. A wedge of mass M is pushed with an constant acceleration of $a = g\tan\theta$ along a smooth horizontal surface and a block of mass m is projected down the smooth incline of the wedge with a velocity v relative to the wedge. Mark the incorrect statement.



(a) The time taken by the block to cover distance L on the inclined plane is L/v.
(b) The time taken by the block to cover distance L on the incline plane is $\sqrt{\dfrac{2L}{g\sin\theta}}$.
(c) The normal reaction between the block and wedge is $mg\sec\theta$.
(d) The horizontal force applied on the wedge to produce acceleration a is $(M + m)\,g\tan\theta$.

6. A body is tied up by a string of length l and is rotated in vertical circle at minimum speed. When it reaches the highest point string breaks and body moves on a parabolic path in presence of gravity according to figure. In the plane of point A, value of horizontal range AC will be



(a) $x = l$ (b) $x = 2l$
(c) $x = \sqrt{2}l$ (d) $x = 2\sqrt{2}l$

7. At 10°C the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 110°C this ratio is

(a) $\frac{10}{110}x$ (b) $\frac{283}{383}x$ (c) x (d) $\frac{383}{283}x$

8. The gear wheels which are meshed together have radii of 0.50 and 0.15 cm. Through how many revolutions does the smaller turn when the larger turns through 3 rev ?

(a) 20 (b) 3 (c) 10 (d) 25

9. A body suspended from a spring balance is immersed in water. If the coefficient of cubical expansion of water is twice that of the suspended body, then on heating the liquid, which one of the following would occur ?

(a) The reading on the spring balance increases.
(b) The reading on the spring balance decreases.
(c) The reading on the spring balance remains the same.
(d) The water flows out of the container.

10. For an ideal gas,

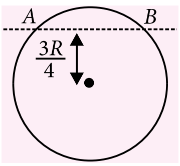
(1) the change in internal energy in a constant pressure process from temperature T_1 to T_2 is equal to $nC_v(T_2 - T_1)$, where C_v is the molar heat capacity at constant volume and n is the number of moles of the gas
(2) the change in internal energy of the gas and the work done by the gas are equal in magnitude in an adiabatic process
(3) the internal energy does not change in an isothermal process
(4) no heat is added or removed in an adiabatic process

(a) only 1, 2 are correct (b) only 2, 4 are correct
(c) only 3, 4 are correct (d) all are correct

11. A stretched string of length 50 cm vibrating in its third overtone emits notes of frequency 2000 Hz. The speed of transverse waves in the string (in m s^{-1}) is

(a) 400 (b) 450 (c) 500 (d) 550

12. The radius of gyration of a solid sphere of mass m and radius R about an axis AB (in the figure) parallel to the diameter at a distance $\frac{3}{4}R$ from this, diameter is



(a) $\sqrt{\frac{80}{77}}R$ (b) $\frac{5R}{4}$ (c) $\frac{5R}{8}$ (d) $\sqrt{\frac{77}{80}}R$

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. **Assertion :** A train travels at a speed of 20 m s^{-1} and covers half its journey. It covers the other half of the journey at 30 m s^{-1}. The average speed of the train to cover the entire distance will be (30 + 20)/2 = 25 m s^{-1}.

Reason : A simple mean of the two speeds gives the average speed.

14. **Assertion :** If the earth were to shrink in size, the length of the day would increase.

Reason : Smaller the object longer is the time required to complete a revolution.

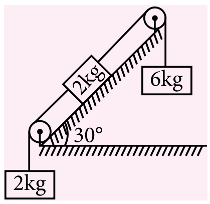
15. **Assertion :** A hollow shaft is found to be stronger than a solid shaft made of same material.

Reason : The torque required to produce a given twist in hollow cylinder is greater than that required to twist a solid cylinder of same size and material.

JEE MAIN / ADVANCED

Only One Option Correct Type

16. Find the acceleration of the 6 kg block in the figure. All the surfaces and pulleys are smooth. Also the strings are inextensible and light. (Take g = 10 m s^{-2})



(a) 3 m s^{-2} (b) 4 m s^{-2} (c) 5 m s^{-2} (d) 2 m s^{-2}

17. The speed v of a wave on a string depends on the tension F in the string and the mass per unit length m/l of the string. If it is known that $[F] = [MLT^{-2}]$, find the constants a and b in the following equation for the speed of a wave on a string; $v = (\text{constant})F^a(m/l)^b$.

(a) $a = \frac{1}{2}, b = \frac{1}{2}$ (b) $a = \frac{-1}{2}, b = \frac{1}{2}$
(c) $a = 0, b = 1$ (d) $a = \frac{1}{2}, b = \frac{-1}{2}$

18. A tank is designed to store 18 kg of N_2 (Nitrogen) gas at a pressure of 4.5 atm. If H_2 (Hydrogen) gas is filled in the tank at 3.5 atm, then amount of gas in the tank will be

(a) 18 kg (b) 5 kg
(c) 1 kg (d) 7 kg

19. A locomotive approaching a crossing at a speed of 80 mile h^{-1}, sounds a whistle of frequency 400 Hz, when 1 mile from the crossing. There is no wind and the speed of sound in air is 0.2 mile s^{-1}. What frequency is heard by an observer 0.6 mile from the crossing on the straight road, which crosses the rail road at right angles ?

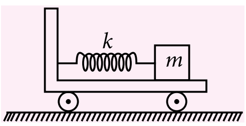
(a) 450 Hz (b) 442 Hz
(c) 420 Hz (d) 432 Hz

More than One Options Correct Type

20. A block of density 2000 kg m^{-3} and mass 10 kg is suspended by a spring of stiffness 100 N m^{-1}. The other end of the spring is attached to a fixed support. The block is completely submerged in a liquid of density 1000 kg m^{-3}. If the block is in equilibrium position,

(a) the elongation of the spring is 1 cm
(b) the magnitude of buoyant force acting on the block is 50 N
(c) the spring potential energy is 12.5 J
(d) magnitude of spring force on the block is greater than the weight of the block.

21. A block of mass m is attached to a massless spring of force constant k, the other end of which is fixed from the wall of a truck as shown in the figure. The block is placed on the smooth horizontal surface of the truck and initially the spring is unstretched. Suddenly the truck starts moving towards left with a constant acceleration a_0. As seen from the truck,

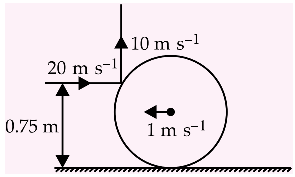


(a) the particle will executes SHM
(b) the time period of oscillation will be $2\pi\sqrt{\frac{m}{k}}$
(c) the amplitude of oscillation will be $\frac{ma_0}{k}$
(d) the energy of oscillation will be $\frac{m^2a_0^2}{k}$.

22. Just as a car starts to accelerate from rest with acceleration 1.4 m s^{-1}, a bus moving with constant speed of 12 m s^{-1} passes it in a parallel lane.

(a) car will overtakes the bus in 17 s
(b) the final velocity of the car is 24 m s^{-1}
(c) the initial velocity of car is 2 m s^{-1}
(d) car travels a distance of 204 m

23. A thin ring of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal plane with velocity 1 m s^{-1}. A small ball of mass 0.1 kg, moving with velocity 20 m s^{-1} in the opposite direction, hits the ring at a height of 0.75 m and goes vertically up with velocity 10 m s^{-1}. Immediately after the collision



(a) the ring has pure rotation about its stationary centre of mass.
(b) the ring comes to a complete stop
(c) friction between the ring and the ground is to the left
(d) there is no friction between the ring and the ground.

Integer Answer Type

24. A 20 cm long string, having a mass of 1.0 g, is fixed at both the ends. The tension in the string is 0.5 N. The string is set into vibrations using an external vibrator of frequency 100 Hz. Find the separation (in cm) between the successive nodes on the string.

25. A solid body rotates about a stationary axis with an angular deceleration $\beta \propto \sqrt{\omega}$ where ω is its angular velocity. If at the initial moment of time its angular velocity was equal to ω_0 then the mean angular velocity of the body averaged over the whole time of rotation till it comes to rest is $\frac{\omega_0}{n}$. Find n.

26. A particle of mass 1 kg is moving on a circular path of radius 1 m. Its kinetic energy is $K = bt^4$, where $b = 1$ J s^{-1}. The force acting on the particle at $t = 1$ s is $(2x)^{1/2}$ m s^{-2}. Find the value of x.

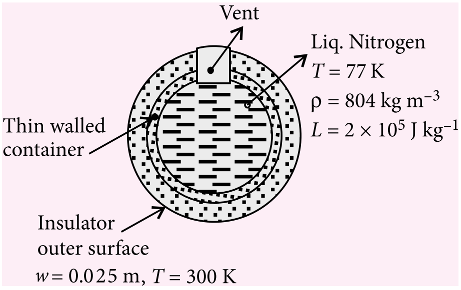
Solution Senders of Physics Musing

SET-57

1. Prashant Bansala, Meerut, Uttar Pradesh
2. Renuka Yadav, Rewari, Haryana
3. Jitendra Kumar, Patna, Bihar

Comprehension Type

A spherical thin walled metallic container is used to store liquid nitrogen at 77 K. The container has a diameter of 0.5 m and is covered with an evacuated, reflective insulation composed of silica powder with $k = 0.0017$ W m^{-1}K^{-1}. The insulation is 25 mm thick and its outer surface is exposed to air at 300 K. The convection heat transfer coefficient is 20 W m^{-2}K^{-1}. The latent heat of vaporisation and the density of liquid nitrogen are 2×10^5 J kg^{-1} and 804 kg m^{-3}

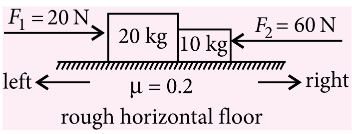


27. Heat flow rate into the container from outside will be approximately
(a) 20 W (b) 13 W
(c) 100 W (d) 130 W

28. Rate at which liquid nitrogen boils off through the vent will be
(a) 50.64 litres per day (b) 21.2 litres per day
(c) 16.53 litres per day (d) 7.0 litres per day

Matrix Match Type

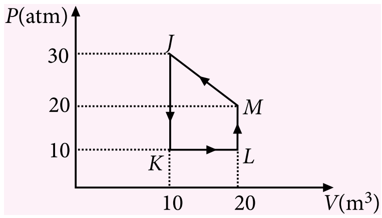
29. Two blocks of masses 20 kg and 10 kg are kept on a rough horizontal floor. The coefficient of friction between both blocks and floor is $\mu = 0.2$. The surface of contact of both blocks are smooth. Horizontal forces of magnitude 20 N and 60 N are applied on both are blocks as shown in figure. Match the statement in column-I with the statements in column-II.



	Column I		Column II
(A)	Frictional force acting on block of mass 10 kg	(P)	has magnitude 20 N
(B)	Frictional force acting on block of mass 20 kg	(Q)	has magnitude 40 N
(C)	Normal reaction exerted by 20 kg block on 10 kg block	(R)	is zero
(D)	Net force on system consisting of 10 kg block and 20 kg block	(S)	is towards right (in horizontal direction)

	A	B	C	D
(a)	P,S	Q,S	P,S	R
(b)	R	Q,S	P,S	R
(c)	P,S	P,S	Q,S	R
(d)	P,S	P,S	R	Q,S

30. Heat given to process is positive, match the following option of column I with the corresponding option of column II.



	Column I		Column II
(A)	JK	(P)	$\Delta W > 0$
(B)	KL	(Q)	$\Delta Q < 0$
(C)	LM	(R)	$\Delta W < 0$
(D)	MJ	(S)	$\Delta Q > 0$

	A	B	C	D
(a)	R	P, S	S	Q,R
(b)	Q	P,S	S	Q,R
(c)	R	P	Q	S
(d)	P	R,S	S	Q,R

◈◈

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted ......
No. of questions correct ......
Marks scored in percentage ......

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

MPP MONTHLY Practice Paper

Class XII

This specially designed column enables students to self analyse their extent of understanding of complete syllabus. Give yourself four marks for correct answer and deduct one mark for wrong answer.

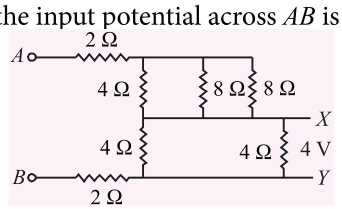
Self check table given at the end will help you to check your readiness.

Total Marks : 120 **Time Taken : 60 min**

NEET / AIIMS

Only One Option Correct Type

1. In the network shown below, if potential across XY is 4 V, then the input potential across AB is



(a) 16 V (b) 20 V (c) 8 V (d) 12 V

2. An inductance L, a capacitance C and a resistance R may be connected to an a.c. source of angular frequency ω, in three different combinations of RC, RL and LC in series. Assume that $\omega L = \frac{1}{\omega C}$. The power drawn by the three combinations are P_1, P_2, P_3 respectively. Then

(a) $P_1 > P_2 > P_3$ (b) $P_1 = P_2 < P_3$
(c) $P_1 = P_2 > P_3$ (d) $P_1 = P_2 = P_3$

3. Work function of potassium metal is 2.30 eV. When light of frequency 8×10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. The stopping potential of the electrons will be equal to

(a) 0.1 V (b) 1.0 V (c) 2.3 V (d) 3.3 V

4. Two similar coils of radius R are lying concentrically with their planes at right angles to each other. The currents flowing in them are I and $2I$, respectively. The resultant magnetic field induction at the centre will be

(a) $\frac{\sqrt{5}\mu_0 I}{2R}$ (b) $\frac{3\mu_0 I}{2R}$ (c) $\frac{\mu_0 I}{2R}$ (d) $\frac{\mu_0 I}{R}$

5. A ray of monochromatic light is incident on the refracting face of a prism (angle 75°). It passes through the prism and is incident on the other face at the critical angle. If the refractive index of the prism is $\sqrt{2}$, then the angle of incidence on the first face of the prism is

(a) 15° (b) 30° (c) 45° (d) 60°

6. When a point charge of $\frac{1}{3}\mu C$ is placed on the axis of a thin disc of total charge $\frac{2}{3}\mu C$ (uniform distribution) and radius 3.95 cm such that distance between point charge and centre of disc is 1 m, then force experienced by disc is approximately

(a) 4 mN (b) 6 mN (c) 3 mN (d) 2 mN

7. Avalanche breakdown in a *p-n* junction diode is due to

(a) sudden shift of fermi level
(b) increase in the width of forbidden gap
(c) sudden increase of impurity concentration
(d) cumulative effect of increased electron collision and creation of added electron hole pairs.

8. A plane wave of monochromatic light falls normally on a uniform thin film of oil which covers a glass plate. The wavelength of source can be varied continuously. Complete destructive interference is observed for λ = 5000 Å and λ = 7000 Å and for no other wavelength in between. If μ of oil is 1.3 and that of glass is 1.5, the thickness of the film will be

(a) 6.7×10^{-5} cm (b) 5.7×10^{-5} cm
(c) 4.0×10^{-5} cm (d) 2.8×10^{-5} cm

9. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is then introduced between the plates which results in the

(a) reduction of charge on the plates and increase of potential difference across the plates
(b) increase in the potential difference across the plates and reduction in stored energy but no change in the charge on the plates.
(c) decrease in potential difference across the plates and reduction in stored energy but no change in the charge on the plates.
(d) none of these

10. To activate the reaction (n, α) with stationary B^{11} nuclei, neutrons must have the activation kinetic energy T_{th} = 4.0 MeV. (n, α) means that n is bombarded to obtain α. Find the energy (in MeV) of this reaction.
(a) +3.7 (b) –4.3 (c) –3.7 (d) +4.3

11. The magnetic flux through each of five faces of a neutral playing dice is given by $\phi_B = \pm N$ Wb, where N(= 1 to 5) is the number of spots on the face. The flux is positive (outward) for N even and negative (inward) for N odd. What is the flux through the sixth face of the dice?
(a) 3 Wb (b) 4 Wb (c) –3 Wb (d) –4 Wb

12. A current I flows through a uniform wire of diameter d when the mean electron drift velocity is v. The same current will flow through a wire of diameter $\frac{d}{2}$ made of the same material if the mean drift velocity of the electron is
(a) $\frac{v}{4}$ (b) $\frac{v}{2}$ (c) $2v$ (d) $4v$

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. Assertion : The induced e.m.f. and current will be same in two identical loops of copper and aluminium, when rotated with same speed in the same magnetic field.

Reason : Induced current is proportional to rate of change of magnetic field while induced e.m.f. depends on resistance of wire.

14. Assertion : Hydrogen atom consists of only one electron but its emission spectrum has many lines.
Reason : Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

15. Assertion : A magnetic needle oscillates in an horizontal plane with a period T at a place where the angle of dip is 60°. The same needle oscillates in a vertical plane coinciding with the magnetic meridian with a period $\frac{T}{\sqrt{2}}$.

Reason : The restoring force is provided by the earth's horizontal component.

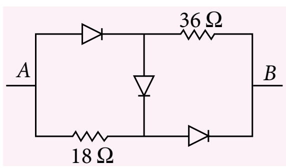
JEE MAIN / ADVANCED

Only One Option Correct Type

16. A conducting rod is in form of parabola $y = kx^2$. It is placed in a region of uniform and perpendicular magnetic field of strength B. At $t = 0$, a conducting straight rod starts sliding up on parabola from ($x = 0$, $y = 0$) with a constant acceleration a and the parabolic frame starts rotating with angular speed ω. Flux through the frame after t second is
(a) $\frac{B}{4}\sqrt{\frac{5}{k}}a^{3/2}t^2\cos\theta$ (b) $\frac{B}{3}\sqrt{\frac{2}{k}}at^3$
(c) $\frac{B}{3}\sqrt{\frac{2}{k}}a^{3/2}t^3\sin\theta$ (d) $\frac{B}{3}\sqrt{\frac{2}{k}}a^{3/2}t^3\cos\theta$

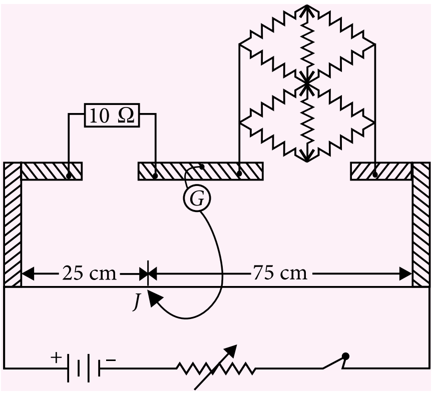
17. A lamp emits monochromatic green light uniformly in all directions. The lamp is 3% efficient in converting electrical power to electromagnetic waves and consumes 100 W of power. The amplitude of the electric field associated with the electromagnetic radiation at a distance of 10 m from the lamp will be
(a) 1.34 V m^{-1} (b) 2.68 V m^{-1}
(c) 5.36 V m^{-1} (d) 9.37 V m^{-1}

18. The equivalent resistance between A and B is



(a) 36 Ω if $V_A > V_B$ (b) 18 Ω if $V_A < V_B$
(c) Zero if $V_A < V_B$ and 54 Ω if $V_A > V_B$
(d) Zero if $V_A > V_B$ and 54 Ω if $V_A < V_B$

19. In the meter bridge, a network of 10 resistors each of resistance r is balanced against a length of 25 cm as shown.



Then, the value of r is

(a) 60 Ω (b) 20 Ω

(c) 30 Ω (d) 40 Ω

More than One Options Correct Type

20. It is observed that only 0.39% of the original radioactive sample remains undecayed after eight hours. Hence,

(a) the half-life of the substance is 1 h

(b) the mean-life of the substance is $\left[\frac{1}{\ln 2}\right]$ h

(c) decay constant of the substance is $(\ln 2)\ h^{-1}$

(d) if the number of radioactive nuclei of this substance at a given instant is 10, then the number left after 30 min would be 7.5.

21. An inductor of inductance 2.0 mH, is connected across a charged capacitor of capacitance 5.0 μF and the resulting LC circuit is set oscillating at its natural frequency. Let Q denotes the instantaneous charge on the capacitor, and I the current in the circuit. It is found that the maximum value of Q is 200 μC. Mark the correct statements.

(a) When $Q = 100\ \mu$C, the value of $\left|\frac{dI}{dt}\right| = 10^4\ \text{A s}^{-1}$.

(b) When $Q = 200\ \mu$C, $I = 1$ A.

(c) Maximum value of I is 2 A.

(d) When I is equal to one half its maximum value, $|Q| = 100\sqrt{3}\ \mu$C.

22. Let $y > 0$ be the region of space with a uniform and constant magnetic field $B\hat{k}$. A particle with charge q and mass m travels along the y-axis and enters in magnetic field at origin with speed v_0. In region the particle is subjected to an additional friction force $\vec{F} = -k\vec{v}$. Assume that particle remains in region $y > 0$ at all times. The coordinates of the particle where it will finally stop are (x, y), then

(a) $x = \frac{kmv_0}{k^2 + (qB)^2}$ (b) $x = \frac{qBmv_0}{k^2 + (qB)^2}$

(c) $y = \frac{kmv_0}{k^2 + (qB)^2}$ (d) $y = \frac{qBmv_0}{k^2 + (qB)^2}$

23. A transparent slab of thickness t and refractive index μ is inserted in front of upper slit of YDSE apparatus. The wavelength of light used is λ. Assume that there is no absorption of light by the slab. Mark the correct statements.

(a) The intensity of dark fringes will be 0, if slits are identical.

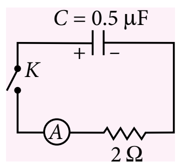
(b) The change in optical path due to insertion of plate is μt.

(c) The change in optical path due to insertion of plate is $(\mu - 1)\,t$.

(d) For making intensity zero at center of screen, the thickness can be $\frac{5\lambda}{2(\mu-1)}$.

Integer Answer Type

24. A charged capacitor is allowed to discharge through a resistor by closing the key at the instant $t = 0$. At the instant $t = (\ln 4)\ \mu$s, the reading of the ammeter falls half the initial value. Find the resistance of the ammeter (in Ω).

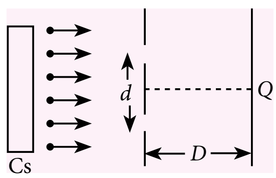


25. Two amplifiers are connected one after the other in series (cascaded). The first amplifier has a voltage gain of 10 and the second has a voltage gain of 20. If the input a.c. signal is 0.01 V, what is the output a.c. signal (in V)?

26. In an amplitude modulation with modulation index 0.5, find the ratio of the amplitude of the carrier wave to that of the side band in the modulated wave.

Comprehension Type

A cesium Cs plate is irradiated with a light of wavelength $\lambda = hc/\phi$, ϕ being the work function of the plate, h Planck's constant, and c the velocity of light in vacuum. Assume all the photoelectrons are moving perpendicular to the plate toward a YDSE setup when accelerated through a potential difference V. Take charge on a proton = e and mass of an electron = m.



27. The fringe width due to the electron beam is

(a) $\dfrac{\lambda D}{d}$ (b) $\dfrac{\lambda D}{2d}$

(c) $\dfrac{hD}{(d\sqrt{2emV})}$ (d) $\dfrac{hcD}{eVd}$

28. If the wavelength of light used in photoemission is less than λ, then the fringe width will

(a) increase (b) decrease

(c) remain same (d) cannot be said.

Matrix Match Type

29. Four particles A, B, C, D are moving with different velocities in front of stationary plane mirror (lying in y-z plane). At t = 0, velocity of A is $\vec{v}_A = \hat{i}$, velocity of B is $\vec{v}_B = -\hat{i} + 3\hat{j}$, velocity of C is $\vec{v}_C = 5\hat{i} + 6\hat{j}$ and velocity of D is $\vec{v}_D = 3\hat{i} - \hat{j}$. Acceleration of particle A and C are $\vec{a}_A = 2\hat{i} + \hat{j}$ and $\vec{a}_C = 2t\hat{j}$ respectively. The particle B and D move with uniform velocity. (Assume no collision will take place till t = 2 s). All quantities are in S.I. units. Relative velocity of image of object A with respect to object A is denoted by $\vec{v}_{A',A}$. Velocity of image relative to corresponding objects are given in column I and their values are given in column II at t = 2 s. Match column I with corresponding values in column II.

Column I	Column II
(A) $\vec{v}_{A',A}$	(P) $2\hat{i}$
(B) $\vec{v}_{B',B}$	(Q) $-6\hat{i}$
(C) $\vec{v}_{C',C}$	(R) $-12\hat{i} + 4\hat{j}$
(D) $\vec{v}_{D',D}$	(S) $-10\hat{i}$

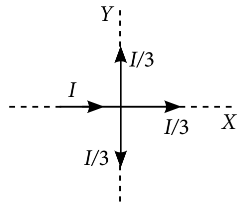
	A	B	C	D
(a)	S	R	P	Q
(b)	R	Q	S	P
(c)	S	P	S	Q
(d)	S	P	R	Q

30. Column II gives four situations in which three or four semi-infinite current carrying wires are placed in XY- plane as shown in the figure. The magnitude of the direction of current is shown in each figure. Column I gives statements regarding the x and y-components of magnetic field at a point P whose coordinates are (0, 0, d). Match the statements in Column I with the corresponding figures in Column II.

Column I **Column II**

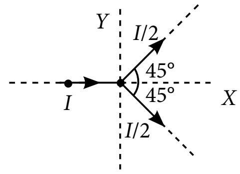
(A) x-components of magnetic field at point P is zero

(P)



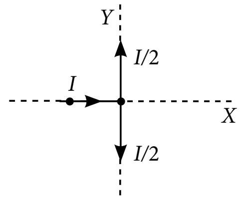
(B) z-component of magnetic field at point P is zero

(Q)



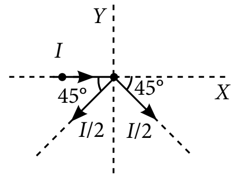
(C) Magnitude of magnetic field at point P is $\dfrac{\mu_0 I}{4\pi d}$

(R)



(D) Magnitude of magnetic field at point P is less than $\dfrac{\mu_0 I}{2\pi d}$

(S)



	A	B	C	D
(a)	P,Q,R	P,Q,R,S	R	P,Q,R,S
(b)	P,Q	Q,R	S,P	P,Q,R
(c)	Q	R	S,P,Q	Q,R,S
(d)	P,Q	R,S	R,P,Q	P,Q,R

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This road is so smart it can charge a car

A 1,080-Metre-Long Stretch In Chinese City Paved With Solar Panels, Sensors & Electric-Battery Recharges

The road to China's autonomous-driving future is paved with solar panels, mapping sensors and electric-battery rechargers as it tests an "intelligent highway" that could speed the transformation of the global transportation industry.

The technologies will be embedded under transparent concrete used to build a 1,080-metre-long stretch of road in Jinan. About 45,000 vehicles barrel over the section every day, and the solar panels generate enough electricity to power highway lights and 800 homes, according to builder Qilu Transportation Development Group Co.

The government says 10% of all cars should be fully self-driving by 2030, and Qilu wants to deliver better traffic updates, accurate mapping and on-the-go recharging of electric-vehicle batteries — from the ground up.

The construction comes as President Xi Jinping's government pushes ahead with a 'Made in China 2025' plan to help the nation become an advanced manufacturing power. The 10 sectors highlighted include new-energy vehicles, information technology and robotics. China also has a separate plan for developing its artificial-intelligence industry that calls for the nation to be the world's primary AI innovation centre by 2030. Part of that effort involves building what the government calls an intelligent transportation system. Coordinating the development of autonomous-driving cars and intelligent-road systems is a focus, said Yuan Peng, the deputy head of the transportation ministry's science and technology department.

"The ministry will offer smart roads for the smart cars that are coming," he said.

Step one makes up a section of the expressway surrounding Jinan, an old industrial hub of about 7 million people. The road has three vertical layers, with the shell of see-through material allowing sunlight to reach the solar cells underneath. The top layer also has space inside to thread recharging wires and sensors that monitor temperature, traffic flow and weight load.

The solar panels spread across two lanes, which feel no different to a driver than the regular road, and are thinner than a 1-yuan coin standing on its edge. The test road is too short to deliver wireless recharging at the moment, Zhou said.

"From the angle of the technology itself, charging is not a problem," Zhou said. "The vehicles that can be charged wirelessly aren't used on roads yet."

Qilu didn't give a time frame for installing the sensors to transmit data and power to EV batteries. Researchers started working on the project 10 years ago. Construction took 55 days and the road opened in December.

"In the future, when cars are running on these roads, it will be like human beings," Zhou Yong, the company's general manager said. "The road will feel and think to figure out how heavy the vehicles are and what kind of data is needed."

Now, contact lenses that darken in bright light

The US Food and Drug Administration (FDA) has approved the world's first contact lens that automatically darkens when exposed to bright light.

The Acuvue Oasys Contact Lenses with Transitions Light Intelligent Technology are soft contact lenses indicated for daily use to correct the vision of people with non-diseased eyes who are nearsighted (myopic) or farsighted (hyperopic). The contact lenses contain a photochromic additive that adapts the amount of visible light filtered to the eye based on the amount of ultra-violet light to which they are exposed.

The results of the study demonstrated there was no evidence of concerns with either driving performance or vision while wearing the lenses.

These contacts are intended for daily wear for up to 14 days.

Courtesy : The Times of India

CROSSWORD

ELECTROSTATICS

CLASS XII

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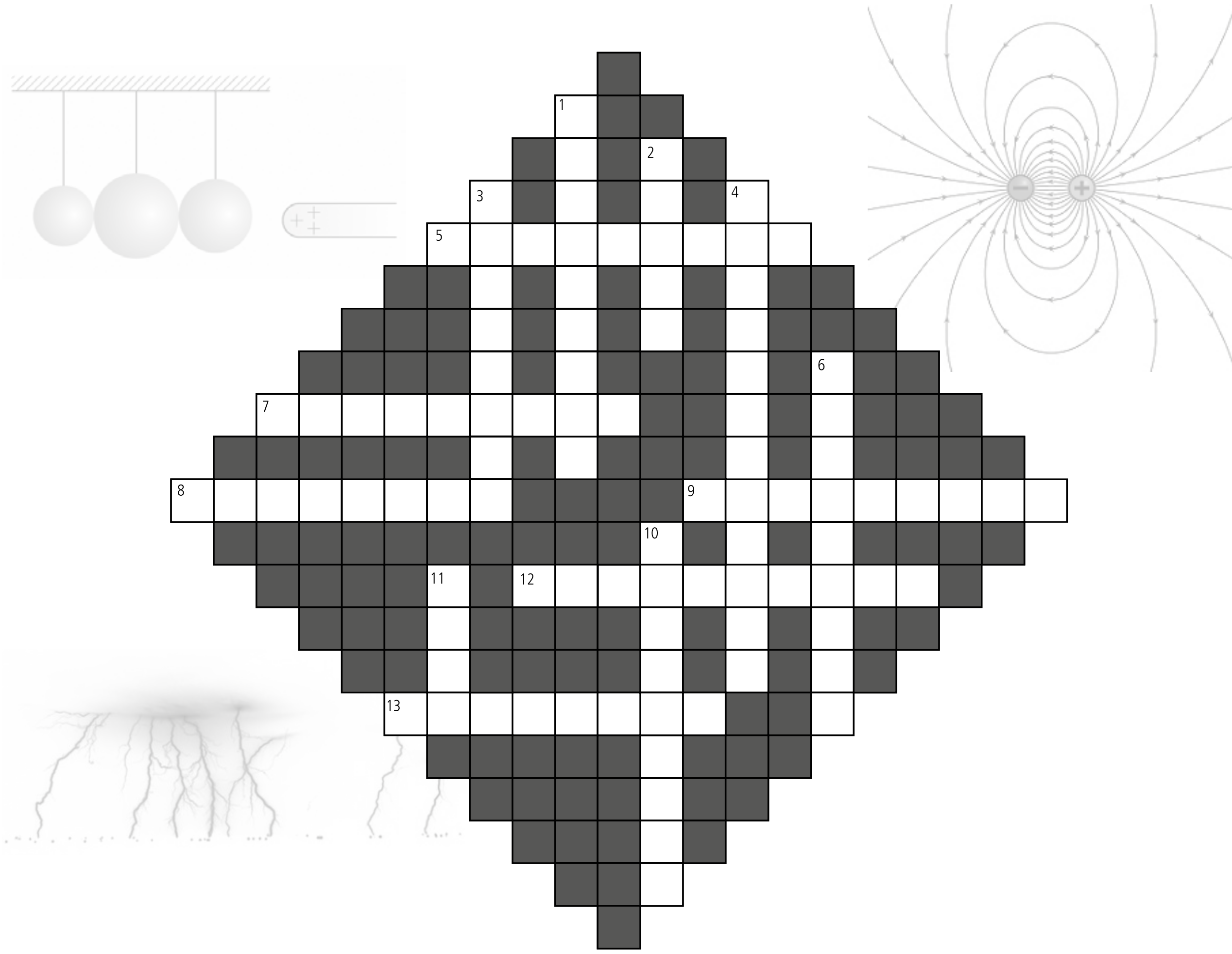

ACROSS

5. One of the methods of charging **(9)**
7. A system of two conductors separated by an insulator **(9)**
8. The type of charge acquired by a glass rod when rubbed with silk **(8)**
9. The optical analogue of an equipotential surface **(9)**
12. One of the basic properties of electric charge **(10)**
13. The property which differentiates the two kinds of charges **(8)**

DOWN

1. A sure test of electrification **(9)**
2. A polar molecule **(5)**
3. The dielectric constant of a metal **(8)**
4. The dipole moment per unit volume **(12)**
6. The nature of symmetry of electric field due to a point charge **(9)**
10. An electrical discharge in the atmosphere between charged clouds and the earth or between the clouds **(9)**
11. The electric field inside a uniformly charged conducting shell **(4)**


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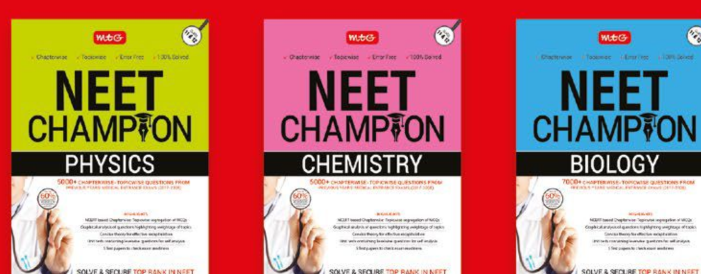
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