www.mtg.in | June 2016 | Pages 92 | ₹ 30

NEET SPECIAL

- NEET Phase-1 Solved Paper 2016 (More than 60% Questions from MTG Books / Magazines)
- NEET Phase-2 Practice Paper

PHYSICS for you

India's #1 PHYSICS MONTHLY FOR JEE (Main & Advanced) & NEET

Solved Papers 2016
- Karnataka CET
- Kerala PET

VK.COM/STOPTHEPRESS

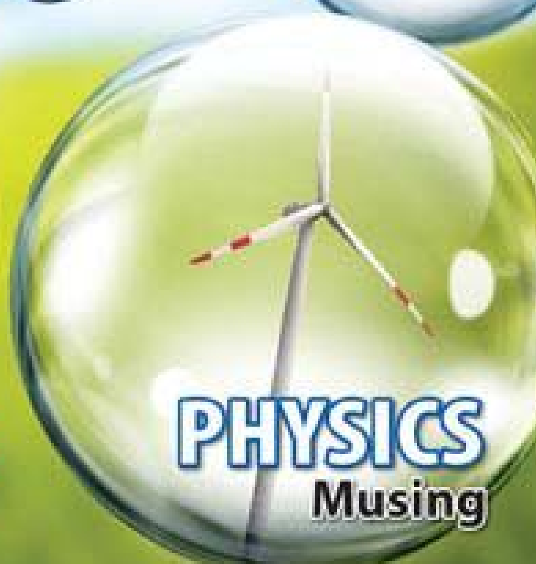
ACE YOUR WAY CBSE XII SERIES 1

Brain Map

CORE CONCEPT

Olympiad Problems

EXAM PREP



mtG

Trust of more than 1 Crore Readers Since 1982

You Ask ? We Answer ✓

PHYSICS Musing

PHYSICS for you

Volume 24 No. 6 June 2016

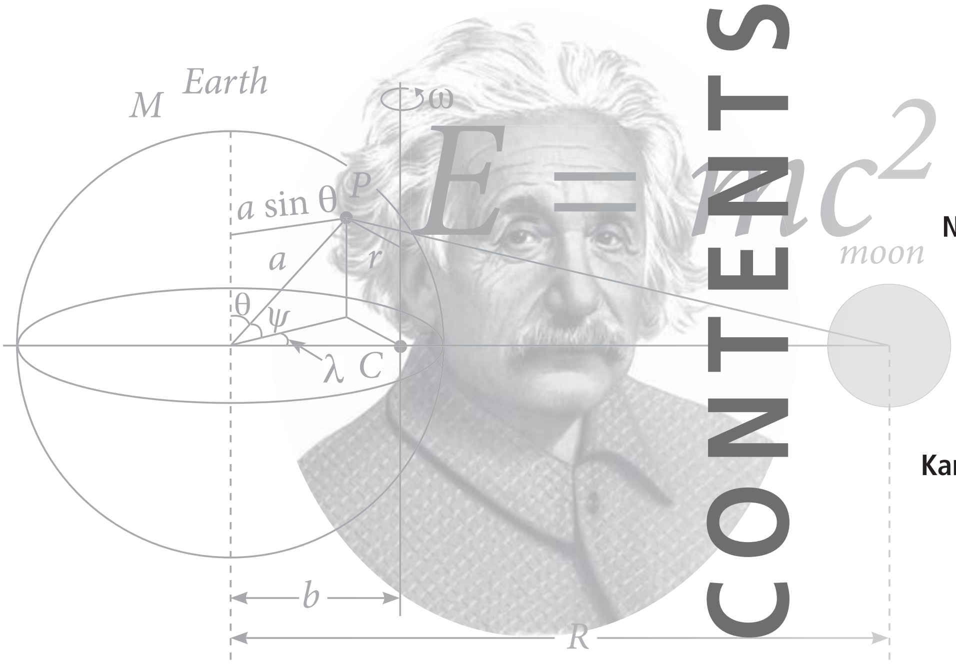
Managing Editor
Mahabir Singh

Editor
Anil Ahlawat
(BE, MBA)

Corporate Office:
Plot 99, Sector 44 Institutional area, Gurgaon -122 003 (HR).
Tel : 0124-4951200 e-mail : info@mtg.in website : www.mtg.in

Regd. Office:
406, Taj Apartment, Near Safdarjung Hospital, New Delhi - 110029.

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 five 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 2016 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.

Subscribe online at www.mtg.in

Individual Subscription Rates				Combined Subscription Rates			
	1 yr.	2 yrs.	3 yrs.		1 yr.	2 yrs.	3 yrs.
Mathematics Today	330	600	775	PCM	900	1500	1900
Chemistry Today	330	600	775	PCB	900	1500	1900
Physics For You	330	600	775	PCMB	1000	1800	2300
Biology Today	330	600	775				

Send D.D/M.O in favour of MTG Learning Media (P) Ltd.
Payments should be made directly to : MTG Learning Media (P) Ltd,
Plot No. 99, Sector 44, Gurgaon - 122003 (Haryana)
We have not appointed any subscription agent.

Owned, Printed and Published by Mahabir Singh from 406, Taj Apartment, New Delhi - 29 and printed by Personal Graphics and Advertisers (P) Ltd., Okhla Industrial Area, Phase-II, New Delhi. Readers are adviced to make appropriate thorough enquiries before acting upon any advertisements published in this magazine. Focus/Infocus features are marketing incentives. MTG does not vouch or subscribe to the claims and representations made by advertisers. All disputes are subject to Delhi jurisdiction only.
Editor : Anil Ahlawat

PHYSICS MUSING

Physics Musing was started in August 2013 issue of Physics For You with the suggestion of Shri Mahabir Singh. The aim of Physics Musing is to augment the chances of bright students preparing for JEE (Main and Advanced) / NEET / AIIMS / Other PETs with additional study material.

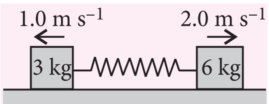
In every issue of Physics For You, 10 challenging problems are proposed in various topics of JEE (Main and Advanced) / NEET / AIIMS / various PETs. The detailed solutions of these problems will be published in next issue of Physics For You.

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.

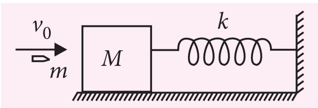
We hope that our readers will enrich their problem solving skills through "Physics Musing" and stand in better stead while facing the competitive exams.

PROBLEM Set 35

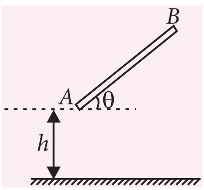
1. Two blocks of masses 3 kg and 6 kg respectively are placed on a smooth horizontal surface. They are connected by a light spring of force constant $k = 200\ \text{N m}^{-1}$. Initially the spring is unstretched and the indicated velocities are imparted to the blocks. Find the maximum extension of the spring.



2. A bullet of mass m strikes a block of mass M connected to a light spring of stiffness k, with a speed v_0. If the bullet gets embedded in the block then find the maximum compression in the spring.



3. A uniform rod AB of length l is released from rest with AB inclined at angle θ with horizontal. It collides elastically with smooth horizontal surface after falling through a height h.



Take $\theta = 60°$. Find the height H after rebound so that the rod is horizontal first time when its centre of mass is at the maximum height. (Assume B does not strike the ground)

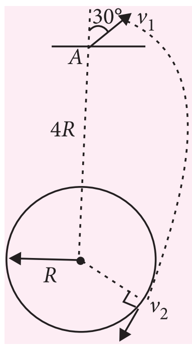
4. Assuming a particle to have the form of a sphere and to absorb all incident light, find the radius of a particle for which its gravitational attraction to the Sun is counterbalanced by the force that light exerts on it. The power of light radiated by the Sun equals $P = 4 \times 10^{26}$ W and the density of the particle is $\rho = 1.0\ \text{g cm}^{-3}$.

[Use $G = \dfrac{20}{3} \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ and mass of the Sun $= 2 \times 10^{30}$ kg]

5. A ray of light is falling on a glass sphere of $\mu = \sqrt{3}$ such that the incident ray and the emergent ray, when produced, intersect at a point on the surface of the sphere. Find the value of angle of incidence.

6. In a YDSE, two thin transparent sheets are used in front of the slits S_1 and S_2 of refractive indices $\mu_1 = 1.6$ and $\mu_2 = 1.4$. If both sheets have thickness t, the central maximum is observed at a distance of 5 mm from centre O. Now the sheets are replaced by two sheets of same material of refractive index $\mu = \dfrac{\mu_1 + \mu_2}{2}$ but having thickness t_1 and t_2 such that $t = \dfrac{t_1 + t_2}{2}$. Now central maximum is observed at distance of 8 mm from centre O on the same side as before. Find the thicknesses t_1 and t_2. [Given, $d = 1$ mm, $D = 1$ m]

7. A particle is projected from point A, that is at a distance $4R$ from the centre of the earth, with speed v_1 in a direction making 30° with the line joining the centre of the earth and point A, as shown. Find the speed v_1 if particle passes grazing the surface of the earth.



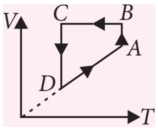
By Akhil Tewari, Author Foundation of Physics for JEE Main & Advanced, Senior Professor Physics, RAO IIT ACADEMY, Mumbai.

Consider gravitational interaction only between these two.

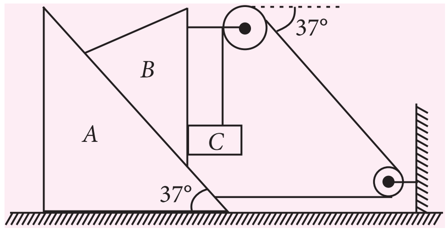
[Use $\frac{GM}{R} = 6.4 \times 10^7\ \text{m}^2\ \text{s}^{-2}$)

8. A parallel beam of light falls normally on the first face of a prism of small angle. At the second face it is partly transmitted and partly reflected, the reflected beam striking at the first face again and emerging from it in a direction making an angle 6° 30′with the reversed direction of the incident beam. The refracted beam is found to have undergone a deviation of 1°15′ from the original direction. Find the refractive index of the glass and the angle of the prism.

9. Some gas ($C_P/C_V = \gamma = 1.25$) follows the cycle $ABCDA$ as shown in the figure. Determine the ratio of the energy given out by the gas to its surroundings during the isochoric section of the cycle to the expansion work done during the isobaric section of the cycle.



10. A system is shown in figure. All contact surfaces are smooth and string is tight and inextensible. Wedge A moves towards right with speed 10 m s^{-1} and velocity of B relative to A is in downward direction along the incline having magnitude 5 m s^{-1}. Find the horizontal and vertical component of velocity of block C.



PRACTICE PAPER

PMT

*K P Singh

1. A ball of mass 400 g is dropped from a height of 5 m. A boy on the ground hits the ball vertically upwards with a bat with an average force of 100 N. So, that it attains a vertical height of 20 m. The time for which the ball remains in contact with the bat is (g = 10 m s^{-2})

(a) 0.12 s (b) 0.08 s (c) 0.04 s (d) 12 s

2. The moment of inertia of a rod (length L, mass m) about an axis perpendicular to the length of the rod and passing through a point equidistant from its mid point and one end is

(a) $\frac{mL^2}{12}$ (b) $\frac{7}{48}mL^2$

(c) $\frac{13}{48}mL^2$ (d) $\frac{19}{48}mL^2$

3. On heating the cathode 1.8×10^{17} electrons are emitted per second. On using the anode (positive pole) at 400 V, whole the electrons are collected at positive pole. If the charge of electron is 1.6×10^{-19} C, then the maximum positive pole current will be

(a) 29 mA (b) 2.7 mA

(c) 72 μA (d) 29 μA

4. Which of the following statements about the Bohr's model of the hydrogen atom is false?

(a) Acceleration of electron in n = 2 orbit is less than that in n = 1 orbit.

(b) Angular momentum of electron in n = 2 orbit is more than that in n = 1 orbit.

(c) Kinetic energy of electron in n = 2 orbit is less than that in n = 1 orbit.

(d) Potential energy of electron in n = 2 orbit is less than that in n = 1 orbit.

5. A mass m = 100 g is attached at the end of a light spring which oscillates on a frictionless horizontal table with an amplitude equal to 0.16 m and time period equal to 2 s. Initially the mass is released from rest at t = 0, and displacement x = –0.16 m. The expression for the displacement of mass at any time (t) is

(a) $x = 0.16 \cos(\pi t)$

(b) $x = -0.16 \sin(\pi t)$

(c) $x = 0.16 \cos(\pi t + \pi)$

(d) $x = -0.16 \cos(\pi t + x)$

6. A particle executing simple harmonic motion has a time period of 4 s. After how much interval of time from t = 0 will its displacement be half of its amplitude?

(a) $\frac{1}{3}$ s (b) $\frac{1}{2}$ s (c) $\frac{2}{3}$ s (d) $\frac{1}{6}$ s

7. Two spheres A and B of radii a and b, respectively are at same electric potential. The ratio of the surface charge densities of A and B is

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

8. For a metallic wire, the ratio V/i (V = applied potential difference and i = current flowing)

(a) is independent of temperature

(b) increases as the temperature rises

(c) decreases as the temperature rises

(d) increases or decreases as temperature rises depending upon the metal

9. An aircraft executes horizontal loop with a speed of 150 m s^{-1} when its wings are banked at an angle of 12°. The radius of the loop is

(a) 10.6 km (b) 5.3 km

(c) 7.5 km (d) 8.3 km

*A renowned physics expert, KP Institute of Physics, Chandigarh, 09872662552

10. A carnot engine used first an ideal monoatomic gas. If the source and sink temperature on 411 °C and 69 °C respectively and the engine extracts 1000 J of heat from the source in each cycle. Then area enclosed by the

(a) *PV* diagram is 30 J
(b) *PV* diagram is 700 J
(c) *PV* diagram is 500 J
(d) none of these

11. A square coil 20 cm × 20 cm has 100 turns and carries a current of 1 A. It is placed in a uniform magnetic field B = 0.5 T with the direction of magnetic field parallel to the plane of the coil. The magnitude of the torque required to hold this coil, in this position is

(a) zero (b) 200 N m
(c) 2 N m (d) 10 N m

12. A galvanometer has resistance of 400 Ω and deflects full scale for current of 0.2 mA through it. The shunt resistance required to convert it into 3 A ammeter is

(a) 0.027 Ω (b) 0.054 Ω
(c) 0.0135 Ω (d) 0.27 Ω

13. The eccentricity of earth's orbit is 0.0167. The ratio of its maximum speed in its orbit to its minimum speed is

(a) 2.507 (b) 1.0339
(c) 8.324 (d) 1.000

14. *A* and *B* are two wires. The radius of *A* is twice that of *B*. These are stretched by the same force. Then, the stress on *B* is

(a) equal to that on *A*
(b) four times that on *A*
(c) two times that on *A*
(d) half that on *A*

15. The time period of oscillation of magnet in a vibration magnetometer is 1.5 s. The time period of oscillation of another magnet similar in size, shape and mass but having one-fourth magnetic moment that of the first magnet oscillating at the same place, will be

(a) 0.75 s (b) 1.5 s
(c) 3.0 s (d) 6.0 s

16. The number of turns and radius of cross-section of the coil of a tangent galvanometer are doubled. The reduction factor K will be

(a) K (b) $2K$ (c) $4K$ (d) $K/4$

17. An energy of 484 J is spent in increasing the speed of flywheel from 60 rpm to 360 rpm. The moment of inertia of wheel is

(a) 0.2 kg m^2 (b) 0.7 kg m^2
(c) 2 kg m^2 (d) 3 kg m^2

18. The ratio of radii of two spheres of same material is 1 : 4. Then the ratio of their heat capacity will be

(a) $\frac{1}{64}$ (b) $\frac{1}{32}$ (c) $\frac{1}{2}$ (d) $\frac{1}{4}$

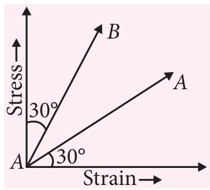
19. A convex lens of focal length 12 cm is made up of a glass of refractive index 3/2. When it is immersed in a liquid of refractive index 5/4, its focal length will be

(a) 15 cm (b) 6 cm (c) 30 cm (d) 24 cm

20. For a particle performing SHM, the acceleration of particle is plotted against displacement. The curve will be a

(a) straight line with positive slope
(b) straight line with negative slope
(c) curve whose nature can't be predicted
(d) parabola

21. Find the ratio of Young's modulus of wire *A* to wire *B*



(a) 1:1
(b) 1 :1
(c) 1 :3
(d) 1: 4

22. The plane faces of two identical plano-convex lenses each having focal length of 40 cm, are placed against each other to form a common convex lens. The distance from this lens at which an object must be placed to obtain a real, inverted image with magnification equal to unity is

(a) 80 cm (b) 40 cm (c) 20 cm (d) 160 cm

23. Two capillary tubes of same diameter are put vertically one each in two liquids whose relative densities are 0.8 and 0.6 and surface tensions are 60 and 50 dyn cm^{-1} respectively. Ratio of height of liquid in the two tubes h_1/h_2 is

(a) $\frac{10}{9}$ (b) $\frac{3}{10}$ (c) $\frac{10}{3}$ (d) $\frac{9}{10}$

24. The temperature of the hydrogen at which the rms speed of its molecules is equal to that of oxygen molecules at a temperature of 31 °C is

(a) – 216 °C (b) – 235 °C
(c) – 254 °C (d) – 264 °C

25. When the electron in the hydrogen atom jumps from second orbit to first orbit, the wavelength of radiation emitted is λ. When the electrons jump from third orbit to first orbit, then wavelength of emitted radiation would be

(a) $\frac{27}{32}\lambda$ (b) $\frac{32}{27}\lambda$ (c) $\frac{2}{3}\lambda$ (d) $\frac{3}{2}\lambda$

26. 16 g sample of a radioactive element is taken from Mumbai to Delhi in 2 h and it was found that 1 g of the element remained. Half-life of the element is

(a) 2 h (b) 1 h (c) $\frac{1}{2}$ h (d) $\frac{1}{4}$ h

27. A 5 m aluminium wire ($Y = 7 \times 10^{10}$ N m^{-2}) of diameter 3 mm supports a 40 kg mass. In order to have the same elongation in a copper wire ($Y = 12 \times 10^{10}$ N m^{-2}) of the same length under the same weight, the diameter should be in mm

(a) 1.75 (b) 2.0 (c) 2.3 (d) 5.0

28. A vessel containing 5 L of gas at 0.8 mm pressure, is connected to an evacuated vessel of volume 3 L. The resultant pressure inside will be

(a) $\frac{4}{3}$ mm (b) 0.5 mm
(c) 2.0 mm (d) $\frac{3}{4}$ mm

29. A particle performing SHM along x-axis, with $x = 0$ as the mean position is released from rest at $x = 2$ cm of $t = 0$. The time taken by the particle in crossing the position $x = 1.6$ cm for the second time is (Take amplitude of SHM as 2 cm and its period as 1 s)

(a) $\frac{1}{12}$ s (b) $\frac{11}{12}$ s
(c) $\frac{323}{360}$ s (d) Information insufficient.

30. A man can swim with a speed of 4 km h^{-1} in still water. How long does he take to cross a river 1 km wide, if the river flows steadily 3 km h^{-1} and he makes his strokes normal to the river current. How far down the river does he go when he reaches the other bank?

(a) 850 m (b) 750 m
(c) 650 m (d) None

31. On sounding tuning fork A with another tuning fork B of frequency 384 Hz, 6 beats are produced per second. After loading the prongs of A with some wax and then sounding it again with B, 4 beats are produced per second. What is the frequency of the tuning fork A?

(a) 388 Hz (b) 380 Hz
(c) 378 Hz (d) 390 Hz

32. An air capacitor of capacity $C = 10$ μF is connected to a constant voltage battery of 12 V. Now, the space between the plates is filled with a liquid of dielectric constant 5. The charges that flows now from battery to the capacitor is

(a) 120 μC (b) 600 μC
(c) 480 μC (d) 24 μC

33. Compressed air in the tube of a wheel of a cycle at normal temperature suddenly starts coming out from a puncture. The air inside

(a) starts becoming hotter
(b) remains at the same temperature
(c) starts becoming cooler
(d) may become hotter or cooler depending upon the amount of water vapour present

34. The amplitude of SHM $y = 2(\sin 5\pi t + \sqrt{3}\cos 5\pi t)$ is

(a) 2 (b) $2\sqrt{2}$ (c) 4 (d) $2\sqrt{3}$

35. Two perfectly elastic particles P and Q of equal mass travelling along the line joining them with velocities 15 m s^{-1} and 10 m s^{-1} respectively collide. Their velocities after the collision will be (in m s^{-1})

	P	Q
(a)	0	25
(b)	5	20
(c)	10	15
(d)	20	5

36. A solid sphere is rotating about a diameter at an angular velocity ω. If it cools so that its radius reduces to $1/n$ of its original value, its angular velocity becomes

(a) $\frac{\omega}{n}$ (b) $\frac{\omega}{n^2}$ (c) $n\omega$ (d) $n^2\omega$

37. The current through choke coil increases from 0 to 6 A in 0.3 s and an induced emf of 30 V is produced. The inductance of the coil of choke is

(a) 2.5 H (b) 5 H (c) 1.5 H (d) 2 H

38. A resistance R, inductance L and capacitor C are connected in series to an oscillator of frequency υ. If resonant frequency is υ_r then current will lag the voltage when

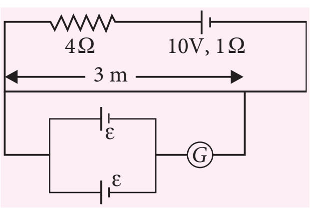
(a) $\upsilon = 0$ (b) $\upsilon < \upsilon_r$
(c) $\upsilon = \upsilon_r$ (d) $\upsilon > \upsilon_r$

39. In relation $X = 3YZ$, X and Z represents the dimensions of charge and magnetic field respectively. The dimensions of Y in MKS system is

(a) $[ML^{-2}T^{-1}A]$ (b) $[M^{-1}L^0T^3A^2]$
(c) $[M^{-2}L^2T^{-1}A]$ (d) $[MLT^{-1}A^2]$

40. Doppler's shift in frequency does not depend upon
(a) the frequency of wave produced
(b) the velocity of the source
(c) the velocity of the observer
(d) distance from the source to the observer

41. A resistance of 4 Ω and a wire of length 5 m and resistance 5 Ω are joined in series and connected to a cell of emf of 10 V and internal resistance 1 Ω. A parallel combination of two identical cells is balanced across 300 cm of the wire, then emf of unknown cell is



(a) 1.5 V (b) 3.0 V (c) 0.67 V (d) 1.33 V

42. A long solenoid is formed by winding 20 turns/cm the current necessary to produce a magnetic field of 20 mT inside the solenoid will be approximately

$\left(\frac{\mu_0}{4\pi} = 10^{-7}\ \text{T m A}^{-1}\right)$

(a) 8.0 A (b) 4.0 A (c) 2.0 A (d) 1.0 A

43. A moving coil galvanometer converted into an ammeter reads upto 0.03 A by connecting a shunt of resistance $4r$ across it and converted into an ammeter reads upto 0.06 A, when a shunt of resistance r is connected across it. What is the maximum current which can be sent through this galvanometer if no shunt is used?

(a) 0.01 A (b) 0.02 A (c) 0.03 A (d) 0.04 A

44. In a photoelectric experiment, the stopping potential V_S is plotted against the frequency υ of incident light. The resulting curve is a straight line which makes an angle θ with the x-axis. Then, $\tan\theta$ will be equal to (ϕ = work function of surface)

(a) $\frac{h}{e}$ (b) $\frac{e}{h}$ (c) $\frac{-\phi}{e}$ (d) $\frac{eh}{\phi}$

45. In a sample of radioactive substance, what percentage decays in one mean life time?

(a) 69.3 % (b) 63 % (c) 50 % (d) 36 %

ANSWER KEYS

1.	(a)	2.	(b)	3.	(a)	4.	(d)	5.	(c)
6.	(a)	7.	(b)	8.	(b)	9.	(a)	10.	(c)
11.	(c)	12.	(a)	13.	(b)	14.	(b)	15.	(c)
16.	(a)	17.	(b)	18.	(d)	19.	(c)	20.	(b)
21.	(c)	22.	(b)	23.	(d)	24.	(c)	25.	(a)
26.	(c)	27.	(c)	28.	(b)	29.	(c)	30.	(b)
31.	(d)	32.	(b)	33.	(c)	34.	(c)	35.	(c)
36.	(d)	37.	(c)	38.	(d)	39.	(b)	40.	(d)
41.	(b)	42.	(a)	43.	(b)	44.	(a)	45.	(b)

Solution Senders of Physics Musing

SET-34

1. Asit Srivastava, Meerut (Uttar Pradesh)
2. G. Geeth Nischal, Visakhapatnam (Andhra Pradesh)
3. B. Akhil, Hyderabad (Telangana)
4. Samarth Hawaldar, Indore (Madhya Pradesh)
5. Sudipta Ganguly, Paraganas (West Bengal)

CORE CONCEPT on

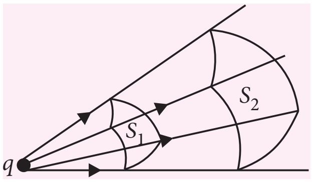
Electric Flux and Gauss's Law

Electric flux has two definitions, one conceptual and the other mathematical.

Conceptually it is defined in two different ways depending on the type of surface we are considering.

For open surface : It means the count of field lines that intersect the given surface.

For example, the flux through two surfaces S_1 and S_2 in front of the point charge q are identical since there cannot be a single field line which passes through S_1 but not through S_2, as below:



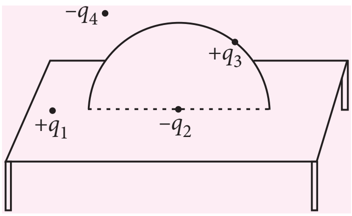
If the field lines are parallel to a surface, they are said to be grazing field lines and such field lines are not considered in flux since they are not intersecting.

For closed surface : It means the net count of field lines that either enter or leave a surface.

Conventionally, field lines that leave the surface are considered to be positive flux whereas field lines that enter the surface are negative flux.

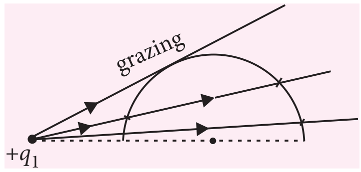
Let us see through examples what these definitions mean.

We consider a hemispherical bowl kept inverted on a table and few charges placed in its surroundings.



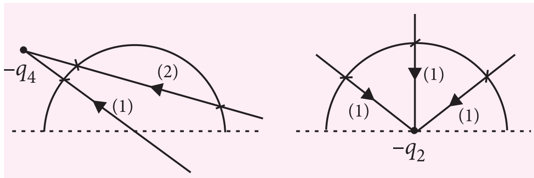
Which of the charges create a non-zero flux through the surface?

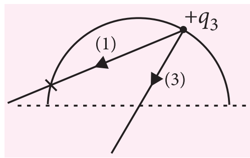
$+q_1$ is kept outside the hemisphere, hence if there is any field line which enters it at one point will necessarily leave at some other point since it is placed at the diametric plane as shown :



Hence flux due to $+q_1 = 0$.

$-q_4$ is also kept outside but there are some field lines which would intersect the surface only at one place hence would create a non-zero flux. Similarly, for $-q_2$ and $+q_3$ as well.





Lines marked (1) intersect surface only once hence they contribute in non-zero flux.

Line marked (2) intersects twice hence zero flux.

Line marked (3) does not intersect even once hence has a zero flux contribution.

From these discussions, one thing is obvious that for a closed surface there cannot be any net flux of a charge placed outside it, a charge placed inside or on the surface will only have a non-zero flux.

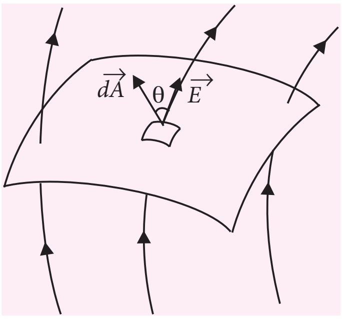
Now let us see the mathematical definition.

Mathematically, flux through any surface is defined as the integral of dot product of elemental area vector with the electric field strength.

A small element of the entire surface of area dA is chosen where the strength of electric field is $\vec{E}$. The direction of area vector is perpendicular to the surface, hence we chose an elemental area since the normal's direction would keep on changing for a curved surface

Contributed By: Bishwajit Barnwal, Aakash Institute, Kolkata

and moreover the strength of electric flux will remain constant even in variable field for this small element.

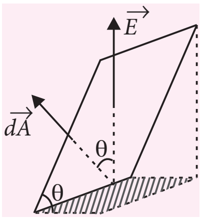


The electric flux through this small elemental area

$$d\phi = \vec{E}\cdot d\vec{A}$$

∴ Total flux through surface

$$\phi = \int \vec{E}\cdot d\vec{A} = \int EdA\cos\theta$$

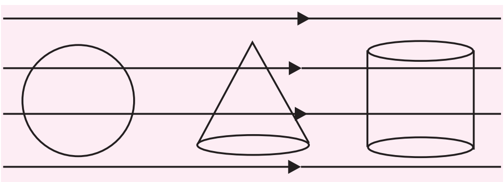


Let us try to decode the expression.

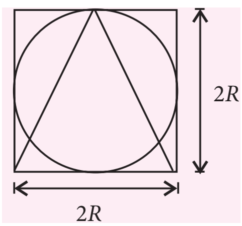
Let an elemental area $d\vec{A}$ be inclined at an angle θ with $\vec{E}$.

$dA\cos\theta$ which is the shaded portion, is the projection of the area dA perpendicular to the electric field. Hence, the flux through the actual surface (inclined at θ with electric field) is equal to the flux through the shaded surface.

For example, consider three surfaces - a sphere, a cylinder and a cone each of radius R placed in a uniform electric field as shown.



If we want to calculate the flux entering or leaving the surfaces of each, we can take the projection perpendicular to the uniform field as below:



$$\therefore \quad \phi_{\text{sphere}} = E(\pi R^2)$$

$$\phi_{\text{cone}} = E\left(\frac{1}{2}(2R)(2R)\right)$$

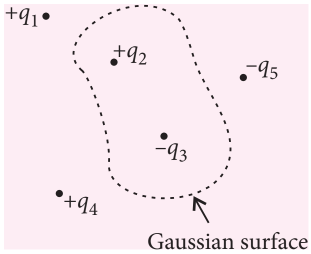
$$\phi_{\text{cylinder}} = E(2R)(2R)$$

With these basic understanding of flux clear we can move towards next section : Gauss's law.

GAUSS'S LAW

It states that the net electric flux through a closed surface is proportional to the charge enclosed within the surface, with a proportionality constant of $\left(\frac{1}{\varepsilon_0}\right)$.

The law is very analytical. Since the count of number of field lines emanating from a positive charge or terminating on a negative charge is proportional to the magnitude of the charge. Therefore, if positive charge enclosed with a surface is greater than negative charge, more field lines will emerge out of the surface than come inside. And obviously for the outside charges there would not be any flux as already discussed.



Let us try to understand this better with an example. In the diagram shown, we have arbitrarily chosen an irregular shaped closed surface which encloses charges $+q_2$ and $-q_3$.

∴ According to Gauss's law, flux through the Gaussian surface drawn,

$$\phi = \frac{+q_2 - q_3}{\varepsilon_0}$$

Generalising we can say, the flux through any closed surface

$$\phi = \oint \vec{E}\cdot d\vec{A} = \frac{q_{en}}{\varepsilon_0}$$

where $\vec{E}\cdot d\vec{A}$ is the flux through an elemental open surface of the given closed surface, where obviously the field lines of all non-touching charges will create flux. Hence $\vec{E}$ is the vector sum of the field due to all inside as well as outside charges.

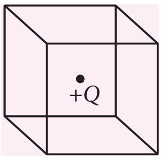
Now, let us see some beautiful applications of Gauss's law where even though we would not be knowing the strength of electric field at all places of the surface but using symmetry we would come to know the amount of flux through the surface desired.

Ex. A point charge $+Q$ is kept at
(i) body centre of a cube
(ii) face centre of a cube
(iii) edge centre of a cube
(iv) a vertex of a cube
Find the flux through faces of the cube in each case.

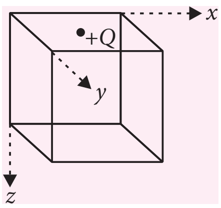
Soln.: (i) Since the charge's location from each of the 6 faces of cube identical, we conclude that the field lines will equally be distributed amongst all faces. The entire cube encloses charge $+Q$.

$$\therefore\ \phi_{cube} = \frac{+Q}{\varepsilon_0} = 6\phi_{each\ face}$$

$$\phi_{each\ face} = \frac{1}{6}\frac{Q}{\varepsilon_0}$$



(ii) The charge is placed at centre of the face in xy plane. With respect to this charge, four faces are identically placed - the one which are perpendicular to the xy plane. Hence, let flux through each of them be $\phi_\perp$.

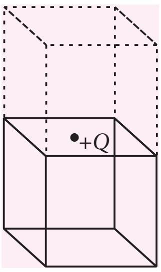


The face on the xy plane contains the charge hence field lines over this face are grazing. Hence will have no flux through it.

The other face which is parallel to xy plane will have a non-zero flux and different from the perpendicular faces, let this value be $\phi_{||}$. If we construct another cube just above the face on which the charge is placed. This will enclose the charge and the flux will equally be divided amongst the two as below:

$$\therefore\ 2\phi_{cube} = \frac{+Q}{\varepsilon_0}$$

$$\Rightarrow\ \phi_{cube} = \frac{1}{2}\frac{Q}{\varepsilon_0} = 4\phi_\perp + \phi_{||}$$

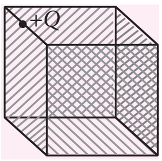


Individually flux values $\phi_\perp$ and $\phi_{||}$ cannot be calculated further.

(iii) To find the flux through cube, 3 more cubes needs to be symmetrically placed to enclose the charge.

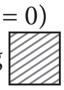
$$\therefore\ 4\phi_{cube} = \frac{+Q}{\varepsilon_0}$$

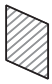
$$\therefore\ \phi_{cube} = \frac{1}{4}\frac{Q}{\varepsilon_0}$$



This flux is divided amongst 6 faces -

(a) 2 touching faces ($\phi = 0$)

(b) 2 faces with shading  and  has identical flux because of identical placement. Let this flux be ϕ_1 each.

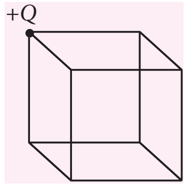
(c) 2 faces with shading  and  has identical flux for same reason. Let this flux be ϕ_2 each.

$$\therefore\ \phi_{cube} = \frac{1}{4}\frac{Q}{\varepsilon_0} = 2\phi_1 + 2\phi_2$$

(iv) To enclose the charge, 7 more cubes would be required.

$$\therefore\ 8\phi_{cube} = \frac{+Q}{\varepsilon_0}$$

$$\therefore\ \phi_{cube} = \frac{1}{8}\frac{Q}{\varepsilon_0}$$



Here, 3 faces are touching for which $\phi = 0$ but for remaining 3 non-touching faces flux will be identical.

$$3\phi_{non\text{-}touching} = \phi_{cube} = \frac{1}{8}\frac{Q}{\varepsilon_0}$$

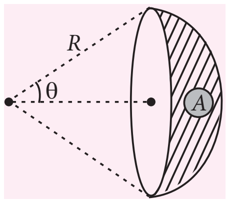
$$\Rightarrow\ \phi_{non\text{-}touching} = \frac{1}{24}\frac{Q}{\varepsilon_0}$$

Once you have understood this, we can move ahead, else visit the article again.

Concept of solid angle in flux calculation

Unlike planar angle, solid angle cannot be measured using a protractor. It has to be calculated as below:

The shaded portion is said to be cap of sphere and it is said to subtend a solid angle Ω at the centre where $\Omega = \frac{A}{R^2}$.



This value is found to be $2\pi(1-\cos\theta)$.

$$\therefore\ \Omega = \frac{A}{R^2} = 2\pi(1-\cos\theta)$$

It is measured in steradian.

Note that when $\theta = 180°$, entire sphere is formed for which $\Omega = 4\pi$ steradian.

Field lines from a point charge are uniformly distributed in three dimensional space. Therefore if the solid angle subtended by a surface on a point charge is known, we can apply unitary method to calculate the flux through the surface as below:

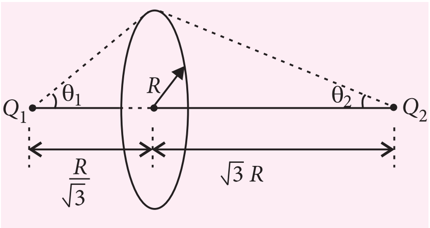
$$\text{Flux per unit solid angle} = \frac{Q/\varepsilon_0}{4\pi}$$

$\therefore$ Flux through the surface subtending solid angle Ω

$$\phi = \frac{Q/\varepsilon_0}{4\pi}\cdot\Omega = \frac{Q/\varepsilon_0}{4\pi}2\pi(1-\cos\theta)$$

$$\phi = \frac{Q}{2\varepsilon_0}(1-\cos\theta)$$

Ex. Two point charges $+Q_1$ and $+Q_2$ are placed on opposite sides of a circular disc as shown in the figure. Find the flux through the disc.



Soln.: Here, $\tan\theta_1 = \frac{R}{R/\sqrt{3}} = \sqrt{3}, \theta_1 = 60°$

$$\tan\theta_2 = \frac{R}{\sqrt{3}R} = \frac{1}{\sqrt{3}}, \theta_2 = 30°$$

The field lines from both point charges cross from opposite direction. Hence the difference of the flux would have to be taken.

$$\phi = \frac{Q_1}{2\varepsilon_0}(1-\cos\theta_1) - \frac{Q_2}{2\varepsilon_0}(1-\cos\theta_2)$$

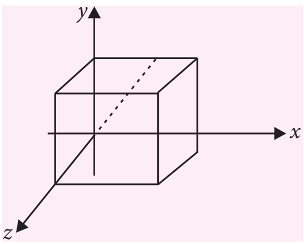
$$= \frac{Q_1}{2\varepsilon_0}\left(1-\frac{1}{2}\right) - \frac{Q_2}{2\varepsilon_0}\left(1-\frac{\sqrt{3}}{2}\right)$$

Many a times, we see questions in which position dependent field is given which is uniform in direction and then flux for a surface is to be calculated.

Let us see one such example :

Ex. A cubical surface of side length a is placed in a region where electric field is given by

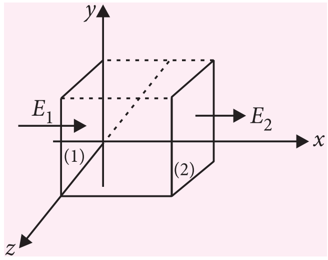
$$\vec{E} = E_0\left(1+\frac{x}{a}\right)\hat{i}$$



where x is the x-coordinate of the point. Find the charge enclosed within the cube.

Soln.: The direction of $\vec{E}$ suggests that only two surfaces will have non-zero flux, *i.e.* the ones parallel to yz plane while for remaining four faces the field lines are grazing.

For surface (1) and (2), the field are different but over their respective surfaces they are constant since x-coordinate does not change.



$$\therefore \quad \phi_{net} = \phi_{exit} - \phi_{enter} = E_2a^2 - E_1a^2$$

$$= \left(E_0\frac{(x_2-x_1)}{a}\right)a^2 = E_0a^2$$

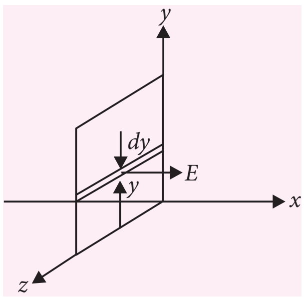
$$\therefore \quad \phi_{net} = \frac{q_{en}}{\varepsilon_0} = E_0a^2 \Rightarrow q_{en} = \varepsilon_0(E_0a^2)$$

Now, suppose the field was $\vec{E} = E_0\left(1+\frac{y}{a}\right)\hat{i}$, how would the answer change?

Again, the flux would be through those two surfaces only since the direction of the field has not changed. But now the field isn't dependent on x-coordinate and for the two surfaces (1) and (2), only x-co-ordinates is different. Therefore flux would be identical for them and through one of them field line enters while through other it leaves.

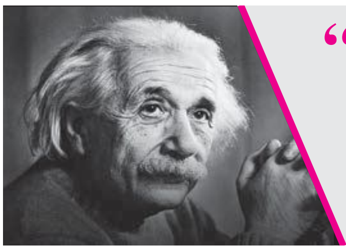
Hence $\phi_{net} = 0$. *i.e.,* $q_{en} = 0$

But if entering or exiting flux was supposed to be calculated, it could have been found out as below;



$$d\phi = EdA = E_0\left(1+\frac{y}{a}\right)(ady)$$

$$\Rightarrow \quad \phi = E_0\int_0^a (a+y)dy = E_0\left(a^2+\frac{a^2}{2}\right) = E_0\frac{3a^2}{2}$$



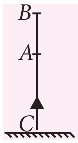
"Everybody is a genius. But if you judge a fish by its ability to climb a tree it will live its whole life believing that it is stupid"

– Albert Einstein

PHYSICS MUSING

SOLUTION SET-34

1. (d) : Taking upward direction as positive.
Initial velocity can be obtained by second kinematic equation, *i.e*, $s = ut + (1/2)\,at^2$
considering motion from C to A



$$14 = u \times 0.8 - \frac{1}{2} \times 10 \times 0.8^2$$

$$\therefore \quad u = \frac{43}{2}\ \text{m s}^{-1}$$

Let velocity magnitude at point $A = v$

so, $v = u - gt$

$$v = \frac{43}{2} - 10 \times 0.8 = \frac{27}{2}\ \text{m s}^{-1}$$

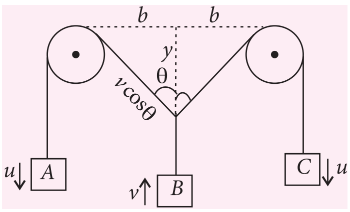
Hence time taken from A to B to A *i.e.* till same level

$$= \frac{2v}{g} = 2.7\ \text{s}$$

Hence the time instant at which the particle comes to the same level = 0.8 + 2.7 = 3.5 s

2. (b) : $v \cos\theta = u \Rightarrow v = u \sec\theta$

$$\frac{dv}{dt} = u \sec\theta \tan\theta \frac{d\theta}{dt} \qquad \text{... (i)}$$



$$\tan\theta = \frac{b}{y}$$

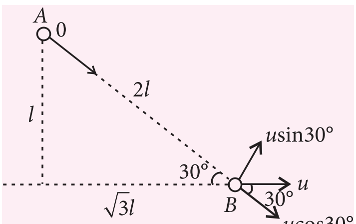
$$\Rightarrow \quad \sec^2\theta \frac{d\theta}{dt} = -\frac{b}{y^2}\frac{dy}{dt} \Rightarrow \frac{d\theta}{dt} = +\frac{b}{y^2}\cos^2\theta \frac{u}{\cos\theta}$$

$$\text{or,} \quad \frac{d\theta}{dt} = \frac{u\cos\theta}{b}\tan^2\theta \qquad \text{... (ii)}$$

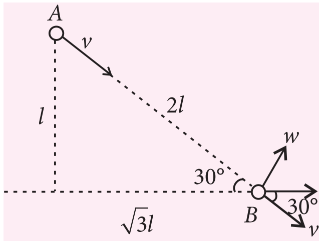
From equations (i) and (ii), we get

$$\Rightarrow \quad \frac{dv}{dt} = \frac{u^2}{b}\tan^3\theta$$

3. (a) :



Before the jerk



After the jerk

$\because \quad \vec{F}_{ext} = 0,$ using conservation of linear momentum along the string

$$mu \cos 30° = mv + mv$$

$$2v = u\frac{\sqrt{3}}{2} \Rightarrow v = \frac{\sqrt{3}}{4}u$$

4. (c): Let v be the speed of particle at B, just when it is about to loose contact.
From Newton's second law, for the particle normal to the spherical surface,

$$\frac{mv^2}{r} = mg\sin\beta \qquad \text{... (i)}$$

Applying conservation of energy as the block moves from A to B

$$\frac{1}{2}mv^2 = mg(r\cos\alpha - r\sin\beta) \qquad \text{... (ii)}$$

Solving equations (i) and (ii), we get

$$3 \sin\beta = 2 \cos\alpha$$

5. (b) : $(\lambda_{max})_S = 510$ nm, $(\lambda_{max})_{NS} = 350$ nm

By Wein's law, $(\lambda_{max})_S\ T_S = (\lambda_{max})_{NS}\ T_{NS}$

$$\frac{T_S}{T_{NS}} = \frac{350}{510} = \frac{35}{51} = 0.69$$

6. (d) : $v_{rms} = \sqrt{\dfrac{1^2 + 2^2 + 3^2 + ... + N^2}{N}}$

$$\Rightarrow \quad v_{rms} = \sqrt{\frac{N(N+1)(2N+1)}{6N}}$$

$$\text{or} \quad v_{rms} = \sqrt{\frac{(N+1)(2N+1)}{6}} \qquad \text{...(i)}$$

$$v_{av} = \frac{1+2+3+....+N}{N}$$

$$\text{or} \quad v_{av} = \frac{N(N+1)}{2N} = \frac{(N+1)}{2} \qquad \text{...(ii)}$$

From equations (i) and (ii)

$$\frac{v_{rms}}{v_{av}} = 2\sqrt{\frac{(2N+1)}{6(N+1)}}$$

7. (d) : $W = \frac{1}{2}P_0V_0$, $T_A = T_0$, $T_B = 2T_0$, $T_C = 4T_0$

Heat supplied $= Q_{AB} + Q_{BC} = C_VT_0 + C_P2T_0$

$$= \frac{13}{2}RT_0 = \frac{13}{2}P_0V_0$$

$\therefore$ Efficiency of the cyclic process

$$= \frac{\frac{1}{2}P_0V_0}{\frac{13}{2}P_0V_0}\times 100 = \frac{1}{13}\times 100 = 7.7\%$$

8. (c): The rate of heat flow through the layer of the ice,

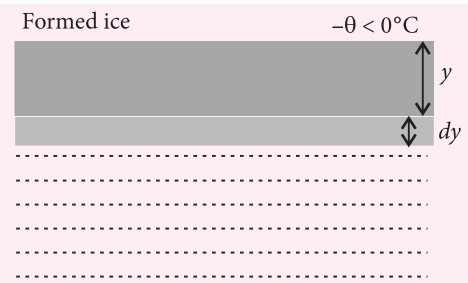
$$i_H = \frac{0-(-\theta)}{(y/KA)} = \frac{\theta KA}{y} = \frac{dQ}{dt} \quad ...(i)$$

Also, rate of heat gain during fusion of ice,

$$\frac{dQ}{dt} = L\frac{dm}{dt} = L\rho.A\frac{dy}{dt} \quad ...(ii)$$

From equations (i) and (ii), we get

$$\frac{KA\theta}{y} = \rho AL\frac{dy}{dt}$$



$$\int_2^4 y\,dy = \int_0^{3600}\left(\frac{K\theta}{\rho L}\right)dt$$

$$\left[\frac{y^2}{2}\right]_2^4 = \frac{K\theta}{\rho L}[t]_0^{3600}$$

$$\Rightarrow \frac{1}{2}\times[16-4] = \frac{4\times 10^{-3}\times\theta\times(3600-0)}{0.9\times 80}$$

$$\Rightarrow \theta = \frac{1}{2}\times\frac{12\times 0.9\times 80}{4\times 3600\times 10^{-3}} = 30°C$$

$\therefore$ The atmospheric temperature $= -\theta = -30°C$

9. (c): Let particle make an angle θ with the horizontal.

$$\tan\theta = \frac{9-1}{4-0} = 2$$

$$y = u_yt + \frac{1}{2}a_yt^2$$

Now, $-1 = u\sin\theta\,(1) - \frac{1}{2}g(1)^2$ or $u\sin\theta = 4$

and $\sin\theta = \frac{2}{\sqrt{5}} \Rightarrow u = 2\sqrt{5}$ m s^{-1}

$$x = u\cos\theta\times 1 = 2\sqrt{5}\times\frac{1}{\sqrt{5}} = 2 \text{ m}$$

10. (c): $dW = dQ - dU$

$dW = nCdT - nC_VdT$

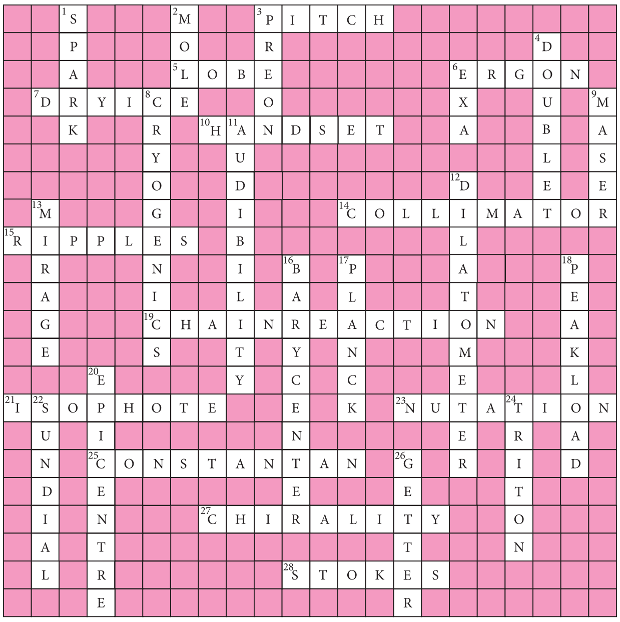
$$W = \int CdT - \int C_VdT$$

$$= \int\frac{a}{T}dT - C_V\Delta T$$

$$= a\ln\left(\frac{\eta T_0}{T_0}\right) - \frac{(\eta T_0 - T_0)R}{\gamma - 1}$$

$$W = a\ln\eta - \frac{(\eta-1)}{(\gamma-1)}RT_0$$

SOLUTION OF MAY 2016 CROSSWORD



Winners (May 2016)

1. Debasrija Mondal, Kharagpur (West Bengal)
2. Vishwajeet Patel, Kota (Rajasthan)
3. K. Srishyam, Mumbai (Maharashtra)

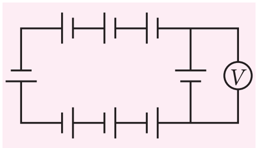
Solution Senders (April 2016)

1. Debasrija Mondal, Kharagpur (West Bengal)
2. Devjit Acharjee, Kolkata (West Bengal)

BOOST your NEET score

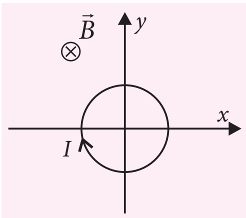
Practice paper for phase II

1. In the circuit shown in the figure, each battery is of 5 V and has an internal resistance of 0.2 Ω. The reading in the ideal voltmeter V is



(a) zero (b) 5 V (c) 7.5 V (d) 10 V

2. A conducting loop, carrying a current I, is placed in a uniform magnetic field pointing into the plane of the paper as shown in the figure. The loop will have a tendency to



(a) contract (b) expand
(c) move towards +x-axis
(d) move towards –x-axis.

3. A spherical black body with a radius of 12 cm radiates 450 W power at 500 K. If the radius is halved and the temperature is doubled, the power radiated in watt would be
(a) 225 (b) 450 (c) 900 (d) 1800

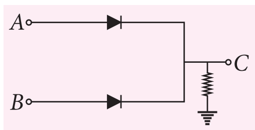
4. An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon_r = 4$.
(a) The wavelength and frequency both remain unchanged.
(b) The wavelength is doubled and the frequency remains unchanged.
(c) The wavelength is doubled and the frequency becomes half.
(d) The wavelength is halved and the frequency remains unchanged.

5. The Earth's magnetic field at a given point is 0.5×10^{-5} Wb m^{-2}. This field is to be annulled by magnetic induction at the centre of a circular loop of radius 5 cm. The current required to be flown in the loop is nearly
(a) 0.2 A (b) 0.4 A (c) 4 A (d) 40 A

6. The molar heat capacity of oxygen gas at STP is nearly 2.5 R. As the temperature is increased, it gradually increases and approaches 3.5 R. The most appropriate reason for this behaviour is that at high temperatures
(a) oxygen does not behave as an ideal gas
(b) oxygen molecules dissociate in atoms
(c) the molecules collide more frequently
(d) molecular vibrations gradually become effective.

7. Two cells of emfs approximately 5 V and 10 V are to be accurately compared using a potentiometer of length 400 cm.
(a) The battery that runs the potentiometer should have voltage of 8 V.
(b) The battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V.
(c) The first portion of 50 cm of wire itself should have a potential drop of 10 V.
(d) Potentiometer is usually used for comparing resistances and not voltages.

8. In the circuit below, A and B represent two inputs and C represents the output. The circuit represents



(a) OR gate (b) NOR gate
(c) AND gate (d) NAND gate

9. A metal rod moves at a constant velocity in a direction perpendicular to its length. A constant uniform magnetic field exists in space in a direction perpendicular to the rod as well as its velocity. Select the correct statement from the following.

(a) The entire rod is at same electric potential.
(b) There is an electric field in the rod.
(c) The electric potential is highest at the centre of the rod and decreases towards its ends.
(d) The electric potential is lowest at the centre of the rod and increases towards its ends.

10. The Marina trench is located in the Pacific Ocean and at one place it is nearly 11 km beneath the surface of water. The water pressure at the bottom of the trench is about 1.01×10^8 Pa. A steel ball of initial volume 0.32 m^3 is dropped into the ocean and falls to the bottom of the trench. What is the change in the volume of the ball when it reaches to the bottom? (Bulk modulus of steel = 1.6×10^{11} Pa)
(a) 1.01×10^{-4} m^3 (b) 2.02×10^{-4} m^3
(c) 3.03×10^{-5} m^3 (d) 4.04×10^{-3} m^3

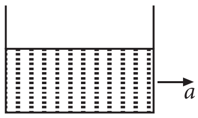
11. A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth $4y$ from the top. When the tank is completely filled with water, the quantities of water flowing out per second from both holes are the same. Then, R is equal to
(a) $\frac{L}{\sqrt{2\pi}}$ (b) $2\pi L$ (c) L (d) $\frac{L}{2\pi}$

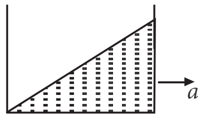
12. An ideal gas is filled in a closed rigid and thermally insulated container. A coil of 100 Ω resistor carrying current 1 A supplies heat for 5 minute to the gas. The change in internal energy of gas is
(a) 10 kJ (b) 30 kJ (c) 20 kJ (d) 0 kJ

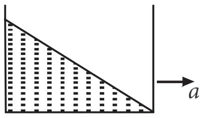
13. A nucleus of $^{210}_{84}Po$ originally at rest emits α-particle with speed v. What will be the recoil speed of the daughter nucleus?
(a) $\frac{4v}{206}$ (b) $\frac{4v}{214}$ (c) $\frac{v}{206}$ (d) $\frac{v}{214}$

14. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field $\vec{B}$. The work done to rotate the loop by 30° about an axis perpendicular to its plane is
(a) MB (b) $\sqrt{3}\frac{MB}{2}$ (c) $\frac{MB}{2}$ (d) zero

15. A vessel containing water is given a constant acceleration a towards the right along a straight horizontal path. Which of the following diagrams in the figure represent the surface of the liquid?

(a) 

(b) 

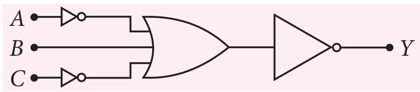
(c) 

(d) none of these

16. A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance $2C$ is similarly charged to a potential difference $2V$. The charging battery is now disconnected and the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of the other. The final energy of the configuration is
(a) zero (b) $\frac{3}{2}CV^2$ (c) $\frac{25}{6}CV^2$ (d) $\frac{9}{2}CV^2$

17. A composite rod made of copper ($\alpha = 1.8 \times 10^{-5}$ K^{-1}) and steel ($\alpha = 1.2 \times 10^{-5}$ K^{-1}) is heated. Then
(a) it bends with steel on concave side
(b) it bends with copper on concave side
(c) it does not expand
(d) data is insufficient

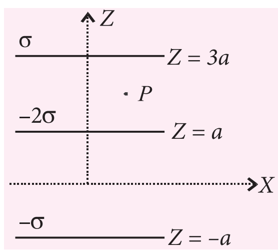
18. The logic circuit given in the figure performs the logic operation



(a) $A \cdot B \cdot C$ (b) $A \cdot B \cdot \bar{C}$ (c) $A \cdot \bar{B} \cdot C$ (d) $\bar{A} \cdot B \cdot \bar{C}$

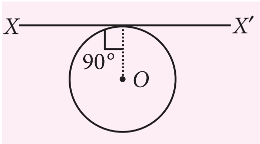
19. The coordinates of a moving particle at any time are given by $x = \alpha t^3$ and $y = \beta t^3$. The speed of the particle at time t is given by
(a) $3t\sqrt{\alpha^2 + \beta^2}$ (b) $3t^2\sqrt{\alpha^2 + \beta^2}$
(c) $t^2\sqrt{\alpha^2 + \beta^2}$ (d) $\sqrt{\alpha^2 + \beta^2}$

20. Three infinitely long charge sheets are placed as shown in figure. The electric field at point P is



(a) $\frac{2\sigma}{\varepsilon_0}\hat{k}$
(b) $\frac{4\sigma}{\varepsilon_0}\hat{k}$
(c) $-\frac{2\sigma}{\varepsilon_0}\hat{k}$ (d) $-\frac{4\sigma}{\varepsilon_0}\hat{k}$

21. A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown in the figure.



The moment of inertia of the loop about the axis XX' is

(a) $\frac{\rho L^3}{8\pi^2}$ (b) $\frac{\rho L^3}{16\pi^2}$ (c) $\frac{5\rho L^3}{16\pi^2}$ (d) $\frac{3\rho L^3}{8\pi^2}$

22. Two rods of lengths d_1 and d_2 and coefficients of thermal conductivities K_1 and K_2 are kept in contact with each other end to end. The equivalent thermal conductivity is

(a) $K_1d_1 + K_2d_2$ (b) $K_1 + K_2$

(c) $\frac{K_1d_1 + K_2d_2}{d_1 + d_2}$ (d) $\frac{d_1 + d_2}{\left(\frac{d_1}{K_1} + \frac{d_2}{K_2}\right)}$

23. Monochromatic radiation of wavelength λ is incident on a hydrogen sample in ground state. Hydrogen atoms absorb a fraction of light and subsequently emit radiation of six different wavelengths. Find the value of λ.

(a) 120 nm (b) 130 nm

(c) 97.5 nm (d) 107.5 nm

24. A liquid drop of diameter 4 mm breaks into 1000 droplets of equal size. Calculate the resultant change in surface energy, the surface tension of the liquid is 0.07 N m^{-1}.

(a) 1.5×10^{-3} J (b) 2.5×10^{-5} J

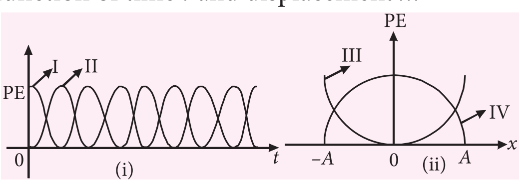
(c) 2.1×10^{-3} J (d) 3.2×10^{-5} J

25. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Two objects each of mass m, are attached gently to the opposite ends of a diameter of the ring. The wheel now rotates with an angular velocity

(a) $\frac{\omega M}{(M+m)}$ (b) $\frac{\omega(M-2m)}{(M+2m)}$

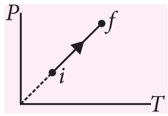
(c) $\frac{\omega M}{(M+2m)}$ (d) $\frac{\omega(M+2m)}{M}$

26. For a particle executing SHM, the displacement x is given by $x = A\cos\omega t$. Identify the graph which represents the variation of potential energy (PE) as a function of time t and displacement x.



(a) I, III (b) II, IV (c) II, III (d) I, IV

27. An ideal gas goes from the state i to the state f as shown in the figure. The work done by the gas during the process

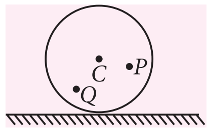


(a) is positive (b) is negative

(c) is zero

(d) cannot be obtained from this information.

28. A disc is rolling without slipping with angular velocity ω. P and Q are two points equidistant from the centre C. The order of magnitude of velocity is



(a) $v_Q > v_C > v_P$ (b) $v_P > v_C > v_Q$

(c) $v_P = v_C$, $v_Q = v_C/2$ (d) $v_P < v_C > v_Q$

29. Two vibrating strings of the same material but lengths L and $2L$ have radii $2r$ and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes, one of length L with frequency υ_1 and the other with frequency υ_2. The ratio υ_1/υ_2 is given by

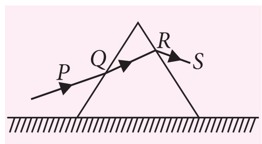
(a) 2 (b) 4 (c) 8 (d) 1

30. A pendulum suspended from the roof of an elevator at rest has a time period T_1. When the elevator moves up with an acceleration a its time period becomes T_2, when the elevator moves down with an acceleration a, its time period becomes T_3, then

(a) $T_1 = \sqrt{T_2T_3}$ (b) $T_1 = \sqrt{T_2^2 + T_3^2}$

(c) $T_1 = \frac{T_2T_3\sqrt{2}}{\sqrt{T_2^2 + T_3^2}}$ (d) $T_1 = \frac{T_2T_3}{\sqrt{T_2^2 + T_3^2}}$

31. An equilateral prism is placed on a horizontal surface. A ray PQ is incident onto it. For minimum deviation



(a) PQ is horizontal (b) QR is horizontal

(c) RS is horizontal (d) any one will be horizontal.

32. If g is the acceleration due to gravity on the earth's surface, the gain in the potential energy of an object of mass m raised from the surface of the earth to a height equal to the radius R of the earth, is

(a) $\frac{1}{2}mgR$ (b) $2mgR$ (c) mgR (d) $\frac{1}{4}mgR$

33. A vessel contains 1 mole of O_2 gas (molar mass 32) at a temperature T. The pressure of the gas is P. An identical vessel containing one mole of He gas (relative molar mass 4) at a temperature $2T$ has a pressure of

(a) $P/8$ (b) P (c) $2P$ (d) $8P$

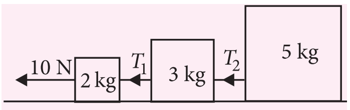
34. A body of mass $4m$ at rest explodes into three pieces. Two of the pieces each of mass m move with a speed v each in mutually perpendicular directions. The total kinetic energy released is

(a) $\frac{1}{2}mv^2$ (b) mv^2 (c) $\frac{3}{2}mv^2$ (d) $\frac{5}{2}mv^2$

35. Temperature of oxygen kept in a vessel is raised by 1°C at constant volume. Heat supplied to the gas may be taken partly as translational and partly rotational kinetic energies. Their respective shares are

(a) 60%, 40% (b) 50%, 50%
(c) 100%, zero (d) 40%, 60%

36. Three blocks of masses 2 kg, 3 kg and 5 kg are connected to each other with light string and are then placed on a frictionless surface as shown in the figure. The system is pulled by a force F = 10 N, then tension T_1 is



(a) 1 N (b) 5 N (c) 8 N (d) 10 N

37. A freshly prepared radioactive source of half-life 2 h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is

(a) 6 h (b) 12 h (c) 24 h (d) 128 h

38. A ball, whose kinetic energy is E, is projected at an angle of 45° to the horizontal. What will be the kinetic energy of the ball at the highest point of its flight?

(a) E (b) $2E$ (c) $E/2$ (d) $E/3$

39. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between the resultant intensities at A and B is

(a) I (b) $4I$ (c) $5I$ (d) $7I$

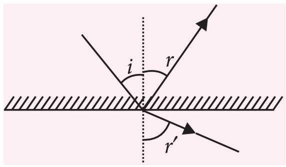
40. A heat engine operates between a cold reservoir at temperature T_2 = 300 K and a hot reservoir at temperature T_1. It takes 200 J of heat from the hot reservoir and delivers 120 J of heat to the cold reservoir in a cycle. What could be the minimum temperature of the hot reservoir?

(a) 350 K (b) 400 K (c) 300 K (d) 500 K

41. An engine of mass 6.5 metric ton is going up on incline of 5 in 13 at the rate of 9 km h^{-1}. Calculate the power of the engine if $\mu = \frac{1}{12}$ and g = 9.8 m s^{-2}.

(a) 29.5 kW (b) 73.5 kW
(c) 51.5 kW (d) 105.3 kW

42. A ray of light from a denser medium strikes a rarer medium at an angle of incidence i (see figure). The reflected and refracted rays make an angle of 90° with each other. The angles of reflection and refraction are r and r'. The critical angle is



(a) $\sin^{-1}(\tan r)$ (b) $\sin^{-1}(\tan i)$
(c) $\sin^{-1}(\tan r')$ (d) $\tan^{-1}(\sin i)$

43. The dimensions of $\left(\frac{1}{2}\varepsilon_0 E^2\right)$ is

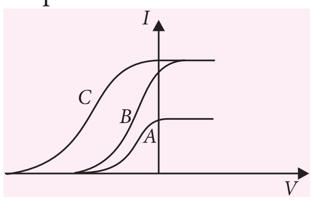
(ε_0 : permittivity of free space, E : electric field)

(a) $[MLT^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^{-1}T^{-2}]$ (d) $[ML^2T^{-1}]$

44. The size of the image of an object, which is at infinity, as formed by a convex lens of focal length 30 cm is 2 cm. If a concave lens of focal length 20 cm is placed between the convex lens and the image at a distance of 26 cm from the convex lens, calculate the new size of the image.

(a) 1.25 cm (b) 2.5 cm
(c) 1.05 cm (d) 2 cm

45. In a photoelectric experiment anode potential is plotted against plate current.



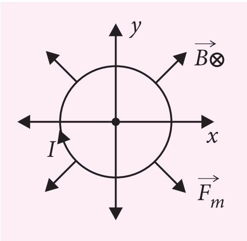
(a) A and B will have same intensities while B and C will have different frequencies
(b) B and C will have different intensities while A and B will have different frequencies
(c) A and B will have different intensities while B and C will have equal frequencies
(d) B and C will have equal intensities while A and B will have same frequencies.

SOLUTIONS

1. (a) : Current in the circuit, $I = \frac{8\times 5\text{ V}}{8\times 0.2\ \Omega} = 25$ A

Reading of voltmeter, $V = \varepsilon - Ir = 5 - 25\times 0.2 = 0$

2. **(b) :** According to Fleming's left hand rule, it is clear that force acting on each part of the loop is radially outwards. The loop will have a tendency to expand under the force acting along outward drawn normal.



3. **(d) :** According to Stefan's law,
Energy radiated, $E = eA\sigma T^4(\Delta t)$

$\therefore \frac{E}{\Delta t} = e \times 4\pi r^2 \times \sigma T^4$

or Power $(P) = (4\pi e\sigma)r^2T^4 \therefore \frac{P_2}{P_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4$

or $\frac{P_2}{450} = \left(\frac{r_1/2}{r_1}\right)^2 \times \left(\frac{2T_1}{T_1}\right)^4$

or $P_2 = 450 \times \left(\frac{1}{4}\right) \times \left(\frac{16}{1}\right) = 450 \times 4$

or $P_2 = 1800$ W

4. **(d) :** Frequency remains unchanged with change of medium.

$$n(\text{refractive index}) = \frac{c}{v} = \frac{\frac{1}{\sqrt{\varepsilon_0\mu_0}}}{\frac{1}{\sqrt{\varepsilon\mu}}} = \sqrt{\varepsilon_r\mu_r}$$

Since μ_r is very close to 1, $n = \sqrt{\varepsilon_r} = \sqrt{4} = 2$

Thus, $\lambda_{\text{medium}} = \frac{\lambda}{n} = \frac{\lambda}{2}$

5. **(b) :** Magnetic induction at the centre of a current carrying circular loop

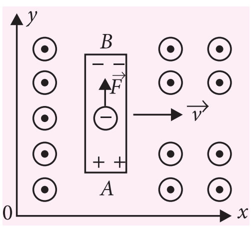
$$B = 10^{-7}\left(\frac{2\pi I}{R}\right) \Rightarrow I = \frac{BR}{2\pi \times 10^{-7}}$$
$$= \frac{(0.5\times10^{-5})(5\times10^{-2})}{2(3.14)\times10^{-7}} \approx 0.4 \text{ A}$$

6. **(d)**

7. **(b) :** The balance point can be obtained only if the potential difference across the wire is greater than the emfs to be compared (or measured).

8. **(a) :** The given circuit represents an OR gate. When either A or B or both inputs are high, the output C is high.

9. **(b) :** Let the metal rod AB move parallel to x-axis. Let the uniform magnetic field point in positive z-direction. The free electrons of the metal rod will experience magnetic force towards B.



There will be excess of electrons on B-end and shortage of electrons on A-end.
The end A becomes positively charged and the end B becomes negatively charged. An electric field is therefore set up in the metal rod. Option (b) is correct.

10. **(b) :** Here $p = 1.01 \times 10^8$ Pa, $V = 0.32$ m^3
For steel, $\kappa = 1.6 \times 10^{11}$ Pa

As $\kappa = \frac{p}{\Delta V/V}$

$\therefore \Delta V = \frac{pV}{\kappa} = \frac{1.01\times10^8\times0.32}{1.60\times10^{11}} = 2.02 \times 10^{-4}$ m^3

11. **(a) :** Velocity of efflux, $v = \sqrt{2gh}$
where h denotes the depth of the hole.
The quantities of water flowing out per second from both holes are given to be the same.
Applying equation of continuity, we have

$a_1v_1 = a_2v_2$ or $L^2 \times \sqrt{2gy} = \pi R^2 \times \sqrt{2g(4y)}$

or $L^2 = 2\pi R^2$ or $R = \frac{L}{\sqrt{2\pi}}$

12. **(b) :** Internal energy = Heat supplied, as $\Delta W = 0$.
$\therefore \Delta U = I^2Rt$
$= (1)^2 \times (100) \times (5 \times 60) = 30{,}000$ J = 30 kJ.

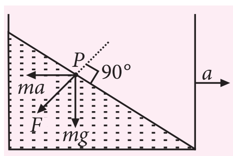
13. **(a) :** ${}^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{X} + {}^{4}_{2}\text{He}$
Using linear momentum conservation principle,
$mv = m_1v_1 + m_2v_2$

$210 \times 0 = 206\, v_1 + 4v$ or $v_1 = -\frac{4v}{206}$

Recoil speed of daughter nucleus $= \frac{4v}{206}$

14. **(d) :** No work is done to rotate the loop about an axis perpendicular to its plane as $\vec{M}$ is directed along the axis. Work is done only when the plane of the loop rotates.

15. **(c):** When a vessel containing water is given a constant acceleration a towards the right, a force acts on water towards right.



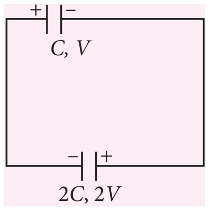
As an action the water exerts a force on the wall of vessel towards right. As a reaction the wall pushes the water towards left. The slope of water is as shown in figure. At equilibrium, consider P is a particle of water. F is the resultant of mg and ma (pseudo force).
The surface of water should set itself at 90° to F.
Hence (c) represents the surface of liquid.

16. **(b) :** C and $2C$ are in parallel to each other.
$\therefore$ Resultant capacity, $C_R = (2C + C) = 3C$

Net potential, $V_R = 2V - V = V$

$\therefore$ Final energy $= \frac{1}{2}C_R(V_R)^2$

$= \frac{1}{2}(3C)(V)^2 = \frac{3}{2}CV^2$



17. (a) : As $\alpha_{copper} > \alpha_{steel}$
Copper expands more than steel. So rod bends with copper on convex side and steel on concave side.

18. (c) : The output of the circuit is

$$Y = \overline{\overline{A} + B + \overline{C}} \quad \therefore \quad \overline{Y} = \overline{A} + B + \overline{C}$$

Applying De Morgan's theorem,

$$\overline{\overline{Y}} = \overline{\overline{A}} \cdot \overline{B} \cdot \overline{\overline{C}} \quad \text{or} \quad Y = A \cdot \overline{B} \cdot C$$

19. (b) : As $x = \alpha t^3$

$\therefore \quad v_x = \frac{dx}{dt} = 3\alpha t^2$

Also, $y = \beta t^3$ $\qquad \therefore \quad v_y = \frac{dy}{dt} = 3\beta t^2$

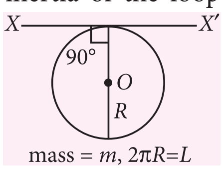
Hence, $v = \sqrt{v_x^2 + v_y^2} = \sqrt{(3\alpha t^2)^2 + (3\beta t^2)^2}$

$= 3t^2\sqrt{\alpha^2 + \beta^2}$

20. (c): All the three charge sheets will produce electric field at P. The field will be along negative Z-axis.

Hence $\vec{E} = \left[\frac{\sigma}{2\varepsilon_0} + \frac{2\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}\right](-\hat{k})$ or $\vec{E} = -\frac{2\sigma}{\varepsilon_0}\hat{k}$

21. (d) : Let I denote moment of inertia of the loop about the axis XX'.



$\therefore \quad I = \frac{mR^2}{2} + mR^2 = \frac{3}{2}mR^2$

Now m = mass of loop
or $m = L\rho$

Again $2\pi R = L$ or $R = \frac{L}{2\pi}$

$\therefore \quad I = \frac{3}{2}(L\rho)\left(\frac{L}{2\pi}\right)^2$ or $I = \frac{3L^3\rho}{8\pi^2}$

22. (d) : Same amount of heat flows through the two rods in series combination. Let T_0 be the temperature of the junction.

$$Q = \frac{A(T_1 - T_2)t}{\frac{d_1 + d_2}{K}} = \frac{A(T_1 - T_0)t}{(d_1/K_1)} = \frac{A(T_0 - T_2)t}{(d_2/K_2)}$$

Also, $(T_1 - T_2) = (T_1 - T_0) + (T_0 - T_2)$

$\therefore \quad \frac{d_1 + d_2}{K} = \frac{d_1}{K_1} + \frac{d_2}{K_2} \qquad \therefore \quad K = \frac{d_1 + d_2}{\frac{d_1}{K_1} + \frac{d_2}{K_2}}$

23. (c): As the hydrogen atoms emit radiation of six different wavelengths, some of them must have been excited to $n = 4$. The energy in $n = 4$ state is

$$E_4 = \frac{E_1}{4^2} = -\frac{13.6\text{ eV}}{16} = -0.85\text{ eV}.$$

The energy needed to take a hydrogen atom from its ground state to $n = 4$ is 13.6 eV – 0.85 eV = 12.75 eV.
The photons of the incident radiation should have 12.75 eV of energy. So

$$\frac{hc}{\lambda} = 12.75\text{ eV}$$

or $\quad \lambda = \frac{hc}{12.75\text{ eV}} = \frac{1242\text{ eV nm}}{12.75\text{ eV}} \approx 97.5\text{ nm}$

24. (d) : Volume of 1000 droplets = Volume of larger drop

$$1000 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$r = \frac{R}{10} = \frac{2 \times 10^{-3}\text{ m}}{10} = 2 \times 10^{-4}\text{ m}$$

Surface area of larger drop
$= 4\pi R^2 = 4\pi\,(2 \times 10^{-3})^2 = 16\pi \times 10^{-6}\text{ m}^2$
Surface area of 1000 droplets
$= 4\pi r^2 \times 1000 = 4\pi \times (2 \times 10^{-4})^2 \times 1000$
$= 16\pi \times 10^{-5}\text{ m}^2$
$\therefore$ Increase in surface area
$= 16\pi \times 10^{-6}(10 - 1) = 144\pi \times 10^{-6}\text{ m}^2$
The resultant increase in surface energy
= Surface tension × increase in surface area

$$= 0.07 \times 144 \times \frac{22}{7} \times 10^{-6} = 3168 \times 10^{-8}\text{ J} \approx 3.2 \times 10^{-5}\text{ J}$$

25. (c): Since the two objects are attached gently to the ring, no external torque is applied to the system. Therefore angular momentum of the system remains constant.

$$I_1\omega_1 = I_2\omega_2$$

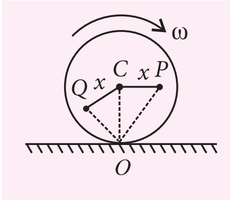
$$\therefore \quad \omega_2 = \frac{I_1\omega_1}{I_2} = \frac{Mr^2\omega}{(Mr^2 + 2mr^2)} = \frac{\omega M}{(M + 2m)}$$

26. (a) : The first graph illustrates variation of potential energy with time.
The equation $x = A\cos\omega t$ describes SHM when the particle starts swinging from the extreme position. PE is maximum at the extreme position. Hence at $t = 0$, the potential energy is maximum. The curve I represents PE versus t graph.
The second graph illustrates the variation of PE with x, PE $= \frac{1}{2}m\omega^2x^2$

27. (c) : We know, $PV = nRT$
From given figure, $P \propto T$ and n and R are constant,
$\therefore \quad V$ = constant *i.e.* process is isochoric.
So, work done by the gas during the isochoric process is zero.

28. (b) : Given: $CP = CQ = x$

where C is the centre of the rolling disc. P and Q are two points on disc. In pure rolling, the instantaneous velocity is zero at the lower most point.



This point is denoted as O which is the instantaneous point of rotation. Linear velocity $v = r\omega$, where r is the distance of the point from O.

From figure, $OP > OC > OQ$ or $r_P > r_C > r_Q$

$\therefore \quad v_P > v_C > v_Q$

29. (d) : For a vibrating string, in fundamental mode,

$$\upsilon = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \quad \because \quad \mu = \frac{\text{Mass}}{\text{length}}$$

$$\therefore \ \mu = \frac{\text{volume} \times \text{density}}{\text{length}} = \frac{\pi r^2 l \rho}{l} = \pi r^2 \rho$$

$$\therefore \ \upsilon = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} = \frac{1}{2lr}\sqrt{\frac{T}{\pi\rho}}$$

$$\therefore \ \frac{\upsilon_1}{\upsilon_2} = \left(\frac{l_2}{l_1}\right)\left(\frac{r_2}{r_1}\right) \text{ as } T, \rho \text{ are same.}$$

For υ_1, $l_1 = L$ and $r_1 = 2r$

For υ_2, $l_2 = 2L$ and $r_2 = r$.

$$\therefore \ \frac{\upsilon_1}{\upsilon_2} = \left(\frac{2L}{L}\right)\left(\frac{r}{2r}\right) \Rightarrow \frac{\upsilon_1}{\upsilon_2} = 1$$

30. (c) : $T_1 = 2\pi\sqrt{\dfrac{l}{g}}$ or $\dfrac{4\pi^2 l}{T_1^2} = g$

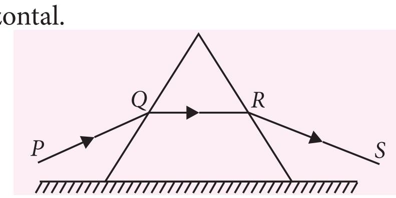
$$T_2 = 2\pi\sqrt{\frac{l}{g+a}} \text{ or } \frac{4\pi^2 l}{T_2^2} = g + a$$

$$T_3 = 2\pi\sqrt{\frac{l}{g-a}} \text{ or } \frac{4\pi^2 l}{T_3^2} = g - a$$

$$\therefore \ \frac{4\pi^2 l}{T_2^2} + \frac{4\pi^2 l}{T_3^2} = 2g = 2\frac{4\pi^2 l}{T_1^2}$$

$$\text{or} \quad T_1 = \frac{\sqrt{2}T_2T_3}{\sqrt{T_2^2 + T_3^2}}.$$

31. (b) : In equilateral prism, the refracted ray QR runs parallel to base. Base is horizontal. Hence QR is horizontal.



32. (a) : At surface of earth, $U_1 = -\dfrac{GmM}{R}$

At height h from surface, $U_2 = \dfrac{-GmM}{R+h}$

If $h = R, U_2 = -\dfrac{GmM}{2R}$

$\therefore \quad \Delta U = U_2 - U_1$

or $\quad \Delta U = -\dfrac{GmM}{2R} + \dfrac{GmM}{R}$

$$= \frac{GmM}{2R} = \frac{mgR}{2} \quad \left(\because \ g = \frac{GM}{R^2}\right)$$

$\therefore$ Gain in PE of object raised up $= \dfrac{mgR}{2}$

33. (c) : We know, $PV = nRT$

$$\frac{P_1}{P_2} = \frac{T_1}{T_2} \quad (\because \ V \text{ and } n \text{ are same})$$

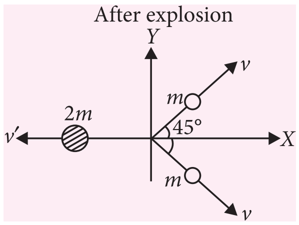
$$\frac{P}{P_2} = \frac{T}{2T} \text{ or } P_2 = 2P$$

34. (c) : Total mass = $4m$

Mass of each of the two small pieces = m

Mass of third piece = $4m - 2m = 2m$

By conservation of momentum along horizontal direction,



$2mv' = mv\cos45° + mv\cos45°$

$$= 2mv\frac{1}{\sqrt{2}} \qquad \therefore \quad v' = \frac{v}{\sqrt{2}}$$

Total kinetic energy released

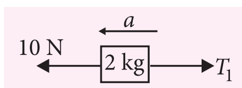
$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2} \times 2m \times \left(\frac{v}{\sqrt{2}}\right)^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}mv^2 = \frac{3}{2}mv^2$$

35. (a) : A diatomic oxygen molecule has 3 degrees of freedom due to translatory motion and 2 degrees of freedom due to rotatory motion. Their associated kinetic energies will be in the ratio 3 : 2 or 60% and 40%.

36. (c): Acceleration of the blocks

$$a = \frac{10}{2+3+5} = 1 \text{ m s}^{-2}$$



FBD for 2 kg mass

Using Newton's second law of motion,

$10 - T_1 = 2a$, $T_1 = 10 - 2a = 10 - 2 \times 1 = 8$ N

37. (b)

38. (c): Suppose the ball is projected with velocity u. Then

$$E=\frac{1}{2}mu^2$$

At the highest point, the velocity of the ball will be v = horizontal component of the velocity of projection

$$=u\cos 45°=\frac{u}{\sqrt{2}}$$

The kinetic energy of the ball at the highest point,

$$E=\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{u}{\sqrt{2}}\right)^2=\frac{1}{2}\times\frac{1}{2}mu^2=\frac{1}{2}E$$

39. (b) : Resultant intensity of interference pattern

$$I(\phi) = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

Here $I_1 = I$, $I_2 = 4I$

$\therefore$ At point A when $\phi = \pi/2$, $I_A = I + 4I = 5I$

Again at point B when $\phi = \pi$,

$I_B = I + 4I + 2\sqrt{I\times 4I}\cos\pi$ or $I_B = 5I - 4I$

or $I_B = I$

$\therefore$ $I_A - I_B = 5I - I$ or $I_A - I_B = 4I$

40. (d) : The work done by the engine in a cycle is

$W = 200\text{ J} - 120\text{ J} = 80\text{ J}$

The efficiency of the engine is

$$\eta=\frac{W}{Q}=\frac{80\text{ J}}{200\text{ J}}=0.40$$

From Carnot's theorem, no engine can have an efficiency greater than that of a Carnot engine.

Thus, $0.40\le 1-\frac{T_2}{T_1}=1-\frac{300\text{ K}}{T_1}$

or $\frac{300\text{ K}}{T_1}\le 1-0.40=0.60$

or $T_1\ge\frac{300\text{ K}}{0.60}$ or $T_1\ge 500\text{ K}$

The minimum temperature of the hot reservoir has to be 500 K.

41. (b) : Here

$m = 6.5$ metric ton $= 6500$ kg, $g = 9.8\text{ m s}^{-2}$

$v=9\text{ km h}^{-1}=9\times\frac{5}{18}=2.5\text{ m s}^{-1}$, $\sin\theta=\frac{5}{13}$

$$\cos\theta=\sqrt{1-\sin^2\theta}=\sqrt{1-\frac{25}{169}}=\frac{12}{13}$$

Total force required against which the engine needs to work

$F = mg\sin\theta + f = mg\sin\theta + \mu mg\cos\theta$

$= mg(\sin\theta + \mu\cos\theta)$

$$=6500\times 9.8\left[\frac{5}{13}+\frac{1}{12}\times\frac{12}{13}\right]=29400\text{ N}$$

Power of the engine $= Fv$

$= 29400 \times 2.5 = 73500\text{ W} = 73.5\text{ kW}$

42. (a) : $r + r' + 90° = 180°$

$\therefore$ $r' = 90° - r$

Also, $i = r$

Apply Snell's law, $\mu_D\sin i = \mu_R\sin r'$

or $\mu_D\sin r = \mu_R\sin(90° - r) = \mu_R\cos r$

$$\frac{\mu_R}{\mu_D}=\tan r$$

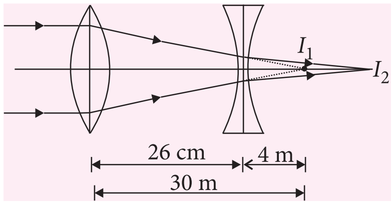
$$\therefore\ \theta_C=\sin^{-1}\left(\frac{\mu_R}{\mu_D}\right)=\sin^{-1}(\tan r)$$

43. (c): $\frac{1}{2}\varepsilon_0E^2$ = Energy per unit volume

$$\therefore\ \left[\frac{1}{2}\varepsilon_0E^2\right]=\left[\frac{\text{Energy}}{\text{Volume}}\right]=\left[\frac{\text{ML}^2\text{T}^{-2}}{\text{L}^3}\right]=[\text{ML}^{-1}\text{T}^{-2}]$$

44. (b) : Convex lens forms the image at I_1. I_1 is at the second focus of convex lens. Size of $I_1 = 2$ cm.

I_1 acts as virtual object for concave lens. Concave lens forms the image of I_1 at I_2.



Lens formula : $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

For concave lens,

$$\frac{1}{v}-\frac{1}{4}=-\frac{1}{20}\text{ or }\frac{1}{v}=-\frac{1}{20}+\frac{1}{4}=\frac{4}{20}=\frac{1}{5}$$

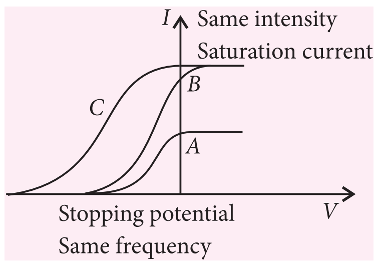
or $v = 5$ cm = Distance of I_2 from concave lens.

$$\therefore\ \text{Magnification}=\frac{v}{u}=\frac{\text{size of image}}{\text{size of object}}=\frac{5}{4}$$

or $\frac{\text{size of image}}{2}=1.25$

or size of image due to concave lens = 2.5 cm

45. (d) : At stopping potential, photoelectric current is zero. It is same for A and B.



$\therefore$ A and B will have equal frequencies.

Saturation current is proportional to intensity. B and C will have equal intensity.

Option (d) represents correct answer.

NEET

Phase - 1 held on 1st May

SOLVED PAPER 2016

GOOD NEWS

We are happy to inform our readers that more than 60% questions asked in NEET (Phase-1) 2016 Exam are very similar to the problems given in **MTG Physics Books.**

GOOD NEWS

1. A siren emitting a sound of frequency 800 Hz moves away from an observer towards a cliff at a speed of 15 m s^{-1}. Then, the frequency of sound that the observer hears in the echo reflected from the cliff is (Take velocity of sound in air = 330 m s^{-1})
   (a) 838 Hz (b) 885 Hz (c) 765 Hz (d) 800 Hz

2. Out of the following options which one can be used to produce a propagating electromagnetic wave?
   (a) A chargeless particle
   (b) An accelerating charge
   (c) A charge moving at constant velocity
   (d) A stationary charge

3. An inductor 20 mH, a capacitor 50 μF and a resistor 40 Ω are connected in series across a source of emf $V = 10 \sin 340t$. The power loss in A.C. circuit is
   (a) 0.76 W (b) 0.89 W (c) 0.51 W (d) 0.67 W

4. Match the corresponding entries of **column 1** with **column 2**. [Where m is the magnification produced by the mirror]

Column 1	Column 2
(A) $m = -2$	(p) Convex mirror
(B) $m = -\frac{1}{2}$	(q) Concave mirror
(C) $m = +2$	(r) Real image
(D) $m = +\frac{1}{2}$	(s) Virtual image

   (a) A → p and s; B → q and r; C → q and s; D → q and r
   (b) A → r and s; B → q and s; C → q and r; D → p and s
   (c) A → q and r; B → q and r; C → q and s; D → p and s
   (d) A → p and r; B → p and s; C → p and q; D → r and s

5. Coefficient of linear expansion of brass and steel rods are α_1 and α_2. Lengths of brass and steel rods are l_1 and l_2 respectively. If $(l_2 - l_1)$ is maintained same at all temperatures, which one of the following relations holds good?
   (a) $\alpha_1^2 l_2 = \alpha_2^2 l_1$ (b) $\alpha_1 l_1 = \alpha_2 l_2$
   (c) $\alpha_1 l_2 = \alpha_2 l_1$ (d) $\alpha_1 l_2^2 = \alpha_2 l_1^2$

6. At what height from the surface of earth the gravitation potential and the value of g are -5.4×10^7 J kg^{-2} and 6.0 m s^{-2} respectively? Take the radius of earth as 6400 km.
   (a) 1400 km (b) 2000 km
   (c) 2600 km (d) 1600 km

7. A piece of ice falls from a height h so that it melts completely. Only one-quarter of the heat produced is absorbed by the ice and all energy of ice gets converted into heat during its fall. The value of h is [Latent heat of ice is 3.4×10^5 J/ kg and $g = 10$ N/kg]
   (a) 136 km (b) 68 km
   (c) 34 km (d) 544 km

8. In a diffraction pattern due to a single slit of width a, the first minimum is observed at an angle 30° when light of wavelength 5000 Å is incident on the slit. The first secondary maximum is observed at an angle of
   (a) $\sin^{-1}\left(\frac{1}{2}\right)$ (b) $\sin^{-1}\left(\frac{3}{4}\right)$
   (c) $\sin^{-1}\left(\frac{1}{4}\right)$ (d) $\sin^{-1}\left(\frac{2}{3}\right)$

9. A potentiometer wire is 100 cm long and a constant potential difference is maintained across it. Two cells are connected in series first to support one another and then in opposite direction. The balance points are obtained at 50 cm and 10 cm from the positive end of the wire in the two cases. The ratio of emf's is
   (a) 3 : 4 (b) 3 : 2 (c) 5 : 1 (d) 5 : 4

10. A particle of mass 10 g moves along a circle of radius 6.4 cm with a constant tangential acceleration. What is the magnitude of this acceleration if the

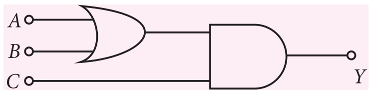
kinetic energy of the particle becomes equal to 8×10^{-4} J by the end of the second revolution after the beginning of the motion?

(a) 0.18 m/s^2 (b) 0.2 m/s^2
(c) 0.1 m/s^2 (d) 0.15 m/s^2

11. An air column, closed at one end and open at the other, resonates with a tuning fork when the smallest length of the column is 50 cm. The next larger length of the column resonating with the same tuning fork is

(a) 150 cm (b) 200 cm
(c) 66.7 cm (d) 100 cm

12. To get output 1 for the following circuit, the correct choice for the input is



(a) $A = 1, B = 1, C = 0$ (b) $A = 1, B = 0, C = 1$
(c) $A = 0, B = 1, C = 0$ (d) $A = 1, B = 0, C = 0$

13. A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then

(a) Compressing the gas isothermally or adiabatically will require the same amount of work.
(b) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.
(c) Compressing the gas isothermally will require more work to be done.
(d) Compressing the gas through adiabatic process will require more work to be done.

14. The intensity at the maximum in a Young's double slit experiment is I_0. Distance between two slits is $d = 5\lambda$, where λ is the wavelength of light used in the experiment. What will be the intensity in front of one of the slits on the screen placed at a distance $D = 10d$?

(a) $\frac{3}{4}I_0$ (b) $\frac{I_0}{2}$ (c) I_0 (d) $\frac{I_0}{4}$

15. A car is negotiating a curved road of radius R. The road is banked at an angle θ. The coefficient of friction between the tyres of the car and the road is μ_s. The maximum safe velocity on this road is

(a) $\sqrt{\frac{g}{R}\frac{\mu_s + \tan\theta}{1-\mu_s\tan\theta}}$ (b) $\sqrt{\frac{g}{R^2}\frac{\mu_s + \tan\theta}{1-\mu_s\tan\theta}}$

(c) $\sqrt{gR^2\frac{\mu_s + \tan\theta}{1-\mu_s\tan\theta}}$ (d) $\sqrt{gR\frac{\mu_s + \tan\theta}{1-\mu_s\tan\theta}}$

16. An electron of mass m and a photon have same energy E. The ratio of de-Broglie wavelengths associated with them is

(a) $c(2mE)^{\frac{1}{2}}$ (b) $\frac{1}{c}\left(\frac{2m}{E}\right)^{\frac{1}{2}}$

(c) $\frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$ (d) $\left(\frac{E}{2m}\right)^{\frac{1}{2}}$

(c being velocity of light)

17. A black body is at a temperature of 5760 K. The energy of radiation emitted by the body at wavelength 250 nm is U_1, at wavelength 500 nm is U_2 and that at 1000 nm is U_3. Wien's constant, $b = 2.88 \times 10^6$ nmK. Which of the following is correct?

(a) $U_1 > U_2$ (b) $U_2 > U_1$
(c) $U_1 = 0$ (d) $U_3 = 0$

18. Given the value of Rydberg constant is 10^7 m^{-1}, the wave number of the last line of the Balmer series in hydrogen spectrum will be

(a) 0.25×10^7 m^{-1} (b) 2.5×10^7 m^{-1}
(c) 0.025×10^4 m^{-1} (d) 0.5×10^7 m^{-1}

19. A *npn* transistor is connected in common emitter configuration in a given amplifier. A load resistance of 800 Ω is connected in the collector circuit and the voltage drop across it is 0.8 V. If the current amplification factor is 0.96 and the input resistance of the circuit is 192 Ω, the voltage gain and the power gain of the amplifier will respectively be

(a) 4, 4 (b) 4, 3.69
(c) 4, 3.84 (d) 3.69, 3.84

20. Two non-mixing liquids of densities ρ and $n\rho$ $(n > 1)$ are put in a container. The height of each liquid is h. A solid cylinder of length L and density d is put in this container. The cylinder floats with its axis vertical and length pL $(p < 1)$ in the denser liquid. The density d is equal to

(a) $\{2 + (n - 1)p\}\rho$ (b) $\{1 + (n - 1)p\}\rho$
(c) $\{1 + (n + 1)p\}\rho$ (d) $\{2 + (n + 1)p\}\rho$

21. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1 s and 2 s is

(a) $\frac{3}{2}A + \frac{7}{3}B$ (b) $\frac{A}{2} + \frac{B}{3}$

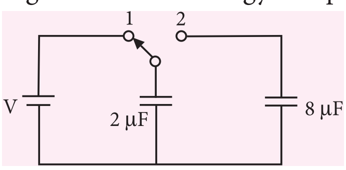
(c) $\frac{3}{2}A + 4B$ (d) $3A + 7B$

22. A astronomical telescope has objective and eyepiece of focal lengths 40 cm and 4 cm respectively. To view an object 200 cm away from the objective, the lenses must be separated by a distance
(a) 50.0 cm (b) 54.0 cm
(c) 37.3 cm (d) 46.0 cm

23. The ratio of escape velocity at earth (v_e) to the escape velocity at a planet (v_p) whose radius and mean density are twice as that of earth is
(a) 1 : 4 (b) $1:\sqrt{2}$ (c) 1 : 2 (d) $1:2\sqrt{2}$

24. A long straight wire of radius a carries a steady current I. The current is uniformly distributed over its cross-section. The ratio of the magnetic fields B and B', at radial distances $\frac{a}{2}$ and $2a$ respectively, from the axis of the wire is
(a) 1 (b) 4 (c) $\frac{1}{4}$ (d) $\frac{1}{2}$

25. A capacitor of 2 μF is charged as shown in the diagram. When the switch S is turned to position 2, the percentage of its stored energy dissipated is



(a) 75% (b) 80% (c) 0% (d) 20%

26. When a metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V. If the same surface is illuminated with radiation of wavelength 2λ, the stopping potential is $\frac{V}{4}$. The threshold wavelength for the metallic surface is
(a) $\frac{5}{2}\lambda$ (b) 3λ (c) 4λ (d) 5λ

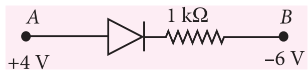
27. If the magnitude of sum of two vectors is equal to the magnitude of difference of the two vectors, the angle between these vectors is
(a) 45° (b) 180° (c) 0° (d) 90°

28. A body of mass 1 kg begins to move under the action of a time dependent force $\vec{F} = (2t\,\hat{i} + 3t^2\,\hat{j})$N, where $\hat{i}$ and $\hat{j}$ are unit vectors along x and y axis. What power will be developed by the force at the time t?
(a) $(2t^3 + 3t^4)$ W (b) $(2t^3 + 3t^5)$ W
(c) $(2t^2 + 3t^3)$ W (d) $(2t^2 + 4t^4)$ W

29. The angle of incidence for a ray of light at a refracting surface of a prism is 45°. The angle of prism is 60°. If the ray suffers minimum deviation through the prism, the angle of minimum deviation and refractive index of the material of the prism respectively, are
(a) 45°; $\sqrt{2}$ (b) 30°; $\frac{1}{\sqrt{2}}$
(c) 45°; $\frac{1}{\sqrt{2}}$ (d) 30°; $\sqrt{2}$

30. A particle moves so that its position vector is given by $\vec{r} = \cos\omega t\,\hat{x} + \sin\omega t\,\hat{y}$, where ω is a constant. Which of the following is true?
(a) Velocity of perpendicular to $\vec{r}$ and acceleration is directed towards the origin.
(b) Velocity is perpendicular to $\vec{r}$ and acceleration is directed away from the origin.
(c) Velocity and acceleration both are perpendicular to $\vec{r}$.
(d) Velocity and acceleration both are parallel to $\vec{r}$.

31. Consider the junction diode as ideal. The value of current flowing through AB is



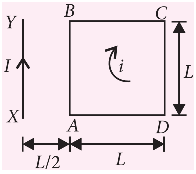
(a) 10^{-1} A (b) 10^{-3} A (c) 0 A (d) 10^{-2} A

32. Two identical charged spheres suspended from a common point by two massless strings of lengths l, are initially at a distance d ($d << l$) apart because of their mutual repulsion. The charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity v. Then v varies as a function of the distance x between the spheres, as
(a) $v \propto x^{-1/2}$ (b) $v \propto x^{-1}$
(c) $v \propto x^{1/2}$ (d) $v \propto x$

33. A small signal voltage $V(t) = V_0 \sin\omega t$ is applied across an ideal capacitor C
(a) Current $I(t)$ is in phase with voltage $V(t)$.
(b) Current $I(t)$ leads voltage $V(t)$ by 180°.
(c) Current $I(t)$, lags voltage $V(t)$ by 90°.
(d) Over a full cycle the capacitor C does not consume any energy from the voltage source.

34. The magnetic susceptibility is negative for
(a) ferromagnetic material only
(b) paramagnetic and ferromagnetic materials
(c) diamagnetic material only
(d) paramagnetic material only

35. A square loop $ABCD$ carrying a current i, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be



(a) $\frac{2\mu_0 IiL}{3\pi}$ (b) $\frac{\mu_0 IiL}{2\pi}$ (c) $\frac{2\mu_0 Ii}{3\pi}$ (d) $\frac{\mu_0 Ii}{2\pi}$

36. A uniform rope of length L and mass m_1 hangs vertically from a rigid support. A block of mass m_2 is attached to the free end of the rope. A transverse pulse of wavelength λ_1 is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope is λ_2. The ratio λ_2/λ_1 is

(a) $\sqrt{\frac{m_2}{m_1}}$ (b) $\sqrt{\frac{m_1+m_2}{m_1}}$

(c) $\sqrt{\frac{m_1}{m_2}}$ (d) $\sqrt{\frac{m_1+m_2}{m_2}}$

37. When an α-particle of mass m moving with velocity v bombards on a heavy nucleus of charge Ze, its distance of closest approach from the nucleus depends on m as

(a) $\frac{1}{m^2}$ (b) m (c) $\frac{1}{m}$ (d) $\frac{1}{\sqrt{m}}$

38. A disk and a sphere of same radius but different masses roll off on two inclined planes of the same altitude and length. Which one of the two objects gets to the bottom of the plane first?

(a) Both reach at the same time
(b) Depends on their masses
(c) Disk (d) Sphere

39. From a disc of radius R and mass M, a circular hole of diameter R, whose rim passes through the centre is cut. What is the moment of inertia of the remaining part of the disc about a perpendicular axis, passing through the centre?

(a) $11\ MR^2/32$ (b) $9\ MR^2/32$
(c) $15\ MR^2/32$ (d) $13\ MR^2/32$

40. A long solenoid has 1000 turns. When a current of 4 A flows through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is

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

41. What is the minimum velocity with which a body of mass m must enter a vertical loop of radius R so that it can complete the loop?

(a) $\sqrt{3gR}$ (b) $\sqrt{5gR}$ (c) $\sqrt{gR}$ (d) $\sqrt{2gR}$

42. The molecules of a given mass of a gas have r.m.s. velocity of 200 m s^{-1} at 27°C and 1.0×10^5 N m^{-2} pressure. When the temperature and pressure of the gas are respectively, 127°C and 0.05×10^5 N m^{-2}, the r.m.s. velocity of its molecules in m s^{-1} is

(a) $\frac{100\sqrt{2}}{3}$ (b) $\frac{100}{3}$ (c) $100\sqrt{2}$ (d) $\frac{400}{\sqrt{3}}$

43. The charge flowing through a resistance R varies with time t as $Q = at - bt^2$, where a and b are positive constants. The total heat produced in R is

(a) $\frac{a^3R}{2b}$ (b) $\frac{a^3R}{b}$ (c) $\frac{a^3R}{6b}$ (d) $\frac{a^3R}{3b}$

44. A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the temperature of the refrigerated space constant. The power required is (Take 1 cal = 4.2 Joules)

(a) 236.5 W (b) 2365 W
(c) 2.365 W (d) 23.65 W

45. A uniform circular disc of radius 50 cm at rest is free to turn about an axis which is perpendicular to its plane and passes through its centre. It is subjected to a torque which produces a constant angular acceleration of 2.0 rad s^{-2}. Its net acceleration in m s^{-2} at the end of 2.0 s is approximately

(a) 6.0 (b) 3.0 (c) 8.0 (d) 7.0

SOLUTIONS

1. **(a):** Here, frequency of sound emitted by siren, $\upsilon_0 = 800$ Hz
Speed of source, $v_s = 15$ m s^{-1}
Speed of sound in air, $v = 330$ m s^{-1}
Apparent frequency of sound at the cliff = frequency heard by observer = υ
Using Doppler's effect of sound

$$\upsilon = \left(\frac{v}{v-v_s}\right)\upsilon_0 = \frac{330}{330-15}\times 800$$
$$= \frac{330}{315}\times 800 = 838.09 \text{ Hz} \approx 838 \text{ Hz}$$

2. **(b) :** An accelerating charge is used to produce oscillating electric and magnetic fields, hence the electromagnetic wave.

3. **(c):** Here, $L = 20$ mH $= 20 \times 10^{-3}$ H,
$C = 50\ \mu$F $= 50 \times 10^{-6}$ F
$R = 40\ \Omega$, $V = 10 \sin 340t = V_0 \sin\omega t$
$\omega = 340$ rad s^{-1}, $V_0 = 10$ V
$X_L = \omega L = 340 \times 20 \times 10^{-3} = 6.8\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{340\times 50\times 10^{-6}} = \frac{10^4}{34\times 5} = 58.82\ \Omega$$

$$Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{(40)^2 + (58.82 - 6.8)^2}$$

$$= \sqrt{(40)^2 + (52.02)^2} = 65.62\ \Omega$$

The peak current in the circuit is

$$I_0 = \frac{V_0}{Z} = \frac{10}{65.62}\text{ A}, \cos\phi = \frac{R}{Z} = \left(\frac{40}{65.62}\right)$$

Power loss in A.C. circuit,

$$= V_{\text{rms}} I_{\text{rms}} \cos\phi = \frac{1}{2} V_0 I_0 \cos\phi$$

$$= \frac{1}{2}\times 10\times \frac{10}{65.62}\times\frac{40}{65.62} = 0.46\text{ W}$$

4. (c): Magnification in the mirror, $m = -\frac{v}{u}$

$m = -2 \Rightarrow v = 2u$

As v and u have same signs so the mirror is concave and image formed is real.

$m = -\frac{1}{2} \Rightarrow v = \frac{u}{2} \Rightarrow$ Concave mirror and real image.

$m = +2 \Rightarrow v = -2u$

As v and u have different signs but magnification is 2 so the mirror is concave and image formed is virtual.

$$m = +\frac{1}{2} \Rightarrow v = -\frac{u}{2}$$

As v and u have different signs with magnification $\left(\frac{1}{2}\right)$ so the mirror is convex and image formed is virtual.

5. (b) : Linear expansion of brass $= \alpha_1$

Linear expansion of steel $= \alpha_2$

Length of brass rod $= l_1$

Length of steel rod $= l_2$

On increasing the temperature of the rods by ΔT, new lengths would be

$$l_1' = l_1(1 + \alpha_1 \Delta T) \quad \text{...(i)}$$

$$l_2' = l_2(1 + \alpha_2 \Delta T) \quad \text{...(ii)}$$

Subtracting eqn. (i) from eqn. (ii), we get

$$l_2' - l_1' = (l_2 - l_1) + (l_2\alpha_2 - l_1\alpha_1)\Delta T$$

According to question,

$$l_2' - l_1' = l_2 - l_1 \quad \text{(for all temperatures)}$$

$\therefore\ l_2\alpha_2 - l_1\alpha_1 = 0$ or $l_1\alpha_1 = l_2\alpha_2$

6. (c): Gravitation potential at a height h from the surface of earth, $V_h = -5.4\times 10^7$ J kg^{-2}

At the same point acceleration due to gravity,

$g_h = 6$ m s^{-2}

$R = 6400$ km $= 6.4\times 10^6$ m

We know, $V_h = -\frac{GM}{(R+h)}$, $g_h = \frac{GM}{(R+h)^2} = -\frac{V_h}{R+h}$

$$\Rightarrow\quad R + h = -\frac{V_h}{g_h}$$

$$\therefore\quad h = -\frac{V_h}{g_h} - R = -\frac{(-5.4\times 10^7)}{6} - 6.4\times 10^6$$

$= 9\times 10^6 - 6.4\times 10^6 = 2600$ km

7. (a) : Gravitational potential energy of a piece of ice at a height $(h) = mgh$

Heat absorbed by the ice to melt completely

$$\Delta Q = \frac{1}{4} mgh \quad \text{...(i)}$$

Also, $\Delta Q = mL$ ...(ii)

From eqns. (i) and (ii), $mL = \frac{1}{4} mgh$ or, $h = \frac{4L}{g}$

Here $L = 3.4\times 10^5$ J kg^{-1}, $g = 10$ N kg^{-1}

$$\therefore\quad h = \frac{4\times 3.4\times 10^5}{10} = 4\times 34\times 10^3 = 136\text{ km}$$

8. (b) : For first minimum, the path difference between extreme waves, $a\sin\theta = \lambda$

Here $\theta = 30° \Rightarrow \sin\theta = \frac{1}{2}\quad \therefore\ a = 2\lambda$ ...(i)

For first secondary maximum, the path difference between extreme waves

$$a\sin\theta' = \frac{3}{2}\lambda \text{ or } (2\lambda)\sin\theta' = \frac{3}{2}\lambda \quad \text{[Using eqn (i)]}$$

$$\text{or}\quad \sin\theta' = \frac{3}{4}\quad \therefore\quad \theta' = \sin^{-1}\left(\frac{3}{4}\right)$$

9. (b) : Suppose two cells have emfs ε_1 and ε_2 (also $\varepsilon_1 > \varepsilon_2$).

Potential difference per unit length of the potentiometer wire $= k$ (say)

When ε_1 and ε_2 are in series and support each other then

$\varepsilon_1 + \varepsilon_2 = 50\times k$ ...(i)

When ε_1 and ε_2 are in opposite direction

$\varepsilon_1 - \varepsilon_2 = 10\times k$ ...(ii)

On adding eqn. (i) and eqn. (ii)

$2\varepsilon_1 = 60k \Rightarrow \varepsilon_1 = 30k$ and $\varepsilon_2 = 50k - 30k = 20k$

$$\therefore\quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{30k}{20k} = \frac{3}{2}$$

10. (c): Here, $m = 10$ g $= 10^{-2}$ kg,

$R = 6.4$ cm $= 6.4\times 10^{-2}$ m, $K_f = 8\times 10^{-4}$ J

$K_i = 0$, $a_t = ?$

Using work energy theorem,

Work done by all the forces = Change in KE

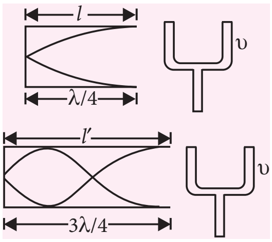
$$W_{\text{tangential force}} + W_{\text{centripetal force}} = K_f - K_i$$

$$\Rightarrow \quad F_t \times s + 0 = K_f - 0 \quad \Rightarrow \quad ma_t \times (2 \times 2\pi R) = K_f$$

$$\Rightarrow a_t = \frac{K_f}{4\pi Rm} = \frac{8\times10^{-4}}{4\times\frac{22}{7}\times6.4\times10^{-2}\times10^{-2}}$$

$$= 0.099 \approx 0.1 \text{ m s}^{-2}$$

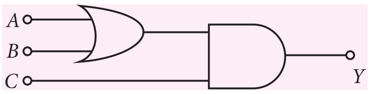
11. (a) : From figure,
First harmonic is obtained at $l = \frac{\lambda}{4} = 50$ cm



Third harmonic is obtained for resonance,

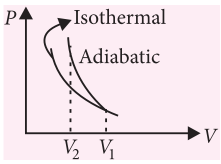
$$l' = \frac{3\lambda}{4} = 3\times50 = 150 \text{ cm.}$$

12. (b) :



Output of the circuit, $Y = (A + B)\cdot C$
$Y = 1$ if $C = 1$ and $A = 0$, $B = 1$ or $A = 1$,
$B = 0$ or $A = B = 1$

13. (d) : $V_1 = V$
$V_2 = V/2$



On P-V diagram,
Area under adiabatic curve
> Area under isothermal curve.
So compressing the gas through adiabatic process will require more work to be done.

14. (b) : Here, $d = 5\lambda$, $D = 10d$, $y = \frac{d}{2}$.

Resultant Intensity at $y = \frac{d}{2}, I_y = ?$

The path difference between two waves at $y = \frac{d}{2}$

$$\Delta x = d\tan\theta = d\times\frac{y}{D} = \frac{d\times\frac{d}{2}}{10d} = \frac{d}{20} = \frac{5\lambda}{20} = \frac{\lambda}{4}$$

Corresponding phase difference, $\phi = \frac{2\pi}{\lambda}\Delta x = \frac{\pi}{2}$.

Now, maximum intensity in Young's double slit experiment,

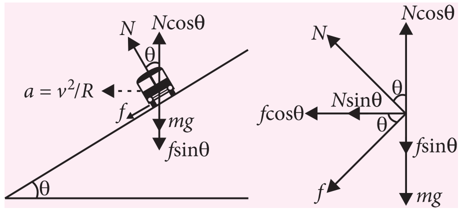
$$I_{max} = I_1 + I_2 + 2I_1I_2$$

$$I_0 = 4I \qquad (\because \; I_1 = I_1 = I)$$

$$\therefore \; I = \frac{I_0}{4}.$$

Required intensity $I_y = I_1 + I_2 + 2I_1I_2\cos\frac{\pi}{2} = 2I = \frac{I_0}{2}$

15. (d) :



For vertical equilibrium on the road,
$N\cos\theta = mg + f\sin\theta$
$mg = N\cos\theta - f\sin\theta$ ...(i)
Centripetal force for safe turning,

$$N\sin\theta + f\cos\theta = \frac{mv^2}{R} \qquad \text{...(ii)}$$

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

$$\frac{v^2}{Rg} = \frac{N\sin\theta + f\cos\theta}{N\cos\theta - f\sin\theta}$$

$$\Rightarrow \frac{v^2_{\max}}{Rg} = \frac{N\sin\theta + \mu_s N\cos\theta}{N\cos\theta - \mu_s N\sin\theta}$$

$$v_{\max} = \sqrt{Rg\left(\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}\right)}$$

16. (c): For electron of energy E,

de-Broglie wavelength, $\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$

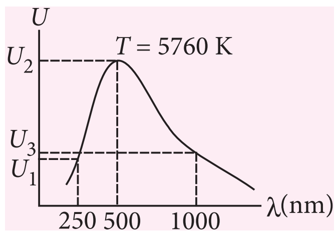
For photon of energy, $E = h\upsilon = \frac{hc}{\lambda_p}$

$$\Rightarrow \lambda_p = \frac{hc}{E} \qquad \text{...(ii)}$$

$$\therefore \frac{\lambda_e}{\lambda_p} = \frac{h}{\sqrt{2mE}}\times\frac{E}{hc} = \frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$$

17. (b) : According to Wein's displacement law

$$\lambda_m = \frac{b}{T} = \frac{2.88\times10^6 \text{ nm K}}{5760 \text{ K}} = 500 \text{ nm}$$



Clearly from graph, $U_1 < U_2 > U_3$

18. (a) : Here, $R = 10^7$ m^{-1}
The wave number of the last line of the Balmer series in hydrogen spectrum is given by

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4} = \frac{10^7}{4} = 0.25\times10^7 \text{ m}^{-1}$$

19. (c): Here, $R_0 = 800\ \Omega$, $R_i = 192\ \Omega$, current gain, $\beta = 0.96$

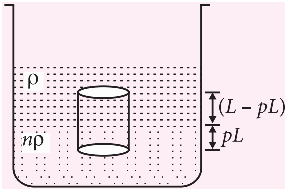
Voltage gain = Current gain × Resistance gain

$$= 0.96 \times \frac{800}{192} = 4$$

Power gain = [Current gain] × [Voltage gain]

$= 0.96 \times 4 = 3.84$

20. (b) :



d = density of cylinder

A = area of cross-section of cylinder

Using law of floatation,

Weight of cylinder = Upthrust by two liquids

$L \times A \times d \times g = n\rho \times (pL \times A)g + \rho(L - pL)Ag$

$d = np\rho + \rho(1 - p) = (np + 1 - p)\rho$

$d = \{1 + (n - 1)p\}\ \rho$

21. (a) : Velocity of the particle is $v = At + Bt^2$

$$\frac{ds}{dt} = At + Bt^2,\ \int ds = \int (At + Bt^2)dt$$

$$\therefore\ s = \frac{At^2}{2} + B\frac{t^3}{3} + C$$

$$s(t = 1\,\text{s}) = \frac{A}{2} + \frac{B}{3} + C,\ s(t = 2\,\text{s}) = 2A + \frac{8}{3}B + C$$

Required distance = $s(t = 2\text{ s}) - s(t = 1\text{ s})$

$$= \left(2A + \frac{8}{3}B + C\right) - \left(\frac{A}{2} + \frac{B}{3} + C\right) = \frac{3}{2}A + \frac{7}{3}B$$

22. (b) : Here $f_o = 40$ cm, $f_e = 4$ cm

Tube length(l) = Distance between lenses = $v_o + f_e$

For objective lens,

$u_o = -200$ cm, $v_o = ?$

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \text{ or } \frac{1}{v_o} - \frac{1}{-200} = \frac{1}{40}$$

$$\text{or } \frac{1}{v_o} = \frac{1}{40} - \frac{1}{200} = \frac{4}{200} \quad \therefore \quad v_o = 50\text{ cm}$$

$\therefore\ l = 50 + 4 = 54$ cm

23. (d) : As escape velocity, $v = \sqrt{\dfrac{2GM}{R}}$

$$= \sqrt{\frac{2G}{R} \cdot \frac{4\pi R^3}{3}\rho} = R\sqrt{\frac{8\pi G}{3}\rho}$$

$$\therefore\ \frac{v_e}{v_p} = \frac{R_e}{R_p} \times \sqrt{\frac{\rho_e}{\rho_p}}$$

$$= \frac{1}{2} \times \sqrt{\frac{1}{2}} = \frac{1}{2\sqrt{2}} \qquad (\because R_p = 2R_e \text{ and } \rho_p = 2\rho_e)$$

24. (a) : Magnetic field at a point inside the wire at distance $r\left(=\dfrac{a}{2}\right)$ from the axis of wire is

$$B = \frac{\mu_0 I}{2\pi a^2} r = \frac{\mu_0 I}{2\pi a^2} \times \frac{a}{2} = \frac{\mu_0 I}{4\pi a}$$

Magnetic field at a point outside the wire at distance $r(= 2a)$ from the axis of wire is

$$B' = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi} \times \frac{1}{2a} = \frac{\mu_0 I}{4\pi a} \qquad \therefore\ \frac{B}{B'} = 1$$

25. (b) : Initially, the energy stored in 2 μF capacitor is

$$U_i = \frac{1}{2}CV^2 = \frac{1}{2}(2 \times 10^{-6})V^2 = V^2 \times 10^{-6}\text{ J}$$

Initially, the charge stored in 2 μF capacitor is $Q_i = CV = (2 \times 10^{-6})V = 2V \times 10^{-6}$ coulomb. When switch S is turned to position 2, the charge flows and both the capacitors share charges till a common potential V_C is reached.

$$V_C = \frac{\text{total charge}}{\text{total capacitance}} = \frac{2V \times 10^{-6}}{(2+8)\times 10^{-6}} = \frac{V}{5}\text{ volt}$$

Finally, the energy stored in both the capacitors

$$U_f = \frac{1}{2}[(2 + 8) \times 10^{-6}]\left(\frac{V}{5}\right)^2 = \frac{V^2}{5} \times 10^{-6}\text{ J}$$

$$\%\text{ loss of energy, } \Delta U = \frac{U_i - U_f}{U_i} \times 100\,\%$$

$$= \frac{(V^2 - V^2/5)\times 10^{-6}}{V^2 \times 10^{-6}} \times 100\,\% = 80\%$$

26. (b) : According to Einstein's photoelectric equation,

$$eV_s = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$\therefore$ As per question, $eV = \dfrac{hc}{\lambda} - \dfrac{hc}{\lambda_0}$ ...(i)

$$\frac{eV}{4} = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0} \quad ...(ii)$$

From equations (i) and (ii), we get

$$\frac{hc}{2\lambda} - \frac{hc}{4\lambda} = \frac{hc}{\lambda_0} - \frac{hc}{4\lambda_0}$$

$$\Rightarrow \frac{hc}{4\lambda} = \frac{3hc}{4\lambda_0} \text{ or } \lambda_0 = 3\lambda$$

27. (d) : Let the two vectors be $\vec{A}$ and $\vec{B}$.

Then, magnitude of sum of $\vec{A}$ and $\vec{B}$,

$$|\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

and magnitude of difference of $\vec{A}$ and $\vec{B}$,

$$|\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$$

$|\vec{A} + \vec{B}| = |\vec{A} - \vec{B}|$ (given)

$$\text{or } \sqrt{A^2 + B^2 + 2AB\cos\theta} = \sqrt{A^2 + B^2 - 2AB\cos\theta}$$

$\Rightarrow$ $4\,AB\cos\theta = 0$

$\because$ $4\,AB \neq 0$, $\therefore$ $\cos\theta = 0$ or $\theta = 90°$

28. (b) : Here, $\vec{F} = (2t\hat{i} + 3t^2\hat{j})$ N, $m = 1$ kg

Acceleration of the body, $\vec{a} = \dfrac{\vec{F}}{m} = \dfrac{(2t\hat{i}+3t^2\hat{j})\text{ N}}{1\text{ kg}}$

Velocity of the body at time t,

$$\vec{v} = \int \vec{a}\,dt = \int\left(2t\hat{i} + 3t^2\hat{j}\right)dt = t^2\hat{i} + t^3\hat{j}\ \text{ m s}^{-1}$$

$\therefore$ Power developed by the force at time t,

$$P = \vec{F}\cdot\vec{v} = (2t\hat{i}+3t^2\hat{j})\cdot(t^2\hat{i}+t^3\hat{j})\ \text{W}$$
$$= (2t^3 + 3t^5)\ \text{W}$$

29. (d) : Given, $i = 45°$, $A = 60°$

Since the ray undergoes minimum deviation, therefore, angle of emergence from second face, $e = i = 45°$

$\therefore$ $\delta_m = i + e - A = 45° + 45° - 60° = 30°$

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$= \frac{\sin 45°}{\sin 30°} = \frac{1}{\sqrt{2}} \times \frac{2}{1} = \sqrt{2}$$

30. (a) : Given, $\vec{r} = \cos\omega t\,\hat{x} + \sin\omega t\,\hat{y}$

$\therefore$ $\vec{v} = \dfrac{d\vec{r}}{dt} = -\omega\sin\omega t\,\hat{x} + \omega\cos\omega t\,\hat{y}$

$\vec{a} = \dfrac{d\vec{v}}{dt} = -\omega^2\cos\omega t\,\hat{x} - \omega^2\sin\omega t\,\hat{y} = -\omega^2\vec{r}$

Since position vector $(\vec{r})$ is directed away from the origin, so, acceleration $(-\omega^2\vec{r})$ is directed towards the origin. Also,

$\vec{r}\cdot\vec{v} = (\cos\omega t\,\hat{x} + \sin\omega t\,\hat{y})\cdot(-\omega\sin\omega t\,\hat{x} + \omega\cos\omega t\,\hat{y})$

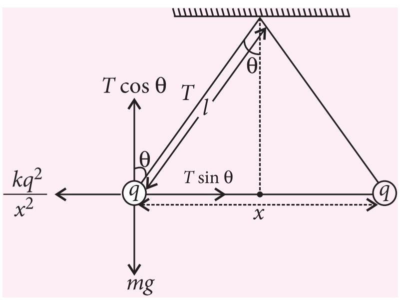
$= -\omega\sin\omega t\cos\omega t + \omega\sin\omega t\cos\omega t = 0$

$\Rightarrow$ $\vec{r} \perp \vec{v}$

31. (d) : Here, the p-n junction diode is forward biased, hence it offers zero resistance.

$\therefore$ $I_{AB} = \dfrac{V_A - V_B}{R_{AB}} = \dfrac{4\text{V} - (-6\text{V})}{1\text{k}\Omega} = \dfrac{10}{1000}\text{A} = 10^{-2}\text{ A}$

32. (a) :



From figure, $T\cos\theta = mg$ ...(i)

$T\sin\theta = \dfrac{kq^2}{x^2}$ ...(ii)

From eqns. (i) and (ii), $\tan\theta = \dfrac{kq^2}{x^2 mg}$

Since θ is small, $\therefore$ $\tan\theta \approx \sin\theta = \dfrac{x}{2l}$

$\therefore$ $\dfrac{x}{2l} = \dfrac{kq^2}{x^2 mg}$ $\Rightarrow$ $q^2 = x^3\dfrac{mg}{2lk}$ or $q \propto x^{3/2}$

$\Rightarrow$ $\dfrac{dq}{dt} \propto \dfrac{3}{2}\sqrt{x}\dfrac{dx}{dt} = \dfrac{3}{2}\sqrt{x}v$. Since, $\dfrac{dq}{dt}$ = constant

$\therefore$ $v \propto \dfrac{1}{\sqrt{x}}$

33. (d) : When an ideal capacitor is connected with an ac voltage source, current leads voltage by 90°. Since, energy stored in capacitor during charging is spent in maintaining charge on the capacitor during discharging. Hence over a full cycle the capacitor does not consume any energy from the voltage source.

34. (c): Magnetic susceptibility is negative for diamagnetic material only.

35. (c): Force on arm AB due to current in conductor XY is

$$F_1 = \frac{\mu_0}{4\pi}\frac{2IiL}{(L/2)} = \frac{\mu_0 Ii}{\pi}$$

acting towards XY in the plane of loop.

Force on arm CD due to current in conductor XY is

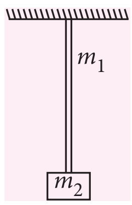
$$F_2 = \frac{\mu_0}{4\pi}\frac{2IiL}{3(L/2)} = \frac{\mu_0 Ii}{3\pi}$$

acting away from XY in the plane of loop.

$\therefore$ Net force on the loop $= F_1 - F_2$

$$= \frac{\mu_0 Ii}{\pi}\left[1 - \frac{1}{3}\right] = \frac{2}{3}\frac{\mu_0 Ii}{\pi}$$

36. (d) : Wavelength of pulse at the lower end $(\lambda_1) \propto$ velocity $(v_1) = \sqrt{\dfrac{T_1}{\mu}}$



Similarly, $\lambda_2 \propto v_2 = \sqrt{\dfrac{T_2}{\mu}}$

$\therefore$ $\dfrac{\lambda_2}{\lambda_1} = \sqrt{\dfrac{T_2}{T_1}} = \sqrt{\dfrac{(m_1+m_2)g}{m_2 g}} = \sqrt{\dfrac{m_1+m_2}{m_2}}$

37. (c): Distance of closest approach when an α-particle of mass m moving with velocity v is bombarded on a heavy nucleus of charge Ze, is given by

$$r_0 = \frac{Ze^2}{\pi\varepsilon_0 mv^2} \qquad \therefore \quad r_0 \propto \frac{1}{m}$$

38. (d) : Time taken by the body to reach the bottom when it rolls down on an inclined plane without slipping is given by

$$t=\sqrt{\frac{2l\left(1+\frac{k^2}{R^2}\right)}{g\sin\theta}}$$

Since g is constant and l, R and $\sin\theta$ are same for both

$$\therefore \frac{t_d}{t_s}=\frac{\sqrt{1+\frac{k_d^2}{R^2}}}{\sqrt{1+\frac{k_s^2}{R^2}}}=\sqrt{\frac{1+\frac{R^2}{2R^2}}{1+\frac{2R^2}{5R^2}}}\quad\left(\because k_d=\frac{R}{\sqrt{2}}, k_s=\sqrt{\frac{2}{5}}R\right)$$

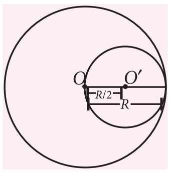
$$=\sqrt{\frac{3}{2}\times\frac{5}{7}}=\sqrt{\frac{15}{14}}\Rightarrow t_d>t_s$$

Hence, the sphere gets to the bottom first.

39. (d) : Mass per unit area of disc $=\frac{M}{\pi R^2}$

Mass of removed portion of disc,

$$M'=\frac{M}{\pi R^2}\times\pi\left(\frac{R}{2}\right)^2=\frac{M}{4}$$



Moment of inertia of removed portion about an axis passing through centre of disc O and perpendicular to the plane of disc,

$$I'_O=I_{O'}+M'd^2$$

$$=\frac{1}{2}\times\frac{M}{4}\times\left(\frac{R}{2}\right)^2+\frac{M}{4}\times\left(\frac{R}{2}\right)^2=\frac{MR^2}{32}+\frac{MR^2}{16}=\frac{3MR^2}{32}$$

When portion of disc would not have been removed, the moment of inertia of complete disc about centre O is

$$I_O=\frac{1}{2}MR^2$$

So, moment of inertia of the disc with removed portion is

$$I=I_O-I'_O=\frac{1}{2}MR^2-\frac{3MR^2}{32}=\frac{13MR^2}{32}$$

40. (b) : Here, $N = 1000$, $I = 4$ A, $\phi_0 = 4\times10^{-3}$ Wb

Total flux linked with the solenoid, $\phi = N\phi_0$

$= 1000\times4\times10^{-3}$ Wb $= 4$ Wb

Since, $\phi = LI$

$\therefore$ Self-inductance of solenoid,

$$L=\frac{\phi}{I}=\frac{4\text{ Wb}}{4\text{ A}}=1\text{ H}$$

41. (b)

42. (d) : As, $v_{rms}=\sqrt{\frac{3k_BT}{m}}$

$$\therefore \frac{v_{27}}{v_{127}}=\sqrt{\frac{27+273}{127+273}}=\sqrt{\frac{300}{400}}=\frac{\sqrt{3}}{2}$$

or $v_{127}=\frac{2}{\sqrt{3}}\times v_{27}=\frac{2}{\sqrt{3}}\times200\text{ m s}^{-1}=\frac{400}{\sqrt{3}}\text{ m s}^{-1}$

43. (c): Given, $Q = at - bt^2$ $\therefore I=\frac{dQ}{dt}=a-2bt$

At $t = 0$, $Q = 0 \Rightarrow I = 0$

Also, $I = 0$ at $t = a/2b$

$\therefore$ Total heat produced in resistance R,

$$H=\int_0^{a/2b}I^2Rdt=R\int_0^{a/2b}(a-2bt)^2dt$$

$$=R\int_0^{a/2b}(a^2+4b^2t^2-4abt)dt$$

$$=R\left[a^2t+4b^2\frac{t^3}{3}-4ab\frac{t^2}{2}\right]_0^{a/2b}$$

$$=R\left[a^2\times\frac{a}{2b}+\frac{4b^2}{3}\times\frac{a^3}{8b^3}-\frac{4ab}{2}\times\frac{a^2}{4b^2}\right]$$

$$=\frac{a^3R}{b}\left[\frac{1}{2}+\frac{1}{6}-\frac{1}{2}\right]=\frac{a^3R}{6b}$$

44. (a) : Given, $T_2 = 4°C = 277$ K, $T_1 = 30°C = 303$ K

$Q_2 = 600$ cal per second

Coefficient of performance, $\alpha=\frac{T_2}{T_1-T_2}$

$$=\frac{277}{303-277}=\frac{277}{26}$$

Also, $\alpha=\frac{Q_2}{W}$

$\therefore$ Work to be done per second = power required

$$=W=\frac{Q_2}{\alpha}=\frac{26}{277}\times600\text{ cal per second}$$

$$=\frac{26}{277}\times600\times4.2\text{ J per second }=236.5\text{ W}$$

45. (c): Given, $r = 50$ cm $= 0.5$ m, $\alpha = 2.0$ rad s^{-2}, $\omega_0 = 0$

At the end of 2 s,

Tangential acceleration, $a_t = r\alpha = 0.5\times2 = 1$ m s^{-2}

Radial acceleration, $a_r = \omega^2r = (\omega_0+\alpha t)^2r$

$= (0 + 2\times2)^2\times0.5 = 8$ m s^{-2}

$\therefore$ Net acceleration,

$$a=\sqrt{a_t^2+a_r^2}=\sqrt{1^2+8^2}=\sqrt{65}\approx8\text{ m s}^{-2}$$

EXAM PREP 2016

CHAPTERWISE MCQs FOR PRACTICE

Useful for All National and State Level Medical/Engg. Entrance Exams

RAY OPTICS AND OPTICAL INSTRUMENTS

1. A luminous object is placed 20 cm from surface of a convex mirror and a plane mirror is set so that virtual images formed in two mirrors coincide. If plane mirror is at a distance of 12 cm from object, then focal length of convex mirror is

(a) 2.5 cm (b) 5 cm
(c) 20 cm (d) 40 cm

2. The focal length of a biconvex lens of refractive index 1.5 is 0.06 m. Radii of curvature of two lenses surfaces are in the ratio 1 : 2. Then radii of curvature of two lens surfaces are

(a) 0.045 m, 0.09 m (b) 0.09 m, 0.18 m
(c) 0.04 m, 0.08 m (d) 0.06 m, 0.12 m

3. If the refractive indices of crown glass for red, yellow and violet colours are 1.5140, 1.5170 and 1.5318 respectively and for flint glass, these are 1.6434, 1.6499 and 1.6852 respectively, then the dispersive power for crown and flint glass are respectively

(a) 0.034 and 0.064 (b) 0.064 and 0.034
(c) 1.3 and 0.064 (d) 0.034 and 1.0

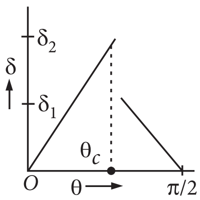
4. A prism (μ = 1.5) has the refracting angle of 30°. The deviation of a monochromatic ray incident normally on its one surface will be
(Given sin 48° 36′ = 0.75)

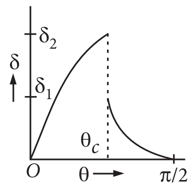
(a) 18° 36′ (b) 22° 36′
(c) 18° (d) 22° 1′

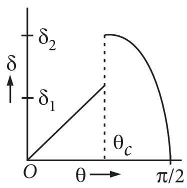
5. A convex lens of focal length f is placed some where in between an object and a screen. The distance between object and screen is x. If numerical value of magnification produced by lens is m, focal length of lens is

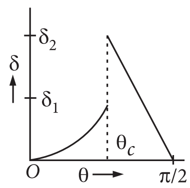
(a) $\frac{mx}{(m+1)^2}$ (b) $\frac{mx}{(m-1)^2}$
(c) $\frac{(m+1)^2}{m}x$ (d) $\frac{(m-1)^2}{m}x$

6. A ray of light travels from a medium of refractive index μ to air. Its angle of incidence in the medium is θ, measured from the normal to the boundary, and its angle of deviation is δ. δ is plotted against θ. Which of the following best represents the resulting curve? θ_c is critical angle.

(a)


(b)


(c)


(d)


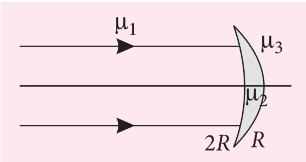
7. Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the centre. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is

(a) −50 cm (b) 50 cm
(c) −20 cm (d) −25 cm

8. A clear transparent glass sphere (μ = 1.5) of radius R is immersed in a liquid of refractive index 1.25. A parallel beam of light incident on it will converge to a point. The distance of this point from the center will be

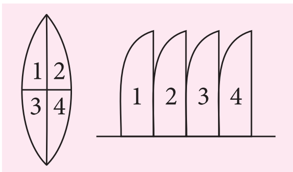
(a) $-3R$ (b) $+3R$
(c) $-R$ (d) $+R$

9. Figure shows a concavo-convex lens of refractive index μ_2. What is the condition on the refractive indices so that the lens is diverging?



(a) $2\mu_3 < \mu_1 + \mu_2$ (b) $2\mu_3 > \mu_1 + \mu_2$
(c) $\mu_3 > 2(\mu_1 - \mu_2)$ (d) None of these

10. The given lens is broken into four parts and rearranged as shown. If the initial focal length is f, then after rearrangement, the equivalent focal length is



(a) f (b) $f/2$
(c) $f/4$ (d) $4f$

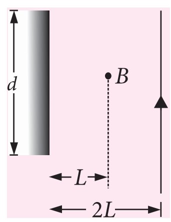
11. The focal length of the objective of a terrestrial telescope is 80 cm and it is adjusted for parallel rays, then its magnifying power is 20. If the focal length of erecting lens is 20 cm, then full length of telescope will be

(a) 84 cm (b) 100 cm
(c) 124 cm (d) 164 cm

12. Magnifying power of a simple microscope when final image is formed at D = 25 cm from eye, is

(a) $\frac{D}{f}$ (b) $1+\frac{D}{f}$
(c) $1+\frac{f}{D}$ (d) $1-\frac{D}{f}$

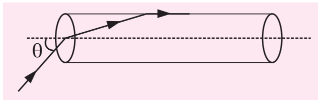
13. A point source of light B is placed at a distance L in front of the centre of a mirror of width d hung vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror at a distance $2L$ from it as shown in the figure.



The greatest distance over which he can see the image of the light source in the mirror is

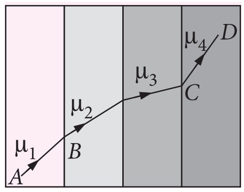
(a) $d/2$ (b) d
(c) $2d$ (d) $3d$

14. A transparent solid cylindrical rod has a refractive index of $(2/\sqrt{3})$. It is surrounded by air. A light ray is incident at the midpoint of one end of the rod as shown in figure. The incident angle θ for which the light ray grazes along the wall of the rod is



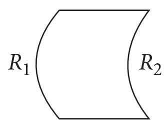
(a) $\sin^{-1}\left(\frac{1}{2}\right)$ (b) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$
(c) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (d) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

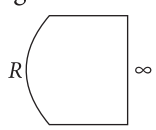
15. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in figure. The surfaces of all media are parallel. If the emerged ray CD is parallel to the incident ray AB, we must have

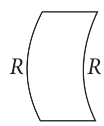


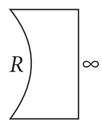
(a) $\mu_1 = \mu_2$ (b) $\mu_2 = \mu_3$
(c) $\mu_3 = \mu_4$ (d) $\mu_4 = \mu_1$

16. Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams

(a) 

(b) 

(c) 

(d) 

17. A biconvex lens of focal length 15 cm is in front of a plane mirror. The distance between the lens and the mirror is 10 cm. A small object is kept at a distance of 30 cm from the lens. The final image is

(a) virtual and at a distance of 16 cm from the mirror
(b) real and at a distance of 16 cm from the mirror
(c) virtual and at a distance of 20 cm from the mirror
(d) real and at a distance of 20 cm from the mirror

18. When an astronomical telescope is focussed on a distant star, the distance of the eyepiece from the objective is 60 cm. When focussed on a distant flag pole, the eyepiece must be drawn out 10 cm. If the focal length of the eye piece is 5 cm, what will be the distance of the pole from the objective ? Assume that the eye is focussed for infinity.

(a) 300 cm (b) 30 cm
(c) 320 cm (d) None of these

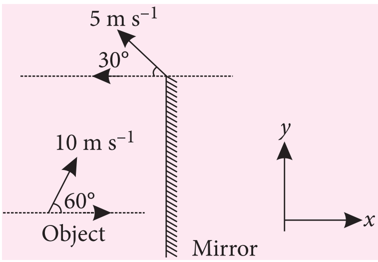
19. The length of the tube of a microscope is 10 cm. The focal lengths of the objective and eye piece are 0.5 cm and 1.0 cm. The magnifying power of the microscope is about (Assume that final image is formed at infinity)

(a) 5 (b) 23 (c) 166 (d) 500

20. The exposure time of a camera lens at $\frac{f}{2.8}$ setting is $\frac{1}{200}$ s. The correct time of exposure at $\frac{f}{5.6}$ is

(a) 0.4 s (b) 0.02 s (c) 0.002 s (d) 0.04 s

21. Figure shows a plane mirror and an object that are moving towards each other. Find the velocity of image.

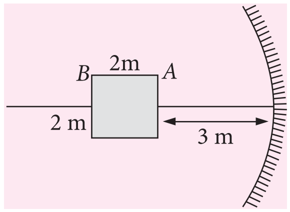


(a) $(5\sqrt{3}\,\hat{i}+5\sqrt{3}\,\hat{j})$ m s^{-1}
(b) $(-5\hat{i}+5\sqrt{3}\,\hat{j})$ m s^{-1}
(c) $(-5(1+\sqrt{3})\,\hat{i}+5\sqrt{3}\,\hat{j})$ m s^{-1}
(d) $(5\sqrt{3}\,\hat{i}-5\,\hat{j})$ m s^{-1}

22. Light from a denser medium 1 passes to a rarer medium 2. When the angle of incidence is θ, the partially reflected and refracted rays are mutually perpendicular. The critical angle will be

(a) $\sin^{-1}(\cot\theta)$ (b) $\sin^{-1}(\tan\theta)$
(c) $\sin^{-1}(\cos\theta)$ (d) $\sin^{-1}(\sec\theta)$

23. A cube of side 2 m is placed in front of a concave mirror of focal length 1 m with its face *A* at a distance of 3 m and face *B* at a distance of 5 m from the mirror. The distance between the images of faces *A* and *B* and heights of images of *A* and *B* are, respectively,

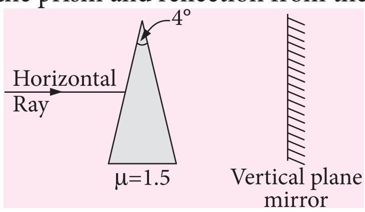


(a) 1 m, 0.5 m, 0.25 m
(b) 0.5 m, 1 m, 0.25 m
(c) 0.5 m, 0.25, 1 m
(d) 0.25 m, 1 m, 0.5 m

24. A mango tree is at the bank of river and one of the branch of tree extends over the river. A tortoise lives in the river. A mango falls just on the tortoise. The acceleration of the mango falling from tree as it appears to the tortoise is (refractive index of water is 4/3 and the tortoise is stationary)

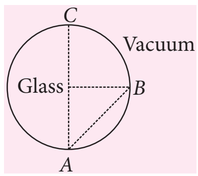
(a) g (b) $3g/4$
(c) $4g/3$ (d) none of these

25. For the situations shown in figure, determine the angle by which the mirror should be rotated, so that the light ray will retrace its path after refraction through the prism and reflection from the mirror?



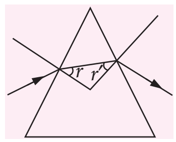
(a) 1° ACW (b) 1° CW
(c) 2° ACW (d) 2° CW

26. It is found that all electro-magnetic signals sent from *A* towards *B* reach point *C* inside the glass sphere, as shown in figure. The speed of electromagnetic signals in glass cannot be



(a) 1×10^8 m s^{-1} (b) 2.4×10^8 m s^{-1}
(c) 2×10^7 m s^{-1} (d) 4×10^7 m s^{-1}

27. Let r and r' denote the angles inside an equilateral prism, as shown, in degrees. Consider that during some interval from $t = 0$ to $t = t$, r' varies with time as $r' = 10 + kt^2$ where k is a dimensional consant. During this time, r will vary as

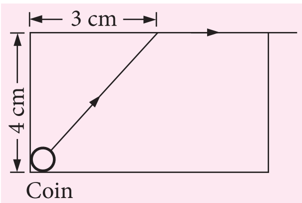


(a) $50 - kt^2$ (b) $50 + kt^2$
(c) $60 - kt^2$ (d) $60 + kt^2$

28. A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refractive indices n_1 and n_2 respectively ($n_2 > n_1 > 1$). The lens will diverge a parallel beam of light if it is filled with
(a) air and placed in air
(b) air and immersed in L_1
(c) L_1 and immersed in L_2
(d) L_2 and immersed in L_1

29. A plastic hemisphere has a radius of curvature of 8 cm and an index of refraction 1.6. On the axis halfway between the plane surface and the spherical one (4 cm from each) is a small object *O*. The distance between the two images when viewed along the axis from the two sides of the hemisphere is approximately
(a) 1.5 cm (b) 2.5 cm
(c) 1.0 cm (d) 3.75 cm

30. A small coin is resting on the bottom of a beaker filled with liquid. A ray of light from the coin travels upto the surface of the liquid and moves along its surface. How fast is the light travelling in the liquid?



(a) 2.4×10^8 m s^{-1} (b) 3.0×10^8 m s^{-1}
(c) 1.2×10^8 m s^{-1} (d) 1.8×10^8 m s^{-1}

SOLUTIONS

1. (b): For convex mirror, $u = -20$ cm,
$v = 12 + 12 - 20 = 4$ cm

$$\therefore \quad \frac{1}{f} = \frac{1}{v} + \frac{1}{u} = \frac{1}{4} - \frac{1}{20} = \frac{4}{20} = \frac{1}{5} \Rightarrow f = 5 \text{ cm}$$

2. (a): As $\dfrac{1}{F} = (\mu - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$$\therefore \quad \frac{1}{0.06} = (1.5 - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

or $\dfrac{1}{R_1} + \dfrac{1}{R_2} = \dfrac{1}{0.06 \times 0.5} = \dfrac{100}{3}$

Now, $\dfrac{R_1}{R_2} = \dfrac{1}{2}$ or $R_2 = 2R_1$

$$\therefore \quad \frac{3}{2R_1} = \frac{100}{3} \text{ or } R_1 = \frac{9}{200} = 0.045 \text{ m}$$

$R_2 = 2R_1 = 2 \times 0.045$ m $= 0.09$ m

3. (a): $\omega_c = \dfrac{\mu_v - \mu_r}{\mu_y - 1} = \dfrac{1.5318 - 1.5140}{1.5170 - 1} = 0.034$

$\omega_f = \dfrac{\mu_v' - \mu_r'}{\mu_y' - 1} = \dfrac{1.6852 - 1.6434}{1.6499 - 1} = 0.064$

4. (a): $\mu = 1.5$, $A = 30°$. For normal incidence, $i_1 = 0°$

$\therefore \quad r_1 = 0°, r_2 = A - r_1 = 30°$

As $\dfrac{\sin i_2}{\sin r_2} = 1.5 = \dfrac{3}{2}$

$\therefore \quad \sin i_2 = \dfrac{3}{2}\sin r_2 = \dfrac{3}{2}\sin 30° = \dfrac{3}{4} = 0.75$

$i_2 = \sin^{-1}(0.75) = 48° \, 36'$

Deviation, $\delta = i_1 + i_2 - A$

$\delta = 0 + 48° \, 36' - 30° = 18° \, 36'$

5. (a): Here, $x = |u| + |v|$ ...(i)

As $m = \dfrac{f}{f+u} = \dfrac{f-v}{f}$

and image is real, magnification is negative.

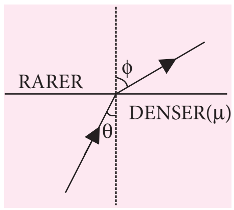
$\therefore \quad -m = \dfrac{f}{f+u} \Rightarrow u = \dfrac{-(m+1)f}{m}$

From $-m = \dfrac{f-v}{f} \Rightarrow v = (m+1)f$

Putting in (i), $x = \dfrac{(m+1)}{m}f + (m+1)f$

Solving, we get, $f = \dfrac{mx}{(m+1)^2}$

6. (d): As is clear from figure, for $\theta < \theta_c$ (critical angle), deviation



$\delta = \phi - \theta$ ...(i)

As $\mu = \dfrac{\sin\phi}{\sin\theta}$

$\therefore \quad \phi = \sin^{-1}(\mu \sin\theta)$

From (i), $\delta = \sin^{-1}(\mu \sin\theta) - \theta$ ...(ii)

This is a non-linear relation. Therefore, choice is between (b) and (d).

When $\theta = \theta_c$, $\phi = \pi/2$

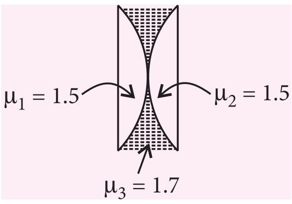
$\therefore \quad$ Value of δ from (i) is $\delta_1 = \dfrac{\pi}{2} - \theta_c$

When $\theta > \theta_c$, total internal reflection occurs, and deviation, $\delta = \pi - 2\theta$.

i.e., δ decreases linearly with θ

Hence, choice (d) is correct.

7. (a): Given combination is equivalent to three lenses. In which two are plano-convex with refractive index 1.5 and one is concave lens of refractive index 1.7.



Using lens maker formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

For plano-convex lens

$R_1 = \infty$, $R_2 = -20$ cm,

$$\therefore \quad \frac{1}{f_1} = \frac{1}{f_2} = (1.5 - 1)\left(\frac{1}{\infty} - \frac{1}{-20}\right) = \frac{0.5}{20} = \frac{1}{40}$$

So, $f_1 = f_2 = 40$ cm

For concave lens,

$\mu = 1.7$, $R_1 = -20$ cm, $R_2 = 20$ cm

$$\therefore \quad \frac{1}{f_3} = (1.7 - 1)\left(\frac{1}{-20} - \frac{1}{20}\right) = 0.7 \times \left(\frac{-2}{20}\right) = -\frac{7}{100}$$

So, $f_3 = -\frac{100}{7}$ cm

Equivalent focal length (f_{eq}) of the system is given by

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_3} + \frac{1}{f_2} = \frac{1}{40} + \frac{1}{-100/7} + \frac{1}{40}$$

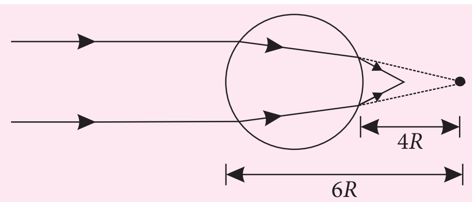
$$= \frac{1}{20} - \frac{7}{100} = -\frac{2}{100} = -\frac{1}{50}$$

$\therefore \quad f_{eq} = -50$ cm

8. (b): As $\frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$

$$\therefore \quad \frac{1.25}{-(-\infty)} + \frac{1.5}{v'} = \frac{1.5 - 1.25}{R}$$

or $\frac{1.5}{v'} = \frac{0.25}{R}$ or $v' = \frac{1.5R}{0.25} = 6R$



Again, $\frac{\mu_2}{-u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R}$

$$\frac{1.5}{-4R} + \frac{1.25}{v} = \frac{1.25 - 1.5}{-R}$$

or $\frac{1.25}{v} = \frac{1}{4R} + \frac{1.5}{4R} = \frac{2.5}{4R} \Rightarrow v = \frac{1.25 \times 4R}{2.5} = \frac{5R}{2.5}$

or $v = 2R$

Distance from the center $= 3R$.

9. (b): $\frac{\mu_2}{v} - \frac{\mu_1}{-u_0} = \frac{\mu_2 - \mu_1}{-2R}$ ...(i)

and $\frac{\mu_3}{v_f} - \frac{\mu_2}{v} = \frac{\mu_3 - \mu_2}{-R}$ ...(ii)

From (i) and (ii)

$$\frac{\mu_3}{v_f} + \frac{\mu_1}{u_0} = \frac{\mu_1 - \mu_2}{2R} + \frac{\mu_2 - \mu_3}{R}$$

$\therefore$ For the lens to be diverging,

$$\Rightarrow \frac{\mu_1 - \mu_2}{2} < \mu_3 - \mu_2 \Rightarrow \mu_1 - \mu_2 < 2\mu_3 - 2\mu_2$$

$$\Rightarrow \mu_1 - \mu_2 < 2\mu_3$$

10. (b): Cutting a lens in transverse direction doubles their focal length, *i.e.*, $2f$.

Using the formula of equivalent focal length,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4}$$

we get equivalent focal length as $\frac{f}{2}$.

11. (d): For terrestrial telescope, magnification

$$M = \frac{f_0}{f_e} = \frac{80}{f_e} = 20 \Rightarrow f_e = 4 \text{ cm}$$

Hence, length of terrestrial telescope

$= f_0 + f_e + 4f = 80 + 4 + 4 \times 20 = 164$ cm

BRAIN MAP

REVIEW-II

A QUICK OVERVIEW TO CONCEPTS OF OPTICS, MODERN PHYSICS, ELECTRONICS AND COMMUNICATION

OPTICS

RAY OPTICS

Reflection

Spherical Mirror :
Mirror formula: $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$; Magnification, $m=-\frac{v}{u}=\frac{h_i}{h_o}$

Refraction

Lens
Lens maker's formula
$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$
Power of lens, $P=\frac{1}{f(\text{in m})}$

Snell's Law
$\mu=\frac{\sin i}{\sin r}$
Normal shift of image
$d=t\left(1-\frac{1}{\mu}\right)$

T I R Conditons
When $i > i_c$ and ray must travel from denser to rarer.
R.I. of medium, $\mu=\frac{1}{\sin i_c}$

Prism
$\delta=(\mu-1)A$
$\mu=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$

WAVE OPTICS

Interference

YDSE
Resultant Intensity
$I_R=I_1+I_2+2\sqrt{I_1}\sqrt{I_2}\cos\phi$

Constructive: $x_n=n\lambda\frac{D}{d}$
Destructive: $x_n=(2n-1)\frac{\lambda}{2}\frac{D}{d}$

Fringe width, $\beta=\frac{\lambda D}{d}$
$\frac{w_1}{w_2}=\frac{I_1}{I_2}=\frac{a_1^2}{a_2^2}$

Diffraction

Angular Positions of
n^{th} minimum: $\theta_n=\frac{n\lambda}{a}$
n^{th} secondary maximum: $\theta'_n=(2n+1)\frac{\lambda}{2a}$

Fresnel's Distance
$Z_F\simeq\frac{a^2}{\lambda}$

Resolving Powers
Microscope : $\frac{1}{d}=\frac{2\mu\sin\theta}{\lambda}$
Telescope : $\frac{1}{d\theta}=\frac{D}{1.22\lambda}$

Polarisation

Malus Law
$I_{(\text{final})}\propto\cos^2\theta$
$\Rightarrow I=I_0\cos^2\theta$

Brewster's Law
Polarisation by Reflection
$\mu=\tan i_p$ and $i_p+r_p=90°$

OPTICAL INSTRUMENTS

Simple Microscope
$m_D=\left(1+\frac{D}{f_e}\right)$; $m_\infty=\left(\frac{D}{f_e}\right)$

Compound Microscope
$m_D=\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)$; $m_\infty=\frac{L}{f_0}\times\frac{D}{f_e}$

Astronomical Telescope
$m_D=-\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)$, $m_\infty=-\frac{f_o}{f_e}$

Reflecting type telescope
Cassergrain telescope:
$m=\frac{f_o}{f_e}=\frac{R/2}{f_e}$

MODERN PHYSICS

DUAL NATURE OF MATTER AND RADIATION

Photoelectric Effect
$K_{max}=E-\phi_0=eV_S$
$\Rightarrow\frac{1}{2}mv_{max}^2=h(\upsilon-\upsilon_0)$

de Broglie Hypothesis
Material particles in motion also possess wave-like properties and waves are called matter waves.

de Broglie Wavelength
$\lambda=\frac{h}{p}=\frac{h}{mv}=\frac{h}{\sqrt{2mK}}=\frac{h}{\sqrt{2mqV}}$

ATOMS

Model of Atom
– Thomson Model
– Rutherford's Model
– Bohr's Model

Bohr's Model of Atom
Electron revolves in certain stable orbits for which angular momentum is
$L=nh/2\pi$

Electron Orbits : Radius, $r_n=\frac{n^2h^2}{4\pi^2mkZe^2}$;
Velocity, $v_n=\frac{2\pi kZe^2}{nh}=\alpha\frac{c}{n}$

Energy
$E_n=\frac{-2\pi^2mk^2Z^2e^4}{n^2h^2}$
$=-\frac{Rhc}{n^2}Z^2=\frac{-13.6}{n^2}Z^2\text{eV}$

Rydberg Formula:
$\bar{v}=\frac{1}{\lambda}=R\left[\frac{1}{n_f^2}-\frac{1}{n_i^2}\right]$

NUCLEI

Binding Energy
$E_b=[Zm_p+(A-Z)m_n-M_N]c^2$
B.E. per nucleon $E_{bn}=\frac{E_b}{A}$

Nuclear Reactions
– **Nuclear Fission:** Used in nuclear reactor
– **Nuclear Fusion :** Source of energy of the sun and stars.

Radioactivity
$N(t)=N_0e^{-\lambda t}$
$T_{1/2}=\frac{\ln 2}{\lambda}=\tau\times\ln 2$

Decay Schemes
${}^A_ZX\xrightarrow{\alpha}{}^{A-4}_{Z-2}Y+{}^4_2He+Q$
${}^A_ZX\xrightarrow{\beta}{}^{A}_{Z+1}Y+{}^0_{-1}e+\bar{\nu}$
${}^A_ZX^*\xrightarrow{\gamma}{}^A_ZX^{(G.S.)}+{}^0_0\gamma+\text{Energy}$

SEMICONDUCTOR ELECTRONICS

DIODES

Halfwave Rectifier
$I_{dc}=\frac{I_m}{\pi}$; $V_{dc}=\frac{I_m}{\pi}R_L$

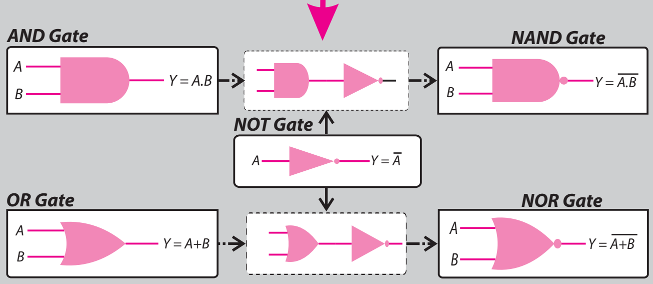
Fullwave Rectifier
$I_{dc}=\frac{2I_m}{\pi}$; $V_{dc}=\frac{2I_m}{\pi}R_L$

Zener Diode
Used as a voltage regulator
$V_Z=V_0-IR$

LED
Converts electrical energy to light energy.

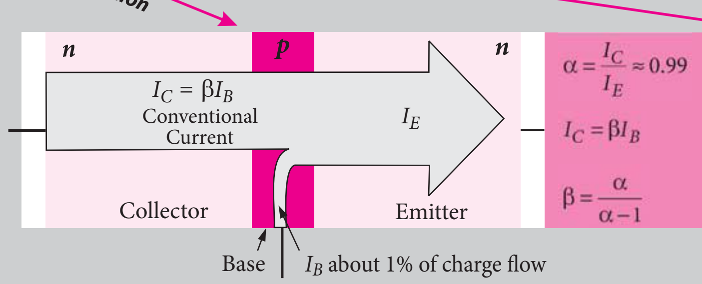
Solar Cells
Convert solar energy into electrical energy

LOGIC GATES



TRANSISTORS

Characteristic Action



$\alpha=\frac{I_C}{I_E}\approx 0.99$
$I_C=\beta I_B$
$\beta=\frac{\alpha}{\alpha-1}$

Application

Amplifier (CE): $A_V=-\beta_{ac}\times\frac{R_0}{R_i}$
$A_P=\beta_{ac}A_V$
Switch : OFF ≡ Cut off region
ON ≡ Saturation region
Oscillator (LC) : $\upsilon=\frac{1}{2\pi\sqrt{LC}}$

COMMUNICATION

COMMUNICATION SYSTEM

Transmitter
Modulation of waves

Communication Channel
Transports modulated signal to receiver

Receiver
Demodulation of waves

PROPAGATION OF EM WAVES

Ground Wave Propagation
Here low frequency signals glides over the curvature of earth from transmitter to receiver

Sky Wave Propagation
Here signal transmits using ionospheric reflection
$\upsilon_c=9(N_{max})^{1/2}$

Space Wave Propagation
Maximum LOS distance between two antennas
$d_m=\sqrt{2H_TR}+\sqrt{2H_RR}$

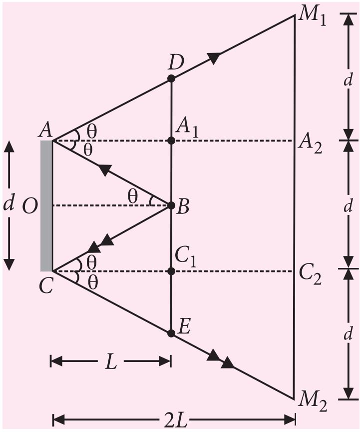
12. (b): In this situation, $v = -D$

from lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$,

we have $\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f}$ *i.e.*, $\frac{D}{u} = 1 + \frac{D}{f}$

So, $M = \frac{D}{u} = \left(1 + \frac{D}{f}\right)$

13. (d): Refer to the course of rays shown in figure.



Clearly, $\tan\theta = \frac{A_2M_1}{AA_2} = \frac{A_2M_1}{2L}$

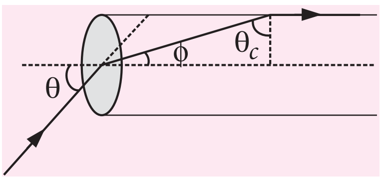
Also, $\tan\theta = \frac{AO}{BO} = \frac{d/2}{L} = \frac{d}{2L}$

Hence, $\frac{A_2M_1}{2L} = \frac{d}{2L}$ or $A_2M_1 = d$

Similarly, $C_2M_2 = d$

Thus, $M_1M_2 = A_2M_1 + A_2C_2 + C_2M_2 = 3d$

14. (d): Refer to figure:



$\phi = (90° - \theta_c)$

Clearly, $\frac{\sin\theta}{\sin\phi} = \mu$ or $\frac{\sin\theta}{\cos\theta_c} = \mu$

or $\sin\theta = \mu\cos\theta_c$

$$\mu = \sqrt{1 - \sin^2\theta_c} = \mu\sqrt{1 - \frac{1}{\mu^2}} = \sqrt{\mu^2 - 1}$$

$$= \sqrt{(2/\sqrt{3})^2 - 1} = \frac{1}{\sqrt{3}}$$

$\Rightarrow$ $\theta = \sin^{-1}(1/\sqrt{3})$

15. (d): Since $\mu \sin\theta$ = constant and θ is the same for two extreme media, $\therefore$ $\mu_4 = \mu_1$.

16. (c) : As $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$,

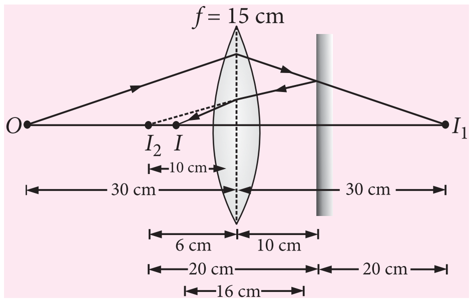
For no dispersion,

$$\frac{d}{d\mu}\left(\frac{1}{f}\right) = \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0 \text{ or } R_1 = R_2.$$

17. (b): In case of lens, for object O, as $u = -30$ cm, $f = 15$ cm, v comes out to be 30 cm and as such its image is formed by the lens at I_1.

I_1 acts as a virtual object for mirror and its real image is formed at I_2 at a distance of 20 cm from the mirror.

I_2 acts as a virtual object for the lens at a distance of 10 cm from lens and its real image I is formed at a distance 6 cm from the lens or 10 cm + 6 cm = 16 cm from the mirror.



18. (d): $f_o + f_e = 60$ cm

Given, $f_e = 5$ cm

$\therefore$ $f_o = 55$ cm

In the second case, $v_o = (60 + 10) - f_e = 65$ cm

From the relation,

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

we have, $\frac{1}{65} - \frac{1}{u_o} = \frac{1}{55}$ $\therefore$ $u_o = -357.5$ cm

19. (d): $M_\infty = \frac{LD}{f_o f_e}$

$\therefore$ $M_\infty = \frac{10 \times 25}{0.5 \times 1} = 500$

20. (b): For camera lens,

Time of exposure $\propto$ (f-number)^2

$\Rightarrow$ $\frac{t_2}{t_1} = \left(\frac{5.6}{2.8}\right)^2 = 4$

$\therefore$ $t_2 = 4t_1 = 4 \times \frac{1}{200} = \frac{1}{50}$ s $= 0.02$ s

21. (c) : Along x-direction, relative velocity of image with respect to mirror = – (relative velocity of object with respect to mirror)

$\Rightarrow \quad v_i - v_m = -(v_o - v_m)$

$\Rightarrow \quad v_i - (-5\cos 30°) = -(10\cos 60° - (-5\cos 30°))$

$\therefore \quad v_i = -5(1+\sqrt{3})\text{ m s}^{-1}$

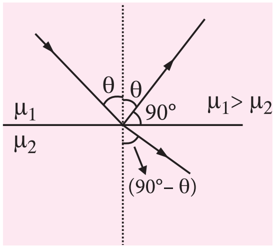
Along y-direction, $v_o = v_i$

$\therefore \quad v_i = 10\sin 60° = 5\sqrt{3}\text{ m s}^{-1}$

$\therefore$ Velocity of the image

$$= -5(1+\sqrt{3})\hat{i} + 5\sqrt{3}\hat{j}\text{ m s}^{-1}.$$

22. (b):



$\mu_1 \sin\theta = \mu_2 \times \sin(90° - \theta)$

$\Rightarrow \quad \dfrac{\mu_2}{\mu_1} = \tan\theta$

For θ_c : $\mu_1 \times \sin\theta_c = \mu_2 \times \sin(90°)$

$\sin\theta_c = \dfrac{\mu_2}{\mu_1} = \tan\theta \Rightarrow \theta_c = \sin^{-1}(\tan\theta)$

23. (d): For A:

$u = -3\text{ m}, v_1 = ?, f = -1\text{ m}$

$$\frac{1}{v_1} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-1} - \frac{1}{-3} = \frac{1}{3} - 1 = -\frac{2}{3} \text{ or } v_1 = -\frac{3}{2}\text{ m}$$

For B:

$$\frac{1}{v_2} = \frac{1}{-1} - \frac{1}{-5}$$

or $\dfrac{1}{v_2} = \dfrac{1}{5} - 1 = -\dfrac{4}{5}$ or $v_2 = -\dfrac{5}{4}\text{m}$

Now, $v_1 - v_2 = -\dfrac{3}{2} - \left(-\dfrac{5}{4}\right)$

$$= -\frac{3}{2} + \frac{5}{4} = -\frac{1}{4}\text{m} = -0.25\text{m}$$

Again, $\dfrac{l_1}{O} = -\dfrac{v_1}{u_1}$

or $l_1 = -\dfrac{v_1}{u_1}O = -\left(\dfrac{-3}{2}\right)\left(\dfrac{-1}{3}\right)2 = -1\text{ m}$

Again, $\dfrac{l_2}{O} = -\dfrac{v_2}{u_2}$

or $l_2 = -\left(-\dfrac{5}{4}\right)\left(\dfrac{1}{-5}\right)2 = -0.5\text{ m}$

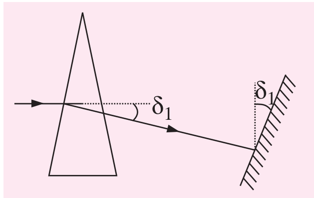
24. (c) : $\dfrac{x}{1} = \dfrac{x_{rel}}{\mu} \Rightarrow x_{rel} = \mu x$

$$\frac{d^2x_{rel}}{dt^2} = \mu\frac{d^2x}{dt^2} \Rightarrow a_{rel} = \mu g = 4g/3$$

25. (d): For light to retrace the path, the light ray falling on the mirror should be along the normal.

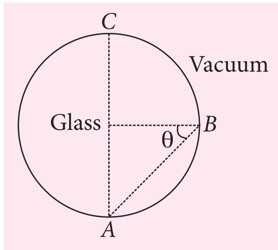
Deviation produced by prism,

$\delta_1 = (\mu - 1)A = (1.5 - 1)4° = 2°$ CW



So, mirror has to be rotated by 2° in CW direction.

26. (b): This is a case of total internal reflection.



Here $\theta = 45°$ and $\theta > \theta_C$

$\Rightarrow \quad 45° > \theta_C \Rightarrow \sin 45° > \sin\theta_C$

$\Rightarrow \quad \dfrac{1}{\sqrt{2}} > \dfrac{1}{\mu} \Rightarrow \mu > \sqrt{2} \qquad \left(\text{As } v = \dfrac{c}{\mu}\right)$

$\Rightarrow \quad \dfrac{c}{v} > \sqrt{2}$

$$v < \frac{c}{\sqrt{2}} = \frac{3\times10^8}{\sqrt{2}} \Rightarrow v < 2.1\times10^8\text{ ms}^{-1}$$

Only (b) is not possible.

27. (a): In a prism: $r + r' = A \Rightarrow r = A - r'$

$\therefore \quad r = 60° - (10° + kt^2) = 50 - kt^2$

28. (d): The lens maker's formula is

$$\frac{1}{f}=\left(\frac{n_L}{n_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

where n_L = refractive index of the lens
n_m = refractive index of medium

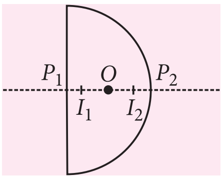
In case of double concave lens, R_1 is negative and R_2 is positive. Therefore, $\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ is negative. For the lens to be diverging in nature, its focal length f should be negative.

$\therefore$ $\left(\frac{n_L}{n_m}-1\right)$ should be positive or $n_L > n_m$

As $n_2 > n_1$,

$\therefore$ the lens should be filled with L_2 and immersed in L_1.

29. (b): As is clear from figure,



$P_1P_2 = 8$ cm

Real depth for plane surface

$x = P_1\,O = 4$ cm

Apparent depth for plane surface,

$$x' = P_1I_1 = \frac{x}{\mu} = \frac{4}{1.6} = 2.5 \text{ cm}$$

For the curved surface,

$u = P_2\,O = -4$ cm, $v = P_2\,I_2 = ?$

$\mu_2 = 1.6$, $\mu_1 = 1$, $R = -8$ cm

As refraction occurs from denser to rarer medium therefore,

$$-\frac{\mu_2}{u}+\frac{\mu_1}{v}=\frac{\mu_1-\mu_2}{R}$$

$$-\frac{1.6}{-4}+\frac{1}{v}=\frac{1-1.6}{-8}=\frac{3}{40}$$

$$v=-\frac{40}{13}\approx -3.0\,\text{cm}$$

i.e., $P_2\,I_2 = 3.0$ cm

$\therefore$ $I_1\,I_2 = P_1\,P_2 - P_1\,I_1 - P_2\,I_2$
$= 8 - 2.5 - 3.0 = 2.5$ cm

30. (d): As $\sin i_C = \frac{3}{\sqrt{3^2+4^2}}=\frac{3}{5}$, $\mu=\frac{1}{\sin i_C}=\frac{5}{3}$

As $\mu = \frac{c}{v_l}$, $v_l = \frac{c}{\mu} = \frac{3\times10^8 \text{ m s}^{-1}}{(5/3)} = 1.8\times10^8 \text{ m s}^{-1}$

◈◈

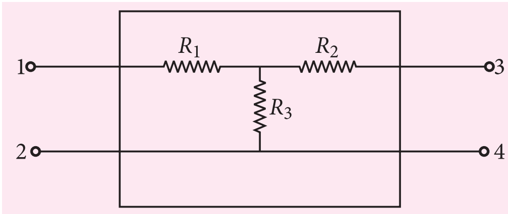
OLYMPIAD PROBLEMS

1. Consider a block of copper of radius 5 cm. Its outer surface is coated black. How much time is required for the block to cool down from 1000 K to 300 K? (Take: density of copper = 9×10^3 kg m^{-3} and specific heat = 4 kJ kg^{-1} K^{-1})
(a) 127 s (b) 127×10^3 s
(c) 343 s (d) 343×10^3 s

2. Find the resulting amplitude and phase of the given four vibrations:
$$x_1 = A\cos\omega t,\ x_2 = \frac{A}{2}\cos\left(\omega t + \frac{\pi}{2}\right),$$
$$x_3 = \frac{A}{4}\cos(\omega t + \pi),\ x_4 = \frac{A}{8}\cos\left(\omega t + \frac{3\pi}{2}\right).$$
(a) $\frac{A}{16}, \tan^{-1}\left(\frac{3}{8}\right)$ (b) $\frac{2\sqrt{2}A}{\sqrt{5}}, \tan^{-1}\left(\frac{1}{4}\right)$
(c) $\frac{3\sqrt{5}}{8}A, \tan^{-1}\left(\frac{1}{2}\right)$ (d) $A, \tan^{-1}(1)$

3. A source of sound of frequency υ_0 = 1300 Hz is dropped from a height H = 505 m above the ground. At the same time, a detector is projected upwards with velocity u = 50 m s^{-1} along the same line. If the velocity of sound is c = 300 m s^{-1}, find the frequency detected by the detector at t = 5 s. (Take g = 10 m s^{-2})
(a) 1100 Hz (b) 1300 Hz
(c) 1500 Hz (d) 1700 Hz

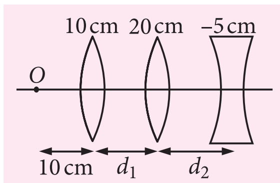
4. If voltage is applied between terminals 1 and 2 when terminals 3 and 4 are open, the power liberated is P_1 = 40 W and when terminals 3 and 4 are connected, the power liberated is P_2 = 80 W. If the same source is connected to the terminals 3 and 4, the power liberated in the circuit when terminals 1 and 2 are open is P_3 = 20 W. Determine the power P_4 consumed in the circuit when the terminals 1 and 2 are connected and the same voltage is applied between the terminals 3 and 4.



(a) 20 W (b) 40 W
(c) 60 W (d) 80 W

5. Two identical metal balls of radius r = 2.5 cm are at a distance a = 1 m from each other and are charged, one with potential V_1 = +1200 V and other with potential V_2 = −1200 V. What are the charges q_1 and q_2 on these balls?
(a) q_1 = 3.42 nC, q_2 = −3.42 nC
(b) q_1 = 2.33 nC, q_2 = −2.33 nC
(c) q_1 = −12.5 nC, q_2 = 12.5 nC
(d) q_1 = −6.77 nC, q_2 = 6.77 nC

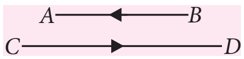
6. The given figure shows a combination of lenses and position of a point object O. Focal lengths of the lenses are written on the lenses.
The values of d_1 and d_2 for final rays to be parallel to the principal axis are



(a) d_1 = 10 cm, d_2 = 5 cm
(b) d_1 = 20 cm, d_2 = 10 cm
(c) d_1 = 30 cm, d_2 = 15 cm
(d) d_1 = 40 cm, d_2 = 20 cm

7. A long horizontal wire AB, which is free to move in a vertical plane and carries a steady current of 20 A, is in equilibrium at a height of 0.01 m over another parallel long wire CD which is fixed in a horizontal plane and carries a steady current of

30 A, as shown in figure. When AB is slightly depressed, it executes simple harmonic motion. Find the period of oscillations.



(a) 0.01 s (b) 0.02 s
(c) 0.1 s (d) 0.2 s

SOLUTIONS

1. (b) : We consider the block as a perfect black body ($\varepsilon = 1$). Therefore rate of heat energy radiated out by the copper block at any instant

$$\frac{dQ}{dt} = \sigma A T^4 \qquad \text{...(i)}$$

where, T is the temperature of the block at that instant and A is the surface area. Temperature T decreases continuously with time as the block cools down.

If m is the mass of the block and c is its specific heat, then heat given out, for unit change of temperature, is given by

$$\frac{dQ}{dT} = -mc \qquad \text{...(ii)}$$

From eqns. (i) and (ii), the relation between change of temperature dT in time dt, that is,

$$\frac{dT}{dt} = -\frac{\sigma A}{mc}T^4 \qquad \text{...(iii)}$$

Minus sign shows that temperature decreases as time increases. Hence, time required for the block to cool down from T_1 to T_2 is given by

$$\int_0^t dt = -\frac{mc}{\sigma A}\int_{T_1}^{T_2}\frac{dT}{T^4}$$

or $\quad t = \frac{mc}{3\sigma A}\left(\frac{1}{T_2^3} - \frac{1}{T_1^3}\right) = \frac{mc}{3\sigma A}\left(\frac{T_1^3 - T_2^3}{T_1^3 T_2^3}\right)$

Further, if r is the radius of the sphere, we have

$$\frac{m}{A} = \frac{\left(\frac{4}{3}\pi r^3\right)\rho}{4\pi r^2} = \frac{r\rho}{3}$$

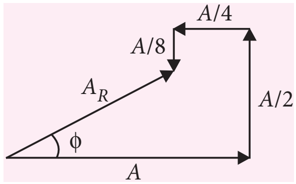
where ρ is density of copper. Then, we get

$$t = \frac{r\rho c}{9\sigma}\left(\frac{T_1^3 - T_2^3}{T_1^3 T_2^3}\right)$$

$$= \frac{(5\times10^{-2})(9\times10^3)(4\times10^3)}{9\times5.67\times10^{-8}}\left(\frac{10^3 - 3^3}{3^3.10^3.10^6}\right)$$

$$= 127 \times 10^3 \text{ s.}$$

2. (c) : From the vector diagram, the resultant amplitude is

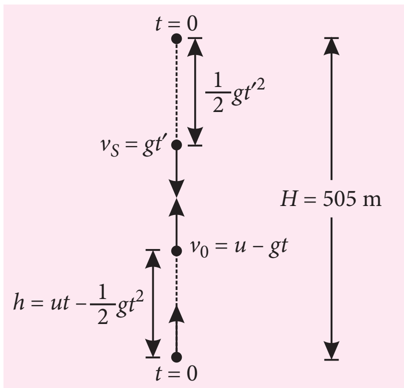


$$A_R = \sqrt{\left(A - \frac{A}{4}\right)^2 + \left(\frac{A}{2} - \frac{A}{8}\right)^2}$$

$$= A\sqrt{\left(\frac{3}{4}\right)^2 + \left(\frac{3}{8}\right)^2} = \frac{3\sqrt{5}A}{8}$$

and $\tan\phi = \dfrac{(A/2) - (A/8)}{A - (A/4)} = \dfrac{1}{2} \Rightarrow \phi = \tan^{-1}\left(\dfrac{1}{2}\right)$

3. (c) : As sound takes finite time to travel, so the sound wave received at $t = 5$ s must be emitted earlier. Let t' be the time at which the source emits a sound wave which is detected at $t = 5$ s.



Then, the time for which the sound wavefronts move is $t - t'$. Distance travelled by wavefronts is $c(t - t')$. Let the distance moved by detector be h, then

$$h = ut - \frac{1}{2}gt^2$$

and $\quad H - \frac{1}{2}gt'^2 - h = c(t - t')$

or $\quad 505 - \frac{1}{2}gt'^2 - \left(ut - \frac{1}{2}gt^2\right) = c(t - t')$

Substituting numerical values, $t = 5$ s, $u = 50$ m s^{-1} $g = 10$ m s^{-2}, $c = 300$ m s^{-1}, we have

$$505 - 5t'^2 - 125 = 300(5 - t')$$

or $\quad t'^2 - 60t' + 224 = 0 \quad$ or $\quad t' = 4$ s

Now applying Doppler's formula

$$\upsilon = \upsilon_0\frac{c + v_0}{c - v_s}$$

where, $v_s = gt' = (10)(4) = 40 \text{ m s}^{-1}$
$v_0 = u - gt = 50 - (10)(5) = 0$

$$\therefore \upsilon = 1300\left(\frac{300}{300-40}\right) = 1500 \text{ Hz}$$

4. (b) : When 1 and 2 are connected to voltage supply V and 3 and 4 are open,

$$P_1 = (R_1+R_3)\left(\frac{V}{R_1+R_3}\right)^2 = \frac{V^2}{R_1+R_3}$$

When 3 are 4 are closed and 1 and 2 are connected to V,

$$R_{eq} = R_1 + \frac{R_2R_3}{R_2+R_3}$$

$$\therefore \quad P_2 = \frac{V^2(R_2+R_3)}{R_1R_2+R_2R_3+R_3R_1}$$

When 3 and 4 are connected to V and 1 and 2 are open, $P_3 = \dfrac{V^2}{R_2+R_3}$

When 3 and 4 are connected to V and 1 and 2 are closed

$$R_{eq} = R_2 + \frac{R_3R_1}{R_3+R_1} = \frac{R_1R_2+R_2R_3+R_3R_1}{R_3+R_1}$$

$$\therefore \quad P_4 = \frac{V^2(R_3+R_1)}{R_1R_2+R_2R_3+R_3R_1}$$

Now, $\dfrac{P_1}{P_3} = \dfrac{R_2+R_3}{R_1+R_3}$

and $\dfrac{P_2}{P_4} = \dfrac{R_2+R_3}{R_1+R_3} \Rightarrow \dfrac{P_1}{P_3} = \dfrac{P_2}{P_4}$

or $\quad P_4 = \dfrac{P_2}{P_1} \times P_3 = \dfrac{80\times 20}{40} = 40 \text{ W}$

5. (a) : The potential of the first ball, V_1 = potential established by the charge on one ball + potential set-up by charge on the second ball

$$\Rightarrow \quad V_1 = k\frac{q_1}{r} + k\frac{q_2}{a} \qquad \text{...(i)}$$

Similarly, $V_2 = k\dfrac{q_2}{r} + k\dfrac{q_1}{a}$ ...(ii)

Solving (i) and (ii) for q_1 and q_2, we get

$$q_1 = \frac{ar}{k}\left(\frac{rV_2 - aV_1}{r^2 - a^2}\right) \text{ and } q_2 = \frac{ar}{k}\left(\frac{rV_1 - aV_2}{r^2 - a^2}\right)$$

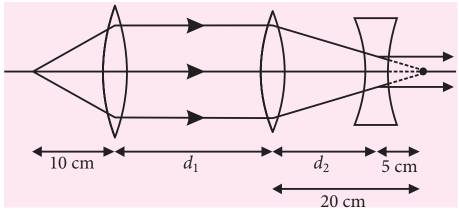
Since $r^2 << a^2$

$$\therefore \quad q_1 = \frac{-r}{ka}(rV_2 - aV_1) \text{ and } q_2 = \frac{-r}{ka}(rV_1 - aV_2)$$

On putting values, we get

$q_1 = 3.42$ nC and $q_2 = -3.42$ nC

6. (c) :

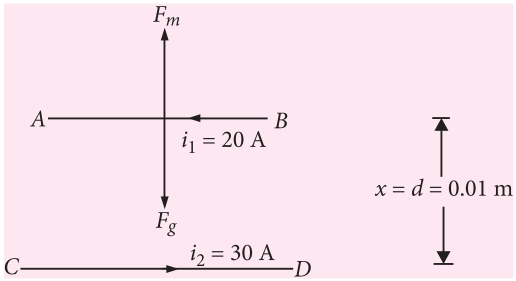


$\therefore \quad d_2 = 20 - 5 = 15$ cm

d_1 can take any value.

7. (d) : Let m be the mass per unit length of wire AB. At a height x above the wire CD, magnetic force per unit length on wire AB will be given by

$$F_m = \frac{\mu_0}{2\pi}\frac{i_1i_2}{x} \quad \text{(upwards)} \qquad \text{...(i)}$$



Weight per unit length of wire AB is

$F_g = mg$ (downwards)

At $x = d$, wire is in equilibrium, *i.e.*,

$$F_m = F_g \text{ or } \frac{\mu_0}{2\pi}\frac{i_1i_2}{d} = mg$$

When AB is depressed, x decreases therefore, F_m will increase, while F_g remains the same. Let AB be displaced by dx downwards.

Differentiating eq. (i) with respect to x, we get

$$dF_m = -\frac{\mu_0}{2\pi}\frac{i_1i_2}{x^2}dx = -\frac{\mu_0}{2\pi}\frac{i_1i_2}{d^2}dx$$

$$\Rightarrow \quad dF_m = -\left(\frac{mg}{d}\right)dx \qquad \text{...(ii)}$$

i.e., restoring force, $dF_m \propto -dx$

Hence, the motion of wire is simple harmonic.

$$\therefore \quad \text{Acceleration of wire, } a = \frac{dF_m}{m} = -\left(\frac{g}{d}\right)dx$$

Hence, period of oscillation

$$T = 2\pi\sqrt{\frac{|\text{displacement}|}{|\text{acceleration}|}} = 2\pi\sqrt{\left|\frac{dx}{a}\right|}$$

or $\quad T = 2\pi\sqrt{\dfrac{d}{g}} = 2\pi\sqrt{\dfrac{0.01}{9.8}}$ or $T = 0.2$ s

◈◈

ACE YOUR WAY CBSE XII

Series 1

CHAPTERWISE PRACTICE PAPER : ELECTRIC CHARGES AND FIELDS | ELECTROSTATIC POTENTIAL AND CAPACITANCE

Time Allowed : 3 hours | Maximum Marks : 70

GENERAL INSTRUCTIONS

(i) All questions are compulsory.
(ii) Q. no. 1 to 5 are very short answer questions and carry 1 mark each.
(iii) Q. no. 6 to 10 are short answer questions and carry 2 marks each.
(iv) Q. no. 11 to 22 are also short answer questions and carry 3 marks each.
(v) Q. no. 23 is a value based question and carries 4 marks.
(vi) Q. no. 24 to 26 are long answer questions and carry 5 marks each.
(vii) Use log tables if necessary, use of calculators is not allowed.

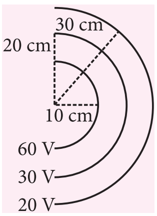
SECTION - A

1. An infinite line of charge produces an electric field of 4.2×10^4 N C^{-1} at a distance of 1.8 m. Calculate the linear charge density.

2. Force experienced by an electron in an electric field $\vec{E}$ is $\vec{F}$ newton. What will be the force experienced by a proton in the same field? Given that mass of a proton is 1836 times the mass of an electron.

3. Can a body have a charge 8.0×10^{-20} C? Give reason.

4. Figure shows some equipotential surfaces. What can you say about the magnitude and the direction of the electric field?



5. Why does the electric field inside a dielectric decrease when it is placed in an electric field?

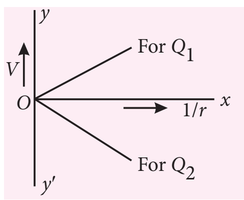
SECTION - B

6. A parallel plate capacitor is filled completely with a dielectric layer of Mylar film ($\varepsilon_r = 3.1$) that is 12 μm thick. The effective area of the film and the conducting plates is 0.1 m^2. What is the capacitance of the capacitor and what voltage it can stand? Dielectric strength of Mylar = 240×10^6 V m^{-1}.

7. Two charges q_1 and q_2 of 0.1 pC and –0.1 pC respectively are 10 Å apart. What is the electric field at a point on the line joining them at a distance of 10 cm from their midpoint?

8. What is the electric field in the cavity, if a conductor having a cavity is charged. Does the result depend on the shape and size of cavity of the conductor?

9. Figure shows the variation of electric potential V with $1/r$, where r is the distance from the two charges Q_1 and Q_2. Determine

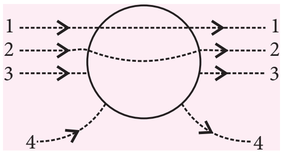


(i) signs of two charges Q_1 and Q_2

(ii) which of the two charges has a larger magnitude? Justify.

OR

A metallic solid sphere is placed in a uniform electric field as shown in figure. Which path is followed by the lines of force? Give reason.



10. A hemispherical body is placed in a uniform electric field $\vec{E}$. What is the flux linked with the curved surface, if field is (a) parallel to base and (b) perpendicular to base?

SECTION - C

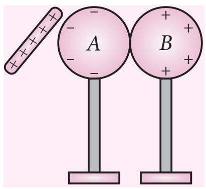
11. A thin spherical shell of radius 0.20 m has a uniform surface charge density of $+2.0 \times 10^{-8}$ C m^{-2}. Calculate the magnitude of electric field at a point

(a) distant 0.50 m from centre of the shell,

(b) on the surface of shell, and

(c) distant 0.10 m from the centre of shell.

12. A glass rod rubbed with silk is brought close to two uncharged metallic spheres in contact with each other, inducing charges on them as shown in the following figure. Describe what happens, when

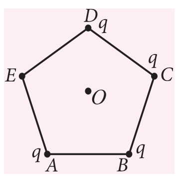


(a) the spheres are slightly separated,

(b) the glass rod is subseqently removed, and

(c) the spheres are separated far apart.

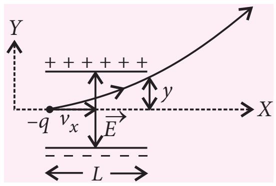
13. Four point charges, each of $+q$, are placed on four vertices of a regular pentagon as shown in the figure. Find the net electric field at the centre point O of the pentagon. Given that distance of point O from each vertex point is a.



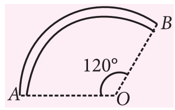
14. A dielectric slab of thickness 1.0 cm and dielectric constant 5 is placed between the plates of a parallel plate capacitor of plate area 0.01 m^2 and separation 2.0 cm. Calculate the change in capacity on introduction of dielectric. What would be the change, if the dielectric slab is replaced by conducting slab?

15. Two pieces of copper, each weighing 0.01 kg are placed at a distance of 0.1 m from each other. One electron from per 1000 atoms of one piece is transferred to other piece of copper. What will be the coulomb force between two pieces after the transfer of electrons? Atomic weight of copper is 63.5 g mol^{-1}. Avogadro's number = 6×10^{23} /gram mole.

16. A particle of mass m and charge $(-q)$ enters the region between the two charged plates initially moving along X-axis with speed v_x shown in the following figure. The length of plate is L and an uniform electric field E is maintained between the plates. Show that the vertical deflection of the particle at the far edge of the plate is $\dfrac{qEL^2}{2mv_x^2}$.



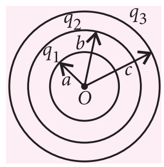
17. A thin plastic rod having a linear charge density of 0.2 nC m^{-1} is bent into a circular arc of radius 3.2 m and central angle 120° as shown in the adjoining figure. Find the potential at point O, the centre of curvature.



OR

What are (a) the charge, (b) the charge density, and (c) electric field at the surface of a conducting sphere of radius 0.3 m whose potential is 150 V?

18. Three concentric conducting spherical shells of radii a, b and c ($c > b > a$) carrying charges q_1, q_2 and q_3 respectively are arranged as shown in the figure. What is the value of electrostatic potential at the surface of three shells? Which is higher?



19. An electrical technician requires a capacitance of 2 μF in a circuit across a potential difference of 1 kV. A large number of 1 μF capacitors are available to him, each of which can withstand a potential difference of not more than 400 V. Suggest a possible arrangement that requires a minimum number of capacitors.

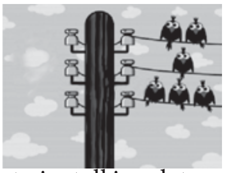
20. A 600 pF capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 600 pF capacitor. How much electrostatic energy is lost in the process?

21. Show that the force on each plate of a parallel plate capacitor has magnitude equal to $\frac{1}{2}QE$, where Q is the charge on the capacitor, and E is the magnitude of electric field between the plates. Explain the origin of the factor $\frac{1}{2}$.

22. A solid sphere of radius R has a charge Q distributed in its volume with a charge density, $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at $r = R/2$ is 1/8 times that at $r = R$, find the value of constant a.

SECTION - D

23. Toshit generally observes birds in large groups sitting on high tension power lines and thinks why these birds do not get electric shock while sitting on electric power lines. One day he observed a small bird burnt when the two parallel power lines touched the bird due to strong wind which brought the power lines so close.



He immediately called his teacher and enquired about the reason and knowing it well he requested his father to contact the electricity persons and to tighten the wires and also to install insulators between the parallel wires so that space between the wires is maintained.

His father immediately contacted the authorities and got the permanent arrangement done. This way he was able to save the lives of many birds.

(i) What are the values possessed by Toshit and his elders?

(ii) Why were the birds not getting electric shock when sitting on a single power line?

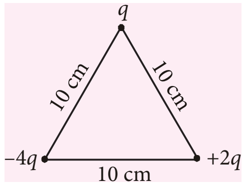
(iii) Why was the bird burned when came in contact with two power line?

(iv) How did the distancing of lines solve the problem?

SECTION - E

24. (a) Derive an expression for the torque experienced by an electric dipole kept in a uniform electric field.

(b) Calculate the work done to dissociate the system of three charges placed on the vertices of a triangle as shown. Here $q = 1.6 \times 10^{-10}$ C.



OR

(a) Define the term electrostatic potential. Give the dependence of electrostatic potential due to a small electric dipole at a far off point lying on (i) the axial line, and (ii) equatorial line.

(b) Briefly explain the principle of a capacitor. Obtain the expression for the capacitance of a parallel plate capacitor.

25. Using Gauss' law, deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point (i) outside and (ii) inside the shell. Plot a graph showing variation of electric field as a function of $r > R$ and $r < R$. (r being the distance from the centre of the shell).

OR

State Gauss' theorem in electrostatics and express it mathematically. Using it, derive an expression for electric field at a point near a thin infinite plane sheet of electric charge. How does this electric field change for a uniformly thick sheet of charge?

26. Derive an expression for the magnitude of electric field intensity at any point along the equatorial line of a short dipole. Give the direction of electric field intensity at that point. For a short dipole, what is the ratio of electric field intensities at two equidistant points from the centre of dipole, one along the axial line and another on equatorial line?

OR

(a) Derive the expression for the energy stored in a parallel plate capacitor. Hence obtain the expression for the energy density of the electric field.

(b) A cylindrical capacitor has two co-axial cylinders of length 15 cm and radii 1.5 cm and 1.4 cm. The outer cylinder is earthed and the inner cylinder is given a charge of 3.5 μC. Determine the capacitance of the system and the potential of the inner cylinder. Neglect end effects (*i.e.*, bending of the field lines at the ends).

SOLUTIONS

1. Here, electric field, $E = 4.2 \times 10^4$ N C^{-1} and $r = 1.8$ m

$\because \quad E = \dfrac{\lambda}{2\pi\varepsilon_0 r} = \dfrac{2\lambda}{4\pi\varepsilon_0 .\ r}$

$\therefore$ Linear charge density,

$$\lambda = \frac{1}{2}(Er\ .\ 4\pi\varepsilon_0) = \frac{4.2\times 10^4 \times 1.8}{2\times 9\times 10^9}$$

$= 4.2 \times 10^{-6}$ C m^{-1} = 4.2 μC m^{-1}

2. Since charges on an electron and proton have same magnitude, hence force experienced by a proton in the electric field $\vec{E}$ will have exactly same magnitude as force experienced by electron. However, direction of force is opposite because proton charge is positive whereas electron charge is negative. Thus, force acting on proton will be $-\vec{F}$.

3. A body cannot have a charge of 8.0×10^{-20} C, because it is less than the charge on an electron or proton and according to quantised nature of charge, no charge less than $e = 1.6 \times 10^{-19}$ is possible independently.

4. For the equipotential surface of 60 V,

$$60\text{ V} = \frac{kq}{r} = \frac{kq}{0.10\text{ m}}$$

or $\quad kq = 60\text{ V} \times 0.10\text{ m} = 6\text{ V m}$

$\therefore \quad E = \dfrac{kq}{r} = \dfrac{6}{r^2}$ V m^{-1}

Clearly, E decreases with r. The direction of electric field will be radially outward because V decreases with r.

5. An electric field (E_i) is induced inside the dielectric in a direction opposite to the external electric field (E_0) due to polarisation. On account of this, the net electric field (E) inside the slab is less than the external field as $E = E_0 - E_i$.

6. Here, d =12 μm= 12×10^{-6} m, $A = 0.1$ m^2, $\varepsilon_r = 3.1$

$$C = \frac{\varepsilon_r\varepsilon_0 A}{d} = \frac{3.1(8.85\times 10^{-12})(0.1)}{12\times 10^{-6}}\text{F}$$

$= 0.23 \times 10^{-6}$ F = 0.23 μF

Further, V_{max} = dielectric strength × d

$= (240 \times 10^6\text{ Vm}^{-1})\,(12 \times 10^{-6}\text{ m}) = 2880$ V

7. Here, $q_1 = q_2 = q = 0.1$ pC $= 10^{-13}$ C (in magnitude)
Length of the electric dipole formed by these charges,

$2a = 10$ Å $= 10^{-9}$ m

Thus, electric dipole moment,

$p = 2qa = 10^{-13} \times 10^{-9}$ C m $= 10^{-22}$ C m

Distance of the point under consideration on the axial line from the midpoint, $r = 10$ cm $= 0.1$ m

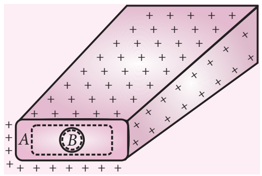
Since $a << r$, electric field at a point on the axial line, *i.e.*,

$$E = k\frac{2p}{r^3}$$

or $\quad E = (9 \times 10^9)\dfrac{2\times 10^{-22}}{(0.1)^3}$ N C^{-1}

$= 18 \times 10^{-10}$ N C^{-1}

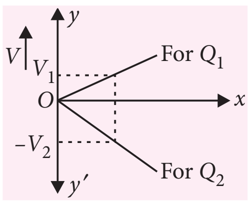
8. When a conductor is charged, charge resides on its outer surface. In figure for Gaussian surface A in the conductor or B in the cavity,



$\phi = \oint \vec{E}\cdot\vec{ds} = \dfrac{q}{\varepsilon_0} = 0 \quad \therefore \ E = 0$

i.e., electric field vanishes in a conductor or in a cavity. This is independent of shape and size of conductor and cavity.

9. (i) Electric potential due to a point charge Q at a point distant r from the charge is $V = \dfrac{Q}{4\pi\varepsilon_0 r}$



V is positive only when Q is positive. Therefore, from figure, Q_1 is positive and Q_2 is negative.

(ii) For a given value of r, we find from figure that $|V_2| > |V_1|$

$\therefore \quad |Q_2| > |Q_1|$

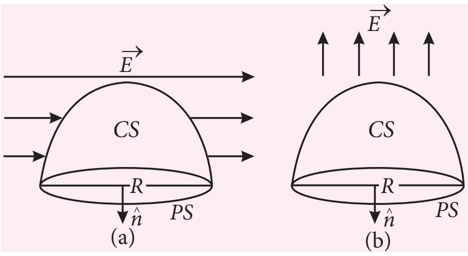
OR

When a solid conducting sphere is placed in a uniform electric field $\vec{E}$, free electrons of the conductor move in a direction opposite to $\vec{E}$. This results in the development of some negative charge on the left part of the sphere and an equal positive charge on right part of the sphere. Electric lines of force end normally on left part, and start normally from the right part. Therefore, path 4 is correct.

10. Considering the hemispherical body as a closed body with a curved surface (CS) and a plane surface (PS), the total flux (ϕ) linked with the body will be zero, as no charge is enclosed by the body

i.e., $\phi = \phi_{CS} + \phi_{PS} = 0$ ...(i)

It implies that number of electric field lines entering the surface is equal to number of electric field lines leaving the surface.



(a) When field is parallel to the base,

$\phi_{PS} = E \times \pi R^2 \cos 90° = 0$

$\therefore$ From (i), $\phi = \phi_{CS} = 0$

(b) When field is perpendicular to the base,

$\phi_{PS} = E \times \pi R^2 \cos 180° = -E\pi R^2$.

$\therefore$ From (i), $\phi_{CS} - E\pi R^2 = 0$ or $\phi_{CS} = E\pi R^2$.

11. Here, radius of a shell, R = 0.20 m and uniform surface density of charge, $\sigma = +2.0 \times 10^{-8}$ C m^{-2}

(a) At a point having radius, r = 0.50 m ($r > R$), electric field,

$$E_1 = \frac{\sigma R^2}{\varepsilon_0 r^2} = \frac{2.0\times10^{-8}\times(0.20)^2}{8.85\times10^{-12}\times(0.50)^2}$$

$= 3.6 \times 10^2$ N C^{-1}

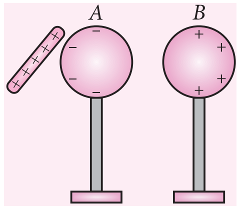
(b) Electric field at a point on the surface of shell,

$$E_2 = \frac{\sigma}{\varepsilon_0} = \frac{2.0\times10^{-8}}{8.85\times10^{-12}} = 2.3 \times 10^3 \text{ N C}^{-1}$$

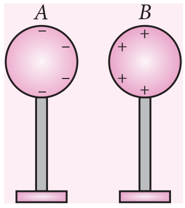
(c) At a point having r = 0.10 m ($r < R$), the electric field is zero.

12. When a glass rod rubbed with silk, *i.e.,* positively charged glass rod is brought close to two uncharged metallic spheres A and B in contact, as shown, negative charge is induced on near side of sphere A and positive charge is induced on far side of sphere B.

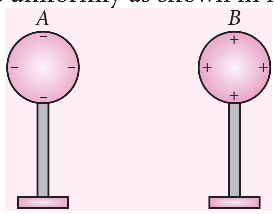
(a) If the spheres are slightly separated keeping charged glass rod in the neighbour, the two spheres are found to be oppositely charged and attract each other.



(b) If now the glass rod is removed, charges on spheres A and B rearrange themselves as shown in figure due to force of mutual attraction.



(c) When the spheres are separated far apart, negative and positive charges on spheres A and B spread uniformly as shown in figure.



13. Charges of q each are placed at vertices A, B, C and D of the pentagon $ABCDE$. If a charge q is also placed at vertex E, then from the principle of symmetry, the net electric field at point O will be zero.

It means that field at O due to four charges at A, B, C and D, taken together, is equal and opposite to the field due to the charge q at point E alone.

The field at O due to q charge at point E alone is $q/4\pi\varepsilon_0 a^2$ along EO.

$\therefore$ Electric field at point O due to four point charges placed at four vertices A, B, C and D of regular pentagon will be

$$\vec{E} = \frac{q}{4\pi\varepsilon_0 a^2} \text{ along } OE$$

14. Here, $t = 1.0$ cm $= 10^{-2}$ m, $\varepsilon_r = K = 5$,
$A = 0.01\ \text{m}^2 = 10^{-2}\ \text{m}^2$, $d = 2$ cm $= 2 \times 10^{-2}$ m

Capacity with air in between the plates

$$C_0 = \frac{\varepsilon_0 A}{d} = \frac{8.85\times10^{-12}\times10^{-2}}{2\times10^{-2}}$$
$$= 4.425 \times 10^{-12}\ \text{F}$$

Capacity with dielectric slab in between the plates

$$C = \frac{\varepsilon_0 A}{d - t\left(1-\frac{1}{K}\right)} = \frac{8.85\times10^{-12}\times10^{-2}}{2\times10^{-2}-10^{-2}\left(1-\frac{1}{5}\right)}$$
$$= 7.375 \times 10^{-12}\ \text{F}$$

Capacity with conducting slab in between the plates

$$C' = \frac{\varepsilon_0 A}{d-t} = \frac{8.85\times10^{-12}\times10^{-2}}{2\times10^{-2}-1\times10^{-2}}$$
$$= \frac{8.85\times10^{-14}}{10^{-2}} = 8.85 \times 10^{-12}\ \text{F}$$

Increase in capacity on introduction of dielectric

$$= C - C_0 = 7.375 \times 10^{-12} - 4.425 \times 10^{-12}$$
$$= 2.95 \times 10^{-12}\ \text{F}$$

Increase in capacity on introduction of conducting slab

$$= C' - C_0 = 8.85 \times 10^{-12} - 4.425 \times 10^{-12}$$
$$= 4.425 \times 10^{-12}\ \text{F}$$

15. Mass of each piece of copper = 0.01 kg = 10 g

Number of atoms in each piece of copper

$$= \frac{6\times10^{23}\times10}{63.5} = 9.45 \times 10^{22}$$

Number of electrons transferred

$$n = \frac{1}{1000} \times 9.45 \times 10^{22} = 9.45 \times 10^{19}$$

$\therefore$ Charges on each piece after transfer of electrons,

$$q_1 = q_2 = \pm ne = \pm 9.45 \times 10^{19} \times 1.6 \times 10^{-19}$$
$$= \pm 15.12\ \text{C}$$
$$r = 0.1\ \text{m}$$

$$\therefore\ F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = 9\times10^9 \times \frac{(15.12)^2}{(0.1)^2}$$
$$= 2.06 \times 10^{14}\ \text{N}$$

16. Let a particle of mass m, charge $-q$ enter normally the region between two charged plates, each of length L, as shown in the figure. Uniform electric field $\vec{E}$ between the plates is along $-Y$-axis and initial velocity of particle v_x is along X-axis.

Along X-axis, there is no force acting on charged particle and it moves with a constant velocity v_x and takes a time $t = \frac{L}{v_x}$ to reach the far edge of plate.

However, charged particle experiences a force $F = qE$ towards positive charged plate along Y-axis. Thus, it is experiencing an acceleration,

$$a_y = \frac{F}{m} = \frac{qE}{m}$$

As a result, in time t, the particle will cover a distance y along Y-axis, where

$$y = \frac{1}{2}at^2 = \frac{1}{2}\frac{qE}{m}\cdot\left(\frac{L}{v_x}\right)^2 = \frac{qEL^2}{2mv_x^2}$$

So, the vertical deflection of charged particle at the far edge of the plate is $\frac{qEL^2}{2mv_x^2}$.

17. As per question, linear charge density,

$$\lambda = 0.2\ \text{nC m}^{-1} = 2 \times 10^{-10}\ \text{C m}^{-1}$$

Radius of arc, $R = 3.2$ m

and central angle, $\theta = 120° = \frac{2\pi}{3}$ rad

$\therefore$ Total charge on plastic rod,

$$q = \lambda l = \lambda R\theta = 2 \times 10^{-10} \times 3.2 \times \frac{2\pi}{3}\ \text{C}$$

As distance of point O from each and every point of charged arc is same as $R = 3.2$ m, hence electric potential at O,

$$V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R}$$
$$= \frac{9\times10^9\times\left(2\times10^{-10}\times3.2\times\frac{2\pi}{3}\right)}{3.2} = 3.8\ \text{V}$$

OR

(a) Radius of conducting sphere, $R = 0.3$ m
Potential, $V = 150$ V

From the relation, $V = \frac{q}{4\pi\varepsilon_0 R}$, we have

Charge on conducting sphere,

$q = 4\pi\varepsilon_0 RV$

$$\therefore\ q = \frac{0.3\times150}{9\times10^9} = 5.0 \times 10^{-9}\ \text{C}$$

(b) Surface charge density,

$$\sigma = \frac{q}{4\pi R^2} = \frac{5.0\times10^{-9}}{4\times3.14\times(0.3)^2} = 4.42\times10^{-9}\ \text{C m}^{-2}$$

(c) Electric field at the surface of a conducting sphere,

$$E = \frac{\sigma}{\varepsilon_0} = \frac{4.42\times10^{-9}}{8.85\times10^{-12}} = 500 \text{ V m}^{-1}$$

18. We know that potential at any point inside a charged spherical conducting shell is exactly same as on its surface. Making use of this principle, we can say that

Potential on the surface of the smallest shell,

$$V_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{a}+\frac{q_2}{b}+\frac{q_3}{c}\right]$$

Potential on the surface of the intermediate shell,

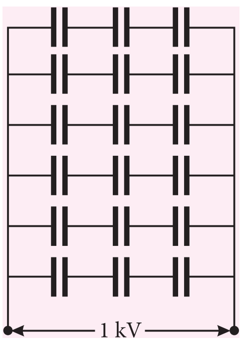
$$V_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1+q_2}{b}+\frac{q_3}{c}\right]$$

and the potential on the surface of the outer shell,

$$V_3 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1+q_2+q_3}{c}\right]$$

Obviously, $V_1 > V_2 > V_3$

19. Potential difference which each available capacitor of 1 μF can withstand = 400 V.



Thus, to withstand a potential difference of 1 kV, minimum number of capacitors which must be connected in series

$$= \frac{1\text{ kV}}{400\text{ V}} = \frac{1000\text{ V}}{400\text{ V}}$$

= 2.5 *i.e.*, 3.

The capacitance of such a combination of three capacitors of 1 μF each in series = $\frac{1}{3}$ μF

In order to obtain a capacitance of 2 μF from such a combination of three capacitors in series, total number of such combinations required to be connected in parallel = $\dfrac{2\,\mu\text{F}}{\frac{1}{3}\,\mu\text{F}} = 6$

Thus, total number of capacitors required

= 6 × 3 = 18

The arrangement of these 18 capacitors is as shown in figure.

20. $C_1 = 600$ pF, $V_1 = 200$ V, $C_2 = 600$ pF, $V_2 = 0$

On connecting charged capacitor to uncharged capacitor, the common potential V across the capacitors is

$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

$$= \frac{600\times10^{-12}\times200+600\times10^{-12}\times0}{(600+600)\times10^{-12}}$$

or $V = 100$ V

Energy stored in capacitors before connection is

$$U_i = \frac{1}{2}C_1V_1^2 + 0 = \frac{1}{2}\times600\times10^{-12}\times200^2$$

or $U_i = 12$ μJ

and energy stored in capacitors after connection is

$$U_f = \frac{1}{2}(C_1+C_2)V^2 = \frac{1}{2}(600+600)\times10^{-12}\times100^2$$

or $U_f = 6$ μJ

Hence the energy lost in the process is

$\Delta U = U_i - U_f = (12 - 6)$ μJ

or $\Delta U = 6$ μJ.

21. Magnitude of electric field between the plates of charged capacitor is

$$E = \frac{\sigma}{\varepsilon_0}$$

However, magnitude of electric field of one plate on the other plate of charged capacitor is $E_1 = \frac{\sigma}{2\varepsilon_0}$ So, force on the one plate of charged capacitor due to the other is

$$F = QE_1 = Q\frac{\sigma}{2\varepsilon_0} = \frac{1}{2}\times Q\times\frac{\sigma}{\varepsilon_0}$$

$$F = \frac{1}{2}QE$$

The factor $\frac{1}{2}$ is because the electric field of one plate on the other plate of charged capacitor is $\frac{1}{2}$ of the resultant electric field E between the plates of charged capacitor.

22. Given that $\rho = kr^a$ and $E\left(\text{at } r = \frac{R}{2}\right) = \frac{1}{8}E\,(\text{at } r = R)$

$$\Rightarrow \frac{q_{\text{enclosed}}}{4\pi\varepsilon_0\left(\frac{R}{2}\right)^2} = \frac{1}{8}\times\frac{Q}{4\pi\varepsilon_0 R^2}$$

$$\Rightarrow q_{\text{enclosed}} = \frac{Q}{32}$$

But $q_{enclosed} = \int_0^{R/2} (kr^a)4\pi r^2 dr$

$$= \int_0^{R/2} 4\pi k r^{a+2} dr = 4\pi k.\left[\frac{r^{a+3}}{a+3}\right]_0^{R/2} = \frac{4\pi k}{(a+3)}.\left[\frac{R}{2}\right]^{a+3}$$

and $Q = \int_0^{R} (kr^a)4\pi r^2 dr = \frac{4\pi k}{(a+3)}.R^{a+3}$

$$\therefore \quad \frac{4\pi k}{(a+3)}.\left[\frac{R}{2}\right]^{a+3} = \frac{1}{32}\times\frac{4\pi k}{a+3}.[R]^{a+3}$$

$$\Rightarrow \quad \left[\frac{1}{2}\right]^{a+3} = \frac{1}{32} = \left(\frac{1}{2}\right)^5$$

$\Rightarrow \quad a + 3 = 5$ or $a = 2.$

23. (i) Toshit has a scientific aptitude, affection towards birds and is highly concerned towards the safety of birds. His elders are highly responsive and sensitive towards their duties.

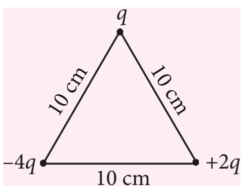
(ii) When a bird is sitting on a single power line, it does not get the shock because its whole body is at the same potential, hence no current passes through its body.

(iii) When a bird comes in contact with two parallel lines, it gets a strong electric shock due to high difference of potential developed across its body, which results in flow of strong current.

(iv) By ensuring proper distance, the danger of electric shock to birds will be reduced.

24. (a) Refer to point 1.4 (5), page no. 6, 7 (MTG Excel in Physics)

(b) $W = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right]$



$$W = \frac{1}{4\pi\varepsilon_0}\left[\frac{q\times -4q}{r} + \frac{q\times 2q}{r} + \frac{-4q\times 2q}{r}\right]$$

$$= \frac{q^2}{4\pi\varepsilon_0 r}\left[-4+2-8\right] = \frac{-10q^2}{4\pi\varepsilon_0 r}$$

$$= -10\times 9\times 10^9 \times \frac{(1.6\times 10^{-10})^2}{10\times 10^{-2}}$$

$$= -2.30 \times 10^{-8}\ \text{J}$$

OR

(a) Refer to points 1.5 (1, 10), page no. 7, 9 (MTG Excel in Physics)

(b) Refer to points 1.11 (2, 4), page no. 15 (MTG Excel in Physics)

25. Refer to point 1.8 (4), page no. 13 (MTG Excel in Physics)

OR

Refer to point 1.8 (2), page no. 11, 12 (MTG Excel in Physics)

26. Refer to points 1.4 (3, 4), page no. 6 (MTG Excel in Physics)

OR

(a) Refer to point 1.11 (9), page no. 16, 17 (MTG Excel in Physics)

(b) Capacitance of cylindrical capacitor is

$$C = \frac{2\pi\varepsilon_0 L}{2.303\log_{10}\frac{b}{a}}$$

$$= \frac{15\times 10^{-2}}{2\times 9\times 10^9\times 2.303\times\log_{10}\frac{1.5}{1.4}}$$

or $\quad C = 1.21 \times 10^{-10}$ F

Electric potential of the inner cylinder is

$$V = \frac{Q}{C} = \frac{3.5\times 10^{-6}\,\text{C}}{1.21\times 10^{-10}\,\text{F}}$$

or $\quad V = 2.89 \times 10^4$ V.

SOLVED PAPER 2016

KARNATAKA CET

1. A body falls freely for 10 sec. Its average velocity during this journey (take $g = 10$ m s^{-2})
(a) 100 m s^{-1} (b) 10 m s^{-1}
(c) 50 m s^{-1} (d) 5 m s^{-1}

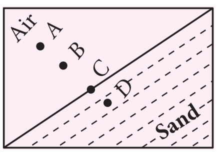
2. Three projectiles A, B and C are projected at an angle of 30°, 45°, 60° respectively. If R_A, R_B and R_C are ranges of A, B and C respectively then (velocity of projection is same for A, B and C)
(a) $R_A = R_B = R_C$ (b) $R_A = R_C > R_B$
(c) $R_A < R_B < R_C$ (d) $R_A = R_C < R_B$

3. The component of a vector $\vec{r}$ along x-axis will have a maximum value if
(a) $\vec{r}$ is along +ve x-axis
(b) $\vec{r}$ is along +ve y-axis
(c) $\vec{r}$ is along –ve y-axis
(d) $\vec{r}$ makes an angle of 45° with the x-axis

4. Maximum acceleration of the train in which a 50 kg box lying on its floor will remain stationary (Given : Co-efficient of static friction between the box and the train's floor is 0.3 and $g = 10$ m s^{-2})
(a) 5.0 m s^{-2} (b) 3.0 m s^{-2}
(c) 1.5 m s^{-2} (d) 15 m s^{-2}

5. A 12 kg bomb at rest explodes into two pieces of 4 kg and 8 kg. If the momentum of 4 kg piece is 20 N s, the kinetic energy of the 8 kg piece is
(a) 25 J (b) 20 J (c) 50 J (d) 40 J

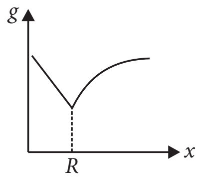
6. Which of the points is likely position of the centre of mass of the system shown in the figure ?

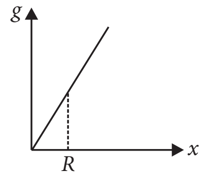


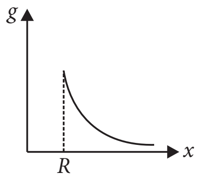
(a) A (b) D (c) B (d) C

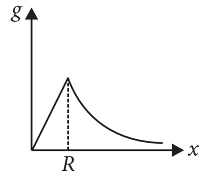
7. Three bodies a ring (R), a solid cylinder (C) and a solid sphere (S) having same mass and same radius roll down the inclined plane without slipping. They start from rest, if v_R, v_C and v_S are velocities of respective bodies on reaching the bottom of the plane, then
(a) $v_R = v_C = v_S$ (b) $v_R > v_C > v_S$
(c) $v_R < v_C < v_S$ (d) $v_R = v_C > v_S$

8. Variation of acceleration due to gravity (g) with distance x from the centre of the earth is best represented by ($R \longrightarrow$ Radius of the earth)

(a) 

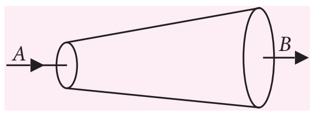
(b) 

(c) 

(d) 

9. A spring is stretched by applying a load to its free end. The strain produced in the spring is
(a) Volumetric (b) Shear
(c) Longitudinal and Shear
(d) Longitudinal

10. An ideal fluid flows through a pipe of circular cross section with diameters 5 cm and 10 cm as shown. The ratio of velocities of fluid at A and B is



(a) 4 : 1 (b) 1 : 4 (c) 2 : 1 (d) 1 : 2

11. A pan filled with hot food cools form 94 °C to 86 °C in 2 minutes. When the room temperature is 20 °C. How long will it cool from 74 °C to 66 °C ?
(a) 2 minutes (b) 2.8 minutes
(c) 2.5 minutes (d) 1.8 minutes

12. Four rods with different radii r and length l are used to connect two heat reservoirs at different temperatures. Which one will conduct most heat ?
(a) $r = 1$ cm, $l = 1$ m (b) $r = 1$ cm, $l = \frac{1}{2}$ m
(c) $r = 2$ cm, $l = 2$ m (d) $r = 2$ cm, $l = \frac{1}{2}$ m

13. A Carnot engine working between 300 K and 400 K has 800 J of useful work. The amount of heat energy supplied to the engine from the source is
(a) 2400 J (b) 3200 J
(c) 1200 J (d) 3600 J

14. A particle executing SHM has maximum speed of 0.5 m s^{-1} and maximum acceleration of 1.0 m s^{-2}. The angular frequency of oscillation is
(a) 2 rad s^{-1} (b) 0.5 rad s^{-1}
(c) 2π rad s^{-1} (d) 0.5π rad s^{-1}

15. A source of sound is moving with a velocity of 50 m s^{-1} towards a stationary observer. The observer measures the frequency of sound as 500 Hz. The apparent frequency of sound as heard by the observer when source is moving away from him with the same speed is (Speed of sound at room temperature 350 m s^{-1})
(a) 400 Hz (b) 666 Hz
(c) 375 Hz (d) 177.5 Hz

16. If there is only one type of charge in the universe, then ($\vec{E} \to$ Electric field, $\overrightarrow{ds} \to$ Area vector)
(a) $\oint \vec{E}\cdot\overrightarrow{ds} \neq 0$ on any surface
(b) $\oint \vec{E}\cdot\overrightarrow{ds}$ could not be defined
(c) $\oint \vec{E}\cdot\overrightarrow{ds} = \infty$ if charge is inside
(d) $\oint \vec{E}\cdot\overrightarrow{ds} = 0$ if charge is outside,
$= \frac{q}{\varepsilon_0}$ if charge is inside

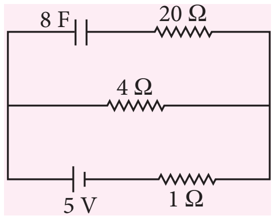
17. An electron of mass m, charge e falls through a distance h meter in a uniform electric field E. Then time of fall
(a) $t = \sqrt{\frac{2hm}{eE}}$ (b) $t = \frac{2hm}{eE}$
(c) $t = \sqrt{\frac{2eE}{hm}}$ (d) $t = \frac{2eE}{hm}$

18. If $\vec{E}_{ax}$ and $\vec{E}_{eq}$ represents electric field at a point on the axial and equatorial line of a dipole. If points are at a distance r from the centre of the dipole, for $r >> a$
(a) $\vec{E}_{ax} = \vec{E}_{eq}$ (b) $\vec{E}_{ax} = -\vec{E}_{eq}$
(c) $\vec{E}_{ax} = -2\vec{E}_{eq}$ (d) $\vec{E}_{eq} = 2\vec{E}_{ax}$

19. Nature of equipotential surface for a point charge is
(a) Ellipsoid with charge at foci.
(b) Sphere with charge at the centre of the sphere.
(c) Sphere with charge on the surface of the sphere.
(d) Plane with charge on the surface.

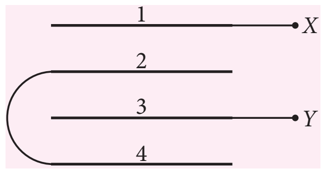
20. A particle of mass 1 gm and charge 1 μC is held at rest on a frictionless horizontal surface at distance 1 m from the fixed charge 2 mC. If the particle is released, it will be repelled. The speed of the particle when it is at a distance of 10 m from the fixed charge is
(a) 60 m s^{-1} (b) 100 m s^{-1}
(c) 90 m s^{-1} (d) 180 m s^{-1}

21. A capacitor of 8 F is connected as shown. Charge on the plates of the capacitor



(a) 32 C (b) 40 C (c) 0 C (d) 80 C

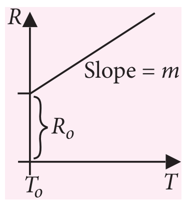
22. Four metal plates are arranged as shown. Capacitance between X and Y ($A \to$ Area of each plate, $d \to$ distance between the plates)



(a) $\frac{3}{2}\frac{\varepsilon_0 A}{d}$ (b) $\frac{2\varepsilon_0 A}{d}$
(c) $\frac{2}{3}\frac{\varepsilon_0 A}{d}$ (d) $\frac{3\varepsilon_0 A}{d}$

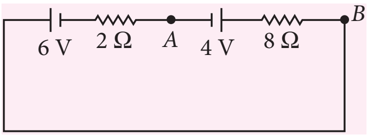
23. Mobility of free electrons in a conductor is
(a) directly proportional to electron density.
(b) directly proportional to relaxation time.
(c) inversely proportional to electron density.
(d) inversely proportional to relaxation time.

24. Variation of resistance of the conductor with temperature is as shown.



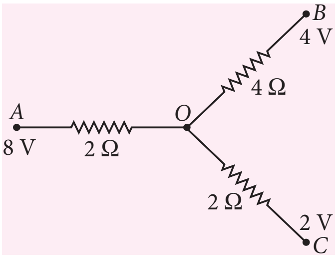
The temperature co-efficient (α) of the conductor is
(a) $\frac{R_o}{m}$ (b) mR_o (c) m^2R_o (d) $\frac{m}{R_o}$

25. Potential difference between A and B in the following circuit



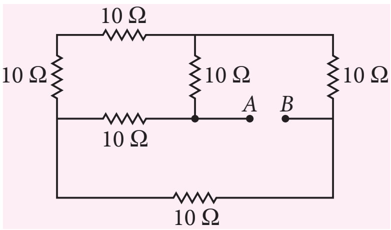
(a) 4 V (b) 5.6 V (c) 2.8 V (d) 6 V

26. In the following network potential at O



(a) 4 V (b) 3 V (c) 6 V (d) 4.8 V

27. Effective resistance between A and B in the following circuit



(a) 10 Ω (b) 20 Ω (c) 5 Ω (d) $\frac{20}{3}$ Ω

28. Two heating coils of resistances 10 Ω and 20 Ω are connected in parallel and connected to a battery of emf 12 V and internal resistance 1 Ω. The power consumed by them are in the ratio

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

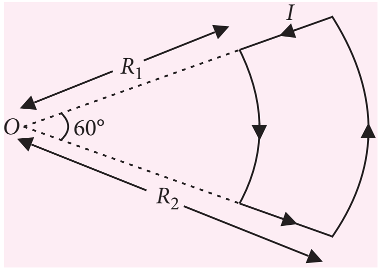
29. A proton is projected with a uniform velocity v along the axis of a current carrying solenoid, then

(a) the proton will be accelerated along the axis.
(b) the proton path will be circular about the axis.
(c) the proton moves along helical path.
(d) the proton will continue to move with velocity v along the axis.

30. In the cyclotron, as radius of the circular path of the charged particle increases (ω = angular velocity, v = linear velocity)

(a) both ω and v increases
(b) only ω increases, v remains constant
(c) v increases, ω remains constant
(d) v increases, ω decreases

31. A conducting wire carrying current is arranged as shown. The magnetic field at O



(a) $\frac{\mu_0 i}{12}\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$ (b) $\frac{\mu_0 i}{12}\left[\frac{1}{R_1}+\frac{1}{R_2}\right]$

(c) $\frac{\mu_0 i}{6}\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$ (d) $\frac{\mu_0 i}{6}\left[\frac{1}{R_1}+\frac{1}{R_2}\right]$

32. The quantity of a charge that will be transferred by a current flow of 20 A over 1 hour 30 minutes period is

(a) 10.8×10^3 C (b) 10.8×10^4 C
(c) 5.4×10^3 C (d) 1.8×10^4 C

33. A galvanometer coil has a resistance of 50 Ω and the meter shows full scale deflection for a current of 5 mA. This galvanometer is converted into voltmeter of range 0 – 20 V by connecting

(a) 3950 Ω in series with galvanometer
(b) 4050 Ω in series with galvanometer
(c) 3950 Ω in parallel with galvanometer
(d) 4050 Ω in parallel with galvanometer

34. χ_1 and χ_2 are susceptibility of a paramagnetic material at temperatures T_1 K and T_2 K respectively, then

(a) $\chi_1 = \chi_2$ (b) $\chi_1 T_1 = \chi_2 T_2$
(c) $\chi_1 T_2 = \chi_2 T_1$ (d) $\chi_1\sqrt{T_1} = \chi_2\sqrt{T_2}$

35. At certain place, the horizontal component of earth's magnetic field is 3.0 G and the angle dip at that place is 30°. The magnetic field of earth at that location

(a) 4.5 G (b) 5.1 G (c) 3.5 G (d) 6.0 G

36. The process of superimposing message signal on high frequency carrier wave is called

(a) Amplification (b) Demodulation
(c) Transmission (d) Modulation

37. A long solenoid with 40 turns per cm carries a current of 1 A. The magnetic energy stored per unit volume is _______ J/m^3.

(a) 3.2 π (b) 32 π (c) 1.6 π (d) 6.4 π

38. A wheel with 10 spokes each of length L m is rotated with a uniform angular velocity ω in a plane normal to the magnetic field B. The emf induced between the axle and the rim of the wheel

(a) $\frac{1}{2}N\omega BL^2$ (b) $\frac{1}{2}\omega BL^2$

(c) ωbL^2 (d) $N\omega BL^2$

39. The rms value of current in a 50 Hz AC circuit is 6 A. The average value of AC current over a cycle is

(a) $6\sqrt{2}$ (b) $\frac{3}{\pi\sqrt{2}}$ (c) Zero (d) $\frac{6}{\pi\sqrt{2}}$

40. A capacitor of capacitance 10 μF is connected to an AC source and an AC ammeter. If the source voltage varies as $V = 50\sqrt{2}\ \sin 100t$, the reading of the ammeter is

(a) 50 mA (b) 70.7 mA

(c) 5.0 mA (d) 7.07 mA

41. In a series LCR circuit, the potential drop across L, C and R respectively are 40 V, 120 V and 60 V. Then the source voltage is

(a) 220 V (b) 160 V (c) 180 V (d) 100 V

42. In a series LCR circuit, an alternating emf (v) and current (i) are given by the equation $v = v_0 \sin \omega t$, $i = i_0 \sin\left(\omega t + \frac{\pi}{3}\right)$. The average power dissipated in the circuit over a cycle of AC is

(a) $\frac{v_0 i_0}{2}$ (b) $\frac{v_0 i_0}{4}$ (c) $\frac{\sqrt{3}}{2}v_0 i_0$ (d) Zero

43. Electromagnetic radiation used to sterilise milk is

(a) X-ray (b) γ-ray

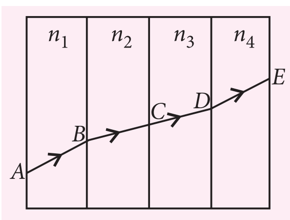
(c) UV rays (d) Radiowaves

44. A plane glass plate is placed over a various coloured letters (violet, green, yellow, red). The letter which appears to raised more is

(a) Red (b) Yellow

(c) Green (d) Violet

45. A ray of light passes through four transparent media with refractive indices n_1, n_2, n_3 and n_4 as shown. The surface of all media are parallel.



If the emergent ray DE is parallel to incident ray AB, then

(a) $n_1 = n_4$ (b) $n_2 = n_4$

(c) $n_3 = n_4$ (d) $n_1 = \frac{n_2 + n_3 + n_4}{3}$

46. Focal length of a convex lens is 20 cm and its RI is 1.5. It produces an erect, enlarged image if the distance of the object from the lens is

(a) 40 cm (b) 30 cm (c) 15 cm (d) 20 cm

47. A ray of light suffers a minimum deviation when incident on an equilateral prism of refractive index $\sqrt{2}$. The angle of incidence is

(a) 30° (b) 45° (c) 60° (d) 50°

48. In Young's double slit experiment the source is white light. One slit is covered with red filter and the other with blue filter. There shall be

(a) Alternate red and blue fringes

(b) Alternate dark and pink fringes

(c) Alternate dark and yellow fringes

(d) No interference

49. Light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. The angular width of central maxima in the diffraction pattern is (measured from minimum to minimum)

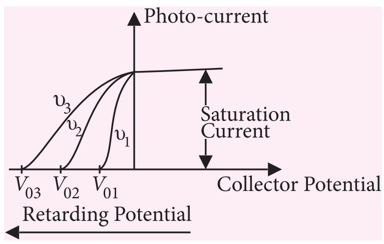
(a) 6×10^{-3} rad (b) 4×10^{-3} rad

(c) 2.4×10^{-3} rad (d) 4.5×10^{-3} rad

50. For what distance is ray optics is good approximation when the aperture is 4 mm and the wavelength of light is 400 nm ?

(a) 24 m (b) 40 m (c) 18 m (d) 30 m

51. The variation of photo-current with collector potential for different frequencies of incident radiation υ_1, υ_2 and υ_3 is as shown in the graph, then



(a) $\upsilon_1 = \upsilon_2 = \upsilon_3$ (b) $\upsilon_1 > \upsilon_2 > \upsilon_3$

(c) $\upsilon_1 < \upsilon_2 < \upsilon_3$ (d) $\upsilon_3 = \frac{\upsilon_1 + \upsilon_2}{2}$

52. The de Broglie wavelength of an electron accelerated to a potential of 400 V is approximately

(a) 0.03 nm (b) 0.04 nm

(c) 0.12 nm (d) 0.06 nm

53. Total energy of electron in an excited state of hydrogen atom is – 3.4 eV. The kinetic and potential energy of electron in this state
(a) $K = -3.4$ eV $U = -6.8$ eV
(b) $K = 3.4$ eV $U = -6.8$ eV
(c) $K = -6.8$ eV $U = +3.4$ eV
(d) $K = +10.2$ eV $U = -13.6$ eV

54. When electron jumps from $n = 4$ level to $n = 1$ level, the angular momentum of electron changes by
(a) $\frac{h}{2\pi}$ (b) $\frac{2h}{2\pi}$ (c) $\frac{3h}{2\pi}$ (d) $\frac{4h}{2\pi}$

55. A radio-active sample of half-life 10 days contains 1000 x nuclei. Number of original nuclei present after 5 days is
(a) 707 x (b) 750 x (c) 500 x (d) 250 x

56. An element X decays into element Z by two-step process.

$$X \longrightarrow Y + {}_2^4\text{He},\ Y \longrightarrow Z + 2e^- \text{ then}$$

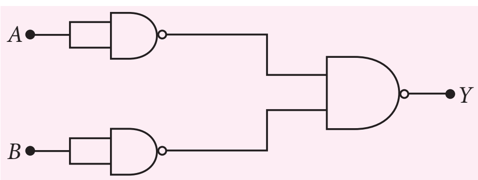
(a) X and Z are isobars.
(b) X and Y are isotopes.
(c) X and Z are isotones.
(d) X and Z are isotopes.

57. A nucleus of mass 20 u emits a γ photon of energy 6 MeV. If the emission assume to occur when nucleus is free and at rest, then the nucleus will have kinetic energy nearest to (take 1 u = 1.6×10^{-27} kg)
(a) 10 keV (b) 1 keV
(c) 0.1 keV (d) 100 keV

58. Constant DC voltage is required from a variable AC voltage. Which of the following is correct order of operation ?
(a) Regulator, filter, rectifier
(b) Rectifier, regulator, filter
(c) Rectifier, filter, regulator
(d) Filter, regulator, rectifier

59. In a transistor, the collector current varies by 0.49 mA and emitter current varies by 0.50 mA. Current gain β measured is
(a) 49 (b) 150 (c) 99 (d) 100

60. Identify the logic operation carried out by the following circuit.



(a) AND (b) NAND (c) NOR (d) OR

SOLUTIONS

1. **(c) :** Average velocity,

$$v_{av} = \frac{\text{Net displacement}}{\text{Time taken}} = \frac{s_2 - s_1}{t_2 - t_1}$$

Here, $t_1 = 0$ s, $s_1 = 0$ m, $t_2 = 10$ s, $g = 10$ m s^{-2}

$$s_2 = ut_2 + \frac{1}{2}gt_2^2 = 0 \times 10 + \frac{1}{2} \times 10 \times 10^2 = 500 \text{ m}$$

$$\therefore \quad v_{av} = \frac{500 - 0}{10 - 0} = 50 \text{ m s}^{-1}$$

2. **(d) :** Range, $R = \frac{u^2 \sin 2\theta}{g}$

Here g is constant and u is same for the projectiles A, B and C. $\therefore$ $R \propto \sin 2\theta$

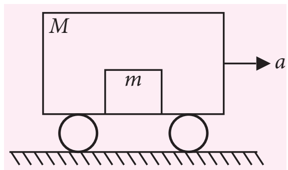
$\Rightarrow$ $R_A : R_B : R_C = \sin 60° : \sin 90° : \sin 120°$

$$R_A : R_B : R_C = \frac{\sqrt{3}}{2} : 1 : \frac{\sqrt{3}}{2} = \sqrt{3} : 2 : \sqrt{3}$$

Hence, $R_A = R_C < R_B$.

3. **(a) :** A vector has a maximum value along its own direction only. Hence the component of a vector $\vec{r}$ along x-axis will have a maximum value if $\vec{r}$ is along positive x-axis.

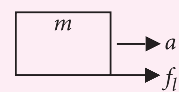
4. **(b) :** $m = 50$ kg
$\mu = 0.3$
$g = 10$ m s^{-2}



Suppose a is the common acceleration of the box and the train.
Block will be at rest if limiting friction (f_l) is equal to ma (a = maximum acceleration).

$\therefore$ $f_l = ma \Rightarrow \mu N = ma$
$\Rightarrow$ $\mu mg = ma \Rightarrow a = \mu g$
$\therefore$ $a = 0.3 \times 10 = 3$ m s^{-2}.

F.B.D. of mass m



5. **(a) :** $M = 12$ kg, $u = 0$, $m_1 = 4$ kg, $m_2 = 8$ kg
$p_1 = 20$ N s, $p_2 = ?$, $K_2 = ?$
Using linear momentum conservation principle,
$p = p_1 + p_2$
$\Rightarrow$ $0 = p_1 + p_2 \Rightarrow p_2 = -p_1 = -20$ N s

Kinetic energy of 8 kg piece, $K_2 = \frac{p_2^2}{2m}$

$$K_2 = \frac{(-20)^2}{2 \times 8} = \frac{400}{16} = 25 \text{ J}$$

6. **(b) :** The centre of mass of the system lies at point D because half portion is filled with the sand.

7. **(c) :** Velocity of the body at the bottom of incline when it rolls down the inclined plane,

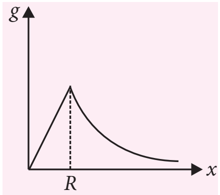
$$v = \sqrt{\frac{2gh}{(1 + I/mR^2)}}$$

$$I_R = mR^2,\ I_C = \frac{1}{2}mR^2,\ I_S = \frac{2}{5}mR^2$$

$\because$ $I_R > I_C > I_S$ $\therefore$ $v_R < v_C < v_S$

8. (d) : Acceleration due to gravity

$$g = \begin{cases} \dfrac{GM}{R^3}x & ;\ x < R \\ \dfrac{GM}{x^2} & ;\ x \geq R \end{cases}$$



9. (c)

10. (a) :

Using continuity equation, $A_1v_1 = A_2v_2$

$$\frac{v_1}{v_2} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2} = \left(\frac{r_2}{r_1}\right)^2 = \frac{4}{1}$$

11. (b) : According to Newton's law of cooling

$$\frac{d\theta}{dt} = k\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right) \quad \text{...(i)}$$

Here $\dfrac{d\theta}{dt} = \dfrac{94 - 86}{2} = 4\ °\text{C min}^{-1}$

$\theta_1 = 94\ °\text{C},\ \theta_2 = 86\ °\text{C},\ \theta_0 = 20\ °\text{C}$

Using eqn (i),

$$4 = k\left(\frac{94 + 86}{2} - 20\right) = 70k$$

$$k = \frac{4}{70} \quad \text{...(ii)}$$

For fall in temperature from 74 °C to 66 °C,
Using eqn (i),

$$\frac{74 - 66}{t} = \frac{4}{70}\left(\frac{74 + 66}{2} - 20\right) = \frac{4}{70} \times 50$$

$$t = \frac{8 \times 7}{4 \times 5} = 2.8 \text{ minutes}$$

12. (d) : Rate of heat conduction through a rod of radius r and length l,

$$\frac{dQ}{dt} = \frac{K(\pi r^2)(T_2 - T_1)}{l}$$

For given K and $(T_2 - T_1)$, $\dfrac{dQ}{dt} \propto \dfrac{r^2}{l}$

Hence, rod with $r = 2$ cm and $l = \dfrac{1}{2}$ m will conduct most heat.

13. (b) : As, $\eta = 1 - \dfrac{T_2}{T_1} = \dfrac{W}{Q}$ $\therefore$ $Q = W\Big/\left(1 - \dfrac{T_2}{T_1}\right)$

Here, $T_1 = 400$ K, $T_2 = 300$ K, $W = 800$ J

$$\therefore \quad Q = \frac{800}{\left(1 - \frac{300}{400}\right)} = \frac{800}{(1/4)} = 3200 \text{ J}$$

14. (a) : In SHM, $a_{max} = A\omega^2$ and $v_{max} = A\omega$

$$\omega = \frac{a_{max}}{v_{max}}$$

Here, $a_{max} = 1$ m s^{-2}, $v_{max} = 0.5$ m s^{-1}

$$\therefore \quad \omega = \frac{1}{0.5} = 2 \text{ rad s}^{-1}$$

15. (c) : $v_s = 50$ m s^{-1}, $v_o = 0$, $\upsilon' = 500$ Hz, $v = 350$ m s^{-1}

When source is moving towards stationary observer

$$\upsilon' = \left(\frac{v}{v - v_s}\right)\upsilon \quad \text{...(i)}$$

When source is moving away from stationary observer,

$$\upsilon'' = \left(\frac{v}{v + v_s}\right)\upsilon$$

or, $$\upsilon'' = \left(\frac{v - v_s}{v + v_s}\right)\upsilon' \quad \text{[Using eqn. (i)]}$$

$$= \left(\frac{350 - 50}{350 + 50}\right) \times 500 = 375 \text{ Hz}$$

16. (d) : If there is only one type of charge in the universe then it will produce electric field somehow. Hence Gauss's law is valid.

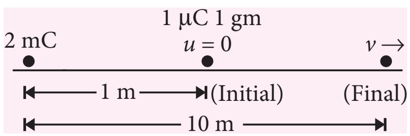
17. (a)

18. (c) : $\vec{E}_{ax} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{2\vec{p}}{r^3}$; $\vec{E}_{eq} = -\dfrac{1}{4\pi\varepsilon_0}\dfrac{\vec{p}}{r^3} = -\dfrac{\vec{E}_{ax}}{2}$

$\therefore$ $\vec{E}_{ax} = -2\vec{E}_{eq}$

19. (b)

20. (d) :



Using energy conservation principle, $E_i = E_f$

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1 q}{r_1^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q}{r_2^2} + \frac{1}{2}mv^2$$

$$\frac{1}{2}mv^2 = \frac{q_1 q}{4\pi\varepsilon_0}\left(\frac{1}{r_1^2} - \frac{1}{r_2^2}\right)$$

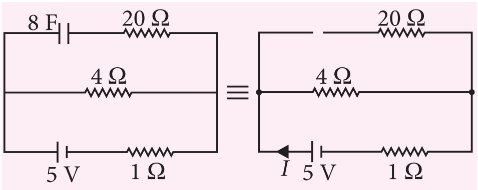
$$= 9 \times 10^9 \times 2 \times 10^{-3} \times 1 \times 10^{-6}\left(\frac{1}{1^2} - \frac{1}{10^2}\right)$$

$$\Rightarrow \quad \frac{1}{2}mv^2 = 18\left(\frac{99}{100}\right)$$

$$v^2 = \frac{18\times 2\times 99}{10^{-3}\times 100} = 36\times 990$$

$$v = \sqrt{36\times 990} \approx 189 \text{ m s}^{-1}$$

21. (a) : In steady state,



current in the circuit,

$$I = \frac{5}{4+1} = 1\text{ A}$$

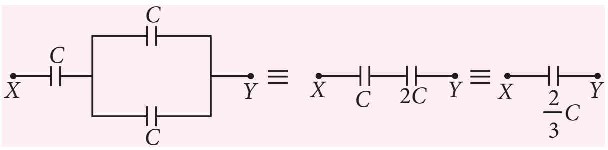
Voltage across each branch,

$V = I \times 4$ or $5 - I \times 1 = 4$ V

Hence charge on capacitor,

$q = CV = 8 \times 4 = 32$ C

22. (c) : Given capacitors can be rearranged as



Here $C = \dfrac{\varepsilon_0 A}{d}$ $\therefore$ $C_{XY} = \dfrac{2}{3}C = \dfrac{2}{3}\dfrac{\varepsilon_0 A}{d}$

23. (b) : Mobility of free electrons in a conductor,

$$\mu = \frac{e\tau_e}{m_e} \;\; i.e., \; \mu \propto \tau_e$$

24. (d) : Equation of the line,

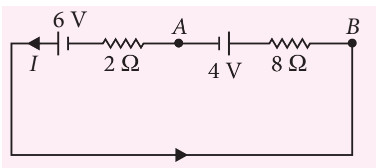
$R = R_o + m\,(T - T_o)$ ...(i)

We know, $R = R_o\,[1 + \alpha\,(T - T_o)]$ ...(ii)

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

$$R_o\,\alpha = m \;\; \therefore \;\; \alpha = \frac{m}{R_o}$$

25. (b) :



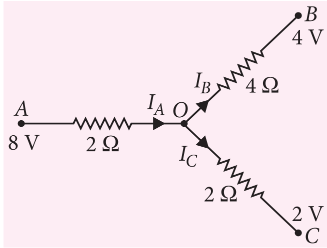
Apply KVL in the given circuit,

$6 - 8I - 4 - 2I = 0$

or, $2 - 10I = 0$ or, $I = 2/10 = 0.2$ A

$V_{AB} = 4 + I \times 8 = 4 + 0.2 \times 8 = 5.6$ V

26. (d) : Using KCL, $I_A = I_B + I_C$



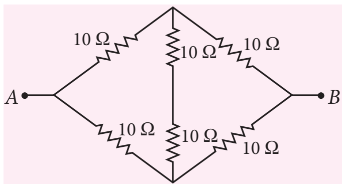
$$\frac{V_A - V_O}{R_{AO}} = \frac{V_O - V_B}{R_{OB}} + \frac{V_O - V_C}{R_{OC}}$$

$$\Rightarrow \frac{8 - V_O}{2} = \frac{V_O - 4}{4} + \frac{V_O - 2}{2}$$

$\Rightarrow$ $16 - 2V_O = V_O - 4 + 2V_O - 4$

$\Rightarrow$ $5V_O = 24 \Rightarrow V_O = \dfrac{24}{5} = 4.8$ V

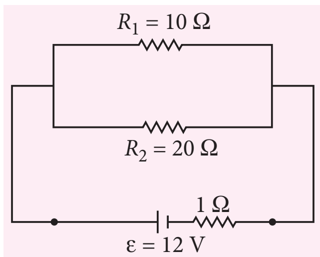
27. (a) : Equivalent circuit of the given circuit



This is balanced Wheatstone bridge.

So, $R_{AB} = \dfrac{20\times 20}{20+20} = 10\ \Omega$

28. (c) : As, $P = \dfrac{V^2}{R}$



For R_1 and R_2, value of V is same.

$\therefore$ $P \propto \dfrac{1}{R} \Rightarrow \dfrac{P_1}{P_2} = \dfrac{R_2}{R_1} = \dfrac{20}{10}$

$P_1 : P_2 = 2 : 1$

29. (d) : Force on the proton, $\vec{F}_B = e(\vec{v}\times\vec{B})$

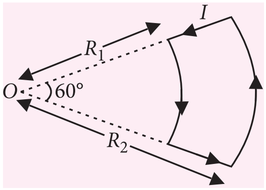
Since, $\vec{v}$ is parallel to $\vec{B}$

$\therefore$ $\vec{F}_B = 0$

Hence proton will continue to move with velocity v along the axis of solenoid.

30. (c)

31. (a) :



$$\vec{B}_O = \vec{B}_1 + \vec{B}_2 + \vec{B}_3 + \vec{B}_4$$

$$\vec{B}_O = \frac{\mu_0 i}{4\pi R_1}\left(\frac{\pi}{3}\right)(-\hat{z}) + \vec{0} + \frac{\mu_0 i}{4\pi R_2}\left(\frac{\pi}{3}\right)(\hat{z}) + \vec{0}$$

$$= \frac{\mu_0 i}{12}\left(\frac{1}{R_2} - \frac{1}{R_1}\right)\hat{z}$$

$$|\vec{B}_O| = \frac{\mu_0 i}{12}\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

32. (b) : Current, $I = \dfrac{dQ}{dt} \Rightarrow dQ = Idt$

$\therefore \quad Q = I \times t$

Here, $I = 20$ A, $t = 1$ h 30 min = 5400 s

$\therefore \quad Q = 20 \times 5400 = 108000 = 10.8 \times 10^4$ C

33. (a) : $V = I(R + G) \Rightarrow R = \dfrac{V}{I} - G$

Here, $V = 20$ V, $G = 50\ \Omega$, $I = 5$ mA $= 5 \times 10^{-3}$ A

$$R = \frac{20}{5 \times 10^{-3}} - 50 = 4000 - 50 = 3950\ \Omega$$

34. (b) : According to Curie's law

$$M = C\frac{B_0}{T} \Rightarrow \frac{\chi B_0}{\mu_0} = C\frac{B_0}{T} \Rightarrow \chi \propto \frac{1}{T}$$

$\therefore \quad \chi_1 T_1 = \chi_2 T_2$

35. (c) : Given $B_H = B\cos\theta = 3$ G, $\theta = 30°$

$$B = \frac{B_H}{\cos 30°} = \frac{3}{\sqrt{3}/2} = 2\sqrt{3} = 3.5 \text{ G}$$

36. (d)

37. (a) : n = 40 turns/cm = 4000 turns/m, $I = 1$ A

$B = \mu_0 n I$

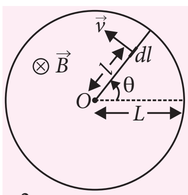
Magnetic energy per unit volume,

$$U_B = \frac{1}{2}\frac{B^2}{\mu_0} = \frac{1}{2}\frac{(\mu_0 n I)^2}{\mu_0} = \frac{\mu_0 n^2 I^2}{2}$$

$$= 2\pi \times 10^{-7} \times (4 \times 10^3)^2 \times 1^2$$

$$= 2\pi \times 16 \times 10^{-7+6} = 3.2\pi \text{ J m}^{-3}$$

38. (b) : Consider a single spoke in the wheel as shown in the figure. Motional emf developed in the small element dl



$$d\varepsilon = B\,v\,dl$$

$$\varepsilon = \int d\varepsilon = \int_0^L B\omega l\,dl = B\omega\int_0^L l\,dl = \frac{1}{2}B\omega L^2.$$

39. (c) : Average value of AC current over a cycle is zero.

40. (a) : $C = 10\ \mu\text{F} = 10^{-5}$ F, $V_0 = 50\sqrt{2}\sin 100t$

$\omega = 100$ rad s^{-1}

$$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 10^{-5}} = 1000\ \Omega$$

$Z = 1000\ \Omega$, $I_{rms} = ?$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{V_0}{\sqrt{2}Z} = \frac{50\sqrt{2}}{\sqrt{2} \times 1000}$$

$$= 0.05 \text{ A} = 50 \text{ mA}$$

41. (d) : Here, $V_L = 40$ V, $V_C = 120$ V, $V_R = 60$ V

Source voltage, $V = \sqrt{V_R^2 + (V_C - V_L)^2}$

$$V = \sqrt{(60)^2 + (120 - 40)^2}$$

$$V = \sqrt{(60)^2 + (80)^2} = 100 \text{ V}$$

42. (b) : In a series LCR circuit,

$$v = v_0\sin\omega t \text{ and } i = i_0\sin\left(\omega t + \frac{\pi}{3}\right)$$

Average power dissipated over a cycle,

$$P = v_{rms}\, i_{rms}\cos\phi$$

$$= \frac{v_0}{\sqrt{2}} \times \frac{i_0}{\sqrt{2}} \times \cos\frac{\pi}{3} = \frac{v_0 i_0}{4}$$

43. (c)

44. (d) : Shift in the image of letter due to glass plate,

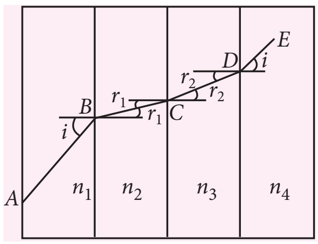
$$s = \left(d - \frac{d}{\mu}\right) = d\left(1 - \frac{1}{\mu}\right)$$

Since, $\lambda_v < \lambda_g < \lambda_y < \lambda_r$; so, $\mu_v > \mu_g > \mu_y > \mu_r$

$\therefore \quad s_v > s_g > s_y > s_r$

Hence maximum shift appears for violet letters.

45. (a) : Apply Snell's law



$${}^1n_2 = \frac{\sin i}{\sin r_1}$$

$${}^2n_3 = \frac{\sin r_1}{\sin r_2}$$

$${}^3n_4 = \frac{\sin r_2}{\sin i}$$

$${}^1n_2 \times {}^2n_3 \times {}^3n_4 = 1 \text{ or } \frac{n_2}{n_1} \times \frac{n_3}{n_2} \times \frac{n_4}{n_3} = 1$$

or $\quad n_4 = n_1$.

46. (c) : A convex lens produces an erect, enlarged image if the object lies between focus and pole *i.e.*, $u < f$. Hence, $u = 15$ cm

47. (b) : For minimum deviation in a prism (A = 60°)

$\delta_m = 2i - A$

Also, $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin(A/2)}$

Here, A = 60°, $\mu = \sqrt{2}$

$\therefore \quad \sqrt{2} = \dfrac{\sin\left(30° + \dfrac{\delta_m}{2}\right)}{\sin 30°}$

or, $\quad \sin\left(30° + \dfrac{\delta_m}{2}\right) = \dfrac{1}{\sqrt{2}} = \sin 45°$

or, $\quad 30° + \dfrac{\delta_m}{2} = 45°$ or, $\delta_m = 30°$

Angle of incidence, $i = (A + \delta_m)/2$

$i = (60° + 30°)/2 = 45°$.

48. (d)

49. (a) : Here, λ = 600 nm = 6×10^{-7} m

a = 0.2 mm = 2×10^{-4} m, θ = ?

Angular width of central maxima,

$$\theta = \frac{2\lambda}{a} = \frac{2\times 6\times 10^{-7}}{2\times 10^{-4}} = 6\times 10^{-3} \text{ rad}$$

50. (b) : Fresnel distance, $Z_f = \dfrac{a^2}{\lambda}$

Here, a = 4 mm = 4×10^{-3} m

λ = 400 nm = 4×10^{-7} m, Z_f = ?

$$\therefore \quad Z_f = \frac{(4\times 10^{-3})^2}{4\times 10^{-7}} = 40 \text{ m}$$

51. (c) : As $eV_s = K_{max} = h\upsilon - \phi_0$ ...(i)

Saturation current is same. It means each source of radiation has same intensity. But corresponding stopping potential is different so they have different frequencies.

So, from eqn. (i) and given graph we conclude that $\upsilon_1 < \upsilon_2 < \upsilon_3$.

52. (d) : de Broglie wavelength, $\lambda = \dfrac{h}{p} = \dfrac{h}{\sqrt{2meV}}$

Here, V = 400 V

$$\lambda = \frac{6.6\times 10^{-34}}{\sqrt{2\times 9.1\times 10^{-31}\times 1.6\times 10^{-19}\times 400}}$$

$$= \frac{6.6\times 10^{-10}}{\sqrt{2\times 9.1\times 1.6\times 4}} = 0.61\times 10^{-10} \text{ m}$$

$= 0.06 \times 10^{-9}$ m = 0.06 nm

53. (b) : Total energy of electron in an excited state,

$E = -3.4$ eV $\therefore$ $K = -E = 3.4$ eV

$V = E - K = -3.4 - 3.4 = -6.8$ eV.

54. (c) : Angular momentum of electron in an orbit,

$L = \dfrac{nh}{2\pi}$

For $n = 4$, $L_4 = \dfrac{4h}{2\pi}$. For $n = 1$, $L_1 = \dfrac{h}{2\pi}$

$\therefore$ Change in angular momentum = $L_4 - L_1$

$= \dfrac{4h}{2\pi} - \dfrac{h}{2\pi} = \dfrac{3h}{2\pi}$.

55. (a) : Half life of sample, $\tau_{1/2}$ = 10 days

Initial number of nuclei, $N_0 = 1000\,x$, t = 5 days

$\tau_{1/2} = \dfrac{\ln 2}{\lambda} \Rightarrow \lambda = \dfrac{\ln 2}{10}$ disintegration per day.

$N(t) = N_0\, e^{-(\lambda t)}$

$= N_0\, e^{-\left(\frac{\ln 2}{10}\times 5\right)} = N_0\, e^{\left(-\frac{\ln 2}{2}\right)}$

$N(t) = N_0 e^{(-\ln\sqrt{2})} = N_0 e^{(\ln 1/\sqrt{2})}$

$N(t) = \dfrac{N_0}{\sqrt{2}} = \dfrac{1000\,x}{\sqrt{2}} = 707\,x$

56. (d) : X and Z have same number of protons, so they are isotopes.

57. (b) : Mass of nucleus, M = 20 u

E_γ = 6 MeV = $6 \times 1.6 \times 10^{-13}$ J

Using momentum conservation principle,

$0 = Mv + \dfrac{E_\gamma}{c}$

$$\therefore \quad v = -\frac{E_\gamma}{Mc} = -\frac{6\times 1.6\times 10^{-13}}{20\times 1.6\times 10^{-27}\times 3\times 10^{8}}$$

$= -10^5$ m s^{-1}

K.E. of nucleus, $K = \dfrac{1}{2}Mv^2$

$= \dfrac{1}{2} \times 20 \times 1.6 \times 10^{-27} \times (10^5)^2 = 16 \times 10^{-17}$ J

$= \dfrac{16\times 10^{-17}}{1.6\times 10^{-16}}$ keV = 1 keV

58. (c)

59. (a) : Here, I_c = 0.49 mA, I_e = 0.50 mA

$I_b = I_e - I_c$ = 0.01 mA, β = ?

$\therefore \quad \beta = \dfrac{I_c}{I_b} = \dfrac{0.49}{0.01} = 49$

60. (d) : $Y = \overline{(\overline{A}\cdot\overline{B})} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$

$\equiv$ OR gate.

SOLVED PAPER 2016
KERALA PET

1. The one which does not represent a force in any context is
   (a) friction (b) impulse
   (c) tension (d) weight
   (e) viscous drag

2. The work-energy theorem states that the change in
   (a) kinetic energy of a particle is equal to the work done on it by the net force
   (b) kinetic energy of a particle is equal to the work done by one of forces acting on it
   (c) potential energy of a particle is equal to the work done on it by the net force
   (d) potential energy of a particle is equal to the work done by one of forces acting on it
   (e) total energy of a particle is equal to the work done on it by the net force

3. A car of mass 1500 kg is lifted up a distance of 30 m by crane A in 0.5 minutes. The second crane B does the same job in 1 minute. The ratio of their powers is
   (a) 1 : 2 (b) 2 : 1 (c) 1 : 1 (d) 1 : 4 (e) 4 : 1

4. Water from a hose pipe of radius 5 cm strikes a wall normally at a speed of 5 m s^{-1}. The force exerted on the wall in newton is
   (a) 13.5π (b) 6.25π
   (c) 62.5π (d) 27π
   (e) 125π

5. The position vectors of two identical particles with respect to the origin in three dimensional co-ordinate system are $\vec{r}_1$ and $\vec{r}_2$. The position vector of centre of mass of the system is given by
   (a) $\vec{r}_1+\vec{r}_2$ (b) $\frac{\vec{r}_1-\vec{r}_2}{2}$
   (c) $\vec{r}_1-\vec{r}_2$ (d) $\frac{\vec{r}_1+\vec{r}_2}{2}$
   (e) $\frac{\vec{r}_1+\vec{r}_2}{3}$

6. If a body of moment of inertia 2 kg m^2 revolves about its own axis making 2 rotations per second, then its angular momentum (in J s) is
   (a) 2π (b) 4π (c) 6π (d) 8π (e) 10π

7. A rigid body is the one in which
   (a) it can have only rotational motion
   (b) it can have only translational motion
   (c) the distances between all pairs of particles of the body do not change
   (d) its shape can be deformed
   (e) its centre of mass always lies inside the material of the body

8. A body hanging from a massless spring stretches it by 3 cm on earth's surface. At a place 800 km above the earth's surface, the same body will stretch the spring by (Radius of earth = 6400 km)
   (a) $\left(\frac{34}{27}\right)$ cm (b) $\left(\frac{64}{27}\right)$ cm
   (c) $\left(\frac{27}{64}\right)$ cm (d) $\left(\frac{27}{34}\right)$ cm
   (e) $\left(\frac{35}{81}\right)$ cm

9. The acceleration due to gravity on the surface of a planet is one-fourth of the value on earth. When a brass ball is brought to this planet, its
   (a) mass is halved
   (b) weight is halved
   (c) mass becomes one-fourth
   (d) weight becomes one-fourth
   (e) mass and weight remain the same

10. Polar satellites
    (a) are high altitude satellites
    (b) are widely used for telecommunication
    (c) are used for environmental studies
    (d) go around the earth in a east-west direction
    (e) have time-period of rotation of 24 hours

11. If a capillary tube of radius r is immersed in a liquid, the liquid rises to a height h. The corresponding mass of liquid column is m. The mass of water that would rise in another capillary tube of twice the radius is
    (a) $2m$ (b) $5m$ (c) $3m$ (d) $4m$ (e) $\frac{m}{2}$

12. In a horizontal pipe of non-uniform cross-section, water flows with a velocity of 1 m s^{-1} at a point where the diameter of the pipe is 20 cm. The velocity of water (in m s^{-1}) at a point where the diameter of the pipe is 5 cm is
(a) 64 (b) 24 (c) 8 (d) 32 (e) 16

13. A spherical ball of diameter 1 cm and density 5×10^3 kg m^{-3} is dropped gently in a large tank containing viscous liquid of density 3×10^3 kg m^{-3} and coefficient of viscosity 0.1 N s m^{-2}. The distance, the ball moves in 1s after attaining terminal velocity is (g =10 m s^{-2})
(a) $\frac{10}{9}$ m (b) $\frac{2}{3}$ m (c) $\frac{4}{9}$ m (d) $\frac{4}{5}$ m (e) $\frac{9}{10}$ m

14. A stone of density 2000 kg m^{-3} completely immersed in a lake is allowed to sink from rest. If the effect of friction is neglected, then after 4 seconds, the stone will reach a depth of
(a) 78.4 m (b) 39.2 m
(c) 19.6 m (d) 9.8 m
(e) 24.6 m

15. The Zeroth law of thermodynamics leads to the concept of
(a) internal energy (b) heat content
(c) pressure (d) temperature
(e) work done

16. If the average kinetic energy of a molecule of a hydrogen gas at 300 K is E, the average kinetic energy of a molecule of a nitrogen gas at the same temperature is
(a) $7E$ (b) $\frac{E}{14}$ (c) $14E$ (d) $\frac{E}{7}$ (e) E

17. The difference between the specific heats of a gas is 4150 J kg^{-1} K^{-1}. If the ratio of specific heats is 1.4, then the specific heat at constant volume of the gas (in J kg^{-1} K^{-1}) is
(a) 1037.5 (b) 2037.5
(c) 8300 (d) 10375
(e) 4150

18. The Carnot cycle of a reversible heat engine consists of
(a) one isothermal and two adiabatic processes
(b) two isothermal and one adiabatic processes
(c) two isothermal and two adiabatic processes
(d) two isobaric and two isothermal processes
(e) two isochoric and two adiabatic processes

19. Two equal masses hung from two massless springs of spring constants k_1 and k_2 have equal maximum velocity when executing simple harmonic motion. The ratio of their amplitudes is
(a) $\left(\frac{k_1}{k_2}\right)^{1/2}$ (b) $\left(\frac{k_1}{k_2}\right)$
(c) $\left(\frac{k_2}{k_1}\right)$ (d) $\left(\frac{k_2}{k_1}\right)^{1/2}$
(e) $\left(\frac{k_1^2}{k_2^2}\right)$

20. The simple harmonic motion of a particle is given by $x = a\sin 2\pi t$. Then the location of the particle from its mean position at a time $\frac{1}{8}$ th of a second is
(a) a (b) $\frac{a}{2}$ (c) $\frac{a}{\sqrt{2}}$ (d) $\frac{a}{4}$ (e) $\frac{a}{8}$

21. The time period of a simple pendulum of length $\sqrt{5}$ m suspended in a car moving with uniform acceleration of 5 m s^{-2} in a horizontal straight road is (g = 10 m s^{-2})
(a) $\frac{2\pi}{\sqrt{5}}$ s (b) $\frac{\pi}{\sqrt{5}}$ s (c) 5π s (d) 4π s (e) 3π s

22. The apparent change in frequency of sound due to the relative motion between the observer and the source of sound is called
(a) Doppler effect (b) Phenomenon of beats
(c) Phenomenon of stationary waves
(d) Diffraction of sound waves
(e) Interference of sound waves

23. Pick out the condition which is not required for the formation of stationary waves.
(a) The medium on which waves are formed should be bound medium.
(b) Both the waves should have same frequency.
(c) Both the waves should have same velocity.
(d) The waves should travel in same direction.
(e) Both the waves should have same wavelength.

24. The harmonic mode which resonates with a closed pipe of length 22 cm, when excited by a 1875 Hz source and the number of nodes present in it respectively are (velocity of sound in air = 330 m s^{-1})
(a) 1^{st}, 1 (b) 3^{rd}, 1
(c) 3^{rd}, 2 (d) 5^{th}, 4
(e) 5^{th}, 3

25. The force between two point charges placed in a material medium of dielectric constant ε_r is F. If the material is removed, then the force between them becomes

(a) $\varepsilon_r F$ (b) εF (c) $\frac{F}{\varepsilon_r}$ (d) $\frac{\varepsilon}{F}$ (e) $\varepsilon_0 F$

26. The electric field strength in N C^{-1} that is required to just prevent a water drop carrying a charge 1.6×10^{-19} C from falling under gravity is ($g = 9.8$ m s^{-2}, mass of water drop = 0.0016 g)
(a) 9.8×10^{-16} (b) 9.8×10^{16}
(c) 9.8×10^{-13} (d) 9.8×10^{13}
(e) 9.8×10^{10}

27. A cylinder of radius r and length l is placed in a uniform electric field of intensity E acting parallel to the axis of the cylinder. The total flux over curved surface area is
(a) $2\pi rE$ (b) $\left(\frac{2\pi}{l}\right)E$
(c) $2\pi rlE$ (d) $\frac{E}{2\pi rl}$
(e) zero

28. A conductor with a cavity is charged positively and its surface charge density is σ. If E and V represent the electric field and potential, then inside the cavity
(a) $\sigma = 0$ and $V = 0$ (b) $E = 0$ and $V = 0$
(c) $E = 0$ and σ = constant
(d) $V = 0$ and σ = constant
(e) $E = 0$ and V = constant

29. Electric lines of force about a positive point charge are
(a) radially outwards (b) circular clockwise
(c) radially inwards (d) parallel straight lines
(e) circular anticlockwise

30. An ammeter, voltmeter and a resistor are connected in series to a cell and the readings are noted as I and V. If another resistor R is connected in parallel with voltmeter, then
(a) I and V increase
(b) I increases
(c) I and V will remain same
(d) I decreases
(e) I remains constant

31. One gram of copper is deposited in a copper voltameter when a current of 0.5 A flows for 30 minutes. Then the current required to deposit 2 g of sliver in a silver voltameter in the same time is (ece of copper = 3.3×10^{-4} g C^{-1}, ece of silver = 1.1×10^{-4} g C^{-1})
(a) 4 A (b) 6 A (c) 2 A (d) 5 A (e) 3 A

32. The amount of charge flowing per second per unit area normal to the flow is called
(a) electrical conductivity
(b) electrical resistivity
(c) mobility
(d) current density
(e) areal current

33. A galvanometer of resistance G is converted into an ammeter using a shunt of resistance R. If the ratio of the heat dissipated through the galvanometer and shunt is 3 : 4, then R equals
(a) $\frac{4}{3}G$ (b) $\frac{3}{4}G$ (c) $\frac{16}{9}G$ (d) $\frac{9}{16}G$ (e) G

34. Two bulbs of equal power are connected in parallel and they totally consume 110 W at 220 V. The resistances of each bulb is
(a) 550 Ω (b) 440 Ω
(c) 330 Ω (d) 880 Ω
(e) 660 Ω

35. The wire of length l is bent into a circular loop of a single turn and is suspended in a magnetic field of induction B. When a current I is passed through the loop, the maximum torque experienced by it is
(a) $\left(\frac{1}{4\pi}\right)BIl^2$ (b) $\frac{1}{4\pi}BI^2l$
(c) $\left(\frac{1}{4\pi}\right)BIl$ (d) $\left(\frac{1}{4\pi}\right)B^2Il$
(e) $\left(\frac{1}{4\pi}\right)B^2I^2l^2$

36. A particle having charge 10 times that of the electron revolves in a circular path of radius 0.4 m with an angular speed of one rotation per second. The magnetic induction produced at the centre of the circular path is
(a) $4\pi \times 10^{-26}$ T (b) $2\pi \times 10^{-26}$ T
(c) $16\pi \times 10^{-26}$ T (d) $8\pi \times 10^{-25}$ T
(e) $9\pi \times 10^{-25}$ T

37. Pick out the wrong statement among the following.
(a) Time varying magnetic field creates an electric field.
(b) Charges in motion can exert force on a stationary magnet.
(c) Stationary charges can exert torque on a stationary magnet.

(d) A bar magnet in motion can exert force on a stationary charge.
(e) Electric fields produced by static charges have different properties from those produced by time varying magnetic fields.

38. If a magnet is plunged into a coil, then the magnitude of induced emf does not depend upon
(a) the number of turns in the coil
(b) the medium of the core of the coil
(c) the insertion speed of the magnet
(d) the strength of the magnet
(e) the resistance of the coil

39. A bar magnet has a period of oscillation T. If a similar brass piece of the same mass is placed over it, then the number of oscillations it makes in one second is
(a) $\frac{1}{\sqrt{2}T}$ (b) $\frac{\sqrt{2}}{T}$ (c) $\frac{1}{2T}$ (d) $\frac{2}{T}$ (e) $\frac{1}{T}$

40. If 0.1 J of energy is stored for the flow of current of 0.2 A in an inductor, then its inductance value is
(a) 5 H (b) 0.5 H
(c) 5 mH (d) 50 H
(e) 50 mH

41. The self inductance of a long solenoid carrying current is independent of
(a) its length (b) the current
(c) its cross-sectional area
(d) magnetic permeability of the core
(e) the number of turns

42. The r.m.s. value of A.C. which when passed through a resistor produces heat, which is twice that produced by a steady current of 1.414 amp in the same resistor is
(a) 2 A (b) 3.46 A
(c) 2.818 A (d) 1.732 A
(e) 1 A

43. In a series LCR ac circuit, the current is maximum when the impedance is equal to
(a) the reactance (b) the resistance
(c) zero (d) twice the reactance
(e) twice the resistance

44. γ-rays are detected by
(a) point contact diodes
(b) thermopiles (c) ionization chamber
(d) photocells (e) bolometers

45. If the direction of electric and magnetic field vectors of a plane electromagnetic wave are along positive y direction and positive z direction respectively, then the direction of propagation of the wave is along
(a) positive z direction (b) negative z direction
(c) negative y direction (d) positive x direction
(e) negative x direction

46. When an object is viewed with a light of wavelength 6000 Å under a microscope its resolving power is 10^4. The resolving power of the microscope when the same object is viewed with a light of wavelength 4000 Å is
(a) 10^4 (b) 2×10^4
(c) $3\sqrt{2}\times10^4$ (d) 3×10^4
(e) 1.5×10^4

47. Secondary rainbow in the atmosphere is
(a) the result of polarization and dispersion of light
(b) brighter than the primary rainbow
(c) due to the phenomenon of double refraction
(d) formed with red colour on the top
(e) formed due to two reflections in the rain drop

48. For a diffraction from a single slit, the intensity of the central point is
(a) infinite
(b) finite and same magnitude as the surrounding maxima
(c) finite but much larger than the surrounding maxima
(d) finite and substantially smaller than the surrounding maxima
(e) zero

49. If the radius of curvature of the curved surface of a plano-convex lens is 50 cm, its focal length is ($\mu = 1.5$)
(a) 0.5 m (b) 0.75 m
(c) 1.25 m (d) 0.25 m
(e) 1 m

50. The magnification of an image by a convex lens is positive only when the object is placed
(a) at its focus F (b) between F and $2F$
(c) at $2F$
(d) between F and optical centre
(e) beyond $2F$

51. If the work functions of three photosensitive materials are 1 eV, 2 eV and 3 eV respectively, then the ratio of the respective frequencies of light that produce photoelectrons of maximum kinetic energy of 1 eV from each of them is
(a) 1 : 2 : 3 (b) 2 : 3 : 4
(c) 1 : 1 : 1 (d) 3 : 2 : 1
(e) 4 : 3 : 2

52. During β^- emission
(a) a neutron in the nucleus decays emitting an electron
(b) an atomic electron is ejected
(c) an electron already present within the nucleus is ejected
(d) a part of the binding energy of the nucleus is converted into an electron
(e) a proton in the nucleus decays emitting an electron

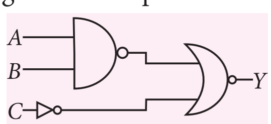
53. The binding energy per nucleon of ^{16}O is 7.97 MeV and that of ^{17}O is 7.75 MeV. The energy in MeV required to remove a neutron from ^{17}O is
(a) 3.52 (b) 3.64 (c) 4.23 (d) 7.86 (e) 1.68

54. If the ratio of the radius of a nucleus with 61 neutrons to that of helium nucleus is 3, the atomic number of this nucleus is
(a) 27 (b) 47 (c) 51 (d) 61 (e) 108

55. The electron density of intrinsic semiconductor at room temperature is 10^{16} m^{-3}. When doped with a trivalent impurity, the electron density is decreased to 10^{14} m^{-3} at the same temperature. The majority carrier density is
(a) 10^{16} m^{-3} (b) 10^{18} m^{-3}
(c) 10^{21} m^{-3} (d) 10^{20} m^{-3}
(e) 10^{19} m^{-3}

56. In a Zener diode regulated power supply, unregulated d.c. input of 10 V is applied. If the resistance (R_s) connected in series with a Zener diode is 200 Ω and the Zener voltage V_z = 5 V, the current across the resistance R_s is
(a) 15 mA (b) 10 mA
(c) 20 mA (d) 5 mA
(e) 25 mA

57. The circuit gives the output as that of



(a) AND gate (b) OR gate
(c) NAND gate (d) NOR gate
(e) NOT gate

58. To detect light of wavelength 500 nm, the photodiode must be fabricated from a semiconductor of minimum bandwidth of
(a) 1.24 eV (b) 0.62 eV
(c) 2.48 eV (d) 3.2 eV
(e) 4.48 eV

59. If the height of TV tower is increased by 21%, the transmission range is enhanced by
(a) 10% (b) 5% (c) 15% (d) 25% (e) 12%

60. The range of a communication system can be extended by a
(a) modulator (b) transmitter
(c) demodulator (d) receiver
(e) repeater

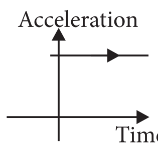
61. For commercial telephonic communication, the frequency range for speech signals is
(a) 50 Hz to 1000 Hz (b) 3000 Hz to 4500 Hz
(c) 1000 Hz to 2000 Hz
(d) 5000 Hz to 6500 Hz
(e) 300 Hz to 3100 Hz

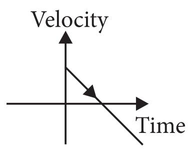
62. The role of envelope detector in an AM receiver is to
(a) retrieve the message signal
(b) rectify the AM signal
(c) modify the AM signal
(d) modulate the message signal
(e) retrieve the AM signal

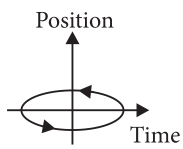
63. When the voltage and current in a conductor are measured as (100 ± 4) V and (5 ± 0.2)A, then the percentage of error in the calculation of resistance is
(a) 8% (b) 4% (c) 20% (d) 10% (e) 6%

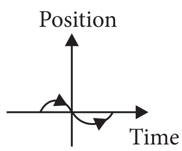
64. The set of physical quantities among the following which are dimensionally different is
(a) Terminal velocity, drift velocity, critical velocity
(b) Potential energy, work done, kinetic energy
(c) Pressure, stress, rigidity modulus
(d) Disintegration constant, frequency, angular velocity
(e) Dipole moment, electric flux, electric field

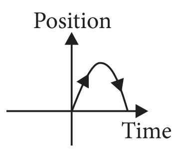
65. The graph which cannot possibly represent one-dimensional motion is

(a) 

(b) 

(c) 

(d) 

(e) 

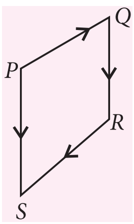
66. An aeroplane is flying with a uniform speed of 150 km hr^{-1} along the circumference of a circle. The change in its velocity in half the revolution (in km hr^{-1}) is
(a) 150 (b) 100 (c) 200 (d) 300 (e) 50

67. In uniform circular motion, the centripetal acceleration is
(a) towards the centre of the circular path and perpendicular to the instantaneous velocity
(b) a constant acceleration
(c) away from the centre of the circular path and perpendicular to the instantaneous velocity
(d) a variable acceleration making 45° with the instantaneous velocity
(e) a variable acceleration, parallel to the instantaneous velocity

68. A man rides a bicycle with a speed of 17.32 m s^{-1} in east-west direction. If the rain falls vertically with a speed of 10 m s^{-1}, the direction in which he must hold his umbrella is
(a) 30° with the vertical towards east
(b) 60° with the vertical towards west
(c) 30° with the vertical towards west
(d) 60° with the vertical towards east
(e) 0° with the vertical

69. A body is thrown up with a speed u, at an angle of projection θ. If the speed of the projectile becomes $\frac{u}{\sqrt{2}}$ on reaching the maximum height, the maximum vertical height attained by the projectile is
(a) $\frac{u^2}{4g}$ (b) $\frac{u^2}{3g}$ (c) $\frac{u^2}{2g}$ (d) $\frac{u^2}{g}$ (e) $\frac{2u^2}{g}$

70. In the given diagram, if $\overrightarrow{PQ} = \vec{A}$, $\overrightarrow{QR} = \vec{B}$ and $\overrightarrow{RS} = \vec{C}$ then $\overrightarrow{PS}$ equals



(a) $\vec{A} - \vec{B} + \vec{C}$ (b) $\vec{A} + \vec{B} - \vec{C}$
(c) $\vec{A} + \vec{B} + \vec{C}$ (d) $\vec{A} - \vec{B} - \vec{C}$
(e) $-\vec{A} - \vec{B} - \vec{C}$

71. The net force acting is not zero on
(a) a retarding train
(b) a ball falling with terminal velocity
(c) a kite held stationary in the sky
(d) a truck moving with constant velocity
(e) a book placed on a table

72. An engine of power 58.8 kW pulls a train of mass 2×10^5 kg with a velocity of 36 km h^{-1}. The coefficient of friction is
(a) 0.3 (b) 0.03 (c) 0.003 (d) 0.0003
(e) 0.04

SOLUTIONS

1. **(b)**

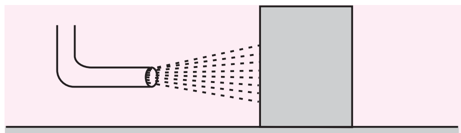
2. **(a) :** The work-energy theorem states that the change in kinetic energy of a particle is equal to the work done on it by the net force.
i.e., $K_f - K_i = W_{net}$

3. **(b) :** As both cranes A and B lift up the car of mass m(= 1500 kg) to the same distance h(= 50 m) in different times t_A(= 0.5 min) and t_B(= 1 min) respectively, so the ratio of their powers is

$$\frac{P_A}{P_B} = \frac{(mgh/t_A)}{(mgh/t_B)} = \frac{t_B}{t_A} = \frac{1\text{ min}}{0.5\text{ min}} = \frac{2}{1}$$

or $P_A : P_B = 2 : 1$

4. **(c):** The situation is shown in figure.



Here,
Radius of the pipe, $r = 5$ cm $= 5 \times 10^{-2}$ m
Speed with which the water strikes the wall, $v = 5$ m s^{-1}
Density of water, $\rho = 1000$ kg m^{-3}
The rate at which the water striking the wall is

$$\frac{dm}{dt} = \pi r^2 v\rho$$
$$= \pi(5 \times 10^{-2}\text{ m})^2(5\text{ m s}^{-1})(1000\text{ kg m}^{-3})$$
$$= 12.5\pi\text{ kg s}^{-1}$$

The force exerted on the wall is

$$F = v\frac{dm}{dt} = (5\text{ m s}^{-1})(12.5\pi\text{ kg s}^{-1}) = 62.5\pi\text{ N}$$

5. **(d) :** The position vector of centre of mass of the system is

$$\vec{R}_{CM} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$$

But $m_1 = m_2 = m$(as both particles are identical)

$$\therefore \quad \vec{R}_{CM} = \frac{m\vec{r}_1 + m\vec{r}_2}{m + m} = \frac{\vec{r}_1 + \vec{r}_2}{2}$$

6. **(d) :** The angular momentum of the body is
$L = I\omega$
Here, $I = 2$ kg m^2,
$\omega = 2$ rps $= 2 \times 2\pi$ rad $s^{-1} = 4\pi$ rad s^{-1}
$\therefore$ $L = (2\text{ kg m}^2)(4\pi\text{ rad s}^{-1}) = 8\pi$ J s

7. **(c) :** A rigid body is the one in which the distances between all pairs of particles do not change.

8. **(b)**

9. (d) : If g_p and g_e are the accelerations due to gravity on the surface of the planet and the earth respectively, then

$$g_p = \frac{g_e}{4} \quad \text{...(i)}$$

Let the mass of the ball be m. Then its weight on the earth's surface is

$$W_e = mg_e \quad \text{...(ii)}$$

As mass remains the same at all places, so when the ball is brought to the planet its mass remains the same but its weight becomes

$$W_p = mg_p = \frac{mg_e}{4} \quad \text{(using (i))}$$

$$= \frac{W_e}{4} \quad \text{(using (ii))}$$

10. (c): Polar satellites are low altitude satellites and they go around the earth in a north-south direction. Their time-period of rotation is around 100 minutes and they are used for environmental studies, remote sensing and meterology.

11. (a)

12. (e): According to equation of continuity

$$A_1 v_1 = A_2 v_2$$

$$\therefore \quad \pi\left(\frac{d_1}{2}\right)^2 v_1 = \pi\left(\frac{d_2}{2}\right)^2 v_2 \text{ (where } d = \text{diameter)}$$

$$\text{or} \quad v_2 = v_1\left(\frac{d_1}{d_2}\right)^2$$

Here, $v_1 = 1 \text{ m s}^{-1}$, $d_1 = 20$ cm, $d_2 = 5$ cm

$$\therefore \quad v_2 = (1\text{ m s}^{-1})\left(\frac{20\text{ cm}}{5\text{ cm}}\right)^2 = 16\text{ m s}^{-1}$$

13. (a) : Here,

Radius of the ball, $r = 0.5$ cm $= 0.5 \times 10^{-2}$ m

Density of the ball, $\rho = 5 \times 10^3$ kg m^{-3}

Density of the liquid, $\sigma = 3 \times 10^3$ kg m^{-3}

Coefficient of viscosity of the liquid, $\eta = 0.1$ N s m^{-2}

The terminal velocity of the ball is

$$v = \frac{2r^2(\rho - \sigma)g}{9\eta} = \frac{10}{9}\text{ m s}^{-1}$$

After attaining terminal velocity, the distance moved by the ball in 1 s is

$$s = vt = \left(\frac{10}{9}\text{ m s}^{-1}\right)(1\text{ s}) = \frac{10}{9}\text{ m}$$

14. (b) : Let V be the volume of the stone. Then

Weight of the stone, $W = V\rho_{\text{stone}}g$

Buoyant force (upthrust) of the water, $F_b = V\rho_{\text{water}}g$

As ρ_{stone} (= 2000 kg m^{-3}) > ρ_{water} (= 1000 kg m^{-3}), so the net downward force acting on the stone is

$$F = W - F_b = V\rho_{\text{stone}}g - V\rho_{\text{water}}g$$

$$= V\rho_{\text{stone}}\left(1 - \frac{\rho_{\text{water}}}{\rho_{\text{stone}}}\right)g$$

The acceleration of the stone is

$$a = \frac{F}{m} = \frac{V\rho_{\text{stone}}\left(1 - \frac{\rho_{\text{water}}}{\rho_{\text{stone}}}\right)g}{V\rho_{\text{stone}}}$$

$$= \left(1 - \frac{\rho_{\text{water}}}{\rho_{\text{stone}}}\right)g = \left(1 - \frac{1000\text{ kg m}^{-3}}{2000\text{ kg m}^{-3}}\right)(9.8\text{ m s}^{-2})$$

$$= 4.9\text{ m s}^{-2}$$

Let h be the required depth. Then by second equation of motion

$$h = \frac{1}{2}at^2 = \frac{1}{2}(4.9\text{ m s}^{-2})(4\text{ s})^2 = 39.2\text{ m} \quad (\because u = 0)$$

15. (d) : The Zeroth law of thermodynamics leads to the concept of temperature.

16. (e) : The average kinetic energy of a gas molecule = $(3/2)k_BT$ which is independent of the nature of gas and depends only on its temperature.

Since the nitrogen gas molecule is at the same temperature as that of the hydrogen gas molecule, so the average kinetic energy of the nitrogen gas molecule is same that of the average kinetic energy of the hydrogen gas molecule *i.e.* E.

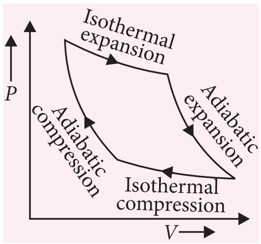
17. (d) : As $C_p - C_v = 4150$ J kg^{-1} K^{-1} (given)

$$\text{But } \frac{C_p}{C_v} = 1.4 \text{ (given)} \quad \therefore\ 1.4C_v - C_v = 4150\text{ J kg}^{-1}\text{ K}^{-1}$$

$$\text{or} \quad 0.4C_v = 4150\text{ J kg}^{-1}\text{ K}^{-1}$$

$$\text{or} \quad C_v = \frac{4150\text{ J kg}^{-1}\text{ K}^{-1}}{0.4} = 10375\text{ J kg}^{-1}\text{ K}^{-1}$$

18. (c): The Carnot cycle of a reversible heat engine consists of two isothermal and two adiabatic processes as shown in adjacent figure.



19. (d) : The maximum velocity of simple harmonic motion is

$$v_{\max} = A\omega$$

where A is the amplitude and ω is the angular velocity.

$$\text{But here } \omega = \sqrt{\frac{k}{m}}$$

$$\therefore \quad v_{max} = A\sqrt{\frac{k}{m}}$$

So $v_{max_1} = A_1\sqrt{\frac{k_1}{m_1}}$ and $v_{max_2} = A_2\sqrt{\frac{k_2}{m_2}}$

But $v_{max_1} = v_{max_2}$ and $m_1 = m_2 = m$ (given)

$$\therefore \quad A_1\sqrt{\frac{k_1}{m}} = A_2\sqrt{\frac{k_2}{m}} \text{ or } \frac{A_1}{A_2} = \sqrt{\frac{k_2}{k_1}} = \left(\frac{k_2}{k_1}\right)^{1/2}$$

20. (c): As $x = a\sin 2\pi t$

$$\therefore \quad \text{At } t = \frac{1}{8}(1\text{ s}) = \frac{1}{8}\text{ s},$$

$$x = a\sin\left(2\pi\left(\frac{1}{8}\right)\right) = a\sin\left(\frac{\pi}{4}\right) = \frac{a}{\sqrt{2}}$$

21. (a) : As the car is moving horizontally with uniform acceleration (a), so g and a are perpendicular to each other. Therefore, the effective acceleration of the bob of the pendulum is

$$g' = \sqrt{a^2 + g^2}$$

So the time period of the pendulum is

$$T = 2\pi\sqrt{\frac{l}{g'}} = 2\pi\sqrt{\frac{l}{\sqrt{a^2+g^2}}}$$

Here, $l = \sqrt{5}$ m, $a = 5\text{ m s}^{-2}$, $g = 10\text{ m s}^{-2}$

$$\therefore \quad T = 2\pi\sqrt{\frac{\sqrt{5}\text{ m}}{\sqrt{(5\text{ m s}^{-2})^2 + (10\text{ m s}^{-2})^2}}} = \frac{2\pi}{\sqrt{5}}\text{ s}$$

22. (a)

23. (d) : Among the given conditions (d) is not required for the formation of stationary waves.

24. (e) : Here,

Length of the pipe, L = 22 cm = 22×10^{-2} m

Velocity of sound in air, v = 330 m s^{-1}

The fundamental frequency (first harmonic) of the closed pipe is

$$\upsilon_1 = \frac{v}{4L} = \frac{330\text{ m s}^{-1}}{4(22\times10^{-2}\text{ m})} = 375\text{ m}$$

As only odd harmonics are present in the closed pipe, so the frequency of third harmonic is

$$\upsilon_3 = 3\upsilon_1 = 3(375\text{ Hz}) = 1125\text{ Hz}$$

and that of fifth harmonic is

$$\upsilon_5 = 5\upsilon_1 = 5(375\text{ Hz}) = 1875\text{ Hz}$$

and so on.

Clearly, the given source of frequency 1875 Hz resonates with 5th harmonic of the closed pipe.

The number of nodes present in 5th harmonic are 3.

25. (a) : The force between two point charges q_1 and q_2 placed in a material medium of dielectric constant ε_r at a distance r is

$$F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{r^2} = \frac{1}{\varepsilon_r}\left(\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}\right) \quad \text{...(i)}$$

When the material is removed, the force between them becomes

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} = \varepsilon_r F \quad \text{(using(i))}$$

26. (d) : Here

Mass of water drop, m = 0.0016 g = 0.0016×10^{-3} kg
= 1.6×10^{-6} kg

Charge on water drop, $q = 1.6 \times 10^{-19}$ C

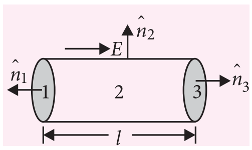
Let E be the strength of the electric field required to just prevent the water drop from falling. Then

Force on water drop due to electric field
= weight of the drop

i.e. $qE = mg$

$$\text{or} \quad E = \frac{mg}{q} = \frac{(1.6\times10^{-6}\text{ kg})(9.8\text{ m s}^{-2})}{(1.6\times10^{-19}\text{ C})}$$
$$= 9.8 \times 10^{13}\text{ N C}^{-1}$$

27. (e) : The situation is shown in adjacent figure.



The total flux over curved surface area is

$$\phi = \int \vec{E}\cdot d\vec{s}$$

$$\phi = E(2\pi rl)\cos 90° = 0$$

Note : Net flux through the cylinder

$$\phi = \phi_1 + \phi_2 + \phi_3 = -E(\pi r^2) + 0 + E(\pi r^2) = 0$$

28. (e) : Inside the cavity

$\sigma = 0$, $E = 0$ and V = constant

29. (a) **30. (b)**

31. (e) : According to Faraday's first law of electrolysis, the mass of a substance deposited or liberated at an electrode when current I flows through the electrolyte for time t is

$$m = ZIt$$

where Z is the electro chemical equivalent of the substance.

$$\therefore \quad I = \frac{m}{Zt}$$

For copper voltameter, $I_{Cu} = \frac{m_{Cu}}{Z_{Cu}t_{Cu}}$

and for silver voltameter, $I_{Ag} = \frac{m_{Ag}}{Z_{Ag}t_{Ag}}$

$$\therefore \quad \frac{I_{Cu}}{I_{Ag}} = \frac{m_{Cu}}{m_{Ag}}\frac{Z_{Ag}}{Z_{Cu}}\frac{t_{Ag}}{t_{Cu}}$$

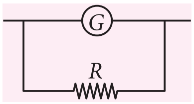
Here, $I_{Cu} = 0.5$ A, $I_{Ag} = ?$, $m_{Cu} = 1$ g, $m_{Ag} = 2$ g
$Z_{Cu} = 3.3 \times 10^{-4}$ g C^{-1}, $Z_{Ag} = 1.1 \times 10^{-4}$ g C^{-1}
$t_{Cu} = t_{Ag} = 30$ min

$$\therefore \quad \frac{0.5\text{ A}}{I_{Ag}} = \left(\frac{1\text{ g}}{2\text{ g}}\right)\left(\frac{1.1\times10^{-4}\text{ g C}^{-1}}{3.3\times10^{-4}\text{ g C}^{-1}}\right)\left(\frac{30\text{ min}}{30\text{ min}}\right) = \frac{1}{6}$$

or $I_{Ag} = 6(0.5\text{ A}) = 3$ A

32. (d) : The amount of charge flowing per second per unit area normal to the flow is called current density.

33. (b) : A galvanometer of resistance G is converted into an ammeter by connecting a shunt of resistance R in parallel with it.



As G and R are connected in parallel, so the potential difference across them is same.

The ratio of the heat dissipated through the galvanometer and shunt is

$$\frac{H_G}{H_R} = \frac{V^2 t / G}{V^2 t / R} = \frac{R}{G}$$

But $\frac{H_G}{H_R} = \frac{3}{4}$(given) $\therefore \quad \frac{3}{4} = \frac{R}{G}$ or $R = \frac{3}{4}G$

34. (d) : Let R and P be the resistance and power of each bulb.

When these two bulbs are connected in parallel, the total power consumed by them is

$$P_p = P + P = 2P$$

But $P_p = 110$ W (given)

$$\therefore \quad 110\text{ W} = 2P \quad \text{or} \quad P = \frac{110\text{ W}}{2} = 55\text{ W}$$

As $P = \frac{V^2}{R}$

$$\therefore \quad R = \frac{V^2}{P} = \frac{(220\text{ V})^2}{55\text{ W}} = 880\ \Omega$$

35. (a) : When the wire of length l is bent into one turn circular loop of radius r, then

$$l = 2\pi r \quad \text{or} \quad r = \frac{l}{2\pi}$$

The area of the loop is

$$A = \pi r^2 = \pi\left(\frac{l}{2\pi}\right)^2 = \frac{l^2}{4\pi}$$

When the loop is suspended in a magnetic field B and current I is passed through it, the maximum torque experienced by it is

$$\tau_{max} = IAB = I\frac{l^2}{4\pi}B = \left(\frac{1}{4\pi}\right)BIl^2$$

36. (d) : The circular motion of the particle constitutes a current I, where

$$I = \frac{q}{T} = \frac{q}{(2\pi/\omega)} = \frac{q\omega}{2\pi}$$

The magnetic induction produced at the centre of the circular path is

$$B = \frac{\mu_0 I}{2r} = \frac{\mu_0 q\omega}{4\pi r}$$

Here, $\mu_0 = 4\pi\times10^{-7}$ T m A^{-1}, $q = 10e = 10\times1.6\times10^{-19}$ C
$\omega = 1$ rps $= 2\pi$ rad s^{-1}, $r = 0.4$ m

$$\therefore \quad B = \frac{(4\pi\times10^{-7}\text{ T m A}^{-1})(10\times1.6\times10^{-19}\text{ C})(2\pi\text{ rad s}^{-1})}{4\pi(0.4\text{ m})}$$

$$= 8\pi \times 10^{-25}\text{ T}$$

37. (c): Among the given statements (c) is the wrong statement.

38. (e) : The magnitude of induced emf does not upon the resistance of the coil but it depends upon all other mentioned factors.

39. (a)

40. (a) : The energy stored in an inductor is

$$U = \frac{1}{2}LI^2 \qquad \therefore \quad L = \frac{2U}{I^2}$$

$$\therefore \quad L = \frac{2(0.1\text{ J})}{(0.2\text{ A})^2} = 5\text{ H}$$

41. (b)

42. (a) : If I_{rms} is the rms value of AC, then the heat produced by it in resistor R in time t is

$$H_{AC} = I_{rms}^2 Rt \qquad \text{...(i)}$$

Heat produced by the steady current I in the same resistor R in the same time t is

$$H = I^2 Rt \qquad \text{...(ii)}$$

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{H_{AC}}{H} = \frac{I_{rms}^2}{I^2}$$

or $$I_{rms}^2 = I^2\frac{H_{AC}}{H}$$

Here, $H_{AC} = 2H$, $I = 1.414\text{ A} = \sqrt{2}$ A

$$\therefore \quad I_{rms}^2 = (\sqrt{2}\text{ A})^2\left(\frac{2H}{H}\right) = (2\text{ A})^2$$

or $I_{rms} = 2$ A

43. (b) : The impedance of series LCR circuit is

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

The current is maximum at resonance.
At resonance, $X_L = X_C$
$\therefore \quad Z = R$

44. (c): γ-rays are deflected by ionization chamber.

45. (d) : In an electromagnetic wave, the direction of wave propagation is along $\vec{E}\times\vec{B}$.
As the direction of $\vec{E}$ and $\vec{B}$ are along positive y direction and positive z direction respectively, so by using vector algebra the direction of propagation of wave is along positive x direction (as $(+\hat{j})\times(+\hat{k})=\hat{i}$).

46. (e) : The resolving power (RP) of a microscope is

$$\text{RP}=\frac{2\mu\sin\theta}{1.22\,\lambda}$$

where μ sinθ is called numerical aperature and λ is the wavelength of the light used.

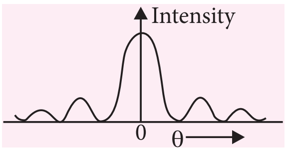
or $\quad \text{RP}\propto\frac{1}{\lambda}\quad\therefore\quad\frac{\text{RP}_1}{\text{RP}_2}=\frac{\lambda_2}{\lambda_1}\quad$ or $\quad\text{RP}_2=\frac{\lambda_1}{\lambda_2}\text{RP}_1$

Here, λ_1 = 6000 Å, λ_2 = 4000 Å, $\text{RP}_1 = 10^4$

$$\therefore\quad \text{RP}_2=\left(\frac{6000\text{ Å}}{4000\text{ Å}}\right)(10^4)=1.5\times10^4$$

47. (e) : Secondary rainbow in the atmosphere is formed due to two reflections in the rain drop.

48. (c): The intensity distribution of single slit diffraction pattern is shown in the figure.



From the graph it is clear that the intensity of the central point is finite but much larger than the surrounding maxima.

49. (e) : According to lens maker's formula, the focal length of a lens is

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

where R_1, R_2 are the radii of curvature of surfaces and μ is the refractive index of the material of the lens.
For given plano-convex lens,

$R_1=\infty$, R_2 = –50 cm, μ = 1.5

$$\therefore\quad\frac{1}{f}=(1.5-1)\left(\frac{1}{\infty}-\frac{1}{-50\text{ cm}}\right)=\frac{0.5}{50\text{ cm}}$$

or $\quad f=\dfrac{50\text{ cm}}{0.5}=100\text{ cm}=1\text{ m}$

50. (d) : The magnification of an image by a convex lens is positive for a virtual image and negative for a real image. Among the given positions of the object the convex lens forms the virtual image only when the object is placed between F and optical centre whereas for all other given positions it forms the real image.

51. (b)

52. (a) : During β^- emission a neutron in the nucleus decays emitting an electron. It is represented as

$$n\to p+e^-+\bar{\upsilon}$$

53. (c) : The energy required to remove a neutron from ^{17}O is

ΔE = (BE of ^{17}O) – (BE of ^{16}O)
= 17 × 7.75 MeV – 16 × 7.97 MeV
= 131.75 MeV – 127.52 MeV = 4.23 MeV

54. (b) : The radius of a nucleus is

$$R=R_0A^{1/3}$$

where R_0 is a constant and A its atomic mass number.

$$\therefore\quad\frac{R}{R_{\text{He}}}=\left(\frac{A}{4}\right)^{1/3}$$

But $\quad\dfrac{R}{R_{\text{He}}}=3\text{ (given)}$

$$\therefore\quad 3=\left(\frac{A}{4}\right)^{1/3}\quad\text{or}\quad 3^3=\frac{A}{4}$$

or $\quad A$ = 4 × 27 = 108

The atomic number of the nucleus is

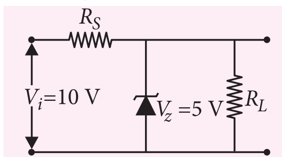
$Z=A-N$ = 108 – 61 = 47

55. (b) : For intrinsic semiconductor, $n_i=n_e=10^{16}\text{ m}^{-3}$
Since the semiconductor is doped with a trivalent impurity, so the holes are the majority charge carriers.
For doped semiconductor, $n_i^2=n_en_h$

$$\therefore\quad n_h=\frac{n_i^2}{n_e}=\frac{(10^{16}\text{ m}^{-3})^2}{10^{14}\text{ m}^{-3}}=10^{18}\text{ m}^{-3}$$

Thus the majority carrier density is 10^{18} m^{-3}.

56. (e) : The circuit diagram is shown in figure.



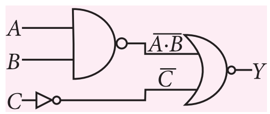
The voltage drop across R_s is

$$V_{R_s}=V_i-V_z=10\text{ V}-5\text{ V}=5\text{ V}$$

The current across R_s is

$$I=\frac{V_{R_s}}{R_s}=\frac{5\text{ V}}{200\ \Omega}=0.025\text{ A}=25\text{ mA}$$

57. (a) :



The Boolean expression of the output Y is

$$Y=\overline{\overline{A\cdot B}+\overline{C}}=\overline{\overline{A\cdot B}}\cdot\overline{\overline{C}}=A\cdot B\cdot C$$

It is the Boolean expression of three inputs AND gate. Hence, the output of given circuit is that of AND gate.

58. (c): Let E_g be the required bandwidth. Then

$$E_g = \frac{hc}{\lambda}$$

Here, $hc = 1240$ eV nm, $\lambda = 500$ nm

$$\therefore \quad E_g = \frac{1240 \text{ eV nm}}{500 \text{ nm}} = 2.48 \text{ eV}$$

59. (a)

60. (e) : The range of communication system can be extended by a repeater.

61. (e) : For speech signals, the frequency range is 300 Hz to 3100 Hz.

62. (a) : The role of envelope detector in an AM receiver is to retrieve the message signal.

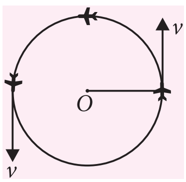
63. (a) : Here,
Voltage, $V = (100 \pm 4)$ V
Current, $I = (5 \pm 0.2)$ A
As resistance $R = \frac{V}{I}$
$\therefore$ The percentage error in R is

$$\frac{\Delta R}{R} \times 100\% = \left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right) \times 100\%$$
$$= \left(\frac{4}{100} + \frac{0.2}{5}\right) \times 100\%$$
$$= 4\% + 4\% = 8\%$$

64. (e)

65. (c): Among the graphs (c) cannot represent one-dimensional motion because at a particular time position cannot have two values.

66. (d) : The situation is shown in adjacent figure.

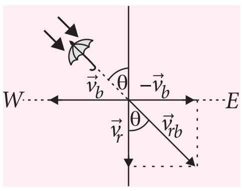


Taking upwards direction to be positive, then
The change in the velocity of the aeroplane in half the revolution is

$$\Delta v = v - (-v) = 2v = 2(150 \text{ km hr}^{-1}) = 300 \text{ km hr}^{-1}$$

67. (a)

68. (b) : In figure, $\vec{v}_r$ represents the velocity of rain and $\vec{v}_b$ the velocity of the bicycle, the man is riding. To protect himself from rain, the man should hold his umbrella



in the direction of relative velocity of rain with respect to the bicycle, $\vec{v}_{rb}$.
From figure,

$$\tan\theta = \frac{v_b}{v_r} = \frac{17.32 \text{ m s}^{-1}}{10 \text{ m s}^{-1}} = \frac{10\sqrt{3} \text{ m s}^{-1}}{10 \text{ m s}^{-1}} = \sqrt{3}$$

or $\quad \theta = \tan^{-1}(\sqrt{3}) = 60°$

Therefore, the man should hold his umbrella at an angle 60° with the vertical towards west.

69. (a) : The speed of the projectile at the maximum height is $v = u\cos\theta$

But $v = \frac{u}{\sqrt{2}}$ (given)

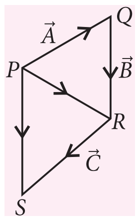
$$\therefore \quad \frac{u}{\sqrt{2}} = u\cos\theta \quad \text{or} \quad \frac{1}{\sqrt{2}} = \cos\theta$$

or $\quad \theta = \cos^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$

The maximum height attained by the projectile is

$$H_{max} = \frac{u^2 \sin^2\theta}{2g} = \frac{u^2 \sin^2 45°}{2g} = \frac{u^2 (1/\sqrt{2})^2}{2g}$$
$$= \frac{u^2}{4g}$$

70. (c) : Join PR.



From the triangle law of addition

$$\overrightarrow{PR} = \overrightarrow{PQ} + \overrightarrow{QR} = \vec{A} + \vec{B}$$

Again from the triangle law of addition

$$\overrightarrow{PS} = \overrightarrow{PR} + \overrightarrow{RS} = \vec{A} + \vec{B} + \vec{C}$$

71. (a) : Among the given cases the net force is not zero in (a) whereas it is zero in all other cases.

72. (c): Here,
Power of the engine, $P = 58.8$ kW $= 58.8 \times 10^3$ W
Mass of the train, $M = 2 \times 10^5$ kg
Velocity with which the engine pulls the train,

$$v = 36 \text{ km h}^{-1} = 36 \times \frac{5}{18} \text{ m s}^{-1} = 10 \text{ m s}^{-1}$$

Let the coefficient of friction be μ. Then the force of friction is

$$f = \mu N = \mu M g$$

and the power of the engine is

$$P = fv = \mu M g v$$

or $\quad \mu = \frac{P}{Mgv} = \frac{58.8 \times 10^3 \text{ W}}{(2 \times 10^5 \text{ kg})(9.8 \text{ m s}^{-2})(10 \text{ m s}^{-1})}$

$$= 0.003$$

Live Physics

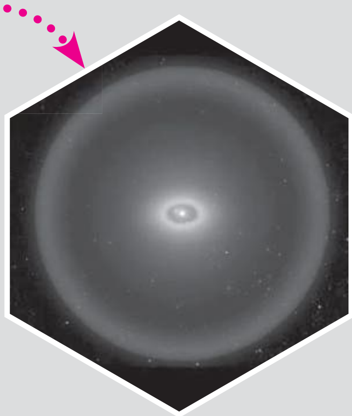
Tailless comet may give clues on earth's formation

Astronomers have found a first-of-its-kind tailless comet whose composition may offer clues into long-standing questions about the solar system's formation and evolution.The so-called `Manx' comet, named after a breed of cats without tails, was made of rocky materials that are normally found near Earth. Most comets are made of ice and other frozen compounds and were formed in solar system's frigid far reaches.

Researchers believe the newly found comet was formed in the same region as Earth, then booted to the solar system's backyard like a gravitational slingshot as planets jostled for position.

Scientists involved in the discovery now seek to learn how many more Manx comets exist, which could help to resolve debate over exactly how and when the solar system settled into its current configuration. "Depending how many we find, we will know whether the giant planets danced across the solar system when they were young, or if they grew up quietly without moving much," paper co-author Olivier Hainaut, an astronomer with the European Southern Observatory in Germany, said in a statement.

The new comet, known as C/2014 S3, was discovered in 2014 by the Panoramic Survey Telescope and Rapid Response System, or Pan-STARRS. This network of telescopes scours the night-time skies for fast-moving comets, asteroids and other celestial bodies.



NASA's Kepler mission discovers over 1,200 new planets

In the largest finding of planets to date, NASA has announced the discovery of 1,284 new planets outside our solar system, more than doubling the number of exoplanets found by the Kepler space telescope.

Nine of the newly found planets may be potentially habitable, NASA said.

"This gives us hope that somewhere out there, around a star much like ours, we can eventually discover another Earth," said Ellen Stofan, chief scientist at NASA Headquarters in Washington.

"This announcement more than doubles the number of confirmed planets from Kepler," said Stofan.

Analysis was performed on the Kepler space telescope's July 2015 planet candidate catalogue, which identified 4,302 potential planets.

For 1,284 of the candidates, the probability of being a planet is greater than 99 per cent – the minimum required to earn the status of "planet".

Light-powered engine is world's tiniest

Scientists have developed the world's tiniest engine -just a few billionths of a metre in size -which is powered by light and may help develop nano-machines that can navigate in water, sense the environment around them, or even enter living cells to fight disease.

The prototype device is made of tiny charged particles of gold, bound together with temperature-responsive polymers in the form of a gel.

When the 'nano-engine' is heated to a certain temperature, it stores large amounts of elastic energy in a fraction of a second, as the polymer coatings expel water from the gel and collapse. "Now we can use light to power a piston engine at the nanoscale," said Ventsislav Valev, now based at the University of Bath.

Crack in ISS window because of space debris

The International Space Station has suffered a problem most motorists can relate to a tiny crack in one of its windows although instead of a pebble from the road, this was caused by a tiny piece of space debris.

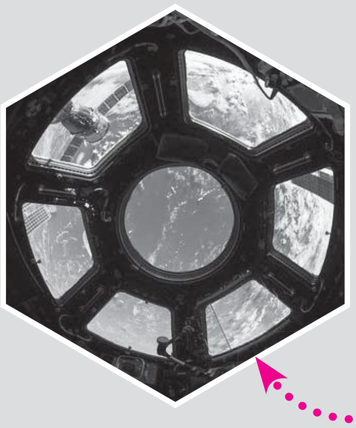
British astronaut Tim Peake, who is currently on a six-month mission to the ISS, said the chip was in one of the Cupola windows. According to the European Space Agency, this damage was caused possibly by "a paint fleck or small metal fragment no bigger than a few thousandths of a millimetre across", leaving a 7 mm crack.

Considering that the ISS travels at around 27,000 km per hour, it's easy for debris to leave its mark, but the windows have been designed to withstand collisions.

The windows on board the space station each have four panes of glass ranging from 1.2 cm to 3.1 cm thick, according to Nasa. There is also an exterior aluminium shutter that can be used for extra protection.

Although this has been classed as a "minor" crack, Nasa says larger debris could pose a "serious threat" with debris up to even 1 cm in size capable of disabling an instrument or a critical flight system on a satellite.

Over six decades of space exploration has left the orbital pathways around our planet littered with junk, creating a zone that would make travel in space hazardous.



Courtesy : The Times of India

YOU ASK WE ANSWER

Do you have a question that you just can't get answered?

Use the vast expertise of our mtg team to get to the bottom of the question. From the serious to the silly, the controversial to the trivial, the team will tackle the questions, easy and tough.

The best questions and their solutions will be printed in this column each month.

Q1. Earth is a magnet but it's two poles are not stable. Every year the poles move approximately 15 km towards north-west. What is the reason behind it?

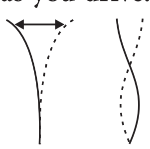
–Taniya Mondal (W.B.)

Ans. Earth's polarity is not a constant. Unlike a classic bar magnet, or the decorative magnets on your refrigerator, the matter governing Earth's magnetic field moves around. The flow of liquid iron in Earth's core creates electric currents, which in turn create the magnetic field.

The magnetic north pole has been creeping northward – by more than 600 miles (1,100 km) – since the early 19th century, when explorers first located it precisely. It is moving faster now, actually, as scientists estimate the pole is migrating northward about 40 miles per year, as opposed to about 10 miles per year in the early 20th century.

The science shows that magnetic pole reversal is, in terms of geologic time scales a common occurrence that happens gradually over millennia. While the conditions that cause polarity reversals are not entirely predictable. The reasons for these reversals and their accelerating rate are not known but presumably involve the dynamo effect in some way.

Q2. Some types of vertical car antenna, especially the whip type, may begin to oscillate as you drive. Why does the antenna oscillate in the pattern of figure (a) for low to moderate speeds and in the pattern of figure (b) for higher speeds?



(a) (b)

–Lakshya Pandey, Gorakhpur (U.P.)

Ans. If we mount the antenna in a vise and some-how made it oscillate, it would oscillate in what are called resonant modes (or patterns) and at resonant frequencies. We are said to set up resonance when our oscillations set up one of the patterns. The simplest pattern is called the fundamental mode, which oscillates at the lowest resonant frequency (figure (a)). In this pattern, the bottom of the antenna does not move because it is fixed in place, the top moves the most, and the intermediate points at intermediate distances. The next more complicated pattern, the first overtone mode, has a point of no oscillation located somewhat down from the top. When the antenna is on a moving car, the passing air tends to create vortexes on the back side of the antenna. The variations in air pressure due to the vortexes tend to make the antenna oscillate. At low to moderate speeds, the fundamental mode is set up. At greater speeds, with vortexes being shed by the antenna at a greater rate, the first overtone mode is set up.

Q3. A ball thrown upward from top of a tower with speed v reaches the ground in t_1 seconds. If the ball is thrown downward from the top of the same tower with speed v, it reaches ground in t_2 seconds. If ball is allowed to fall freely under gravity from top of the tower then find the time taken by the ball to reach the ground in terms of t_1 and t_2.

–Rezaul Karim, Burdwan (W.B.)

Ans. For upward motion,

$$h = -vt_1 + \frac{1}{2}gt_1^2$$

For downward motion,

$$h = +vt_2 + \frac{1}{2}gt_2^2$$

$$\therefore \quad \frac{h}{t_1} + \frac{h}{t_2} = \frac{1}{2}g(t_1 + t_2)$$

or $$h = \frac{1}{2}gt_1t_2 \qquad \text{...(i)}$$

For freely falling ball,

$$h = \frac{1}{2}gt^2 \qquad \text{...(ii)}$$

From eqns (i) and (ii), we get

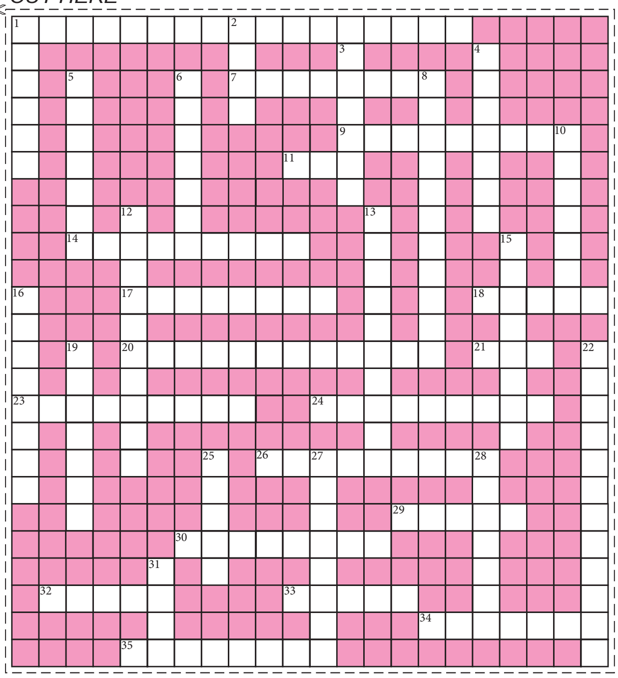
$$\therefore \quad \frac{1}{2}gt^2 = \frac{1}{2}gt_1t_2 \text{ or } t = \sqrt{t_1t_2}$$

◈◈

CROSSWORD

Readers can send their responses at editor@mtg.in or post us with complete address by 25th of every month to win exciting prizes. Winners' name with their valuable feedback will be published in next issue.

CUT HERE



ACROSS

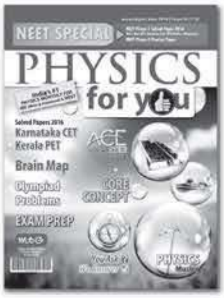
1. Enhanced conductivity of certain semiconductors as a result of exposure to light. [17]
7. Radio waves which are reflected by the electrically conducting ionospheric layers. [3,5]
9. The flow of sea water as a current. [9]
11. The SI unit of illumination. [3]
14. The reciprocal of capacitance. [9]
17. The leakage of gas through a fine orifice. [8]
18. Unit of mass in the customary system of English units of measurement. [5]
20. Shadow of moon falling on the earth. [5, 7]
21. The delay between a correcting signal and the response to it. [3]
23. An electronic equipment to carry out a number of electronic functions in an IC. [9]
24. The science concerned with the production, properties and propagation of sound waves. [9]
26. Most magnetic mineral of all the naturally occurring minerals on earth. [9]
29. The electrode in a FET through which carriers leave the interelectrode region. [5]
30. Point at which an electrical appliance is connected by wires. [8]
32. The movement of one atomic plane over another in a crystal. [5]
33. A simple machine capable of rotating and consisting of a beam or rigid rod. [5]
34. 'C' in LCD, a thin flat panel that can let light go through it or block it. [7]
35. The resistance that a face of the crystal offers to scratching, which may differ in different directions. [8]

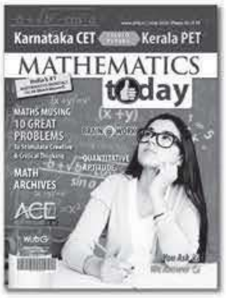
DOWN

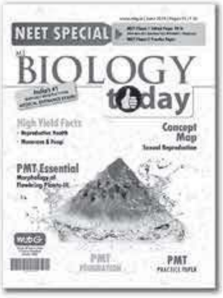
1. An astronomical unit of length equal to 3.08×10^{16} m. [6]
2. A quantity of radiation or absorbed energy. [4]
3. A giant assembly of stars, gas and dust organized by the gravitational interactions between its components. [6]
4. A device for producing spectra by diffraction [7]
5. A magnetic compound of ferric oxide with another metal oxide. [7]
6. The CGS electromagnetic unit of magnetomotive force. [7]
8. An instrument used to hear sounds produced within a body mainly in the heart or lungs. [11]
10. A neucleon discovered in 1932. [7]
12. A tornado over the sea. [10]
13. A device which converts sound energy into electrical signals. [10]
15. The tendency of a liquid to exert an upward force on an object in it. [8]
16. Phase of moon at the time when the position of the sun and the moon is on the opposite side of the earth. [4, 4]
19. Part of inner ear that converts pressure variations into electric signals. [7]
22. A unit of energy extensively employed in atomic, nuclear and particle physics. [12]
25. The slow permanent deformation of a crystal under sustained stresses. [5]
27. An optical lens composed of an inhomogeneous medium in which the refractive index varies in a prescribed fashion. [4, 4]
28. Deposition of a crystalline overlayer on a crystalline substrate. [7]
31. A prefix denoting 10^{15}. [4]

Now, save up to Rs 2,020*

MTG Learning Media







Subscribe to MTG magazines today.

Our 2016 offers are here. Pick the combo best suited for your needs. Fill-in the Subscription Form at the bottom and mail it to us today. If in a rush, log on to www.mtg.in now to subscribe online.

'On cover price of ₹ 30/- each.

For JEE (Main & Advanced), NEET, PMTs, All State Level Engg. & Medical Exams

About MTG's Magazines

Perfect for students who like to prepare at a steady pace, MTG's magazines – Physics For You, Chemistry Today, Mathematics Today & Biology Today – ensure you practice bit by bit, month by month, to build all-round command over key subjects. Did you know these magazines are the only source for solved test papers of all national and state level engineering and medical college entrance exams?

Trust of over 1 Crore readers. Since 1982.

- Practice steadily, paced month by month, with very-similar & model test papers
- Self-assessment tests for you to evaluate your readiness and confidence for the big exams
- Content put together by a team comprising experts and members from MTG's well-experienced Editorial Board
- Stay up-to-date with important information such as examination dates, trends & changes in syllabi
- All-round skill enhancement – confidence-building exercises, new studying techniques, time management, even advice from past IIT/PMT toppers
- **Bonus:** exposure to competition at a global level, with questions from Intl. Olympiads & Contests

SUBSCRIPTION FORM

Please accept my subscription to:
(Confirm your choice by ticking the appropriate boxes)

Best Offer

PCMB combo

☐ 1 yr: ₹ 1000 *(save ₹ 440)*	☐ 2 yrs: ₹ 1,800 *(save ₹ 1,080)*	☐ 3 yrs: ₹ 2,300 *(save ₹ 2,020)*

PCM combo

☐ 1 yr: ₹ 900 *(save ₹ 180)*	☐ 2 yrs: ₹ 1,500 *(save ₹ 660)*	☐ 3 yrs: ₹ 1,900 *(save ₹ 1,340)*

PCB combo

☐ 1 yr: ₹ 900 *(save ₹ 180)*	☐ 2 yrs: ₹ 1,500 *(save ₹ 660)*	☐ 3 yrs: ₹ 1,900 *(save ₹ 1,340)*

Individual magazines

☐ Physics ☐ Chemistry ☐ Mathematics ☐ Biology

☐ 1 yr: ₹ 330 *(save ₹ 30)*	☐ 2 yrs: ₹ 600 *(save ₹ 120)*	☐ 3 yrs: ₹ 775 *(save ₹ 305)*

Name: ______________________

Complete Postal Address: ______________________

Pin Code ☐☐☐☐☐☐ Mobile # ☐☐☐☐☐☐☐☐☐☐

Other Phone # 0 ☐☐☐☐☐☐☐☐☐☐☐

Email ______________________

Enclose Demand Draft favouring **MTG Learning Media (P) Ltd**, payable at New Delhi. You can also pay via Money Orders. Mail this Subscription Form to Subscription Dept., **MTG Learning Media (P) Ltd**, Plot 99, Sector 44, Gurgaon – 122 003 (HR).

Note: Magazines are despatched by Book-Post on 4th of every month (each magazine separately). Should you want us to send you your copies by Courier or Regd. Post instead, additional charges apply (₹ 240, ₹ 450, ₹ 600 for 1-yr, 2-yr, 3-yr subscriptions respectively).

E-mail *info@mtg.in*. Visit *www.mtg.in* to subscribe online. **Call (0)8800255334/5 for more info.**