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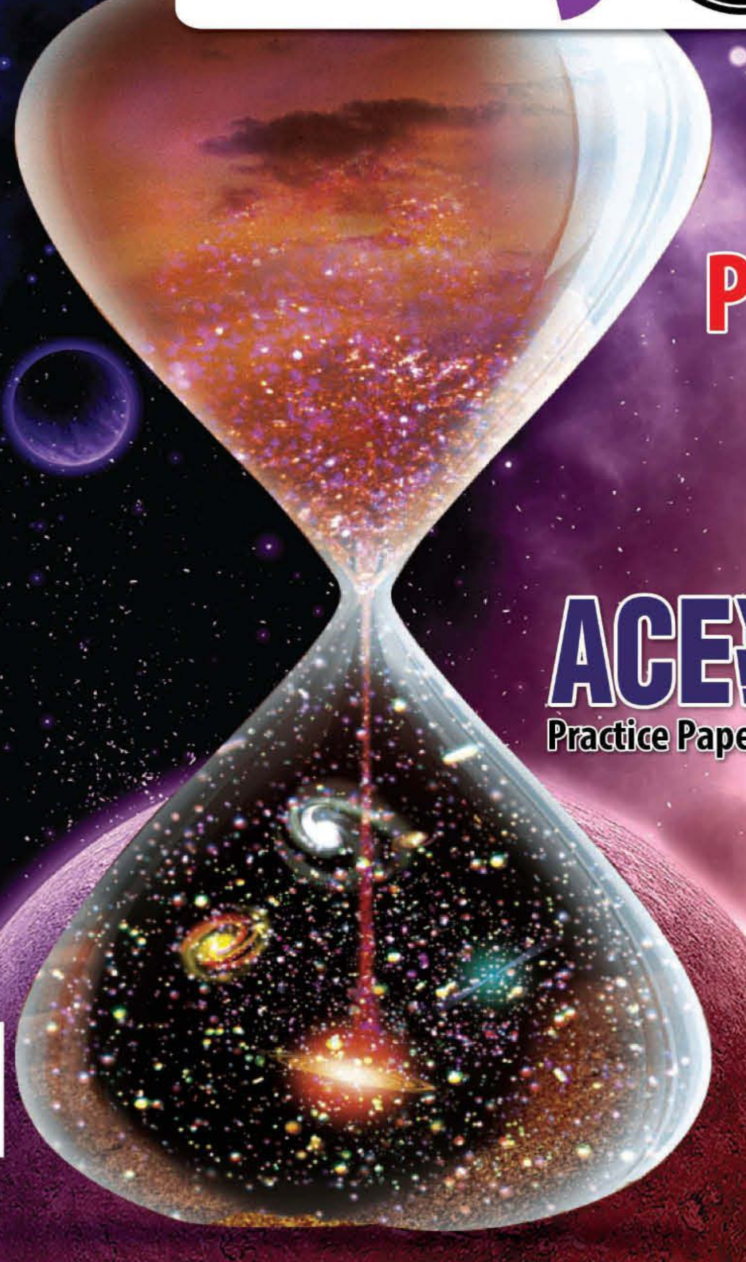

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PHYSICS for you

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PHYSICS MUSING

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

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

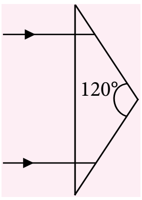
The readers who have solved five or more problems may send their detailed solutions with their names and complete address. The names of those who send atleast five correct solutions will be published in the next issue.

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

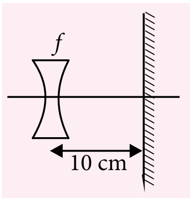
PROBLEM Set 44

1. Some amount of a radioactive substance (half-life = 10 days) is spread inside a room and consequently the level of radiation becomes 50 times the permissible level for normal occupancy of the room. After how many days the room will be safe for occupation?

2. An isosceles prism of angle 120° has a refractive index $\sqrt{2}$. Two parallel monochromatic rays enter the prism parallel to each other in air as shown in figure. Find the angle between the emerging rays.



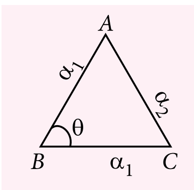
3. A diverging lens of focal length 10 cm is placed 10 cm in front of a plane mirror as shown in the figure. Light from a very far away source falls on the lens. What is the distance of final image?



4. A convex lens of focal length f is mounted on a stand of total mass m, which is connected through a spring with a fixed surface. A point object is placed on the optical axis at a distance $3f$ from the pole. If the amplitude of vibration of the lens is 'a', find the distance between the two extreme ends of the vibration of the image.

5. An H atom in ground state is moving with initial kinetic energy K. It collides head on with He^+ ion in ground state kept at rest but free to move. Find minimum value of K so that both the particles can excite to their first excited state.

6. Three rods A, B and C form an equilateral triangle at 0 °C. Rods AB and BC have same coefficient of expansion α_1 and rod AC has α_2. If temperature of the system is increased to T °C, what is the change in angle θ formed by roads AB and BC?



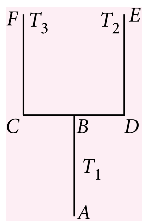
7. In the lower atmosphere the temperature decreases with altitude. Given that the temperature variation is linear $T = T_0(1 - cy)$, where the reference level is at the surface of the earth. Find an expression for the variation of pressure with altitude, assuming an ideal gas for which $PV = \dfrac{mRT}{M}$.

8. A capillary tube of constant cross-sectional area is filled with an ideal gas. The temperature of the gas varies linearly from one end ($x = 0$) to the other ($x = L$) according to the equation

$$T = T_0 + \left(\frac{T_L - T_0}{L}\right)x$$

The volume of the capillary is V and the pressure P is uniform throughout. Determine the number of moles of the gas in the capillary.

9. Four identical rods AB, CD, CF and DE are joined as shown in figure. The length, cross-sectional area and thermal conductivity of each rod are L, A, K respectively. The ends A, E and F are maintained at temperatures T_1, T_2 and T_3 respectively. Assuming no heat loss to surrounding, determine the temperature at B.



10. A conducting cylindrical shell of inner radius R_1 maintained at a temperature T_1 and outer radius R_2 maintained at a temperature T_2 respectively. Thermal conductivity of the shell varies with distance from the axis as $K = \dfrac{\alpha}{r^2}$. Find the temperature as a function of distance R from the axis of the cylinder.

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

Exam on 21st May

JEE ADVANCED

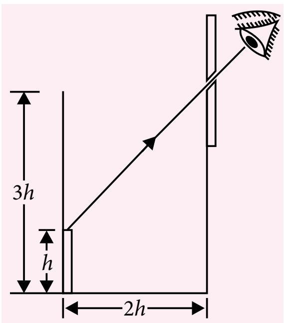
PRACTICE PAPER 2017

PAPER-I

Section 1

Single Option Correct Type

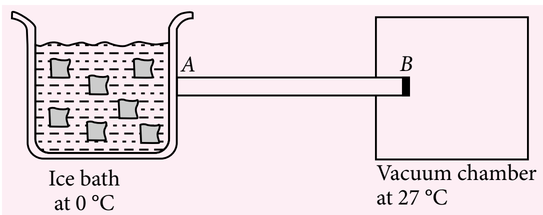
1. An observer can see through a pin-hole at the end top of a thin rod of height h, placed as shown in the figure. The beaker height is $3h$ and its radius is h. When the beaker is filled with a liquid upto a height $2h$, he can see the lower end of the rod. The refractive index of the liquid is:



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

(c) $\frac{5}{2}$ (d) $\frac{3}{2}$

2. A cylindrical rod of 50 cm length and having 1 cm^2 cross-sectional area is used as a conducting material between an ice bath at 0 °C and a vacuum chamber at 27 °C as shown in figure. The end of rod which is inside the vacuum chamber behaves like a black body and is at temperature 17 °C in steady state. The thermal conductivity of the material of rod and rate at which ice is melting in the ice bath are respectively (Given that latent heat of fusion of ice is 3.35×10^5 J kg^{-1})



(a) 1.713 W m^{-1} °C^{-1} and 1.74×10^{-8} kg s^{-1}

(b) 2.7 W m^{-1} °C^{-1} and 4.8×10^{-8} kg s^{-1}

(c) 4.713 W m^{-1} °C^{-1} and 6.2×10^{-8} kg s^{-1}

(d) 0.713 W m^{-1} °C^{-1} and 1.84×10^{-8} kg s^{-1}

3. A small quantity of solution containing ^{24}Na radionuclide (half-life 15 h) of activity 1.0 μCi is injected into the blood of a person. A sample of the blood of volume 1 cm^3 taken after 5 h shown an activity of 296 disintegration min^{-1}. Determine the total volume of blood in the body of the person. Assume that the radioactivity solution mixes uniformly in the blood of the person.

(a) 4.82 L (b) 1.34 L

(c) 5.95 L (d) 2.68 L

4. The two headlights of an approaching automobile are 1.42 m apart. At what angular separation (θ) and maximum distance (D) will the eye resolve them? Assume a pupil diameter of 5.00 mm and a wavelength of 562 nm. Also assume that diffraction effects alone limit the resolution.

(a) $\theta = 1.37 \times 10^{-4}$ rad, $D = 1.04 \times 10^4$ m

(b) $\theta = 0.5 \times 10^{-3}$ rad, $D = 2 \times 10^3$ m

(c) $\theta = 1.37 \times 10^{-6}$ rad, $D = 1.04 \times 10^2$ m

(d) $\theta = 0.5 \times 10^{-4}$ rad, $D = 2 \times 10^2$ m

5. A small sphere of mass m = 0.6 kg carrying a positive charge q = 80 μC is connected with a light, flexible and inextensible string of length r = 30 cm and whirled in a vertical circle. If a horizontal rightward electric field of strength $E = 10^5$ N C^{-1} exists in the space, then the minimum velocity of the sphere required at the highest point so that it may just complete the circle will be (g = 10 m s^{-2})

(a) greater than 5 m s^{-1}

(b) approximately 3 m s^{-1}

(c) less than 2 m s^{-1}

(d) approximately 5 m s^{-1}

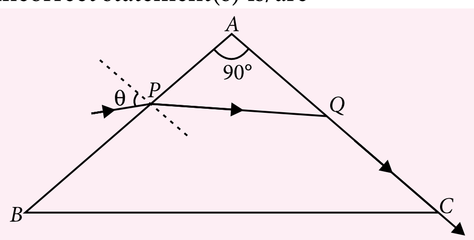
Section 2

One or More Than One Option(s) Correct Type

6. A satellite moves in an elliptical orbit about the earth. The minimum and maximum distances of the satellite from the centre of earth are 7000 km and 8750 km respectively. For this situation mark the correct statement(s). [Take $M_e = 6 \times 10^{24}$ kg]
   (a) The maximum speed of the satellite during its motion is 7.97 km s^{-1}.
   (b) The minimum speed of the satellite during its motion is 6.376 km s^{-1}.
   (c) The length of major axis of orbit is 15750 km.
   (d) None of the above

7. A transparent slab of thickness t and refractive index μ is inserted in front of upper slit of Young's double slit experiment apparatus. The wavelength of light used is λ. Assume that there is no absorption of light by the slab. Select the correct statement (s).
   (a) The intensity of dark fringes will be 0, if slits are identical.
   (b) The change in optical path due to insertion of the plate is μt.
   (c) The change in optical path due to insertion of the plate is $(\mu - 1)t$.
   (d) For making intensity zero at the centre of screen, then thickness could be $\frac{5\lambda}{2(\mu-1)}$.

8. Figure shows a triangular prism of refracting angle 90°. A ray of light incident at face AB at an angle θ refracts at point Q with an angle of refraction 90°. The incorrect statement(s) is/are

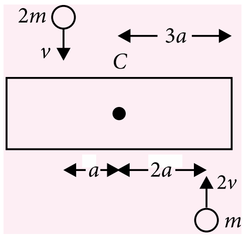


   (a) The refractive index of the prism is $\sqrt{3-\sin^2\theta}$.
   (b) The maximum value of the refractive index is $\sqrt{3}$.
   (c) The light at Q emerges into air if the incident angle at Q is increased slightly.
   (d) The light at Q emerges into air if the incident angle at Q is decreased slightly.

9. The electron in a hydrogen atom makes a transition $n_1 \rightarrow n_2$, where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are
   (a) $n_1 = 4, n_2 = 2$ (b) $n_1 = 8, n_2 = 2$
   (c) $n_1 = 8, n_2 = 1$ (d) $n_1 = 6, n_2 = 3$

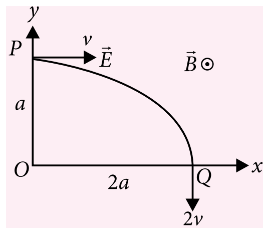
10. In a resonance tube apparatus, the first and second resonance lengths are l_1 and l_2 respectively. If v is the velocity of wave. Then the resonant frequency (υ) and end-correction (e) are given by
   (a) $\upsilon = \frac{v}{2(l_2 - l_1)}$ (b) $e = \frac{l_2 - 3l_1}{2}$
   (c) $e = \frac{l_2 + 3l_1}{4}$ (d) $\upsilon = \frac{v}{4(l_1 - l_2)}$

11. A uniform bar of length $6a$ and mass $8m$ lies on a smooth horizontal table. Two point masses m and $2m$ moving in the same horizontal with speed $2v$ and v respectively, strike the bar as shown in the figure and stick to the bar after collision. Denoting angular velocity about the centre of mass, total energy and centre of mass velocity by ω, E and v_C respectively, we have after collision



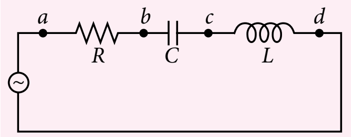
   (a) $v_C = 0$
   (b) $\omega = \frac{3v}{5a}$
   (c) $\omega = \frac{v}{5a}$
   (d) $E = \frac{3mv^2}{5}$.

12. A particle with charge $+q$ and mass m, moving under the influence of a uniform electric field $E\hat{i}$ and a uniform magnetic field $B\hat{k}$, follows a trajectory from P to Q as shown in figure. The velocities at P and Q as shown in figure. The velocities at P and Q $v\hat{i}$ and $-2v\hat{j}$ respectively. Which of the following results are incorrect?



   (a) $E = \frac{3}{2}\left(\frac{mv^2}{qa}\right)$
   (b) The rate of work done by the electric field at P is $\frac{3}{2}\left(\frac{mv^3}{a}\right)$.
   (c) The rate of work done by the electric field at P is 0.
   (d) The rate of work done by both the fields at Q is 0.

13. In figure, $R = 15.0\ \Omega$, $C = 4.72\ \mu F$, and $L = 25.3$ mH. The generator provides a sinusoidal voltage of 75.0 V (rms) and frequency $\upsilon = 550$ Hz.



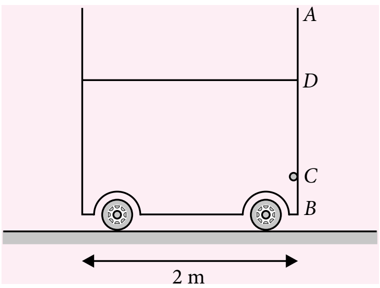
(a) The rms current amplitude is 2.49A.
(b) The rms voltages ΔV_{ab}, ΔV_{bd} are 65V and 37.4 V respectively.
(c) Average power dissipated in the circuit is 93.3 W .
(d) rms voltage, $\Delta V_{bc} = 153$ V.

Section 3

Single Digit Integer Type

14. Two identical wires are stretched by the same tension of 100 N, and each emits a note of frequency 200 cycles s^{-1}. The tension in one wire is increased by 1 N. The number of beats heard in cycle per second when the wires are plucked is

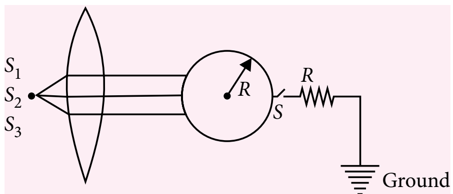
15. A cubical container with side 2 m has a small hole with a cap at point C as shown in the figure. The water level is upto point D. ($BC = 0.5$ m and $BD = 1.5$ m). If container is given an acceleration of 8 m s^{-2} and the hole is opened simultaneously. The amount of water that will spill out of the container is 200 α L. Find the value of α.



16. A thin fixed ring of radius 1 m has a positive charge 1×10^{-5} C uniformly distributed over it. A particle of mass 0.9 g and having a negative charge of 1×10^{-6} C is placed on the axis at a distance of 1 cm from the centre of the ring. The motion of the negatively charged particle is approximately simple harmonic. The time period of oscillations is $\frac{a\pi}{10}$, then value of a is

17. A box is kept on a rough horizontal surface. A horizontal force just strong enough to move the box is applied. This force is maintained for 2 s, and is then removed. The total distance moved by the box is S m. Then find the value of $\frac{9}{5}S$.
[Take $\mu_s = 0.2$ and $\mu_k = 0.15$]

18. Three monochromatic sources having wavelengths 12.42 nm, 6.21 nm and 24.84 nm are placed close to each other in front of a converging lens such that equal powers from the three sources (equal to 1mW each) fall on a converging lens and then on a small spherical conductor of radius $r = 1$ mm and its work function = 62.1 eV. Assume 50% efficiency of emission and no change in effective value of work function due to photoelectric emission. Also, all electrons emitted by the sphere are immediately removed by some non-electrical mechanism and its potential rises. At $t = 8$ s, switch S is closed so that the sphere gets connected to the earth via a resistor of value 6.75 MΩ. If the current flowing just after the switch is closed is given by $10a^3$ A, then the value of a is (Use, $hc = 1242$ eV nm)

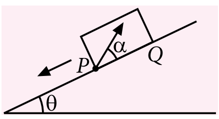


PAPER-II

SECTION 1

Single Option Correct Type

1. A large, heavy box is sliding without friction down a smooth plane of inclination θ. From a point P on the bottom of the box, a particle` is projected inside the box. The initial speed of the particle with respect to the box is u, and the direction of projection makes an angle α with the bottom as shown in figure. The distance along the bottom of the box between the point of projection P and the point Q where the particle lands is (Assume that the particle does not hit any other surface of the box. Neglect air resistance.)



(a) $\frac{u^2 \sin 2\alpha}{g \cos\theta}$ (b) $\frac{u^2 \cos 2\alpha}{g \sin\theta}$

(c) $\frac{u^2 \cos 2\alpha}{g \cos\theta}$ (d) $\frac{u^2 \sin 2\alpha}{g \sin\theta}$

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

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

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

3. A plano-convex lens has a thickness of 4 cm. When placed on a horizontal table, with the curved surface in contact with it, the apparent depth of the bottom most point of the lens is found to be 3 cm. If the lens is inverted such that the plane face is in contact with the table, the apparent depth of the centre of the plane face is found to be (25/8) cm. The focal length of the lens is

(a) 50 cm (b) 75 cm (c) 25 cm (d) 100 cm

4. A ball of radius R carries a positive charge whose volume density depends only on a separation r from the ball's centre as $\rho = \rho_0 (1 - r/R)$, where ρ_0 is a constant. Assuming the permittivities of the ball and the environment to be equal to unity. The magnitude of the electric field strength as a function of the distance r outside the ball and the maximum intensity E_{max} are respectively

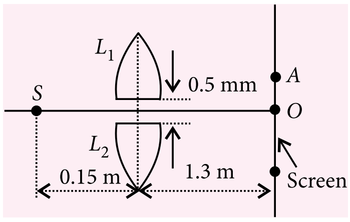
(a) $\frac{\rho_0 R^3}{12r^2\varepsilon_0}$ and $\frac{\rho_0 R}{9\varepsilon_0}$ (b) $\frac{\rho_0 R^3}{9r^2\varepsilon_0}$ and $\frac{\rho_0 R}{12\varepsilon_0}$

(c) $\frac{\rho_0 R^3}{r^2\varepsilon_0}$ and $\frac{\rho_0 R}{\varepsilon_0}$ (d) $\frac{\rho_0 R^3}{4r^2\varepsilon_0}$ and $\frac{\rho_0 R}{2r^2\varepsilon_0}$

5. A uniform disc of radius R is spinned to the angular velocity ω and then carefully placed on a horizontal surface. The disc will be rotating on the surface for a time duration of (The coefficient of friction is equal to k and the pressure exerted by the disc on the surface can be regarded as uniform.)

(a) $\frac{R\omega_0}{2\,kg}$ (b) $\frac{3R\omega_0}{4\,kg}$ (c) $\frac{R\omega_0}{kg}$ (d) $\frac{2R\omega_0}{3\,kg}$

6. In figure, S is a monochromatic point source emitting light of wavelength λ = 500 nm. A thin lens of circular shape and focal length 0.10 m is cut into two identical halves L_1 and L_2 by a plane passing through a diameter. The two halves are placed symmetrically about the central axis SO with a gap of 0.5 mm. The distance along the axis from S to L_1 and L_2 is 0.15 m while that from L_1 and L_2 to O is 1.30 m. The screen is normal to SO.



The third intensity maximum occurs at the point A on the screen, the distance OA will be

(a) 10^{-2} m (b) 100 m (c) 10 cm (d) 10^{-3} m

SECTION 2

One or More than One Option(s) Correct Type

7. The collector of the photocell (in photoelectric experiment) is made of tungsten while the emitter is of platinum having work function of 10 eV. Monochromatic radiation of wavelength 124 Å and power 100 W is incident on emitter which emits photoelectrons with a quantum efficiency of 1%. The accelerating voltage across the photocell is of 10,000 V. (Use : hc = 12400 eV Å)

(a) The power supplied by the accelerating voltage source is 100 W.

(b) The minimum wavelength of photoelectron at the tungsten target (collector) is 1.23 Å.

(c) The power supplied by the accelerating voltage source is 10 W.

(d) The minimum wavelength of photoelectron at the tungsten target (collector) is 2.23 Å.

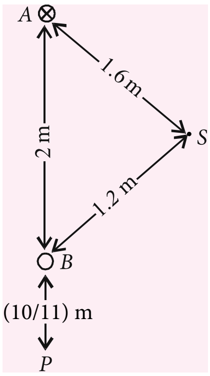
8. Two long straight parallel wires are 2 m apart, perpendicular to the plane of the paper (see figure). The wire A carries a current of 9.6 A, directed into the plane of the paper. The wire B carries a current such that the net magnetic field of induction at the point P, at distance of (10/11) m from the wire B, is zero.

(a) The current in B is 3 A and directed perpendicular to the paper outwards.

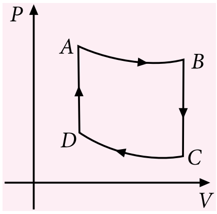
(b) The magnitude of the magnetic field of induction at the point S is 1.3×10^{-6} T.

(c) The force per unit length on the wire B is 5.76×10^{-6} N m^{-1}.

(d) The magnitude of the magnetic field of induction at point S is 2.4×10^{-6} T.



9. One mole of a monatomic ideal gas is taken through the cycle shown in figure.



$A \to B$: adiabatic expansion

$B \to C$: cooling at constant volume

$C \to D$: adiabatic compression

$D \to A$: heating at constant volume.

The pressure and temperature at A, B, etc. are denoted by P_A, T_A, P_B, T_B, etc., respectively. If $T_A = 1000$ K, $P_B = (2/3)P_A$ and $P_C = (1/3)P_A$, then [Given: $(2/3)^{2/5} = 0.85$]

(a) The work done by the gas in the process $A \to B$ is 870 J .

(b) The heat lost by the gas in the process $B \to C$ is 5298 J.

(c) The temperature T_B is 850 K.

(d) The temperature T_C is 250 K.

10. A gas of identical hydrogen-like atoms has some atoms in the lowest (ground) energy level A and some atoms in a particular upper (excited) energy level B and there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level by absorbing monochromatic light of photon energy 2.7 eV. Subsequently, the atoms emit radiation of only six different photon-energies. Some of the emitted photons have energy 2.7 eV, some have energy more and some have less than 2.7 eV.

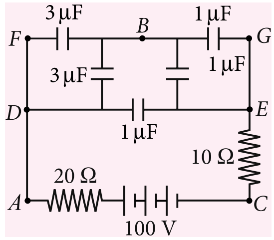
(a) The principal quantum number of the initially excited level B is 2.

(b) The ionization energy for the gas atoms is 14.4 eV.

(c) The maximum energy of the emitted photons is 13.5 eV

(d) The minimum energy of the emitted photon is 7 eV.

11. For the given circuit in the steady state,



(a) $V_{AB} = 50$ V

(b) $V_{AB} = 25$ V

(c) $V_{BC} = 25$ V

(d) $V_{BC} = 75$ V

12. Two point charges $+q$ and $-q$ are held fixed at $(-d, 0)$ and $(d, 0)$ respectively of a x-y coordinate system. Then,

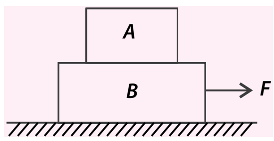
(a) The electric field at all points on x-axis has the same direction

(b) Electric field at all points on y-axis is along x-axis

(c) Work has to be done in bringing a test charge from ∞ to the origin

(d) The dipole moment is $2qd$ along negative x-axis.

13. In the shown figure, the coefficient of friction between the floor and the body B is 0.1. The coefficient of friction between the bodies B and A is 0.2. A force F is applied as shown on B. The mass of A is $m/2$ and that of B is m. Which of the following statements are true?



(a) Both the bodies will move together if $F = 0.25\ mg$.

(b) The body A will slip with respect to B if $F = 0.5\ mg$.

(c) The bodies will move together if $F = 0.5\ mg$.

(d) The bodies will be at rest if $F = 0.1\ mg$.

14. A diminished image of an object is to be obtained on a screen 1.0 m from it. This can be achieved by appropriately placing

(a) a concave mirror of suitable focal length

(b) a convex mirror of suitable focal length

(c) a convex lens of focal length less than 0.25 m

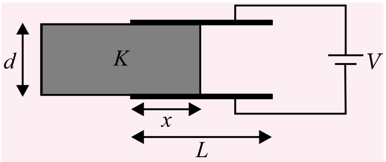
(d) a concave lens of suitable focal length

SECTION 3

Paragraph Based Questions

PARAGRAPH 1

Figure shows a parallel plate capacitor with plates of width b and length L. The separation between the plates is d. The plates are rigidly clamped and connected to a battery with voltage V. A dielectric slab of dielectric constant K is slowly inserted between the plates.



It is found that the dielectric slab is being attracted by the capacitor. Hence external agent has to apply equal and opposite force so that the slab is slowly inserted. The magnitude of the attractive force applied by the capacitor on the dielectric slab can be obtained using energy considerations. Suppose x length of the dielectric slab enters the capacitor then the plate area of the part with the dielectric is bx. Its capacitance is

$$C_1 = \frac{K\varepsilon_0 bx}{d}$$

Similarly, the capacitance of the part without the dielectric is

$$C_1 = \frac{\varepsilon_0 b(L-x)}{d}$$

These two are connected in parallel. The capacitance of the system is, therefore

$$C = C_1 + C_2 = \frac{\varepsilon_0 b}{d}[L + x(K-1)]$$

The energy of the capacitor

$$U = \frac{1}{2}CV^2 = \frac{\varepsilon_0 bV^2}{2d}[L + x(K-1)]$$

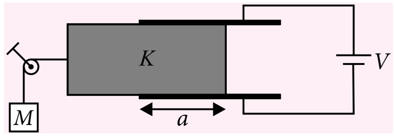
Suppose the electric field attracts the dielectric slab with a force F. An external force of equal magnitude F should be applied in opposite direction so that the plate moves slowly (no acceleration).
The attractive force F will be given by

$$F = \frac{dU}{dx} = \frac{\varepsilon_0 bV^2(K-1)}{2d}$$

15. If E, Q and U refer to the electric field between the plates, charge on capacitor and energy stored in the capacitor and subscripts 1 and 2 respectively refer to conditions in figure before the dielectric slab is introduced and after the dielectric slab completely fills the space between the plates of capacitor, with the battery remaining connected then

(a) $E_2 < E_1$ $\quad Q_2 > Q_1$ $\quad U_2 > U_1$
(b) $E_2 < E_1$ $\quad Q_2 > Q_1$ $\quad U_2 < U_1$
(c) $E_2 = E_1$ $\quad Q_2 > Q_1$ $\quad U_2 > U_1$
(d) $E_2 = E_1$ $\quad Q_2 < Q_1$ $\quad U_2 < U_1$

16. Suppose length 'a' of the dielectric slab is inside the capacitor, then to keep the dielectric slab in equilibrium, a block of mass M is attached to the dielectric slab via a light inextensible string passing over an ideal pulley as shown in figure. The value of mass M is equal to :



(a) $\dfrac{\varepsilon_0 bV^2(K-1)}{2dg}$ (b) $\dfrac{\varepsilon_0 bV^2(K-1)}{dg}$

(c) $\dfrac{\varepsilon_0 bV^2(K-1)}{4dg}$ (d) $\dfrac{\varepsilon_0 bV^2 K}{2dg}$

PARAGRAPH 2

The satellite when launched from the earth are not given the orbital velocity initially, a multistage rocket propeller carries the spacecraft up to its orbit and during each stage rocket has been fired to increase the velocity to acquire the desired velocity for a particular orbit. The last stage of the rocket brings the satellite in circular/elliptical (desired) orbit.
Consider a satellite of mass 150 kg in a low circular orbit. In this orbit, we cannot neglect the effect of air drag. This air opposes the motion of satellite and hence the total mechanical energy of earth-satellite system decreases. That means the total energy becomes more negative and hence the orbital radius decreases which causes the increase in kinetic energy. When the satellite comes in the low enough orbit, excessive thermal energy generation due to air friction may cause the satellite to burn up. Based on the given information, answer the following questions.

17. It has been mentioned in the passage that as r decreases, E decreases but K increases. The increase in K is [E = total mechanical energy, r = orbital radius, K = kinetic energy]

(a) due to increase in gravitational PE
(b) due to decrease in gravitational PE
(c) due to work done by air friction force
(d) both (b) and (c)

18. If due to air drag, the orbital radius of the earth decreases from R to $R - \Delta R$, $\Delta R << R$, the expression for increase in the orbital velocity Δv is

(a) $\frac{\Delta R}{2}\sqrt{\frac{GM}{R^3}}$ (b) $-\frac{\Delta R}{2}\sqrt{\frac{GM}{R^3}}$

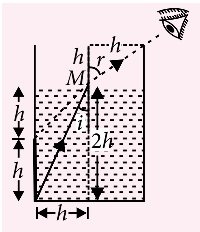
(c) $\Delta R\sqrt{\frac{GM}{R^3}}$ (d) $-\Delta R\sqrt{\frac{GM}{R^3}}$

SOLUTIONS

Paper-I

1. (b): When $2h$ column of liquid is made available, then

$$\mu = \frac{\sin r}{\sin i}$$



From the figure,

$$\sin r = \frac{h}{\sqrt{2}h}$$

$$\sin i = \frac{h}{\sqrt{5}h}$$

$$\therefore \quad \mu = \sqrt{\frac{5}{2}}$$

2. (a): It is given that the system is in steady state. So heat absorbed by the end of the rod in vacuum chamber by radiation is conducted to the ice bath through the rod. Hence

$$\frac{KA(T_B - T_A)}{l} = \sigma A(T_{vc}^4 - T_B^4)$$

or $\frac{K(17)}{0.5} = 5.67 \times 10^{-8}\,[(300)^4 - (290)^4]$

or $K = \frac{5.67\times10^{-8}[(300)^4-(290)^4]\times0.5}{17}$

$= 1.713 \text{ W m}^{-1}\,°\text{C}^{-1}$

The rate of heat obtained by the ice bath is

$$\frac{dQ}{dt} = \frac{KA(T_B - T_A)}{l} = \frac{1.713\times1\times10^{-4}\times17}{0.5}$$

$= 5.82 \times 10^{-3} \text{ J s}^{-1}$

This heat is used to melt the ice in ice bath. If m mass of ice is being melted per second, then we have

$$\frac{dQ}{dt} = mL$$

or $5.82 \times 10^{-3} = m \times 3.35 \times 10^5$

or $m = 1.74 \times 10^{-8} \text{ kg s}^{-1}$

3. (c): Initial activity of ^{24}Na,

$$A = \frac{dN}{dt} = 1.0\ \mu\text{Ci} = 3.7 \times 10^4 \text{ disintegrations s}^{-1}$$

Half-life, $T = 15$ h $= 15 \times 3600$ s

Initial activity,

$$A = \frac{dN}{dt} = \lambda N_0$$

$$3.7 \times 10^4 = \frac{0.693}{15\times3600}N_0 \qquad \left[\because \lambda = \frac{0.693}{T}\right]$$

$$\therefore \quad N_0 = \frac{3.7\times10^4\times15\times3600}{0.693} = 2.883 \times 10^9$$

Let the number of radioactive nuclei present after 5 h be N' in 1 cm^3 of sample of blood. Then,

$$A' = \lambda N' \Rightarrow \left(\frac{296}{60}\right) = \frac{0.693}{15\times3600}N'$$

$$\therefore \quad N' = \frac{296\times15\times3600}{60\times0.693} = 3.844 \times 10^5$$

If N_0' is initial number of radioactive nuclei in 1 cm^3 of sample, then

$$\frac{N'}{N_0'} = \left(\frac{1}{2}\right)^{t/T}$$

$N_0' = (2)^{t/T}N' = (2)^{5/15}N' = (2)^{1/3} \times 3.844 \times 10^5$

$\therefore \quad N_0' = 1.2598 \times 3.844 \times 10^5 = 4.843 \times 10^5$

$$\text{Volume of blood} = \frac{N_0}{N_0'} = \frac{2.883\times10^9}{4.843\times10^5}$$

$= 5.95 \times 10^3 \text{ cm}^3 = 5.95$ L

4. (a): Rayleigh's criterion for resolving images requires that two objects have an angular separation of atleast

$$\theta = \sin^{-1}\left(\frac{1.22\lambda}{d}\right) = \sin^{-1}\left(\frac{1.22(562\times10^{-9})}{(5.00\times10^{-3})}\right)$$

$= 1.37 \times 10^{-4}$ rad

Once again, this is a small angle, so we can use the small angle approximation to find the distance to the car. In that case

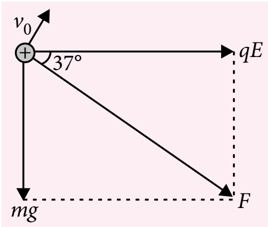
$\theta = y/D$

where y is the headlight separation and D the distance to the car.

$\therefore D = y/\theta_R = (1.42 \text{ m})/(1.37 \times 10^{-4} \text{ rad}) = 1.04 \times 10^4$ m

5. (b): Here, weight, $mg = 0.6 \times 10 = 6$ N (downward) and electric force, $qE = (80 \times 10^{-6})(10^5) = 8$ N (horizontally rightward).

Resultant force F of these two forces is at θ [$= \tan^{-1}(6/8) = 37°$], with the horizontal as shown in figure. Hence, tension is minimum at A, as shown in figure.



Let critical velocity at A be v_0. Considering free body diagram of sphere at A,

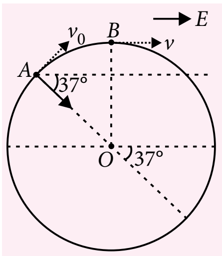
$$qE\cos 37° + mg\sin 37° = \frac{mv_0^2}{r}$$

$$8\times\frac{4}{5}+6\times\frac{3}{5}=\frac{0.6v_0^2}{0.3}$$

or $\quad 2v_0^2 = 10$

or $\quad v_0 = \sqrt{5}\ \text{m s}^{-1}$

As the sphere moves from A to B, work $qE(r\cos 37°)$ is done on the sphere by the electric field and the gravitational potential energy increases by $mg(r - r\sin 37°)$. We can find the required minimum velocity v, at the highest point B, by using work energy theorem between points A and B.



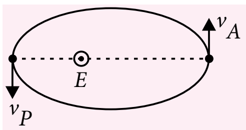
$W_{\text{total}} = \Delta K$

$$\Rightarrow qE\,r\cos 37° - mgr(1-\sin 37°) = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

$$8\times 0.3\times\frac{4}{5}-6\times 0.3\left(1-\frac{3}{5}\right)+\frac{1}{2}\times 0.6\times 5=\frac{1}{2}\times 0.6v^2$$

or $\quad v = 3\ \text{m s}^{-1}$

6. **(a, b, c) :** From conservation of angular momentum



$$mv_P r_P = mv_A r_A$$

$$\Rightarrow \frac{v_P}{v_A}=\frac{r_A}{r_P}=\frac{8750}{7000}=1.25$$

From energy conservation,

$$\frac{mv_P^2}{2}-\frac{GM_e m}{r_P}=\frac{mv_A^2}{2}-\frac{GM_e m}{r_A}$$

$$\Rightarrow \quad v_A^2 - v_P^2 = 2GM_e\left(\frac{1}{r_A}-\frac{1}{r_P}\right)$$

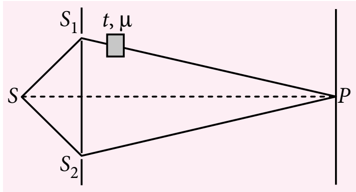
$\Rightarrow \quad v_A = 6.376\ \text{km s}^{-1}$ and $v_P = 7.910\ \text{km s}^{-1}$

Length of major axis $= r_A + r_P = 8750 + 7000$
$= 15750$ km

7. **(a, c, d) :** Path difference at point P

$$\Delta x = (S_1P - t)_{\text{air}} + t_{\text{medium}} - S_2P_{\text{air}}$$

$$= [S_1P - S_2P + \mu t - t]_{\text{air}} = (\mu - 1)t$$



Earlier, path difference at $P = S_1P - S_2P = 0$

So, change in optical path due to insertion of slab $= (\mu - 1)t$

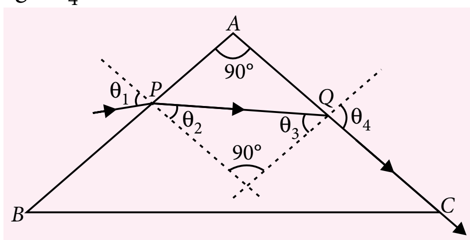
For intensity to be zero at P, we have

$$\Delta x = \frac{(2n-1)\lambda}{2}$$

$$\Rightarrow \quad (\mu-1)t = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots$$

$$\therefore \quad t = \frac{\lambda}{2(\mu-1)}, \frac{3\lambda}{2(\mu-1)}, \frac{5\lambda}{2(\mu-1)}, \ldots$$

8. **(a, b, c) :** Let the ray be incident at an angle θ_1 at face AB. It refracts at an angle θ_2 and is incident at an angle θ_3 at face AC. Finally the ray comes out at an angle $\theta_4 = 90°$.



From figure, the normals at faces AB and AC make an angle 90° with each other.

Hence $\theta_3 = 90° - \theta_2$

$$\sin\theta_3 = \sin(90° - \theta_2) = \cos\theta_2 = \sqrt{1-\sin^2\theta_2} \qquad \ldots\text{(i)}$$

From Snell's law at face AC,

$$\mu\sin\theta_3 = 1$$

$$\mu\sqrt{1-\sin^2\theta_2} = 1 \qquad \ldots\text{(ii)}$$

From Snell's law at face AB,

$$1\sin\theta_1 = \mu\sin\theta_2$$

$$\sin\theta_2 = \frac{\sin\theta_1}{\mu} \qquad \ldots\text{(iii)}$$

From eqns. (ii) and (iii), we have

$$\mu\sqrt{1-\frac{\sin^2\theta_1}{\mu^2}} = 1 \qquad \ldots\text{(iv)}$$

$$\mu = \sqrt{1+\sin^2\theta_1} = \sqrt{1+\sin^2\theta}$$

The greatest possible value of $\sin^2\theta_1$ is 1, hence the greatest possible value of μ is

$$\mu_{\max} = \sqrt{2} = 1.41$$

For a given μ, if θ_1 is increased, the angle of refraction θ_2 increases. As $\theta_3 = 90° - \theta_2$, the angle θ_3 decreases, *i.e.*, the angle of incidence at face AC is less than the critical angle for total reflection; hence light emerges into air.
If the angle of incidence is decreased, the angle of refraction θ_2 decreases. So the angle θ_3 increases. The angle of incidence at the second surface is greater than the critical angle; so light is reflected at Q.

9. (a, d) : The time period of the electron in a Bohr orbit is given by $T = 2\pi r/v$
Since for the n^{th} Bohr orbit, $mvr = n(h/2\pi)$, the time period becomes

$$T = \frac{2\pi r}{nh/(2\pi mr)} = \left(\frac{4\pi^2 m}{nh}\right) r^2 \propto \frac{r^2}{n}$$

The expression of Bohr radius of a hydrogen atom is

$$r = n^2\left(\frac{h^2\varepsilon_0}{\pi me^2}\right) \propto n^2$$

Hence, $T \propto \frac{n^4}{n} = n^3$

For two orbits, $\frac{T_1}{T_2} = \left(\frac{n_1}{n_2}\right)^3$

It is given that $T_1/T_2 = 8$. Hence, $n_1/n_2 = 2$.

10. (a, b) : For end correction e,

$$l_1 + e = \frac{\lambda}{4} \text{ and } l_2 + e = \frac{3\lambda}{4}$$

$$\therefore \quad l_2 - l_1 = \frac{\lambda}{2} = \frac{v}{2\upsilon} \text{ or } \upsilon = \frac{v}{2(l_2 - l_1)}$$

Put $\lambda = 4(l_1 + e)$ in $l_2 + e = \frac{3\lambda}{4}$

Then $l_2 + e = 3(l_1 + e)$

$$l_2 - 3l_1 = 2e \quad \therefore \; e = \frac{l_2 - 3l_1}{2}$$

11. (a, c, d) : Linear momentum is conserved
$\therefore\; 2m(-v) + m(2v) + (8m \times 0) = (2m + m + 8m)v_C$
or $-2mv + 2mv + 0 = 11mv_C$ or $v_C = 0$
Again since angular momentum, about centre of mass is conserved, we have

$$(2mv \times a) + (m \times 2v \times 2a) = I\omega$$

or $2mva + 4mva$

$$= \left[(2m \times a^2) + (m \times 4a^2) + \frac{8m \times (6a)^2}{12}\right]\omega$$

or $6mva = 30ma^2\omega$ or $\omega = \frac{v}{5a}$

After collision, let rotational kinetic energy $= E$

$$\therefore \quad E = \frac{1}{2}I\omega^2$$

or $E = \frac{1}{2} \times (30\,ma^2) \times \left(\frac{v}{5a}\right)^2 = \frac{30\,ma^2 \times v^2}{2 \times 25a^2}$

or $E = \frac{3mv^2}{5}$

12. (a, b, c) : In going from P to Q, increase in kinetic energy, $\frac{1}{2}m(2v)^2 - \frac{1}{2}mv^2 = \frac{1}{2}m(3v^2) =$ work done by electric field.

or $\frac{3mv^2}{2} = Eq \times 2a$ or $E = \frac{3}{4}\left(\frac{mv^2}{qa}\right)$

The rate of work done by electric force at $P = \vec{F}_e \cdot \vec{v}$

$$= (qE)v = qv\left[\frac{3}{2}\left(\frac{mv^2}{qa}\right)\right] = \frac{3}{4}\left(\frac{mv^3}{a}\right)$$

At Q, $\vec{E}$ is perpendicular to $\vec{B}$ and $\vec{v}$, and no work is done by either field.

13. (a, c, d) : The impedance of the circuit is

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

The resistance is $R = 15.0\ \Omega$
The inductive reactance is

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi(550\text{ s}^{-1})(4.72\ \mu\text{F})} = 61.3\ \Omega$$

The inductive reactance is given by

$$X_L = \omega L = 2\pi(550\text{ s}^{-1})(25.3\text{ mH}) = 87.4\ \Omega$$

The impedance is then

$$Z = \sqrt{(15.0\,\Omega)^2 + ((87.4\,\Omega) - (61.3\,\Omega))^2} = 30.1\,\Omega$$

Finally, the rms current is

$$I_{rms} = \frac{\varepsilon_{rms}}{Z} = \frac{(75.0\text{ V})}{(30.1\,\Omega)} = 2.49\text{ A}$$

The rms voltages between any two points is given by

$$(\Delta V)_{rms} = I_{rms} Z'$$

where Z' is the impedance between the two points in question. When only one device is between the two points the impedance is equal to the reactance (or resistance) of that device.

Points	Impedance Expression	Impedance Value (Ω)	$(\Delta V)_{rms}$ (V)
ab	$Z = R$	$Z = 15.0$	37.4
bc	$Z = X_C$	$Z = 61.3$	153
bd	$Z = \lvert X_L - X_C \rvert$	$Z = 26.1$	65

The average power dissipated from a capacitor or inductor is zero; that of the resistor is

$P_R = [(\Delta V_R)_{rms}]^2/R = (37.4\text{ V})^2/(15.0\,\Omega) = 93.3\text{ W}$

14. (1): The frequency of the fundamental note emitted by each wire before the tension change occurs is

$$\upsilon = \frac{1}{2L}\left(\frac{T}{\mu}\right)^{1/2} \qquad \text{...(i)}$$

If T changes, υ will also change. We can find the relation between these two changes by taking the derivative of eqn. (i) w.r.t. T,

$$\frac{d\upsilon}{dT} = \frac{1}{2L}\left[\frac{1}{2}\left(\frac{T}{\mu}\right)^{-1/2}\frac{1}{\mu}\right]$$

$$\frac{d\upsilon}{dT} = \frac{1}{4LT}\left(\frac{T^2\mu}{T\mu^2}\right)^{1/2} = \frac{1}{4LT}\left(\frac{T}{\mu}\right)^{1/2}$$

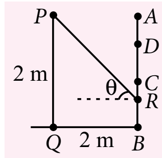
From eqn. (i), $\dfrac{d\upsilon}{dT} = \dfrac{\upsilon}{2T}$

Hence, $\Delta\upsilon \approx \dfrac{\upsilon}{2}\dfrac{\Delta T}{T}$

where $\Delta\upsilon$ is the frequency difference induced in the string as a result of a change in tension ΔT. In other words, $\Delta\upsilon$ is the number of beats observed if the string's tension is changed by a small amount ΔT. Using the given data,

$$\Delta\upsilon = \left(\frac{200}{2}\right)\left(\frac{1}{100}\right) = 1\text{ cycle s}^{-1}$$

15. (6): $\tan\theta = a/g = 4/5$



$\Rightarrow \quad BR = PQ - QB\tan\theta$

$\qquad = 2 - (2 \times 4/5) = 0.4$ m

Volume of water contained, V_{fin}

$$= \left(\frac{PQ + BR}{2}\right) \times 4\text{ m}^2$$

Initial volume of water, $V_{in} = BD \times 4\text{ m}^2$

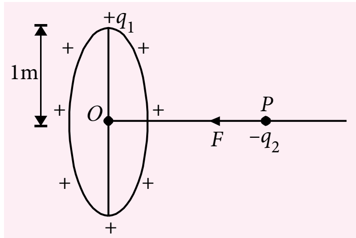
Amount of spill $= V_{in} - V_{fin}$

$\qquad = 2(2BD - PQ - BR) \times 1000$ L

$\qquad = 2(3 - 2 - 0.4) \times 1000 = 1200$ L

$\therefore \quad \alpha = 6$

16. (2): Let E = Electric field at P.



x = Distance from centre of the ring

q_1 = Charge on ring

$-q_2$ = Charge at point P

R = Radius of ring

$$\therefore \quad E = \frac{1}{4\pi\varepsilon_0}\frac{q_1 x}{(R^2 + x^2)^{3/2}}$$

Since $x = 1$ cm, $R = 1$ m, $x << R$.

$\therefore \quad R^2 + x^2 \approx R^2$

$$\therefore \quad E = \frac{q_1 x}{4\pi\varepsilon_0 R^3}, \text{ where } 4\pi\varepsilon_0 = \frac{1}{9\times10^9}.$$

$\therefore$ Force on the particle at $P = -q_2 E$

The particle will be attracted by the positively charged ring towards its centre O along the direction PO.

$$\therefore \quad \text{Force on particle} = \frac{-q_1 q_2 x}{4\pi\varepsilon_0 R^3} \text{ towards } O$$

$$\therefore \quad \text{Acceleration of particle, } a = \frac{F}{m}$$

$$a = \frac{-q_1 q_2 x}{4\pi\varepsilon_0 m R^3}; \text{ Also, } a = -\omega^2 x$$

$$T = 2\pi\sqrt{\left|\frac{x}{a}\right|} = 2\pi\sqrt{\frac{4\pi\varepsilon_0 m R^3}{q_1 q_2}}$$

$$T = 2\pi\sqrt{\frac{(0.9\times10^{-3})\times(1)^3}{9\times10^9\times(10^{-5})(10^{-6})}} = \frac{2\pi}{10}$$

17. (3) : Applied force = $\mu_s N = \mu_s mg$,
When the block is moving, friction acting on it is $\mu_k mg$

$\therefore \quad a = \dfrac{\mu_s mg - \mu_k mg}{m} = (\mu_s - \mu_k)g = 0.5 \text{ m s}^{-2}$

When the applied force is removed, retardation $= \mu_k g = 1.5 \text{ m s}^{-2}$

Distance covered in 2 s, $d_1 = \dfrac{1}{2} \times 0.5 \times 2^2 = 1$ m

Velocity after 2 s = $0.5 \times 2 = 1 \text{ m s}^{-1}$

Distance covered during retardation;

$0^2 = 1^2 - (1.5)d_2 \Rightarrow d_2 = \dfrac{2}{3}$ m

Total distance, $S = d_1 + d_2 = 1 + \dfrac{2}{3} = \dfrac{5}{3}$ m

$\therefore \quad \dfrac{9}{5}S = \dfrac{9}{5} \times \dfrac{5}{3} = 3$ m

18. (2) : $62.1 \text{ eV} = \dfrac{hc}{\lambda_0} = \dfrac{1242 \text{ eV nm}}{\lambda_0} \Rightarrow \lambda_0 = 20$ nm

$\therefore$ Photoelectric emission takes place only for λ_1 and λ_2

Now, for any wavelength

$\therefore$ In time t, incident energy = Pt

Number of photon incident $= \dfrac{Pt}{\left(\dfrac{hc}{\lambda}\right)} = \dfrac{\lambda Pt}{hc}$

$\therefore$ Number of photoelectrons emitted $= \dfrac{1}{2}\left(\dfrac{\lambda Pt}{hc}\right)$

$\therefore$ Charge developed $= \dfrac{1}{2}\left(\dfrac{\lambda Pt}{hc}\right) \times (e)$

$\therefore$ Potential of sphere $= \dfrac{kq}{r} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{\lambda Pte}{2hcr}$

$\therefore$ Potential difference across the resistor

$$= \frac{1}{4\pi\varepsilon_0}\frac{\lambda Pte}{2hcr}$$

$\therefore \quad V_1 = \dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{\lambda_1}{hc}\right)\left(\dfrac{Pte}{2r}\right)$

$\therefore \quad V_1 = (9 \times 10^9)\left(\dfrac{12.42 \text{ nm}}{1242 \text{ eV nm}}\right)\dfrac{(10^{-3})t(e)}{2 \times 10^{-3}}$

$= 9 \times 10^9 \times \left(\dfrac{1}{100}\right) \times \left(\dfrac{1}{2}\right) \times t = 4.5 \times 10^7\, t$

and $V_2 = \dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{\lambda_2}{hc}\right)\left(\dfrac{Pte}{2r}\right)$

$V_2 = (9 \times 10^9)\left(\dfrac{6.21 \text{ nm}}{1242 \text{ eV-nm}}\right)\dfrac{(10^{-3})(t)(e)}{2 \times 10^{-3}}$

$= 9 \times 10^9 \times \dfrac{1}{200} \times \left(\dfrac{t}{2}\right) = \dfrac{4.5}{2} \times 10^7\, t$

$\therefore \quad V = V_1 + V_2 = \dfrac{3}{2} \times (4.5) \times 10^7 \times t$

$I = \dfrac{V}{R} = \dfrac{6.75 \times 10^7 \times t}{6.75 \text{M}\Omega} = 10t$

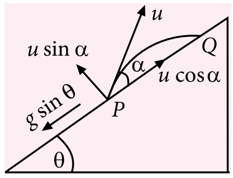
$\therefore$ At $t = 8$ s

$I = 10 \times 8 = 80$ A

So, $a = 2$

Paper-2

1. (a) : The motion of particle, inside the box will be along a parabolic path. Its range, along the bottom of box = R = PQ. Consider the projectile motion of the particle inside the box along the inclined plane. Component of acceleration perpendicular to plane = $g \cos \theta$. Let time for journey $PQ = t$



Distance travelled perpendicular to plane, $s_y = 0$

$\therefore$ from equation of motion

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$0 = (u \sin \alpha)t - \frac{1}{2}(g \cos \theta)t^2$$

or $\quad t = \dfrac{2u \sin \alpha}{g \cos \theta}$

Velocity of particle along the plane is given by $u \cos \alpha$.

$\therefore \quad R$ = velocity $\times$ time

or $\quad PQ = (u \cos \alpha) \times \dfrac{2u \sin \alpha}{g \cos \theta} = \dfrac{u^2 \sin 2\alpha}{g \cos \theta}$

2. (b): When the half-submerged cylinder is pushed down slightly, the restoring force comes into play has two components viz upthrust and spring force.

$\therefore$ Restoring force = – (upthrust + spring force)

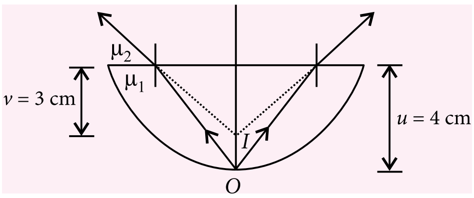
$= -(\rho Axg + kx) = -x(\rho Ag + k)$

or $\quad a = \dfrac{-(\rho Ag + k)}{M}x \qquad \because$ For SHM, $a = -\omega^2 x$

$\therefore \quad \omega = \sqrt{\dfrac{\rho A g + k}{M}}$ or $2\pi\upsilon = \sqrt{\dfrac{\rho A g + k}{M}}$

or frequency $\upsilon = \dfrac{1}{2\pi}\sqrt{\dfrac{k + \rho A g}{M}}$

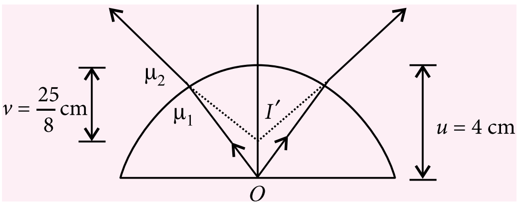
3. **(b):** When curved surface is in contact with table, light refracts from medium μ_1 to medium μ_2 at plane surface of plano-convex lens.



$$\therefore \quad \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \quad \text{or} \quad \frac{\mu_2}{-3} - \frac{\mu_1}{-4} = \frac{\mu_2 - \mu_1}{\infty}$$

$$\text{or} \quad -\frac{\mu_2}{3} + \frac{\mu_1}{4} = 0 \quad \text{or} \quad \mu_1 = \frac{4\mu_2}{3} \qquad \text{...(i)}$$

When plane surface is in contact with table, light refracts from medium μ_1 to medium μ_2 at curved surface.



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\text{or} \quad \frac{\mu_2}{-25/8} - \frac{\mu_1}{-4} = \frac{\mu_2 - \mu_1}{R}$$

$$\text{or} \quad -\frac{8\mu_2}{25} + \frac{4\mu_2}{3 \times 4} = \frac{\mu_2 - \frac{4\mu_2}{3}}{R}$$

$$\text{or} \quad -\frac{8}{25} + \frac{1}{3} = \frac{-1}{3R} \quad \text{or} \quad \frac{-24 + 25}{75} = -\frac{1}{3R}$$

$$\text{or} \quad R = -25 \text{ cm} \qquad \text{...(ii)}$$

Using lens maker's formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$\mu = \dfrac{\mu_1}{\mu_2} = \dfrac{4}{3}$ = refractive index of w.r.t. air

$R_1 = \infty$ for plane surface of plano-convex lens

$R_2 = -25$ cm

$$\therefore \quad \frac{1}{f} = \left(\frac{4}{3} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-25}\right) \quad \text{or} \quad \frac{1}{f} = \frac{1}{3} \times \frac{1}{25}$$

or $f = 75$ cm.

4. **(a):** Let us consider a thin sphere of radius $r < R$ and thickness dr then charge enclosed by the considered sphere.

$$q_{\text{enclosed}} = \int_0^r 4\pi r^2 dr\rho = \int_0^r 4\pi r^2 \rho_0 \left(1 - \frac{r}{R}\right) dr \quad \text{...(i)}$$

Now, applying Gauss's theorem.

$E_r 4\pi r^2 = \dfrac{q_{\text{enclosed}}}{\varepsilon_0}$, where E_r = projection of electric field along the radial line.

$$\therefore \quad E_r(4\pi r^2) = \frac{\rho_0}{\varepsilon_0}\int_0^r 4\pi r^2 \left(1 - \frac{r}{R}\right) dr$$

$$\text{or} \quad E_r = \frac{\rho_0 r}{3\varepsilon_0}\left[1 - \frac{3r}{4R}\right]$$

And for a point outside the sphere $r > R$.

$$q_{\text{enclosed}} = \int_0^R 4\pi r^2\, dr\, \rho_0 \left(1 - \frac{r}{R}\right)$$

(as there is no charge outside the ball)

Again from Gauss' theorem,

$$E_r 4\pi r^2 = \int_0^R \frac{4\pi r^2 dr\, \rho_0 \left(1 - \frac{r}{R}\right)}{\varepsilon_0}$$

or $E_r = \frac{\rho_0}{r^2\varepsilon_0}\left[\frac{R^3}{3} - \frac{R^4}{4R}\right] = \frac{\rho_0 R^3}{12 r^2 \varepsilon_0}$

As magnitude of electric field decreases with increasing r, field will be maximum for $r < R$. Now, for E_r to be maximum,

$$\frac{d}{dr}\left(r - \frac{3r^2}{4R}\right) = 0 \text{ or } 1 - \frac{3r}{2R} = 0 \text{ or } r = r_{max} = \frac{2R}{3}$$

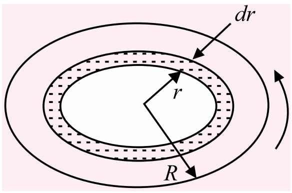
Hence, $E_{max} = \frac{\rho_0 R}{9\varepsilon_0}$

5. **(b):** It is the moment of friction force which brings the disc to rest. The force of friction is applied to each section of the disc, and since these sections lie at different distances from the axis, the moments of the forces of friction differ from section to section. To find N_z, where z is the axis of rotation of the disc, let us partition the disc into thin rings as shown in the figure. The force of friction acting on the considered element

$df_r = k(2\pi r\ dr\ \sigma)\ g$, where σ is the density of the disc.

The moment of this force is friction is

$dN_z = -r\ df_r = -2\pi k\ \sigma\ gr^2\ dr$



Integrating with respect to r from zero to R, we get

$$N_z = -2\pi k \sigma g \int_0^R r^2 dr = -\frac{2}{3}\pi k \sigma g R^3$$

For the rotation of the disc about the stationary axis z, from the equation $N_z = I\alpha_z$

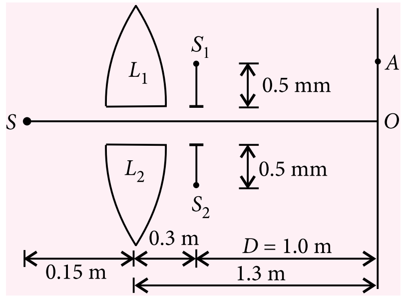
$$-\frac{2}{3}\pi k \sigma g R^3 = \frac{(\pi R^2 \sigma) R^2}{2}\alpha_z \text{ or } \alpha_z = -\frac{4kg}{3R}$$

Thus from the angular kinematical equation

$\omega_z = \omega_{oz} + \alpha_z t$

$$0 = \omega_0 + \left(-\frac{4kg}{3R}\right)t \text{ or } t = \frac{3R\omega_0}{4kg}$$

6. **(d):** The two identical halves L_1 and L_2 of a thin convex lens are placed symmetrically about the central axis SO. The screen at O is normal to SO.



L_1 and L_2 will form two images of source S at S_1 and S_2.

For the lens segments, the object is at S.

$f = +\ 0.1$ m

$$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{0.1} + \frac{1}{-0.15}$$

$$\text{or } \frac{1}{v} = \frac{1}{0.3} \text{ or } v = 0.3 \text{ m} \quad \text{...(i)}$$

Linear magnification $= \frac{v}{u}$

$$\therefore m = \frac{0.3}{-0.15} = -2 \quad \text{....(ii)}$$

$\therefore$ Two images S_1 and S_2 of S will be formed at 0.3 m from the lens.

S_1 will be 0.5 mm above its optic axis as $m = -2$.

S_2 will be 0.5 mm below its optic axis as $m = -2$.

$D = 1.30 - 0.30 = 1.0$ m

$\lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m} = 5 \times 10^{-7}$ m.

$$\therefore \text{ Fringe width } \beta = \frac{D\lambda}{d}$$

$$\text{or } \beta = \frac{(1.0)(5\times10^{-7})}{1.5\times10^{-3}} \text{ or } \beta = \frac{1}{3}\times10^{-3} \text{ m}$$

Since point A is at third maxima,

$$OA = 3\beta = 3\times\left(\frac{1}{3}\times10^{-3}\right) = 10^{-3} \text{ m}$$

7. **(a, b) :** $P = VI_s$, where V = accelerating voltage, I_s = saturation photocurrent

$$I_s = \frac{\left[\begin{array}{c}\text{Power of source of light} \times \text{Quantum} \\ \text{efficiency} \times \lambda\,(\text{in Å})\end{array}\right]}{hc}$$

$$= \frac{100\times0.01\times124}{hc} = 0.01 \text{ A}$$

Power provided by accelerating potential

$= 10000 \times 0.01 = 100$ W

Maximum energy of electron reaching tungsten= Kinetic energy of electron + Energy gained due to accelerating voltage

$$E = \left(\frac{hc}{\lambda} - \phi\right) + eV$$

$$= \left(\frac{12400}{124} - 10 + 10000\right)\text{eV} = 10090 \text{ eV}$$

$$\therefore \quad \lambda_{min} = \frac{hc}{E} = \frac{12400}{10090} = 1.23 \text{ Å}$$

8. **(a, b) :** Direction of current in B should be perpendicular to the paper outwards then only it will cancel out the effect of magnetic field of wire A at point P. Now, as at the point P magnetic field is zero,

$$\therefore \quad B_{PA} = B_{PB}$$

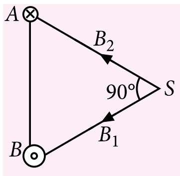
$$\frac{\mu_0}{2\pi}\frac{I_A}{\left(2 + \frac{10}{11}\right)} = \frac{\mu_0}{2\pi}\frac{I_B}{\left(\frac{10}{11}\right)}$$

or $I_B = I_A \times \frac{10}{32}$ or $I_B = 9.6 \times \frac{10}{32} = 3$ A

Magnetic field at S

$\angle ASB = 90°$ by Pythagoras theorem

$AS^2 + SB^2 = AB^2$



Magnetic field due to $I_A = B_1$

$$\therefore \quad B_1 = \frac{\mu_0}{2\pi}\frac{I_A}{AS}$$

$$\text{or} \quad B_1 = \frac{(2 \times 10^{-7})(9.6)}{(1.6)} = 12 \times 10^{-7} \text{ T}$$

Magnetic field due to $I_B = B_2$

$$\therefore \quad B_2 = \frac{\mu_0}{2\pi}\frac{I_B}{(BS)}$$

$$\text{or} \quad B_2 = \frac{(2 \times 10^{-7})(3)}{1.2} = 5 \times 10^{-7} \text{ T}$$

Since B_1 and B_2 are at right angles to each other,

$$B^2 = B_1^{\,2} + B_2^{\,2}$$

$\therefore$ $B^2 = (12 \times 10^{-7})^2 + (5 \times 10^{-7})^2$

or $B^2 = 169 \times (10^{-7})^2$ or $B = 13 \times 10^{-7}$ T

or $B = 1.3 \times 10^{-6}$ T

Force per unit length on the wire B

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_A I_B}{r}, \quad \text{where } r = AB = 2 \text{ m}$$

$$= \frac{(2 \times 10^{-7})(9.6)(3)}{2} = 2.88 \times 10^{-6} \text{ N m}^{-1}$$

9. **(b, c) :** Given: $T_A = 1000$ K, $P_B = \frac{2}{3}P_A$, $P_C = \frac{1}{3}P_A$

$n = 1$, $\gamma = \frac{C_P}{C_V} = \frac{5}{3}$ for monoatomic gas.

Along $A \to B$

$$\left(\frac{P_A}{P_B}\right)^{1-\gamma} = \left(\frac{T_B}{T_A}\right)^{\gamma} \text{ or } T_B = T_A\left(\frac{P_A}{P_B}\right)^{\frac{1-\gamma}{\gamma}}$$

$$\text{or} \quad T_B = (1000)\left(\frac{3}{2}\right)^{-\frac{2}{5}} = (1000)\left(\frac{2}{3}\right)^{2/5}$$

or $T_B = 1000 \times 0.85 = 850$ K

$$W_{AB} = \frac{R}{1-\gamma}(T_B - T_A) = \frac{8.31}{\left(1 - \frac{5}{3}\right)}(850 - 1000)$$

$$= \frac{8.31 \times 150 \times 3}{2} \approx 1870 \text{ J}$$

Along $B \to C$

$$\frac{T_B}{T_C} = \frac{P_B}{P_C}$$

$$\therefore \quad T_C = \left(\frac{P_C}{P_B}\right)T_B = \left(\frac{P_A}{3} \times \frac{3}{2P_A}\right)850 \text{ K}$$

or $T_C = 425$ K

$$\therefore \quad Q_{BC} = nC_V\Delta T = (1)\left(\frac{3R}{2}\right)(T_C - T_B)$$

$$Q_{BC} = \frac{3}{2} \times 8.31 \times (425 - 850)$$

$$Q_{BC} = -\frac{3 \times 8.31 \times 425}{2} \approx -5298 \text{ J}$$

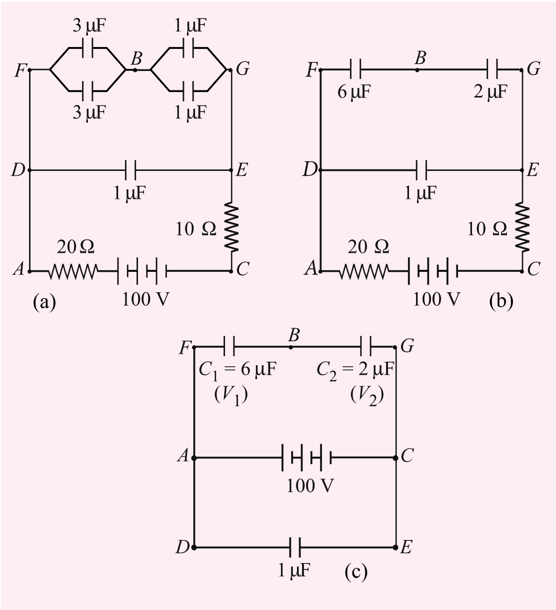
10. **(a, b, c)** **:**

11. **(b, d) :** In steady state, no current will flow in the circuit, hence resistance of 20 Ω and 10 Ω will become ineffective i.e., $V_{AE} = 100 \text{ V} = V_{DE}$

As all the three branches FG, DE and AC are connected in parallel and potential difference across each is equal to 100 V, hence branches AC and DE can be interchanged i.e., circuit in figure (b) is equivalent to that shown in figure (c). This shows that if V_1 and V_2 are potential difference across two capacitors, then

$V_{AB} = V_1$ and $V_{BC} = V_2$

As two capacitors are connected in series acorss a source of 100 V, hence



$V_1 + V_2 = 100$ V ....(i)

Moreover, as charge remains same in series combination of capacitors, hence

$$C_1V_1 = C_2V_2 \Rightarrow \left(\frac{V_1}{V_2}\right) = \left(\frac{C_2}{C_1}\right) = \frac{1}{3} \quad \text{...(ii)}$$

Hence from eqns. (i) and (ii)

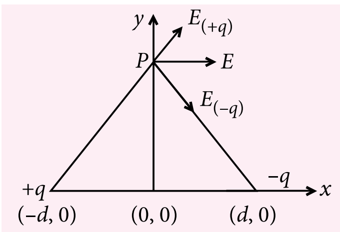
$V_1 = V_{AB} = 25$ V; $V_2 = V_{BC} = 75$ V

12. (b, d) : E on x-axis,

E will not have same direction along entire x-axis.

For $-d \le x \le d$, the field is along $+ x$-axis

For all other points, E is along negative x-axis.



Electric field at P, a point on y-axis is parallel to x-axis.

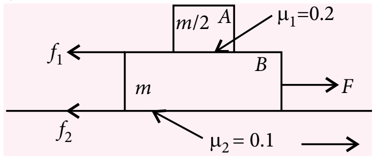
Electric potential at origin = zero

No work has to be done in bringing a test charge from infinity to the origin.

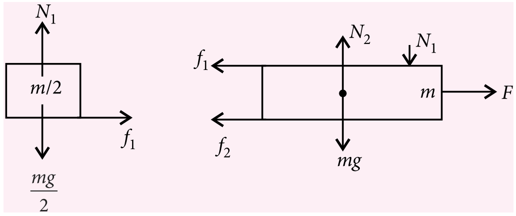
The dipole moment is directed from $-q$ charge to $+q$ charge, along negative direction, of x-axis.

$\therefore$ Dipole moment = 2 qd along negative x-axis.

13. (a, b, d)



Free body diagram :



$$N_1 = \frac{mg}{2}, N_2 = N_1 + mg = \frac{3\,mg}{2}$$

$$f_1 = \mu_1 N_1 = 0.2\left(\frac{mg}{2}\right) = 0.1\,mg$$

and $f_2 = \mu_2 N_2 = 0.1\left(\frac{3\,mg}{2}\right) = 0.15\,mg$

if $F = f_1 + f_2 = 0.1\,mg + 0.15\,mg$

$F = 0.25\,mg$

If, $F = 0.5\,mg$

then $f_1 = F - f_2 = 0.5\,mg - 0.15\,mg$

$= 0.35\,mg \because f_1 > 0.1\,mg$

Hence, A will slip with respect to B.

When $F = 0.5\,mg$, body A will slip with respect to B. Hence both the bodies cannot move together all time.

Minimum force required to move bodies together,

$F = 0.25\,mg$

Hence, for $F = 0.1\,mg$, bodies will be at rest.

14. (a, c) : An image obtained on screen is a real image. Convex mirror and concave lens do not form real image of an object.

$\therefore$ Options (b) and (d) are not correct.

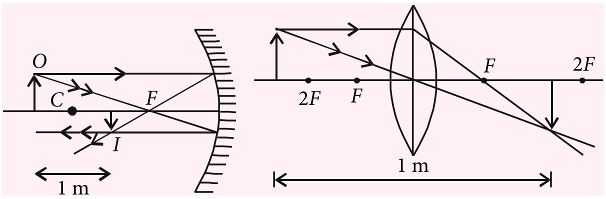
For concave mirror, the object should be beyond C to form a real diminished image between F and C of mirror.

For convex lens, minimum distance between an object and its real image should be $4f$.

$\therefore$ Minimum $(d) = 4f$ or 1 m = $4f$, or $f = 0.25$ m

Convex lens of focal length less than 0.25 m can be used when object is placed beyond $(2f)$ and image is formed between $2f$ and f on other side of the lens.

The image formation is illustrated by the figures.



$\therefore$ Options (a) and (c) are correct.

15. (a) :

	Initially	Finally
Capacitance	$C = \dfrac{bL\varepsilon_0}{d}$	KC
Potential	V = const.	V = const.
Charge	$Q_1 = CV$	$Q_2 = KCV$
Energy stored	$U_1 = \dfrac{1}{2}CV^2$	$U_2 = \dfrac{1}{2}KCV^2$
Electric field strength	$E_1 = \dfrac{V}{d}$	$E_2 = \dfrac{V}{Kd}$
$\therefore$ $E_1 > E_2$	$Q_2 > Q_1$,	$U_2 > U_1$

16. (a) : Free body diagram of the dielectric

$T = Mg$  $F_{\text{inwards}} = \dfrac{\varepsilon_0 bV^2(K-1)}{2d}$

For equilibrium,

$$Mg = \frac{\varepsilon_0 bV^2(K-1)}{2d}$$

$$M = \frac{\varepsilon_0 bV^2(K-1)}{2dg}$$

17. (b) : From work-energy theorem,

$dK = -dU + W_{\text{air friction}}$

$W_{\text{air friction}}$ is negative, so

$dK = -dU +$ (a negative quantity)

As K increases, it means U decreases by an amount greater than magnitude of $W_{\text{air friction}}$.

18. (a) : We have $v = \sqrt{\dfrac{GM}{R}}$

Taking log on both the sides and then differentiating,

$$\frac{dv}{v} = \frac{-1 \times dR}{2R} \Rightarrow \frac{\Delta v}{v} = \frac{\Delta R}{2R} \quad [\because \Delta R = -dR]$$

$$\Delta v = \frac{\Delta R}{2}\sqrt{\frac{GM}{R^3}}$$

Single entrance test for engineering, architecture seats from 2018

The Centre has approved the proposal for a single entrance exam for engineering and architecture at the undergraduate level from 2018, on the lines of the national eligibility and entrance test for medical colleges.

The Union Human Resource Development ministry has asked the All India Council for Technical Education (AICTE) to issue a "suitable regulation" for the implementation of the proposal from the academic year 2018-19.

The test shall be conducted multiple times a year, as is the case with college admission tests like SAT in the US, and is intended to bring uniformity in academic standards and reduce the influence of donations.

The test will, however, not include admissions to IITs, which will continue to hold their own entrance exams. IITs, unlike private and state colleges, are not seen to be affected by fluctuating standards and admission processes.

The HRD ministry has asked AICTE to ensure that the testing process is standardised, keeping "in view the linguistic diversity". AICTE sources said the test was to be held in multiple languages, like NEET which will be conducted in 10 languages this year.

Ministry seeks suggestions from states

According to a senior HRD official, "The admission for IITs will continue as per the present scheme. IITs will conduct the joint entrance examination (advanced). Students who qualify JEE (mains) can appear for the JEE (advanced) examination. Approximately 2,00,000 students qualify to appear for JEE (advanced) examination."

The proposal is seen to be in "accordance with the policy of the government to improve standards and the quality of engineering education" and the switchover will take place next year.

At present, many states conduct their own engineering examination or admissions are done on the basis of Class XII marks. Engineering colleges in five states use the score obtained in JEE (mains) as the basis for admission. There are 3,288 engineering colleges across 27 states, with most of them in Tamil Nadu (527), followed by Maharashtra (372), Andhra Pradesh (328), Uttar Pradesh (295) and Madhya Pradesh (211).

The HRD ministry has requested all state governments/deemed universities "to communicate their constructive suggestions for smooth implementation of the regulation. It may also be useful to request as many institutions as possible to come under a joint seat-allocation system for a more efficient seat allocation process".

Courtesy: The Times of India

3K+ INSTITUTIONS, 40+ TESTS

Total institutions	Students admitted
3,288	**15,55,130**

At present, admissions on basis of

- 40 entrance tests across India
- Joint Entrance Examination (Mains) score, in centrally-funded institutions and engineering colleges in 6 states- Madhya Pradesh, Haryana, Uttarakhand, Nagaland, Odisha and Delhi- and some other individual institutions.
- IITs conduct JEE (Advanced); will continue to do so despite uniform entrance.

Source : AICTE 2016-17

PRACTICE PAPER 2017
JEE MAIN

Exam Dates
OFFLINE : 2nd April
ONLINE : 8th & 9th April

1. A body is projected vertically upwards from the surface of the earth with a velocity sufficient to carry it to infinity. If R is the radius of the earth, the time taken by the body to reach to a height h from ground is
(a) $\sqrt{\dfrac{2R}{g}}$ (b) $\dfrac{1}{3}\sqrt{\dfrac{2R}{g}}$
(c) $\dfrac{1}{3}\sqrt{\dfrac{2R}{g}}\left[\left(1+\dfrac{h}{R}\right)^{3/2}\right]$
(d) $\dfrac{1}{3}\sqrt{\dfrac{2R}{g}}\left[\left(1+\dfrac{h}{R}\right)^{3/2}-1\right]$.

2. A cannon of mass $2m$ located at the base of an inclined plane shoots a shell of mass m in horizontal direction with velocity v_0. The angle of inclination of the plane is 45° and the coefficient of friction between the cannon and the plane is 0.5. The height to which the cannon ascends the plane as a result of recoil is
(a) $\dfrac{v_0^2}{2g}$ (b) $\dfrac{v_0^2}{6g}$ (c) $\dfrac{v_0^2}{g}$ (d) $\dfrac{v_0^2}{12g}$.

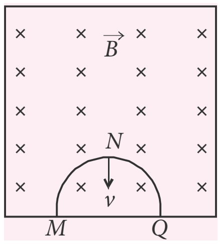
3. The measured mass and volume of a body are 22.42 g and 4.7 cm^3 respectively with possible errors 0.01 g and 0.1 cm^3. The maximum error in density is about
(a) 0.2% (b) 2% (c) 5% (d) 10%.

4. An α-particle and a proton are fired through the same magnetic field which is perpendicular to their velocity vectors. The α-particle and the proton move such that radius of curvature of their paths is same. Find the ratio of their de Broglie wavelengths.
(a) 2 : 3 (b) 3 : 4 (c) 5 : 7 (d) 1 : 2

5. A block released from rest from the top of a smooth inclined plane of angle θ_1 reaches the bottom in time t_1. The same block released from rest from the top of another smooth inclined plane of angle θ_2, reaches the bottom in time t_2. If the two inclined planes have the same height, the relation between t_1 and t_2 is
(a) $\dfrac{t_2}{t_1}=\left(\dfrac{\sin\theta_1}{\sin\theta_2}\right)^{1/2}$ (b) $\dfrac{t_2}{t_1}=1$
(c) $\dfrac{t_2}{t_1}=\dfrac{\sin\theta_1}{\sin\theta_2}$ (d) $\dfrac{t_2}{t_1}=\dfrac{\sin^2\theta_1}{\sin^2\theta_2}$.

6. A wire of density 9 g cm^{-3} is stretched between two clamps 1.00 m apart while subjected to an extension of 0.05 cm. The lowest frequency of transverse vibrations in the wire is (Assume Young's modulus, $Y = 9 \times 10^{10}$ N m^{-2})
(a) 35 Hz (b) 45 Hz (c) 75 Hz (d) 90 Hz.

7. A thin semicircular conducting ring of radius R is falling with its plane vertical in horizontal magnetic induction $\vec{B}$. At the position MNQ the speed of the ring is v, the potential difference developed across the ring is



(a) Zero
(b) $Bv\pi R^2/2$ and M is at higher potential
(c) πRBv and Q is at higher potential
(d) $2RBv$ and Q is at higher potential.

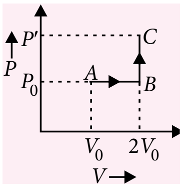
8. If 10% of a radioactive substance decays in every 5 years, then the percentage of the substance that will have decayed in 20 years will be
(a) 40% (b) 50% (c) 65.6% (d) 34.4%.

9. An object of mass 0.2 kg executes simple harmonic oscillations along the x-axis with a frequency $\dfrac{25}{\pi}$ Hz. At the position x = 0.04 m, the object has kinetic energy 0.5 J and potential energy 0.4 J. The amplitude of oscillation is (potential energy is zero at mean position)
(a) 6 cm (b) 4 cm (c) 8 cm (d) 2 cm.

10. A TV transmission tower antenna is at a height of 20 m. The percentage increase in area covered in case if the receiving antenna is at ground level to that at a height of 25 m is
(Radius of earth = 6.4×10^6 m)
(a) 248% (b) 348.9% (c) 150% (d) 360.2%.

11. Two conductors have the same resistance at 0 °C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients of their series and parallel combinations are nearly
(a) $\frac{\alpha_1+\alpha_2}{2}, \frac{\alpha_1+\alpha_2}{2}$ (b) $\frac{\alpha_1+\alpha_2}{2}, \alpha_1+\alpha_2$
(c) $\alpha_1+\alpha_2, \frac{\alpha_1+\alpha_2}{2}$ (d) $\alpha_1+\alpha_2, \frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$.

12. The pressure P' of one mole of monatomic gas in the process ABC, shown in the diagram, if $\Delta U/\Delta Q = 6/7$ is

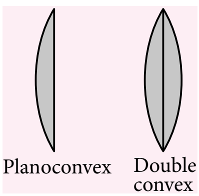


(a) $\frac{5}{2}P_0$ (b) $\frac{3}{2}P_0$
(c) $2P_0$ (d) $\frac{7}{2}P_0$

13. A thin uniform rod AB of mass m and length L is hinged at one end A to the level floor. Initially it stands vertically and is allowed to fall freely to the floor in the vertical plane. The angular velocity of the rod, when its end B strikes the floor is (g is acceleration due to gravity)
(a) $\left(\frac{mg}{L}\right)$ (b) $\left(\frac{mg}{3L}\right)^{1/2}$
(c) $\left(\frac{g}{L}\right)$ (d) $\left(\frac{3g}{L}\right)^{1/2}$.

14. A plane is in level flight at constant speed and each of its two wings has an area of 25 m^2. If the speed of the air on the upper and lower surfaces of the wings are 270 km h^{-1} and 234 km h^{-1} respectively, then the mass of the plane is
(Take the density of the air = 1 kg m^{-3})
(a) 1550 kg (b) 1750 kg
(c) 3500 kg (d) 3200 kg.

15. You are given two identical planoconvex lenses. When you place an object 20 cm to the left of a single plano-convex lens, the image appears 40 cm to the right of the lens.

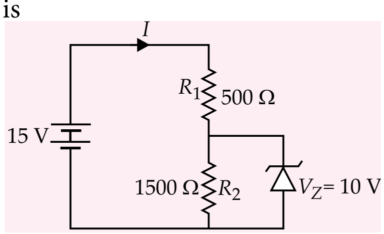


You then arrange the two plano-convex lenses back to back to form a double convex lens. If the object is 20 cm to the left of this new lens, what is the approximate location of the image ?
(a) 10 cm to the right of the lens.
(b) 20 cm to the right of the lens.
(c) 80 cm to the right of the lens.
(d) 80 cm to the left of the lens.

16 In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is
(a) $Q/2$ (b) $Q/\sqrt{3}$
(c) $Q/\sqrt{2}$ (d) Q.

17 A parachutist drops freely from an aeroplane for 10 s and then the parachute opens out. Then he descends with a net retardation of 12 m s^{-2}. If he strikes the ground with a velocity of 20 m s^{-1}, then the height at which he bails out of the plane is (g = 10 m s^{-2})
(a) 400 m (b) 500 m (c) 800 m (d) 900 m.

18. In the circuit given, the current through the Zener diode is



(a) 10 mA (b) 6.67 mA
(c) 5 mA (d) 3.33 mA.

19. The minimum kinetic energy required for ionization of a hydrogen atom is E_1 in case electron is collided with hydrogen atom. It is E_2 if the hydrogen ion is collided and E_3 when helium ion is collided. Then,
(a) $E_1 = E_2 = E_3$ (b) $E_1 > E_2 > E_3$
(c) $E_1 < E_2 < E_3$ (d) $E_1 > E_3 > E_2$.

20. A wire of length L has a linear mass density μ and area of cross-section A and the Young's modulus Y is suspended vertically from a rigid support. The extension produced in the wire due to its own weight is
(a) $\frac{\mu g L^2}{YA}$ (b) $\frac{\mu g L^2}{2YA}$
(c) $\frac{2\mu g L^2}{YA}$ (d) $\frac{2\mu g L^2}{3YA}$.

21. The apparent coefficient of expansion of a liquid when heated, filled in vessel A and B of identical volumes, is found to be γ_1 and γ_2 respectively. If α_1 be the linear expansion of A then that of B will be

(a) $\frac{(\gamma_1-\gamma_2)}{3}-\alpha_1$ (b) $\frac{(\gamma_2-\gamma_1)}{3}+\alpha_1$

(c) $\frac{(\gamma_2-\gamma_1)}{3}-\alpha_1$ (d) $\frac{(\gamma_1-\gamma_2)}{3}+\alpha_1$.

22. An electromagnetic wave of intensity I falls on a surface kept in vacuum and exerts radiation pressure P on it. Which of the following statement is not true?

(a) Radiation pressure is I/c if the wave is totally absorbed.

(b) Radiation pressure is I/c if the wave is totally reflected.

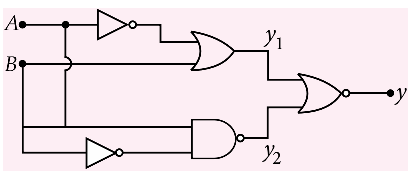
(c) Radiation pressure is $2I/c$ if the wave is totally reflected.

(d) Radiation pressure is in the range $I/c < P < 2I/c$ for real surfaces.

23. The index of refraction of a glass plate is 1.48 at θ_1 = 30 °C and varies linearly with temperature with a coefficient of 2.5×10^{-5} °C^{-1}. The coefficient of linear expansion of the glass is 0.5×10^{-5} °C^{-1}. At 30 °C, the length of the glass plate is 3 cm. This plate is placed along the length in front of one of the slits in Young's double-slit experiment. If the plate is being heated so that its temperature increases at a rate of 5 °C min^{-1}, the light source has wavelength λ = 589 nm and the glass plate initially is at θ = 30 °C. The number of fringes that shift on the screen in each minute is nearly (use approximation)

(a) 1 (b) 11 (c) 110 (d) 1.1×10^3.

24. Figure shows a system of logic gates for $y = 1$. Which one of the following options is satisfied?



(a) $A = 0, B = 1$ (b) $A = 1, B = 1$

(c) $A = 1, B = 0$ (d) $A = 0, B = 0$.

25. Four charges, each equal to $-Q$, are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium, the value of q is

(a) $-\frac{Q}{4}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

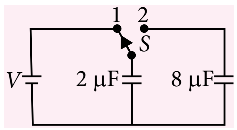
(c) $-\frac{Q}{2}(1+2\sqrt{2})$ (d) $\frac{Q}{2}(1+2\sqrt{2})$.

26 A box contains N molecules of a perfect gas at temperature T_1 and pressure P_1. The number of molecules in the box is doubled keeping the total kinetic energy of the gas same as before. If the new pressure is P_2 and temperature T_2, then

(a) $P_2 = P_1, T_2 = T_1$ (b) $P_2 = P_1, T_2 = \frac{T_1}{2}$

(c) $P_2 = 2P_1, T_2 = T_1$ (d) $P_2 = 2P_1, T_2 = \frac{T_1}{2}$.

27 A 2 μF capacitor is charged as shown in the figure. The percentage of its stored energy dissipated after the switch S is turned to position 2 is



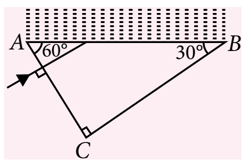
(a) 10% (b) 20% (c) 75% (d) 80%.

28. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2 s. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be

(a) 2 s (b) $\frac{2}{3}$ s

(c) $(2\sqrt{3})$ s (d) $\left(\frac{2}{\sqrt{3}}\right)$ s.

29. ACB is right-angled prism with other angles as 60° and 30°. Refractive index of the prism is 1.5. AB has thin layer of liquid on it as shown in the figure.



Light falls normally on the face AC. For total internal reflections, maximum refractive index of the liquid is

(a) 1.4 (b) 1.3 (c) 1.2 (d) 1.6.

30 A car starting from rest, accelerates at the rate a through a distance s, then continues at constant speed for time t and then decelerates at the rate $a/2$ to come to rest. If the total distance travelled is $15s$, then

(a) $s = at$ (b) $s = \frac{1}{6}at^2$

(c) $s = \frac{1}{2}at^2$ (d) None of these.

SOLUTIONS

1. (d) : Let v be the velocity of the projected body at distance r from the centre of earth. Using the law of conservation of mechanical energy, we have

$$\frac{1}{2}mv^2+\left(\frac{-GMm}{r}\right)=\frac{1}{2}mv_e^2+\left(\frac{-GMm}{R}\right)$$

or $\quad v^2=v_e^2+\frac{2GM}{R}\left[\frac{R}{r}-1\right]$

As $v_e=\sqrt{2gR}$ and $g=(GM/R^2)$

so $\quad v^2 = 2gR + 2gR[(R/r) - 1]$

or $\quad v=\sqrt{2gR^2/r}$

$\therefore \quad \frac{dr}{dt}=\frac{R\sqrt{2g}}{\sqrt{r}}$ or $\int_0^t dt=\frac{1}{R\sqrt{2g}}\int_R^{R+h}\sqrt{r}dr$

or $\quad t=\frac{2}{3}\frac{1}{R\sqrt{2g}}[(R+h)^{3/2}-R^{3/2}]$

$\therefore \quad t=\frac{1}{3}\sqrt{\frac{2R}{g}}\left[\left(1+\frac{h}{R}\right)^{3/2}-1\right]$

2. (d) : From conservation of linear momentum, recoil velocity of cannon,

$$v=\frac{mv_0}{2m}=\frac{v_0}{2}$$

From conservation of mechanical energy,
KE of cannon = increase in gravitational PE + work done against friction

$$\frac{1}{2}(2m)v^2 = (2m)gh + \mu(2m)g\cos45°\times\frac{h}{\sin 45°}$$

$$m\left(\frac{v_0}{2}\right)^2=3mgh \;\therefore\; h=\frac{v_0^2}{12g}$$

3. (b) : As $\rho=\frac{M}{V}$

$$\therefore \quad \frac{\Delta\rho}{\rho}=\frac{\Delta M}{M}+\frac{\Delta V}{V}=\frac{0.01}{22.42}+\frac{0.1}{4.7}=\frac{0.047+2.242}{22.42\times4.7}$$

$$\frac{\Delta\rho}{\rho}\times100=\frac{2.289\times100}{22.42\times4.7}\%=2.172\%\approx2\%$$

4. (d) : Magnetic force experienced by a charged particle in a magnetic field is given by

$$F_B=|q\vec{v}\times\vec{B}|=qvB\sin\theta$$

or $\quad F_B=qvB \qquad$ [as $\theta = 90°$]

Hence, $Bqv=\frac{mv^2}{r}$ or $mv=qBr$

The de Broglie wavelength,

$$\lambda=\frac{h}{mv}=\frac{h}{qBr}$$

Required ratio, $\frac{\lambda_{\alpha-\text{particle}}}{\lambda_{\text{Proton}}}=\frac{q_pr_p}{q_\alpha r_\alpha}$

$\because \quad \frac{r_\alpha}{r_p}=1$ and $\frac{q_\alpha}{q_p}=2$

$\therefore \quad \frac{\lambda_\alpha}{\lambda_p}=\frac{1}{2}$

5. (c): Lengths of the two inclined planes are

$$l_1=\frac{h}{\sin\theta_1} \text{ and } l_2=\frac{h}{\sin\theta_2}$$

Accelerations of the block down the two planes are

$$a_1 = g\sin\theta_1 \text{ and } a_2 = g\sin\theta_2$$

As $\quad l_1=\frac{1}{2}a_1t_1^2$ and $l_2=\frac{1}{2}a_2t_2^2$

$\therefore \quad \frac{l_1}{l_2}=\frac{a_1t_1^2}{a_2t_2^2}$

or $\quad \frac{t_2^2}{t_1^2}=\frac{a_1l_2}{a_2l_1}=\frac{g\sin\theta_1}{g\sin\theta_2}\times\frac{\sin\theta_1}{\sin\theta_2} \quad \therefore \quad \frac{t_2}{t_1}=\frac{\sin\theta_1}{\sin\theta_2}$

6. (a) : Tension in the wire, $T=\frac{YA\Delta l}{l}$

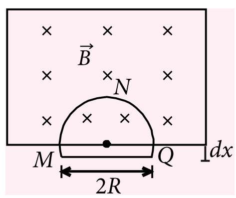
Lowest frequency $=\frac{v}{2l}=\frac{\sqrt{T/\rho A}}{2l}$

$$\upsilon=\frac{1}{2l}\sqrt{\frac{YA\Delta l}{\rho lA}}=\frac{1}{2l}\sqrt{\frac{Y\Delta l}{\rho l}}$$

Substituting the values,

$$\upsilon=\frac{1}{2\times1}\sqrt{\frac{9\times10^{10}\times0.05\times10^{-2}}{(9000)(1)}}\approx 35\text{ Hz}$$

7. (d) : At the position MNQ, the ring is at the point of moving out of the magnetic field. Its speed of fall is v. Due to fall, the flux associated with the ring changes. An emf is therefore induced in the ring.



Induced emf $=\frac{-d\phi}{dt}$ or $\quad \varepsilon=\frac{-d}{dt}(BA\cos\theta)$

or $\quad \varepsilon = -B\frac{dA}{dt}\cos0°$; the ring falls with its plane vertical in horizontal magnetic induction $\vec{B}$.

or $\varepsilon = -B.\frac{d}{dt}(2R\,dx)$ or $\varepsilon = -2RB\left(\frac{dx}{dt}\right)$

$|\varepsilon| = 2RBv$

8. (d) : Since, $N = N_0 e^{-\lambda t}$ or $\frac{N_0}{N} = e^{\lambda t}$

or $t = \frac{1}{\lambda}\ln\frac{N_0}{N}$

$\therefore \quad 5 = \frac{1}{\lambda}\ln\frac{100}{90}$ ...(i)

and $20 = \frac{1}{\lambda}\ln\frac{N_0}{N}$ ...(ii)

Dividing eqn. (i) by eqn. (ii),

$$\frac{5}{20} = \frac{\ln\frac{100}{90}}{\ln\frac{N_0}{N}} \quad \text{or} \quad \ln\frac{N_0}{N} = 4\ln\frac{10}{9}$$

or $\frac{N_0}{N} = \left(\frac{10}{9}\right)^4$ or $\frac{N}{N_0} = 0.6561$

Percentage of substance decayed is

$(1 - 0.6561) \times 100\% = 34.39\%$

9. (a) : Angular velocity, $\omega = 2\pi\upsilon = \sqrt{\frac{k}{m}}$

$\therefore \quad k = (2\pi\upsilon)^2 m$

Total energy of oscillation is 0.5 + 0.4 = 0.9 J

$\therefore \quad 0.9 = \frac{1}{2}kA^2$

$$A = \sqrt{\frac{1.8}{k}} = \sqrt{\frac{1.8}{(2\pi\upsilon)^2 m}}$$

$$= \frac{1}{2\pi\upsilon}\sqrt{\frac{1.8}{0.2}} = \frac{1}{2\pi\left(\frac{25}{\pi}\right)}\sqrt{\frac{1.8}{0.2}} = \frac{3}{50}\text{ m} = 6\text{ cm}$$

10. (b) : Here, $h_T = 20$ m, $R = 6.4 \times 10^6$ m $= 64 \times 10^5$ m

If the receiving antenna is at ground level,

Range, $d = \sqrt{2h_T R} = \sqrt{2 \times 20 \times (64 \times 10^5)}$

$= 16 \times 10^3$ m $= 16$ km

Area covered, $A = \pi d^2 = \frac{22}{7} \times (16)^2 = 804.6\text{ km}^2$

If the receiving antenna is at a height of 25 m,

Range, $d_1 = \sqrt{2h_T R} + \sqrt{2h_R R}$

$= \sqrt{2 \times 20 \times (64 \times 10^5)} + \sqrt{2 \times 25 \times (64 \times 10^5)}$

$= 16 \times 10^3 + 17.9 \times 10^3 = 33.9$ km

Area covered, $A_1 = \pi d_1^2 = \frac{22}{7} \times (33.9)^2 = 3611.8\text{ km}^2$

Percentage increase in area $= \frac{A_1 - A}{A} \times 100$

$= \left(\frac{3611.8 - 804.6}{804.6}\right) \times 100\%$

$= 348.9\%$

11. (a)

12. (a) : In process AB, pressure = constant.

$\therefore \quad V \propto T$

$V_B = 2V_0$ so, $T_B = 2T_0$ (if $T_A = T_0$)

$\Delta W = P_0(2V_0 - V_0) = P_0V_0 = RT_0$

and $\Delta Q = C_P \Delta T = \frac{5}{2}RT_0$

$\Delta U = \Delta Q - \Delta W = \frac{3}{2}RT_0$

In process BC, volume = constant.

$\therefore \quad P \propto T$

$P_B = P_0$ but $T_B = 2T_0$

So, $P' = KP_0$, $T_C = KT_B = K(2T_0)$

$\Delta W = 0$ and $\Delta Q = \Delta U = C_V \Delta T$

$= \frac{3}{2}R \times 2T_0(K - 1) = 3RT_0(K - 1)$

$\Delta Q_{\text{Total}} = \frac{5}{2}RT_0 + 3RT_0(K - 1)$ ...(i)

$\Delta U_{\text{Total}} = \frac{3}{2}RT_0 + 3RT_0(K - 1)$ ...(ii)

Given, $\Delta U/\Delta Q = 6/7$ ...(iii)

Comparing eqns. (i), (ii) and (iii), $K = 5/2$

$\therefore \quad P' = \frac{5}{2}P_0$

13. (d) : As the rod is hinged at one end, its moment of inertia about this end is $I = \frac{mL^2}{3}$

Total energy in upright position = total energy on striking the floor

$$0 + \frac{mgL}{2} = \frac{1}{2}I\omega^2 + 0 = \frac{1}{2}\frac{mL^2}{3}\omega^2$$

$$g = \frac{L\omega^2}{3} \text{ or } \omega = \sqrt{\frac{3g}{L}}$$

14. (c): Let v_1, v_2 are the speed of air on the lower and upper surfaces of the wings of the plane and let P_1 and P_2 are the pressure there.

According to Bernoulli's theorem,

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

Here, $v_1 = 234\ \text{km h}^{-1} = 234 \times \frac{5}{18}\ \text{m s}^{-1} = 65\ \text{m s}^{-1}$

and $v_2 = 270\ \text{km h}^{-1} = 270 \times \frac{5}{18} = 75\ \text{m s}^{-1}$

Area of wings = $2 \times 25\ \text{m}^2 = 50\ \text{m}^2$

$\therefore\ P_1 - P_2 = \frac{1}{2} \times 1\,(75^2 - 65^2)$

Upward force on the plane = $(P_1 - P_2)A$

$$= \frac{1}{2} \times 1 \times (75^2 - 65^2) \times 50\ \text{m}$$

As the plane is in level flight, therefore upward force balances the weight of the plane.

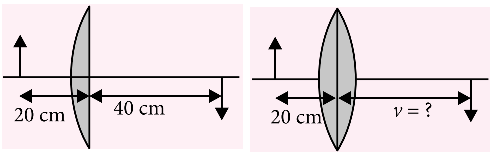
$\therefore\ mg = (P_1 - P_2)\,A$

Mass of the plane, $m = \frac{(P_1 - P_2)}{g}A$

$$= \frac{1}{2} \times \frac{1 \times (75^2 - 65^2)}{10} \times 50$$

$$= 3500\ \text{kg}$$

15. (a) :



$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

or $\frac{1}{f} = \frac{1}{40} - \frac{1}{(-20)}$ or $f = \frac{40}{3}$

Focal length for the combination,

$$f_{eq} = \frac{20}{3} \text{ or } \frac{1}{f_{eq}} = \frac{1}{v} - \frac{1}{u}$$

or $\frac{3}{20} = \frac{1}{v} + \frac{1}{20}$ or $\frac{1}{v} = \frac{3}{20} - \frac{1}{20}$ or $v = 10$ cm

16. (c): Q denotes maximum charge on capacitor. Let q denotes charge when energy is equally shared

$\therefore\ \frac{1}{2}\left(\frac{1}{2}\frac{Q^2}{C}\right) = \frac{1}{2}\frac{q^2}{C}$ or $Q^2 = 2q^2$

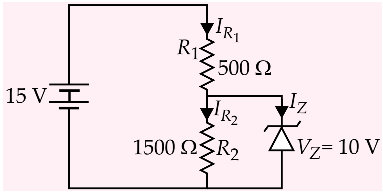
$\therefore\ q = Q/\sqrt{2}$

17 (d) : Velocity acquired after 10 s of fall,
$u = gt = 10 \times 10 = 100\ \text{m s}^{-1}$

Distance travelled, $s_1 = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times 10^2 = 500$ m

Velocity on reaching the ground, $v = 20\ \text{m s}^{-1}$
We have, $u = 100\ \text{m s}^{-1}$, $v = 20\ \text{m s}^{-1}$, $a = -12\ \text{m s}^{-2}$
and $s = s_2$ (say).
Using, $v^2 = u^2 + 2as$,
$20^2 = 100^2 + 2(-12)s_2$ or $s_2 = 400$ m
Total height at which he comes out of the plane
$= s_1 + s_2 = 500 + 400 = 900$ m

18. (d) :



The voltage drop across R_2,

$$V_{R_2} = V_Z = 10\ \text{V}$$

The current through R_2,

$$I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{10}{1500} = 0.667 \times 10^{-2}\ \text{A} = 6.67\ \text{mA}$$

The voltage drop across R_1 is

$$V_{R_1} = 15 - V_{R_2} = 15 - 10 = 5\ \text{V}$$

The current through R_1 is

$$I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{5}{500} = 10^{-2}\ \text{A} = 10\ \text{mA}$$

The current through the zener diode,

$$I_Z = I_{R_1} - I_{R_2} = (10 - 6.67)\ \text{mA} = 3.33\ \text{mA}$$

19. (b) : Assuming that ionization occurs as a result of a completely inelastic collision, we can write

$$mv_0 - 0 = (m + m_H)u$$

where m is the mass of incident particle, m_H the mass of hydrogen atom, v_0 the initial velocity of incident particle, and u the final common velocity of the particle after collision. Prior to collision, the KE of the incident particle was $E_0 = \frac{mv_0^2}{2}$

The total kinetic energy after collision

$$E = \frac{(m + m_H)u^2}{2} = \frac{m^2 v_0^2}{2(m + m_H)}$$

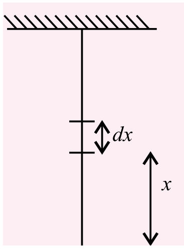
The decrease in kinetic energy must be equal to ionization energy. Therefore,

$$E' = E_0 - E = \left(\frac{m_H}{m + m_H}\right)E_0$$

i.e., $\dfrac{E'}{E_0} = \dfrac{1}{1+\dfrac{m}{m_H}}$

i.e., the greater the mass m, the smaller the fraction of initial kinetic energy that be used for ionization.

20. (b) : Consider a small element of length dx at a distance x from the free end of wire as shown in the figure.



Tension in the wire at distance x from the lower end is

$T(x) = \mu gx$ ... (i)

Let dl be increase in length of the element. Then

$$Y = \frac{T(x)/A}{dl/dx}$$

$$dl = \frac{T(x)dx}{YA} = \frac{\mu gx\, dx}{YA} \qquad \text{[Using (i)]}$$

Total extension produced in the wire,

$$l = \int_0^L \frac{\mu gx}{YA}\, dx = \frac{\mu g}{YA}\left[\frac{x^2}{2}\right]_0^L = \frac{\mu gL^2}{2YA}$$

21. (b) : Let V be the volume of the liquid and ΔT the rise in temperature.

Since, apparent expansion = true expansion – expansion of vessel

$\therefore \quad V\gamma_1\Delta T = V\gamma\Delta T + V(3\alpha_1)\Delta T$

or $\quad \gamma_1 = \gamma + 3\alpha_1$ ...(i) (for vessel A)

and $\quad \gamma_2 = \gamma + 3\alpha_2$ ...(ii) (for vessel B)

where γ is the coefficient of real expansion of the liquid.

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

$\gamma_2 - \gamma_1 = 3(\alpha_2 - \alpha_1)$

or $\alpha_2 - \alpha_1 = (\gamma_2 - \gamma_1)/3$ or $\alpha_2 = [(\gamma_2 - \gamma_1)/3] + \alpha_1$

22. (b) : Momentum per unit time per unit area

$$= \frac{\text{intensity}}{\text{speed of wave}} = \frac{I}{c}$$

Change in momentum per unit time per unit area $= \Delta I/c$ = radiation pressure (P), *i.e.*, $P = \Delta I/c$

Momentum of incident wave per unit time per unit area $= I/c$

When wave is fully absorbed by the surface, the momentum of the reflected wave per unit time per unit area = 0

Radiation pressure (P) = change in momentum per unit time per unit area $= \dfrac{\Delta I}{c} = \dfrac{I}{c} - 0 = \dfrac{I}{c}$

When wave is totally reflected, then momentum of the reflected wave per unit time per unit area $= -I/c$

$$\text{Radiation pressure } (P) = \frac{I}{c} - \left(-\frac{I}{c}\right) = \frac{2I}{c}$$

Here, P lies between $\dfrac{I}{c}$ and $\dfrac{2I}{c}$.

23. (b) : Path difference $= \mu t - \mu_0 t_0 = n\lambda_0$

where n is the number of fringes that shift on the screen.

$$\therefore \quad \frac{\mu_0(1+\alpha_1\Delta\theta)t_0(1+\alpha_2\Delta\theta) - \mu_0 t_0}{\lambda_0} = n$$

$$\frac{\mu_0 t_0(\alpha_1+\alpha_2)\Delta\theta}{\lambda_0} = n$$

($\because\ \alpha_1\alpha_2(\Delta\theta)^2$ is very-very small.)

Given, $\mu_0 = 1.48$, $t_0 = 3 \times 10^{-2}$ m

$\alpha_1 = 2.5 \times 10^{-5}\,°C^{-1}$, $\alpha_2 = 0.5 \times 10^{-5}\,°C^{-1}$, $\Delta\theta = 5\,°C$

and $\lambda_0 = 589$ nm

$$\therefore \quad n = \frac{1.48\times 3\times 10^{-2}(3\times 10^{-5})\times 5}{589\times 10^{-9}} = 11$$

24. (c) : Using Boolean algebra for the gates, we have

$$y_1 = \overline{A} + B;\ y_2 = \overline{A\cdot\overline{B}} = \overline{A} + \overline{\overline{B}} = \overline{A} + B$$

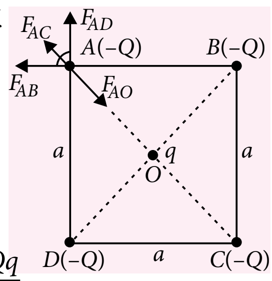
$$y = \overline{y_1 + y_2}$$

Using $A = 1, B = 0, y_1 = \overline{1} + 0 = 0$ and $y_2 = \overline{1} + 0 = 0$

$\therefore \quad y = 0 + 0 = 1$

Thus option (c) is true.

25. (b) : Refer to figure and consider the equilibrium of charge $-Q$ at A.



$$F_{AB} = F_{AD} = \frac{k_e Q^2}{a^2};$$

$$F_{AC} = \frac{k_e Q^2}{(a\sqrt{2})^2} = k_e\frac{Q^2}{2a^2}$$

$$F_{AO} = \frac{k_e Qq}{(a\sqrt{2}/2)^2} = k_e\frac{2Qq}{a^2}$$

For equilibrium, $F_{AO} = F_{AC} + F_{AB}\cos 45° + F_{AD}\cos 45°$

$= F_{AC} + 2F_{AB}\cos 45°$ (as $F_{AD} = F_{AB}$)

whence, $q = \dfrac{Q}{4}(1+2\sqrt{2})$

26 (b) : Kinetic energy of N molecules of gas,

$$E = \frac{3}{2}NkT$$

Initially, $E_1 = \dfrac{3}{2}N_1kT_1$ and finally, $E_2 = \dfrac{3}{2}N_2kT_2$

But according to the problem $E_1 = E_2$ and $N_2 = 2N_1$

$$\frac{3}{2}N_1kT_1 = \frac{3}{2}(2N_1)kT_2 \Rightarrow \quad T_2 = \frac{T_1}{2}$$

Since the kinetic energy is constant

$$\frac{3}{2}N_1kT_1 = \frac{3}{2}N_2kT_2 \Rightarrow N_1T_1 = N_2T_2$$

$\therefore \; NT$ = constant

From ideal gas equation, $PV = NkT$ so, $P_1V_1 = P_2V_2$

$\therefore \; P_1 = P_2$ (as $V_1 = V_2$ and NT = constant)

27 (d) : $U_i = \frac{1}{2}CV^2 = \frac{1}{2}(2)V^2 = V^2, q_i = CV = 2V$

On turning the switch S to position 2, if q is the charge on 8 μF capacitor, charge on 2 μF capacitor is $(2V - q)$.

Thus, $\frac{2V-q}{2} = \frac{q}{8}$, whence $q = \frac{8V}{5} \quad \therefore \quad (2V-q) = \frac{2V}{5}$

Energy dissipated,

$$\Delta U = U_i - U_f = V^2 - \left[\frac{(8V/5)^2}{2\times 8} + \frac{(2V/5)^2}{2\times 2}\right]$$

$$\Delta U = \frac{4V^2}{5} = \frac{4}{5}(V^2) = \frac{4}{5}(U_i) = 80\% \text{ of } U_i$$

28. (b): For a vibrating magnet, $T = 2\pi\sqrt{\frac{I}{MB}}$

where $I = ml^2/12$, $M = xl$, x = pole strength of magnet

For three pieces together

$$I' = \left(\frac{m}{3}\right)\left(\frac{l}{3}\right)^2 \times \frac{3}{12} = \frac{ml^2}{9\times 12} = \frac{I}{9}$$

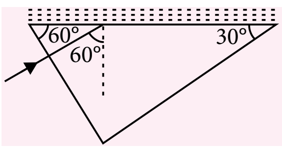
$$M' = (x)\left(\frac{l}{3}\right)\times 3 = xl = M$$

$$\therefore \quad T' = 2\pi\sqrt{\frac{I'}{M'B}} = 2\pi\sqrt{\frac{I/9}{MB}} = \frac{1}{3}\times 2\pi\sqrt{\frac{I}{MB}} = \frac{T}{3}$$

So, $T' = \frac{2}{3}$ s

29. (b) : Clearly, $i_c \le 60°$

So, maximum possible value of i_c is 60°.



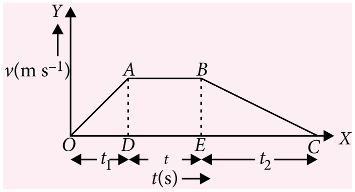
Now, $\;^l\mu_g = \frac{1}{\sin i_c}$

$$\frac{\mu_g}{\mu_l} = \frac{1}{\sin i_c}$$

or $\mu_l = \mu_g \sin i_c = 1.5 \sin 60° = 1.5 \times \frac{\sqrt{3}}{2}$

$= 1.5\,(0.866) = 1.299 = 1.3$

30 (d) : The velocity- time graph for the given situation can be drawn as shown



Magnitude of slope of $OA = a$ and slope of $BC = \frac{a}{2}$

$$v = at_1 = \frac{a}{2}t_2 \qquad \therefore \quad t_2 = 2t_1$$

In graph, area of ΔOAD gives distance, travelled in time t_1,

$$s = \frac{1}{2}at_1^2 \qquad \text{...(i)}$$

Area of rectangle $ABED$ gives distance travelled in time t,

$s_2 = (at_1)t$

Distance travelled in time t_2, $s_3 = \frac{1}{2}\cdot\frac{a}{2}(2t_1)^2 = 2s$

Thus, $s_1 + s_2 + s_3 = 15s$

or $\quad s + (at_1)t + 2s = 15s \quad$ or $\quad (at_1)t = 12s \qquad$ ...(ii)

On dividing eqn. (ii) by eqn. (i), we get

$$\frac{12s}{s} = \frac{2t}{t_1} \text{ or } t_1 = \frac{t}{6} \qquad \text{...(iii)}$$

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

$$s = \frac{1}{2}a\left(\frac{t}{6}\right)^2 = \frac{1}{72}at^2$$

Form IV

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For MTG Learning Media Pvt. Ltd.
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Practice Paper 2017

Exam on 7th May

1. A ball is thrown vertically upwards in air and reaches a maximum height of 50 m. The velocity of projection of ball is (g = 9.8 m s^{-2})
(a) 45 m s^{-1} (b) 31 m s^{-1}
(c) 10 m s^{-1} (d) None of these.

2. A train is moving along a straight path with uniform acceleration. Its engine passes across a pole with a velocity of 60 km h^{-1} and the end (guard's van) passes across the same pole with a velocity of 80 km h^{-1}. The middle point of the train will pass across the same pole with a velocity
(a) 70 km h^{-1} (b) 70.7 km h^{-1}
(c) 65 km h^{-1} (d) 75 km h^{-1}.

3. What is the angle between $\vec{P}$ and the resultant of $(\vec{P}+\vec{Q})$ and $(\vec{P}-\vec{Q})$?
(a) Zero (b) $\tan^{-1}\left(\frac{P}{Q}\right)$
(c) $\tan^{-1}\left(\frac{Q}{P}\right)$ (d) $\tan^{-1}\frac{(P-Q)}{(P+Q)}$

4. A projectile is thrown at an angle of θ = 45° to the horizontal, reaches a maximum height of 16 m. Then choose the incorrect option.
(a) Its velocity at the highest point is zero.
(b) Its range is 64 m.
(c) Its range will decreases when it is thrown at an angle of θ = 30°.
(d) Both (b) and (c) are correct.

5. A disc of mass 100 g is kept floating horizontally in air by firing bullets, each of mass 5 g with the same velocity at the same rate of 10 bullets per second. The bullets rebound with the same speed in opposite direction, the velocity of each bullet at the time of impact is
(a) 196 cm s^{-1} (b) 9.8 cm s^{-1}
(c) 98 cm s^{-1} (d) 980 cm s^{-1}.

6. A ball of mass m is thrown vertically upwards with a velocity v. If air exerts an average resisting force F, the velocity with which the ball returns to the thrower is
(a) $v\sqrt{\frac{mg}{mg+F}}$ (b) $v\sqrt{\frac{F}{mg+F}}$
(c) $v\sqrt{\frac{mg-F}{mg+F}}$ (d) $v\sqrt{\frac{mg+F}{mg}}$.

7. A cyclist rides up a hill with a constant velocity. If the length of the connective rod of the pedal is r = 25 cm, the time of revolution of the rod is t = 2 s and the mean force exerted by his foot on the pedal is F = 15 kg wt. The power developed by the cyclist is
(a) 1154 W (b) 115.4 W
(c) 15 W (d) 11.5 W.

8. Two balls of masses m_1 and m_2 are separated from each other and a charge is placed between them. The whole system is at rest on the ground. Suddenly, the charge explodes and the masses are pushed apart. Mass m_1 travels a distance s_1 and then it stops. If the coefficient of friction between the balls and the ground are same, mass m_2 stops after covering a distance
(a) $s_2=\frac{m_1}{m_2}s_1$ (b) $s_2=\frac{m_2}{m_1}s_1$
(c) $s_2=\frac{m_1^2}{m_2^2}s_1$ (d) $s_2=\frac{m_2^2}{m_1^2}s_1$.

9. The surface densities of a circular disc of radius a depends on the distance as $\rho(r) = A + Br$. The moment of inertia of the disc about the line perpendicular to its plane is
(a) $\pi a^4\left(\frac{A}{2}+\frac{2a}{5}B\right)$ (b) $\pi a^4\left(\frac{A}{2}+\frac{2B}{5}\right)$
(c) $2\pi a^3\left(\frac{A}{2}+\frac{Ba}{5}\right)$ (d) None of these.

10. The angle of contact between glass and water is 0° and it rises in a capillary upto 6 cm when its surface tension is 70 dyne cm^{-1}. Another liquid of surface tension 140 dyne cm^{-1}, angle of contact 60° and relative density 2 will rise in the same capillary by
(a) 12 cm (b) 24 cm (c) 3 cm (d) 6 cm.

11. Aerofoils are so designed that the speed of air
(a) on top side is more than on lower side
(b) on top side is less than on lower side
(c) is same on both sides
(d) is turbulent.

12. Wires A and B have identical lengths and have circular cross-sections. The radius of A is twice the radius of B, *i.e.*, $r_A = 2r_B$. For a given temperature difference between the two ends, both wires conduct heat at the same rate. The relation between the thermal conductivities is given by
(a) $K_A = 4K_B$ (b) $K_A = 2K_B$
(c) $K_A = \frac{K_B}{2}$ (d) $K_A = \frac{K_B}{4}$.

13. If a body (coated black) at 600 K surrounded by atmosphere at 300 K has cooling rate r_0, the same body at 900 K, surrounded by the same atmosphere, will have cooling rate equal to
(a) $\frac{16}{3}r_0$ (b) $\frac{8}{16}r_0$ (c) $16\ r_0$ (d) $4r_0$.

14. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased so as to increase its efficiency of 50% of original efficiency?
(a) 275 K (b) 325 K (c) 250 K (d) 380 K

15. When volume of an ideal gas is increased two times and temperature is decreased half of its initial temperature, then pressure becomes
(a) 2 times (b) 4 times
(c) $\frac{1}{4}$ times (d) $\frac{1}{2}$ times.

16. The ratio of specific heats (γ) of an ideal gas is not given by
(a) $\frac{1}{1-\frac{R}{C_P}}$ (b) $1+\frac{R}{C_V}$
(c) $\frac{R+2C_V}{C_V}$ (d) None of these.

17. A system is subjected to two SHMs given by $y_1 = 6\cos\omega t$ and $y_2 = 8\cos\omega t$.
The resultant amplitude of SHM is given by
(a) 2 (b) 10 (c) 14 (d) 20.

18. An organ pipe, open from both ends produced 5 beats per second when vibrated with a source of frequency 200 Hz in its fundamental mode. The second harmonic of the same pipe produces 10 beats per second with a source of frequency 420 Hz. The fundamental frequency of pipe is
(a) 195 Hz (b) 205 Hz
(c) 190 Hz (d) 210 Hz.

19. The driver of a car travelling with speed 30 m s^{-1} towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m s^{-1}, the frequency of the reflected sound as heard by the driver is
(a) 720 Hz (b) 555.5 Hz
(c) 550 Hz (d) 760 Hz.

20. An air filled parallel plate capacitor charged to potential V_1 is connected to an uncharged identical parallel plate capacitor with dielectric constant K. The common potential is V_2. The value of K is
(a) $\frac{V_1-V_2}{V_1+V_2}$ (b) $\frac{V_1}{V_1-V_2}$
(c) $\frac{V_1-V_2}{V_2}$ (d) $\frac{V_1-V_2}{V_1}$.

21. A wire of length l is bent to form a semicircle. If it has charge q, then electric field intensity at the centre of semicircle is
(a) $\frac{\pi q}{4\varepsilon_0 l^2}$ (b) $\frac{q}{8\pi\varepsilon_0 l^2}$
(c) $\frac{q}{4\pi\varepsilon_0 l^2}$ (d) $\frac{q}{2\varepsilon_0 l^2}$.

22. In a straight conductor of uniform cross-section charge q is flowing for time t. Let s be the specific charge of an electron. The momentum of all the free electrons per unit length of the conductor, due to their drift velocity only is
(a) $\left(\frac{q}{ts}\right)$ (b) $\left(\frac{q}{ts}\right)^2$ (c) $\sqrt{\frac{q}{ts}}$ (d) qts.

23. The current in wire is directed towards east and the wire is placed in magnetic field directed towards north. The force on the wire is
(a) vertically upwards (b) vertically downwards
(c) due south (d) due east.

24. A circular loop and a square loop are formed from the same wire and the same current is passed through them. The ratio of their dipole moments is
(a) 4π (b) $\frac{4}{\pi}$ (c) $\frac{2}{\pi}$ (d) 2π.

25. Two bar magnets having same geometry with magnetic moments M and $2M$, are firstly placed in such a way that their similar poles are same side then its time period of oscillation is T_1. Now the polarity of one of the magnet is reversed then time period of oscillation is T_2, then
(a) $T_1 < T_2$ (b) $T_1 = T_2$
(c) $T_1 > T_2$ (d) $T_2 = \infty$.

26. A coil of inductance 300 mH and resistance 2 Ω is connected to a source of voltage 2 V. The current reaches half of its steady state value in
(a) [illegible] s (b) [illegible] s (c) [illegible] s (d) [illegible] s.

27. A long solenoid has 200 turns per cm and carries a current I. The magnetic field at its centre is 6.28×10^{-2} Wb m^{-2}. Another long solenoid has 100 turns per cm and it carries a current $I/3$. The value of the magnetic field at its centre is
(a) 1.05×10^{-2} Wb m^{-2} (b) 1.05×10^{-5} Wb m^{-2}
(c) 1.05×10^{-3} Wb m^{-2} (d) 1.05×10^{-4} Wb m^{-2}.

28. An electromagnetic wave going through vacuum is described by $E = E_0 \sin(kx - \omega t)$; $B = B_0 \sin(kx - \omega t)$.
Which of the following equations is true ?
(a) $E_0 k = B_0 \omega$ (b) $E_0 \omega = B_0 k$
(c) $E_0 B_0 = \omega k$ (d) None of these

29. A thin rod of length $f/3$ is placed along the principal axis of a concave mirror of focal length f such that its real elongated image just touches the rod. The magnification produced by the mirror is
(a) $\frac{4}{3}$ (b) $\frac{3}{2}$ (c) 3 (d) 2.

30. The maximum number of possible interference maxima for a slit-separation equal to twice the wavelength in Young's double slit experiment is
(a) infinite (b) five (c) three (d) zero.

31. A small particle of mass m moves such that its potential energy is equal to $\frac{1}{2}mr^2\omega^2$. Assuming Bohr's model of quantisation of angular momentum and circular orbit, radius of n^{th} orbit is proportional to
(a) $\sqrt{n}$ (b) $\sqrt{n^3}$ (c) $\frac{1}{\sqrt{n}}$ (d) $\frac{1}{\sqrt{n^3}}$.

32. The half-life period of a radioactive element X is same as the mean life time of another radioactive element Y. Initially, they have the same number of atoms. Then,
(a) X will decay faster than Y
(b) Y will decay faster than X
(c) Y and X have same decay rate initially
(d) X and Y decay at same rate always.

33. A stone weighing 3 kg falls from the top of a tower 100 m high and buries itself 3 m deep in the sand. The time of penetration is
(a) 0.09 s (b) 0.13 s (c) 1.3 s (d) 0.9 s

34. In the middle of the depletion layer of reverse biased p-n junction, the
(a) electric field is zero (b) potential is maximum
(c) electric field is maximum
(d) potential is zero.

35. A body starts from rest, what is the ratio of the distance travelled by the body during the 4^{th} and 3^{rd} second ?
(a) $\frac{7}{5}$ (b) $\frac{5}{7}$ (c) $\frac{7}{3}$ (d) $\frac{3}{7}$

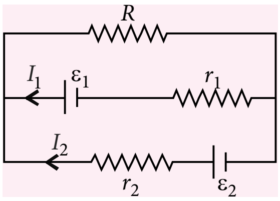
36. A car moves from X to Y with a uniform speed v_u and returns from Y to X with a uniform speed v_d. The average speed for this round trip is
(a) $\sqrt{v_u v_d}$ (b) $\frac{v_d v_u}{v_d + v_u}$
(c) $\frac{v_u + v_d}{2}$ (d) $\frac{2v_d v_u}{v_d + v_u}$.

37. A series combination of n_1 capacitors, each of value C_1, is charged by a source of potential difference $4V$. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2 in terms of C_1 is
(a) $\frac{2C_1}{n_1 n_2}$ (b) $16\frac{n_2}{n_1}C_1$
(c) $2\frac{n_2}{n_1}C_1$ (d) $\frac{16C_1}{n_1 n_2}$.

38. A positively charged particle moving towards east enters a region of uniform magnetic field directed vertically upwards. This particle will
(a) move in a circular path with a decreased speed
(b) move in a circular path with a uniform speed
(c) get deflected in vertically upward direction
(d) move in circular path with an increased speed.

39. In a circuit L, C and R are connected in series with an alternating voltage source of frequency υ. The current leads the voltage by 45°. The value of C is
(a) $\frac{1}{\pi\upsilon(2\pi\upsilon L - R)}$ (b) $\frac{1}{2\pi\upsilon(2\pi\upsilon L - R)}$
(c) $\frac{1}{\pi\upsilon(2\pi\upsilon L + R)}$ (d) $\frac{1}{2\pi\upsilon(2\pi\upsilon L + R)}$.

40. For the electrical circuit shown in the figure, which of the following equations is correct.



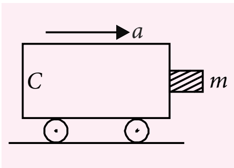
(a) $\varepsilon_2 - I_2r_2 - \varepsilon_1 - I_1r_1 = 0$
(b) $-\varepsilon_2 - (I_1 + I_2)R + I_2r_2 = 0$
(c) $\varepsilon_1 - (I_1 + I_2)R + I_1r_1 = 0$
(d) $\varepsilon_1 - (I_1 + I_2)R - I_1r_1 = 0$

41. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Four objects each of mass m, are kept gently to the opposite ends of two perpendicular diameters of the ring. The angular velocity of the ring will be

(a) $\dfrac{M\omega}{4m}$ (b) $\dfrac{M\omega}{M+4m}$

(c) $\dfrac{(M+4m)\omega}{M}$ (d) $\dfrac{(M-4m)\omega}{M+4m}$.

42. A block of mass m is in contact with the cart C as shown in the figure. The coefficient of static friction between the block and the cart is μ.



The acceleration a of the cart that will prevent the block from falling satisfies

(a) $a > \dfrac{mg}{\mu}$ (b) $a > \dfrac{g}{\mu m}$

(c) $a \geq \dfrac{g}{\mu}$ (d) $a < \dfrac{g}{\mu}$.

43. In a radioactive material the activity at time t_1 is R_1 and at a later time t_2, it is R_2. If the decay constant of the material is λ, then

(a) $R_1 = R_2$ (b) $R_1 = R_2 e^{-\lambda(t_1 - t_2)}$
(c) $R_1 = R_2 e^{\lambda(t_1 - t_2)}$ (d) $R_1 = R_2(t_2/t_1)$.

44. Which of the following statement is false for the properties of electromagnetic waves ?
(a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.
(b) The energy in electromagnetic wave is divided equally between electric and magnetic vectors.
(c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.
(d) These waves do not require any material medium for propagation.

45. The momentum of a photon of an electromagnetic radiation is 3.3×10^{-29} kg m s^{-1}. What is the frequency of the associated waves ?
($h = 6.6 \times 10^{-34}$ J s and $c = 3 \times 10^8$ m s^{-1})
(a) 1.5×10^{13} Hz (b) 7.5×10^{12} Hz
(c) 6×10^3 Hz (d) 3×10^3 Hz

SOLUTIONS

1. **(b):** Given h = 50 m
$a = -g = -9.8$ and $v = 0$.
For vertically upward motion
$v^2 = u^2 - 2gh$
$u = \sqrt{2gh} = \sqrt{19.6 \times 50} \simeq 31.30 \text{ m s}^{-1}$

2. **(b):** From $v^2 - u^2 = 2as$,
$$\frac{(80)^2 - (60)^2}{2a} = s \Rightarrow s = \frac{6400 - 3600}{2a} = \frac{1400}{a}$$
The middle point of the train is to cover a distance
$$\frac{s}{2} = \frac{700}{a}$$
From $v^2 - u^2 = 2as$
$$v^2 - (60)^2 = 2a \times \frac{700}{a} = 1400$$
$v^2 = 1400 + 3600$
$v = \sqrt{5000} = 70.7 \text{ km h}^{-1}$

3. **(a):** The resultant of $(\vec{P} + \vec{Q})$ and $(\vec{P} - \vec{Q})$
$= \vec{P} + \vec{Q} + \vec{P} - \vec{Q} = 2\vec{P}$.
Since $2\vec{P}$ is parallel to $\vec{P}$, hence the angle between them is zero.

4. **(a):** The maximum height reached by the projectile,
$$H = \frac{u^2 \sin^2 \theta}{2g} \text{ or } 16 = \frac{u^2 \sin^2 45°}{19.6}$$
$\therefore\ u = \sqrt{16 \times 2 \times 19.6}$
Horizontal range of a projectile,
$$R = \frac{u^2 \sin 2\theta}{g} = \frac{16 \times 2 \times 19.6 \times \sin 90°}{9.8} = 64 \text{ m}$$
When, $\theta = 45°$, $\sin 2\theta = 1$
But when $\theta = 30°, \sin 2\theta = \dfrac{\sqrt{3}}{2} = 0.866$; the range will decrease.

5. **(d):** At the time of impact, $2m'vn = mg$
$$\therefore\ v = \frac{mg}{2m'n} = \frac{100 \times 980}{2 \times 5 \times 10} = 980 \text{ cm s}^{-1}$$

6. **(c):** For an upward motion,
retarding force = $mg + F$
$$\therefore\ \text{Retardation, } a = \frac{mg + F}{m}$$

and distance, $s = \dfrac{v^2}{2a} = \dfrac{v^2 m}{2(mg+F)}$

For the downward motion,

net force = $mg - F$

$\therefore$ Acceleration, $a' = \dfrac{mg-F}{m}$

and distance, $s' = \dfrac{v'^2}{2a'} = \dfrac{v'^2 m}{2(mg-F)}$

As $s = s'$ $\quad\therefore\quad v' = v\sqrt{\dfrac{mg-F}{mg+F}}$

7. (b): Velocity of the cyclist,

$$v = r\omega = r\frac{2\pi}{t} = \frac{1}{4}\times\frac{2\pi}{2} = \frac{\pi}{4}\text{ m s}^{-1}$$

Power developed by the cyclist,

$$P = F\times v = (15\times 9.8)\times\frac{\pi}{4} = 115.4\text{ W}$$

8. (c): From the conservation of momentum, we get

$m_1v_1 = m_2v_2$ ...(i)

Also, $\frac{1}{2}m_1v_1^2 = f_1s_1 = \mu m_1gs_1$ ...(ii)

and $\frac{1}{2}m_2v_2^2 = f_2s_2 = \mu m_2gs_2$ ...(iii)

where μ = coefficient of friction

Dividing eqn. (ii) by eqn. (iii)

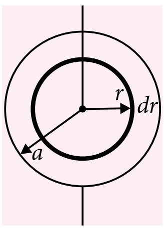
$$\frac{m_1v_1^2}{m_2v_2^2} = \frac{m_1s_1}{m_2s_2} \text{ and } \frac{v_1}{v_2} = \frac{m_2}{m_1} \quad \text{[From eqn. (i)]}$$

Thus, $\dfrac{v_1^2}{v_2^2} = \dfrac{s_1}{s_2}$ or $\dfrac{m_2^2}{m_1^2} = \dfrac{s_1}{s_2}$ or $s_2 = \dfrac{m_1^2}{m_2^2}s_1$

9. (a): $dm = 2\pi r\,dr\,\rho(r) = (A + Br)2\pi r\,dr$

$$I = \int_0^a dmr^2 = \frac{\pi Aa^4}{2} + \frac{2\pi Ba^5}{5}$$

$$= \pi a^4\left(\frac{A}{2} + \frac{2aB}{5}\right)$$



10. (c): Capillary rise, $h = \dfrac{2S\cos\theta}{r\rho g}$

$$\therefore \frac{h_2}{h_1} = \frac{S_2}{S_1}\times\frac{\cos\theta_2}{\cos\theta_1}\times\frac{\rho_1}{\rho_2}\times\frac{r_1}{r_2}$$

or $\dfrac{h_2}{h_1} = \dfrac{140}{70}\times\dfrac{\cos 60^\circ}{\cos 0^\circ}\times\dfrac{1}{2}\times 1 = \dfrac{1}{2}$

or $h_2 = \dfrac{h_1}{2} = 3\text{ cm}$

11. (a): The aerofoils are so designed that

$$P_{\text{upper side}} < P_{\text{lower side}}$$

So that the aerofoils get a lifting force in upward direction.

According to Bernoulli's theorem, where the pressure is large, the velocity will be minimum or vice-versa. Thus, $v_{\text{upper side}} > v_{\text{lower side}}$

12. (d): Heat current, $H = \dfrac{KA\Delta\theta}{l}$

Since, heat current is same for both the wires.

$$\therefore \frac{K_A}{K_B} = \frac{A_B}{A_A} = \left(\frac{r_B}{r_A}\right)^2 = \frac{1}{4} \text{ or } K_A = \frac{K_B}{4}$$

13. (a): Cooling rate $\propto T^4 - T_0^4$

$$r = \left\{\frac{(900)^4 - (300)^4}{(600)^4 - (300)^4}\right\}r_0 = \frac{16}{3}r_0$$

14. (c): The efficiency of Carnot engine $= 1 - \dfrac{T_2}{T_1}$

Here, T_1 is the temperature of source and T_2 is the temperature of sink.

As given, $\eta = 40\% = \dfrac{40}{100} = 0.4$ and $T_2 = 300$ K

$\therefore\ 0.4 = 1 - \dfrac{300}{T_1}$ or $T_1 = \dfrac{300}{1-0.4} = 500$ K

Let temperature of the source be increased by x K, then efficiency becomes

$\eta' = 40\% + 50\%$ of η

$= \dfrac{40}{100} + \dfrac{50}{100}\times 0.4 = 0.4 + 0.5\times 0.4 = 0.6$

Hence, $0.6 = 1 - \dfrac{300}{500+x}$

or $\dfrac{300}{500+x} = 0.4$ or $x = 750 - 500 = 250$ K

15. (c): The ideal gas equation, $PV = nRT$

or $P = \dfrac{nRT}{V}$ ...(i)

Where P is the initial pressure of the gas.

Given, $V' = 2V$ and $T' = \dfrac{T}{2}$

$\therefore\ P' = \dfrac{nRT/2}{2V}$ ...(ii)

Dividing eqn. (ii) by eqn. (i), $P' = \dfrac{1}{4}P$

16. (c): Mayer's relation of an ideal gas,

$C_P - C_V = R$ ...(i)

Dividing eqn. (i) by C_V,

$$\frac{C_P}{C_V} - 1 = \frac{R}{C_V} \text{ or } \gamma - 1 = \frac{R}{C_V} \text{ or } \gamma = 1 + \frac{R}{C_V}$$

Again, dividing eqn. (i) by C_P,

$$1-\frac{1}{\gamma}=\frac{R}{C_P} \text{ or } \gamma=\frac{1}{1-\frac{R}{C_P}}$$

17. (c) : The phase difference between the SHMs is $\phi = 0$. Therefore, resultant amplitude is given by,

$$A=\sqrt{A_1^2+A_2^2+2A_1A_2\cos\phi}$$
$$=\sqrt{A_1^2+A_2^2+2A_1A_2} = A_1 + A_2 = 6 + 8 = 14$$

18. (b): Initially number of beats per second = 5

$\therefore$ Frequency of the pipe

$= 200 \pm 5 = 195$ Hz or 205 Hz ...(i)

Frequency of second harmonic of the pipe

$= 2n$ and number of beats in this case = 10

$\therefore$ $2n = 420 \pm 10 = 410$ Hz or 430 Hz

or $n = 205$ Hz or 215 Hz ...(ii)

From eqns. (i) and (ii), it is clear that the fundamental frequency of the pipe = 205 Hz

19. (a): As $\upsilon=\left[\frac{v+v_c}{v-v_c}\right]\upsilon_0=\left[\frac{330+30}{330-30}\right]\times 600$

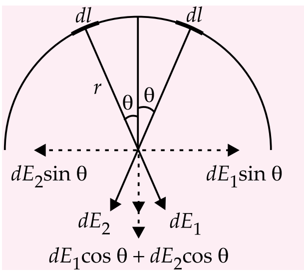
$$=\frac{360}{300}\times 600=720\text{ Hz}$$

20. (c) : Common potential $=\frac{\text{Total charge}}{\text{Total capacity}}$

$$V_2=\frac{C_0V_1+0}{C_0+KC_0}=\frac{V_1}{1+K}$$

or $1+K=\frac{V_1}{V_2}$ or $K=\frac{V_1}{V_2}-1=\frac{V_1-V_2}{V_2}$

21. (d): Consider two small elements of length dl placed symmetrically as shown in the figure.



$dl = r\,d\theta$, where $r=\frac{l}{\pi}$

$$dq=\frac{q}{\pi r}dl=\frac{q}{\pi}d\theta$$

$$\because\ |d\vec{E}_1|=|d\vec{E}_2|\ \therefore\ dE=2dE_1\cos\theta=\frac{2qd\theta\cos\theta}{\pi(4\pi\varepsilon_0r^2)}$$

$$E=\frac{2q}{\pi(4\pi\varepsilon_0r^2)}\int_{0^\circ}^{90^\circ}\cos\theta\,d\theta$$

$$=\frac{2q\times 1}{4\pi^2\varepsilon_0r^2}=\frac{2q}{4\pi^2\varepsilon_0(l^2/\pi^2)}=\frac{q}{2\,\varepsilon_0l^2}$$

22. (a): Drift velocity, $v_d=\frac{I}{nAe}=\frac{q/t}{nAe}$

Number of free electrons per unit length of conductor, $N = nA \times 1$

$\therefore$ Momentum of all the free electrons.

$$p=N\,mv_d=nA\times m\times\frac{q/t}{nAe}=\frac{q/t}{(e/m)}=\frac{q}{ts}$$

Where e/m is the specific charge (s) on the conductor.

23. (a)

24. (b): Suppose the length of wire is l.

When circular loop is formed from the wire, then radius of loop, $r=\frac{l}{2\pi}$

Magnetic dipole moment, $M_C = IA = I\pi r^2$

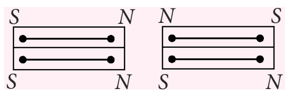
$$=I\pi\times\left(\frac{l}{2\pi}\right)^2=I\times\frac{l^2}{4\pi}$$

When square loop is formed from the wire, then the side of loop, $a=\frac{l}{4}$

Magnetic dipole moment, $M_S=IA=I\times a^2=I\times\frac{l^2}{16}$

$$\therefore\ \frac{M_C}{M_S}=\frac{4}{\pi}$$

25. (a) :



(i) $M = M_1 + M_2$ (ii) $M = M_1 - M_2$

$I = I_1 + I_2$ $I = I_1 + I_2$

(i) Similar poles are placed at the same side (sum position)

(ii) Opposite poles are placed at the same side (difference position)

I_1 and I_2 are the moments of inertia of the magnets and M_1 and M_2 are the moments of the magnets.

Here $M_1 = M$ and $M_2 = 2M$, $I_1 = I_2 = I$ (say), for same geometry.

$\therefore$ For sum position

$$T_1=2\pi\sqrt{\frac{I_1+I_2}{(M_1+M_2)H}}=2\pi\sqrt{\frac{2I}{(M+2M)H}}$$

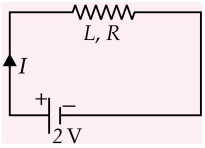
For difference position

$$T_2=2\pi\sqrt{\frac{I_1+I_2}{(M_2-M_1)H}}=2\pi\sqrt{\frac{2I}{(2M-M)H}}$$

$$\therefore\ \frac{T_1}{T_2}=\sqrt{\frac{M}{3M}}=\frac{1}{\sqrt{3}}<1 \quad\text{or}\quad T_1<T_2$$

26. (b): The current at any instant is given by,

$I = I_0\,(1 - e^{R\ t/L})$



or $\dfrac{I_0}{2} = I_0(1 - e^{-Rt/L})$

or $e^{-Rt/L} = \dfrac{1}{2}$ or $\dfrac{Rt}{L} = \ln 2$

$\therefore\ t = \dfrac{L}{R}\ln 2 = \dfrac{300\times10^{-3}}{2}\times 0.693$

$= 150 \times 0.693 \times 10^{-3} = 0.10395\ \text{s} = 0.1\ \text{s}$

27. (a): Magnetic field due to a long solenoid

$B = \mu_0 nI$

or $6.28 \times 10^{-2} = \mu_0 \times 200 \times 10^2 \times I$ ...(i)

and $B = \mu_0 \times 100 \times 10^2 \times \left(\dfrac{I}{3}\right)$ ...(ii)

Solving eqns. (i) and (ii),

$B = 1.05 \times 10^{-2}\ \text{Wb m}^{-2}$

28. (a): We know $E_0 = cB_0$, where c is the velocity of light.

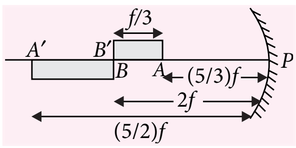
$\therefore\ c = \nu\lambda = \dfrac{\omega}{2\pi}\lambda = \dfrac{\omega}{k}$

Thus, $E_0 = cB_0 = \dfrac{\omega}{k}B_0$ or $E_0 k = B_0\omega$

29. (b): As the image is real and enlarged, the rod must lie between f and $2f$.

Let AB be the rod. The near end of the rod would make its image farther. Therefore the image of A is formed at A' and that of B coincides with itself.

i.e., $v_B = u_B$



$\dfrac{1}{u_B} + \dfrac{1}{u_B} = \dfrac{1}{-f}$

or $u_B = -2f$

Thus the end B is at $2f$ from P.

For end A, $u_A = -\left(2f - \dfrac{f}{3}\right) = -\dfrac{5}{3}f$

$\dfrac{1}{v_A} + \dfrac{1}{u_A} = \dfrac{1}{-f};\ \dfrac{1}{v_A} - \dfrac{3}{5f} = \dfrac{1}{-f}$

or $\dfrac{1}{v_A} = -\dfrac{1}{f} + \dfrac{3}{5f}$ $\quad\therefore\quad v_A = -\dfrac{5}{2}f$

Size of image $A'B' = \dfrac{5}{2}f - 2f = \dfrac{1}{2}f$

Size of object $= \dfrac{f}{3}$

Magnification $|m| = \dfrac{\text{Size of image}}{\text{Size of object}} = \dfrac{f/2}{f/3} = \dfrac{3}{2}$

30. (b): For possible interference maxima of the screen, the condition is, $d\sin\theta = n\lambda$ ...(i)

Given, d = slit width = 2λ $\quad\therefore\ 2\lambda\sin\theta = n\lambda$

The maximum value of $\sin\theta$ is 1, hence $n = 2$.

Thus, eqn. (i) must be satisfied by 5 integer values, *i.e.*, −2, −1, 0, 1, 2. Hence, the maximum number of possible interference maxima is 5.

31. (a): According to Bohr's second postulate of quantisation,

$mvr = \dfrac{nh}{2\pi}$ or $mr^2\omega = \dfrac{nh}{2\pi}$ $\qquad (\because\ v = r\omega)$

or $r^2 = \dfrac{nh}{2\pi m\omega}$ or $r = \sqrt{\dfrac{nh}{2\pi m\omega}}$ or $r \propto \sqrt{n}$

32. (b): According to question,

$T_{1/2}(X) = \tau(Y)$ or $\dfrac{0.693}{\lambda_X} = \dfrac{1}{\lambda_Y}$

or $\lambda_Y = \dfrac{\lambda_X}{0.693}$ or $\lambda_Y > \lambda_X$

So, Y will decay faster than X.

33. (b): Velocity of stone before reaching the sand,

$u = \sqrt{2gh} = \sqrt{2\times10\times100}$

Retardation in sand, $a = \dfrac{v^2 - u^2}{2s} = \dfrac{0 - 2gh}{2\times3}$

$= -\dfrac{2\times10\times100}{2\times3} = -\dfrac{1000}{3}\ \text{m s}^{-2}$

$\therefore$ Time of penetration, $t = \dfrac{u}{a} = \dfrac{\sqrt{2\times10\times100}}{1000/3}$

$= \dfrac{3\times20\sqrt{5}}{1000} = 0.13\ \text{s}$

34. (a): Due to the reverse biasing the width of depletion region increases and current flowing through the diode is almost zero. In this case electric field is almost zero at the middle of the depletion region.

35. (a): Distance covered in n^{th} second is given by

$s_n = u + \dfrac{a}{2}(2n - 1)$

Here, $u = 0$ $\quad\therefore\quad s_4 = 0 + \dfrac{a}{2}(2\times4-1) = \dfrac{7a}{2}$

and $s_3 = 0 + \dfrac{a}{2}(2\times3-1) = \dfrac{5a}{2}$ $\quad\therefore\quad \dfrac{s_4}{s_3} = \dfrac{7}{5}$

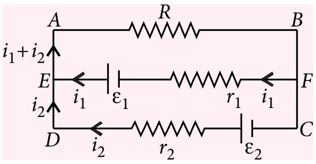
36. (d) **37. (d)** **38. (b)**

39. (d): Since, $\tan\phi = \dfrac{X_C - X_L}{R} \Rightarrow \tan\left(\dfrac{\pi}{4}\right) = \dfrac{\dfrac{1}{\omega C} - \omega L}{R}$

$R = \dfrac{1}{\omega C} - \omega L$

$(R + 2\pi\upsilon L) = \dfrac{1}{2\pi\upsilon C}$ or $C = \dfrac{1}{2\pi\upsilon(R + 2\pi\upsilon L)}$

40. (d) :



Applying Kirchhoff's eqn. to the loop *ABFE*,

$$-(I_1+I_2)R - I_1r_1 + \varepsilon_1 = 0$$

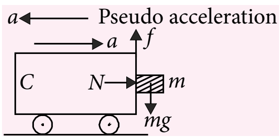
or $\varepsilon_1 - (I_1+I_2)R - I_1r_1 = 0$

41. (b): According to conservation of angular momentum, $L = I\omega$ = constant

Therefore, $I_2\omega_2 = I_1\omega_1$

or $\omega_2 = \dfrac{I_1\omega_1}{I_2} = \dfrac{Mk^2\omega}{(M+4m)k^2} = \dfrac{M\omega}{M+4m}$

42. (c) : Pseudo force or fictitious force, $F_{fic} = ma$



Force of friction,

$$f = \mu N = \mu ma$$

The block of mass m will not fall as long as

$$f \geq mg \text{ or } \mu ma \geq mg \quad \text{or} \quad a \geq \frac{g}{\mu}$$

43. (b): According to activity law, $R = R_0e^{-\lambda t}$

$\therefore \quad R_1 = R_0e^{-\lambda t_1}$ and $R_2 = R_0e^{-\lambda t_2}$

$\therefore \quad \dfrac{R_1}{R_2} = \dfrac{R_0e^{-\lambda t_1}}{R_0e^{-\lambda t_2}} = e^{-\lambda t_1}e^{\lambda t_2} = e^{-\lambda(t_1-t_2)}$

or $\quad R_1 = R_2e^{-\lambda(t_1-t_2)}$

44. (c) : In an electromagnetic wave both electric and magnetic vectors are perpendicular to each other as well as perpendicular to the direction of propagation of wave.

45. (a) : Momentum of the photon, $p = \dfrac{h\upsilon}{c} = \dfrac{h}{\lambda}$

$\therefore \quad \upsilon = \dfrac{c}{\lambda} = \dfrac{cp}{h} = 3\times10^8 \times \dfrac{3.3\times10^{-29}}{6.6\times10^{-34}}$

$= 1.5 \times 10^{13}$ Hz

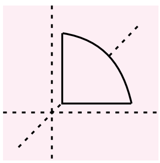
PHYSICS MUSING

SOLUTION SET-43

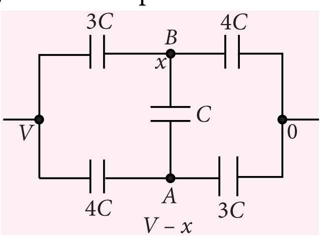
1. **(a)** : Initially, when the hole is closed,
$Mg - T = Ma$ ... (i)
where T is the tension in string and a is the acceleration of the block.
When the hole is opened
$T + \mu v_e - (M - \mu t)g = (M - \mu t)a$ ... (ii)
From eqns. (i) and (ii), we get
$$Mg + \mu v_e - (M - \mu t)g = (2M - \mu t)a$$
$$(\mu v_e + \mu g t) = (2M - \mu t)\,a$$
$$\therefore \quad a = \frac{\mu(v_e + gt)}{(2M - \mu t)}$$

2. **(b)** : Least count of the screw gauge,
$$= \frac{\text{Pitch}}{\text{Number of divisions on the circular scale}}$$
$$= \frac{0.5\text{ mm}}{50} = 0.01\text{ mm}$$
Measured diameter $= 4(0.5\text{ mm}) + (0.01)(8) = 2.08$ mm
Maximum error in D is ΔD = least count of screw gauge $= 0.01$ mm
$$\rho = \frac{R\pi D^2}{4l} \quad \because \left(\frac{\Delta\rho}{\rho}\right)_{max} = \frac{\Delta R}{R} + 2\frac{\Delta D}{D} + \frac{\Delta l}{l}$$
$$= 1\% + 2\frac{(0.01)}{2.08}\times 100\% + 1\% = 3\%$$

3. **(d)** : Since each part will have different principal axis.
So number of images = 4

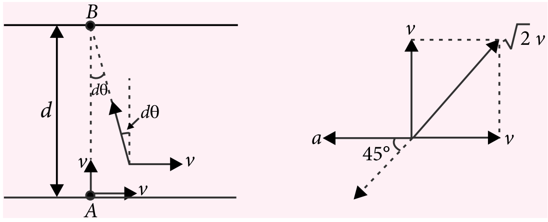


4. **(c)**: Initially when all capacitors are uncharged,



$(x - V)3 + (x - 0)4 + (x - (V - x))1 = 0$
$3x - 3V + 4x + 2x - V = 0$
$$9x = 4V \quad \text{or} \quad x = \frac{4V}{9}$$
In steady state, $V_A - V_B = (V - x) - x = V - 2x$
$$\text{or} \quad 3 = V - \frac{8V}{9} = \frac{V}{9} \quad \text{or} \quad V = 27\text{ V}$$

5. **(b)** : Change in the velocity of the swimmer,
$dv = v d\theta$
Acceleration of the swimmer,
$$a = \frac{dv}{dt} = \frac{v d\theta}{dt} = v\omega = v\left(\frac{v}{d}\right) = \frac{v^2}{d}$$



$$a_r = a\sin 45° = \frac{a}{\sqrt{2}} = \frac{v^2}{\sqrt{2}d} = \frac{(\sqrt{2}v)^2}{R}$$
$$\Rightarrow \quad R = 2\sqrt{2}d$$

6. **(b)** : Let the orbital radius of star having mass M_1 is d_1 and that of mass M_2 is d_2.
$$d_1 = \frac{M_2 d}{M_1 + M_2}, \quad d_2 = \frac{M_1 d}{M_1 + M_2}$$
$$\therefore \quad \frac{d_1}{d_2} = \frac{M_2}{M_1}$$
Ratio of kinetic energies,
$$\frac{K_1}{K_2} = \frac{\frac{1}{2}M_1\omega^2 d_1^2}{\frac{1}{2}M_2\omega^2 d_2^2} = \frac{M_1 d_1^2}{M_2 d_2^2} = \frac{M_2}{M_1}$$
Total energy of the system, $E = -\dfrac{GM_1M_2}{2d}$
Ratio of accelerations, $\dfrac{a_1}{a_2} = \dfrac{F/M_1}{F/M_2} = \dfrac{M_2}{M_1}$

7. **(d)** : CA is adiabatic, BC is isothermal as per slope.
Hence, $V_1 = \dfrac{P_0 V_0}{3P_0} = \dfrac{V_0}{3}$
Using PV^γ = constant
$$3P_0V_1^\gamma = \frac{P_0}{2}V_0^\gamma \quad \therefore \quad \gamma = \frac{\ln 6}{\ln 3}$$

8. **(a)** : The acceleration of the cylinder is caused by the net unbalanced forces acting on it which may be considered to be sum of the excess buoyant force and the additional vertical force exerted by the hinged at A.

ONE ENTRANCE EXAMINATION
ONE COUNSELING

ONE COURSE
ONE FEE

ALL B.Tech PROGRAMMES
ALL CAMPUSES

SRM UNIVERSITY
(Under Section 3 of UGC Act 1956)

SRMJEEE (UG) 2017

Online examination: 1st April to 30th April 2017

Aerospace Automobile Biomedical
Biotechnology Chemical Civil CSE EEE
ECE EIE Genetics IT Mech
Mechatronics Nanotech Software

* No.1 Private Engineering University by Times Engineering, Times of India - i3 Research Consultant survey 2016 | 2015 | 2014

Academics

Choice-based Flexible Credit System (CFCS)

- Aggregation of credits through flexible ways
- Opportunity to enter Honours College
- Earn credits through MOOCs, Industry Modules, and International Competitions
- Choice of subjects, teacher and time of study
- Students are taught by Scientists of SRM Research Institute

National Level Facilities and Industry Partners

- UNESCO Bioethic India Nodal Center
- SRM DBT Platform for Advanced Life Science Technologies
- SRM-ZOLLER Professional Tranining Center for Tool Management Solutions
- Bosch Rexroth Hydraulic and Pneumatic Training Center

Center for Higher Order Thinking (CHOT)

e-Lab | e-Learn | e-Think

Center for Cultural and Language Studies (CCLS)

ELS English Language Center
Taiwan Education Center
European Language Center
Asia and Far East Language Center

Student Abroad and Transfer Program (SATP)

Semester Abroad

- Sponsored by SRM to study one semester abroad
  500+ Students 13 Countries 25+ Universities
  such as MIT, CMU, CORNELL, HARVARD, UC Davis, Warwick, Kyushu University

Dual Degree

USA : University of Pittsburgh | Illinois Institute of Technology | Dayton | Virginia CW | Missouri State
UK : Warwick | Lancaster | Birmingham City
Australia : New South Wales | Royal Melbourne Institute of Technology (RMIT) | LaTrobe University
France : Polytechnic Tours
Germany : University of Applied Sciences Bochum

Twinning

USA : Carnegie Mellon University
UK : Lancaster University

MoUs 80+ with top ranked universities & Industries for exchanges & internships

Placement

- No. of companies - 244, No. of Offers - 6064
- **International Offer:**
  YKK, Japan (Highest pay ₹18 Lacs PA)
- Prime Offers - Amazon | CISCO | Deloitte | Verizon | Ericsson | Airbus | Alcatel | ABB | Fuji Xerox | Goldman Sachs | Honeywell | Vodafone | Schaffer | Siemens | Honda | Hyundai | Mahindra & Mahindra | INFOSYS | Wipro | Cognizant | TCS | Wabag | HP

Diversity of Students

Around 1500 students from 56 countries
Around 600 students are foreign nationals
Around 200 international students on study tours to SRM every year

Research Opportunities

More than ₹90 Crore worth of research projects for students to associate with
Journal publications: H-index of the institution stands at 46
SRMSAT fully designed by students and faculty

Ranking and Accreditation

Ranked in Indias top 30 by Times Higher Education (THE), UK
Ranked Indias No. 1 by India Today (Factual) and Times of India

Accreditation of Kattankulathur Campus Programs

ABET Computing Accreditation Commission
ABET Engineering Accreditation Commission

B.Tech Programs Civil, Mech, EEE and ECE are accredited by Engineering Accreditation Commission and B.Tech IT Program by Computing Accreditation Commission of ABET, USA. http:// www.abet.org

To Apply: Make e-payment or fill application online, download and courier with DD for ₹1060.

Scholarships: **Founders Scholarship, Board Merit Scholarship**

Online applications open from 18th November 2016 onwards

Please visit **www.srmuniv.ac.in** to know about courses offered, eligibility, fees, etc.
For any queries contact: +91-44-2745 5510, 4743 7500. Email: admissions.india@srmuniv.ac.in

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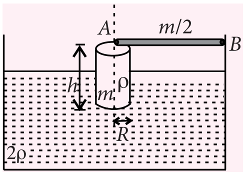


For vertical motion of the cylinder

$$ma = f_{b\,(\text{excess})} - f_1 \quad ...(i)$$

(f_1 = reaction force by the rod)

Writing equation of motion of the rod

$$f_1 l = I\alpha$$

$$f_1 = I\frac{a}{l^2} \qquad (\because\ a = l\alpha) \quad ...(ii)$$

From eqn. (i) and eqn. (ii)

$$\left(m+\frac{I}{l^2}\right)a = f_{b\,(\text{excess})}$$

$$\left(m+\frac{\left(\frac{m}{2}\right)l^2}{3l^2}\right)a = -(2\pi R^2\rho g)x$$

(x = small displacement of the block)

$$a = -\frac{2\pi R^2\rho g}{\left(m+\frac{m}{6}\right)}x = -\left(\frac{12\pi R^2\rho g}{7m}\right)x$$

Mass of cylinder, $m = \pi R^2\rho h$ and $a = -\omega^2 x$

$$\therefore\ \omega = \sqrt{\frac{12g}{7h}}$$

9. (d) : Given, $\vec{F} = x^2y\,\hat{i} + yz^2e^{2z}\,\hat{j} - \left(\frac{z}{x+2y}\right)\hat{k}$

$$d\vec{r} = dx\,\hat{i} + dy\,\hat{j} + dz\,\hat{k}$$

Work done by the force

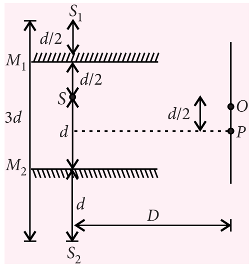
$$dW = \vec{F}\cdot d\vec{r} = x^2y\,dx + yz^2e^{2z}dy - \left(\frac{z}{x+2y}\right)dz$$

For the given path, $z = 0$ and $y = \frac{2x^2}{a}$

$$dW = x^2y\,dx = \frac{2x^4}{a}dx$$

$$W = \int dW = \frac{2}{a}\int_0^a x^4 dx = \frac{2a^4}{5}$$

10. (b) : The situation can be taken as if there are two sources S_1 and S_2 as shown in figure. Due to these S_1 and S_2, the central maxima will be at P at a distance $d/2$ from O.



For O to be a maxima path difference,

$$\frac{3d.d}{2D} = n\lambda \Rightarrow \lambda = \frac{3d^2}{2nD},\ i.e., \lambda = \frac{3d^2}{2D}, \frac{3d^2}{4D}$$

◇◇

BRAIN MAP

THERMAL PROPERTIES OF MATTER

CLASS XI

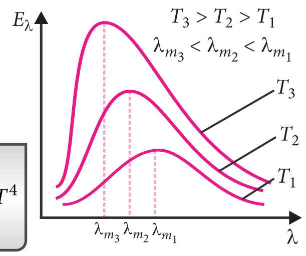
Latent Heat of Fusion (L_f)
Solid $\xrightarrow{Q = mL_f}$ Liquid

Latent Heat of Vapourisation(L_v)
Liquid $\xrightarrow{Q = mL_v}$ Gas

Latent Heat of Sublimation (L_s)
Solid $\xrightarrow{Q = mL_s}$ Gas

$\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$

Wien's Displacement Law
$\lambda_m T = b$ = constant
$b = 2.89 \times 10^{-3}$ m K



Linear Expansion
$L = L_0[1 + \alpha\Delta T]$

Relation between α, β and γ

Superficial Expansion
$A = A_0(1 + \beta\Delta T)$

Volume Expansion
$V = V_0(1 + \gamma\Delta T)$

Stefan's Boltzmann Law
Emissive power, $E \propto T^4 \Rightarrow E = \sigma T^4$
For ordinary body, $E = e\sigma T^4$

CHANGE OF STATE
During the change of phase, temperature remains constant but heat is being supplied to the body.

THERMAL EXPANSION
Increase in configuration of a solid with increasing temperature.

Kirchhoff's Law
Ratio of emissive power to absorptive power at temperature, T is
$\frac{E_1}{A_1} = \frac{E_2}{A_2} = \ldots \left(\frac{E}{A}\right)_{\text{Perfectly black body}}$

Radiation
Heat is transferred without heating the intervening medium.

Convection
Heat is transferred due to actual motion of heated particles.

Applications of Convection
- Formation of trade winds
- Causes monsoons
- Land and sea breezes etc.

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

TEMPERATURE
It is defined as the thermal state of the body, which would determine the direction of flow of heat when this body is placed in contact with another body.

HEAT TRANSFER
Transfer of heat from one system to another system arises due to temperature difference.

Conduction
Heat is transferred without any actual motion of particles of the substance.

Rate of Heat Flow
$\frac{Q}{t} = \frac{KA(T_1 - T_2)}{d}$; $(T_1 > T_2)$
(K = Coefficient of thermal conductivity)

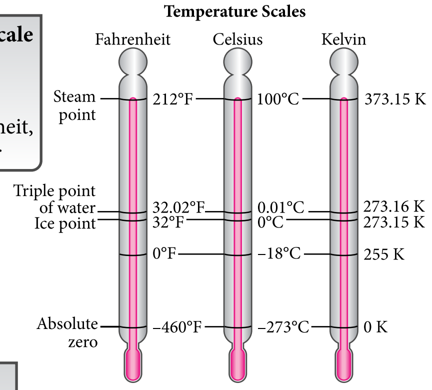
PRINCIPLE OF CALORIMETRY

It is based on the law of conservation of energy.
Heat lost by one body = Heat gained by other body

THERMOMETRY
A branch of physics which deals with the measurement of temperature, is known as the thermometry.

Conversion of Temperature Scale
$\frac{C}{5} = \frac{F - 32}{9} = \frac{K - 273}{5} = \frac{R}{4}$
where, C = Celsius, F = Fahrenheit, K = Kelvin, R= Reaumur

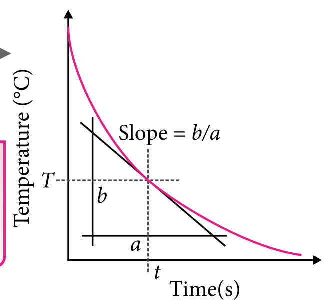
Temperature Scales



Triple Point of Water
Temperature and pressure at which all the three phases of water exists in equilibrium. $T_3 = 273.16$ K

NEWTON'S LAW OF COOLING
The rate of loss of heat by a body is directly proportional to the excess of temperature of the body over surroundings, provided excess is small.

Newton's Law of Cooling
Rate of cooling of a body is proportional to the excess temperature of the body over the surroundings
$$\frac{dT}{dt} = \frac{-k}{ms}(T_2 - T_1)$$



HEAT CAPACITY
The amount of heat absorbed by a given amount of substance to change the temperature by unity.

Molar Specific Heat
The amount of heat required to raise the temperature of one mole of a substance by unity. $C = \frac{\Delta Q}{n\Delta T}$

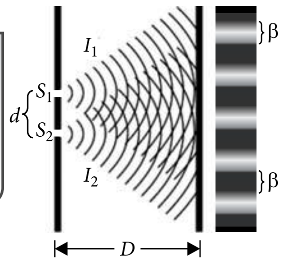
Specific Heat Capacity
The amount of heat required to raise the temperature of 1 g of substance by 1 °C. $s = \frac{\Delta Q}{m\Delta T}$

WAVE OPTICS

BRAIN MAP
CLASS XII

REFLECTION AND REFRACTION

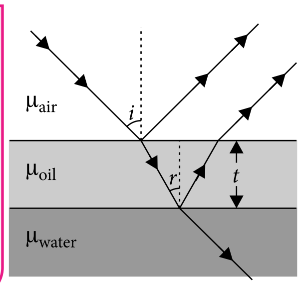
Law of reflection $\angle i = \angle r$ & law of refraction $\frac{\sin i}{\sin r} = \mu$ can be explained by Huygens wave theory.

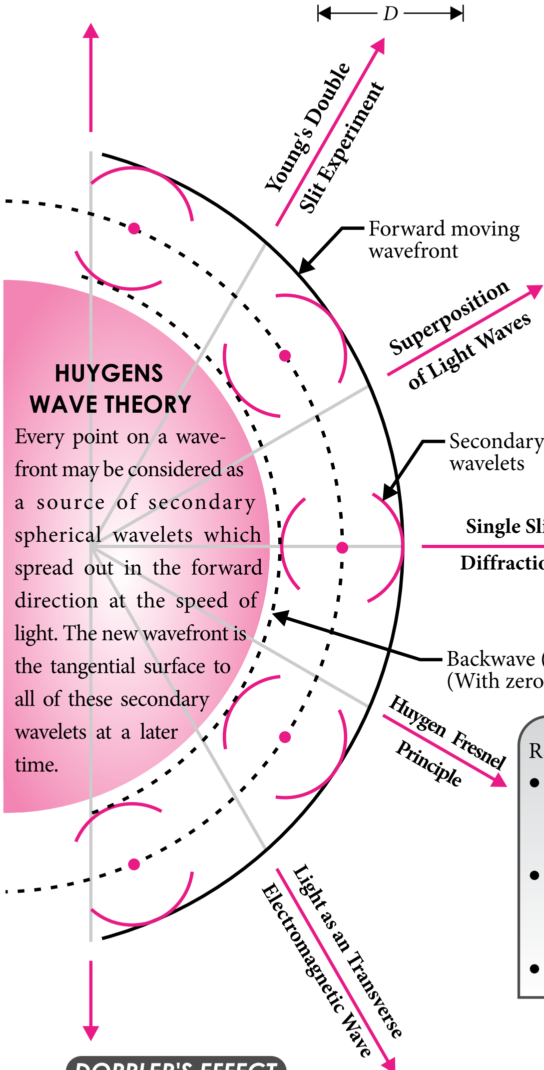


INTERFERENCE OF LIGHT

The superposition of two coherent waves resulting in a pattern of alternating dark and bright fringes of equal width.

- Position of bright fringes $x_n = \frac{n\lambda D}{d}$
- Position of dark fringes $x_n' = \frac{(2n-1)\lambda D}{2d}$
- Fringe width $\beta = \frac{\lambda D}{d}$
- Ratio of slit width with intensity : $\frac{w_1}{w_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$





HUYGENS WAVE THEORY

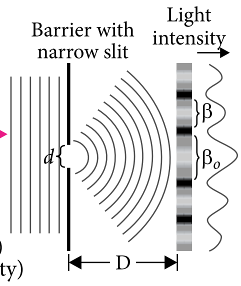
Every point on a wave-front may be considered as a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wavefront is the tangential surface to all of these secondary wavelets at a later time.

ADDITION OF COHERENT WAVE

- Resultant intensity
  $I_R = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$
  for bright fringes,
  $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ at $\phi = 0°, 2\pi, 4\pi...$
  for dark fringes,
  $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$ at $\phi = \pi, 3\pi, 5\pi...$
  for $I_1 = I_2 = I_0$; $I_R = 4I_0\cos^2\frac{\phi}{2}$

INTERFERENCE IN THIN FILM

- For reflected Light
  Maxima $\rightarrow 2\mu t\cos r = (2n+1)\frac{\lambda}{2}$
  Minima $\rightarrow 2\mu t\cos r = n\lambda$
- For transmitted light
  Maxima $\rightarrow 2\mu t\cos r = n\lambda$
  Minima $\rightarrow 2\mu t\cos r = (2n+1)\frac{\lambda}{2}$
  Shift in fringe pattern
  $\Delta x = \frac{\beta}{\lambda}(\mu - 1)t = \frac{D}{d}(\mu - 1)t$
  (t = thickness of film, μ = R.I. of the film)



DIFFRACTION

- Single slit experiment
  - Angular position of n^{th} minima, $\theta_n = \frac{n\lambda}{d}$
  - Angular position of n^{th} maxima, $\theta_n' = \frac{(2n+1)\lambda}{2d}$
  - Width of central maximum $\beta_o = 2\beta = \frac{2D\lambda}{d}$

FRESNEL'S DISTANCE

Ray optics as a limiting case of wave optics

- Diffraction at circular aperture
  Linear spread, $x = D\theta$
  Areal spread, $x^2 = (D\theta)^2$
  $\left\{\theta = \frac{1.22\lambda}{d}\right\}$
- Fresnel's distance : Distance at which diffraction spread is equal to the size of aperture, $D_F = \frac{d^2}{\lambda}$
- Size of Fresnel zone, $d_F = \sqrt{\lambda D}$

RESOLVING POWER (R.P.)

The ability to resolve the images of two nearby point objects distinctly.

R.P. $= \frac{1}{\text{Limit of resolution}}$

R.P. of a microscope $= \frac{1}{d} = \frac{2\mu\sin\theta}{\lambda}$

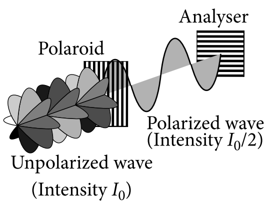
θ = Semi vertical angle subtended at objective.

R.P. of a telescope $= \frac{1}{d\theta} = \frac{D}{1.22\lambda}$

D = Diameter of objective lens of telescope.

DOPPLER'S EFFECT

- Apparent frequency received during relative motion of source and observer
  $\upsilon' = \upsilon\left(1 - \frac{v}{c}\right)$; (red shift)
  $\upsilon' = \upsilon\left(1 + \frac{v}{c}\right)$; (blue shift)
  Doppler shift : $\Delta\upsilon = \pm\frac{v}{c}\times\upsilon$
  $\Delta\lambda = \pm\frac{v}{c}\times\lambda \Rightarrow \lambda' - \lambda = \pm\frac{v}{c}\lambda$



POLARISATION OF LIGHT

Malus Law: The intensity of transmitted light passed through an analyser is
$I = I_0\cos^2\theta$
(θ = angle between transmission directions of polariser and analyser)

POLARISATION BY REFLECTION

- **Brewster's Law:** The tangent of polarising angle of incidence at which reflected light becomes completely plane polarised is numerically equal to refractive index of the medium
  $\mu = \tan i_p$; i_p = Brewster's angle.
  and $i_p + r_p = 90°$

PRACTICE PAPER
BITSAT

Exam date: 16^{th} to 30^{th} May 2017

1. A body falling freely from a given height H hits on an inclined plane in its path at a height h. As a result of this impact, the direction of velocity becomes horizontal. For what value of H/h the body will take maximum time to reach the ground?
(a) 1 (b) 2 (c) 3 (d) 4

2. The Earth is assumed to be a sphere of radius R. A platform is arranged at a height R from the surface of the Earth. The escape velocity of a body from the platform is nv, where v is the escape velocity from the surface of the Earth. The value of n is
(a) 1/2 (b) $\sqrt{2}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{3}$.

3. The displacement y of a particle in a medium can be expressed as $y = 10^{-6}\sin(100t + 20x + \pi/4)$ m, where t is in second and x in meter. The speed of the wave is
(a) 2000 m s^{-1} (b) 5 m s^{-1}
(c) 20 m s^{-1} (d) 50 m s^{-1}

4. In an experiment to measure the height of a bridge by dropping stone into water underneath, if the error in measurement of time is 0.1 s at the end of 2 s, then the error in estimation of height of bridge will be
(a) 0.49 m (b) 0.98 m
(c) 1.96 m (d) 2.12 m

5. A circular coil of radius 10 cm, 500 turns and resistance 2 Ω is placed with its plane perpendicular to the horizontal component of the earth's magnetic field. It is rotated about its vertical diameter through 180° in 0.25 s. The current induced in the coil is (Horizontal component of the earth's magnetic field at the place is 3.0×10^{-5} T.)
(a) 1.9×10^{-3} A (b) 2.9×10^{-3} A
(c) 3.9×10^{-3} A (d) 4.9×10^{-3} A

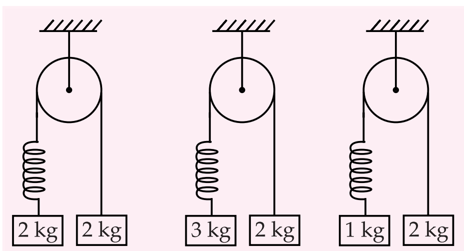
6. A 100 eV electron is fired directly towards a large metal plate having surface charge density -2×10^{-6} C m^{-2}. The distance from where the electron be projected so that it just fails to strike the plate is
(a) 0.22 mm (b) 0.44 mm
(c) 0.66 mm (d) 0.88 mm

7. A U tube containing a liquid moves with a horizontal acceleration a along a direction joining the two vertical limbs. The separation between these limbs is d. The difference in their liquid levels is
(a) $\frac{ad}{g}$ (b) $\frac{2ad}{g}$ (c) $\frac{ad}{2g}$ (d) $d\tan\left(\frac{a}{g}\right)$

8. In the spectrum of singly ionized helium, the wavelength of a line observed is almost the same as the first line of Balmer series of hydrogen. It is due to transition of electron from
(a) $n_1 = 6$ to $n_2 = 4$ (b) $n_1 = 5$ to $n_2 = 3$
(c) $n_1 = 4$ to $n_2 = 2$ (d) $n_1 = 3$ to $n_2 = 2$

9. The resistance of a galvanometer is 100 Ω. It gives full scale deflection for a current of 1 mA. To convert it into a voltmeter of range 50 V a resistor is connected. The resistance of resistor and the resistance of voltmeter so formed are respectively
(a) 46900 Ω and 53000 Ω
(b) 47900 Ω and 52000 Ω
(c) 48900 Ω and 51000 Ω
(d) 49900 Ω and 50000 Ω

10. Similar types of springs are attached with 2 kg, 3 kg and 1 kg blocks in three different cases as shown in the figure. If x_1, x_2 and x_3 be the extensions in the spring in the three cases, then



(a) $x_1 = 0, x_3 > x_2$ (b) $x_1 > x_2 > x_3$
(c) $x_3 > x_2 > x_1$ (d) $x_2 > x_1 > x_3$

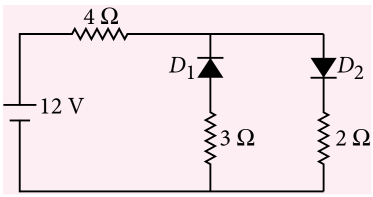
11. A body of mass 0.5 kg travels in a straight line with velocity $v = kx^{3/2}$ where $k = 5\ \text{m}^{-1/2}\ \text{s}^{-1}$. The work done by the net force during its displacement from $x = 0$ to $x = 2$ m is
(a) 1.5 J (b) 50 J (c) 10 J (d) 100 J

12. A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60°. The torque needed to maintain the needle in this position will be
(a) $\sqrt{3}W$ (b) W
(c) $\left(\frac{\sqrt{3}}{2}\right)W$ (d) $2W$

13. An object is kept at a distance of 16 cm from a thin lens and the image formed is real. If the object is kept at a distance of 6 cm from the same lens, the image formed is virtual. If the sizes, of the images formed are equal, the focal length of the lens will be
(a) 15 cm (b) 17 cm
(c) 21 cm (d) 11 cm

14. A solid sphere and a hollow sphere of the same material and size are heated to the same temperature and allowed to cool in the same surroundings. If the temperature difference between each sphere and its surroundings is T, then
(a) the hollow sphere will cool at a faster rate for all values of T
(b) the solid sphere will cool at a faster rate for all values of T
(c) both the spheres will cool at the same rate for all values of T
(d) both the spheres will cool at the same rate only for small values of T.

15. The circuit has two oppositely connect ideal diodes in parallel. What is value of the current in the circuit?



(a) 1.33 A (b) 1.71 A
(c) 2.00 A (d) 2.31 A

16. The work function of a metal is ϕ and λ is the wavelength of the incident radiation. There is no emission of photoelectrons when
(a) $\lambda > hc/\phi$ (b) $\lambda = hc/\phi$
(c) $\lambda < hc/\phi$ (d) None of these

17. A truck starts from rest and accelerates uniformly at 2 m s^{-2}. At $t = 10$ s, a stone is dropped by a person standing on the top of the truck 6 m high from the ground. The velocity of the stone at $t = 11$ s is
(Take $g = 10$ m s^{-2})
(a) $\sqrt{5}$ m s^{-1} (b) $10\sqrt{5}$ m s^{-1}
(c) $\sqrt{20}$ m s^{-1} (d) $5\sqrt{5}$ m s^{-1}

18. A lens of power 6 D is put in contact with a lens of power –4 D. The combination will behave like a
(a) divergent lens of focal length 25 cm
(b) convergent lens of focal length 50 cm
(c) divergent lens of focal length 20 cm
(d) convergent lens of focal length 100 cm.

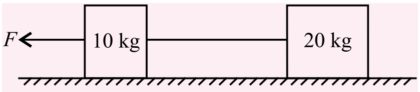
19. When a 33000 N tensile force is applied on a steel rod of area of cross-section 10^{-3} m^2 than there is some change in its length. The change in temperature required to produce the same elongation, if the steel rod is heated, is
(The modulus of elasticity is 3×10^{11} N m^{-2} and coefficient of linear expansion of steel is 1.1×10^{-5} °C^{-1}.)
(a) 20 °C (b) 15 °C (c) 10 °C (d) 0 °C

20. An aluminium sphere is dipped into water. Which of the following statements is true?
(a) Buoyancy will be less in water at 0 °C than that in water at 4 °C.
(b) Buoyancy will be more in water at 0 °C than that in water at 4 °C.
(c) Buoyancy in water at 0 °C will be same as that in water at 4 °C
(d) None of these.

21. A TV tower has a height of 100 m. How much population is covered by the TV broadcast if the average population density around the tower is 1000 km^{-2}? (Radius of the earth = 6.37×10^6 m)
(a) 4 lakh (b) 4 billion
(c) 40,000 (d) 40 lakh

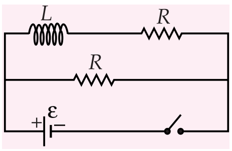
22. A source of sound of frequency 600 Hz is placed inside water. The speed of sound in water is 1500 m s^{-1} and in air it is 300 m s^{-1}. The frequency of sound recorded by an observer who is standing in air is
(a) 200 Hz (b) 3000 Hz
(c) 120 Hz (d) 600 Hz

23. Two blocks of masses 10 kg and 20 kg are connected by a massless string and are placed on a smooth horizontal surface as shown in the figure. If a force $F = 600$ N is applied to 10 kg block, then the tension in the string is



(a) 100 N (b) 200 N
(c) 300 N (d) 400 N

24. A coil of self inductance L and resistance R is connected to the resistance R and a cell of emf ε, as shown in the figure. The switch is kept closed for a long time and then opened. The heat produced in the coil, after opening the switch, is



(a) $\dfrac{L\varepsilon^2}{2R^2}$ (b) $\dfrac{L\varepsilon^2}{4R^2}$ (c) $\dfrac{L\varepsilon^2}{8R^2}$ (d) $\dfrac{2L\varepsilon^2}{3R^2}$

25. Two simple harmonic motions for two particles are represented by the equations $y_1 = 0.1\sin\left(100\pi t + \dfrac{\pi}{3}\right)$ and $y_2 = 0.1\cos\pi t$. The phase difference of the velocity of particle 1 with respect to the velocity of particle 2 is

(a) $-\pi/3$ (b) $\pi/6$ (c) $-\pi/6$ (d) $\pi/3$.

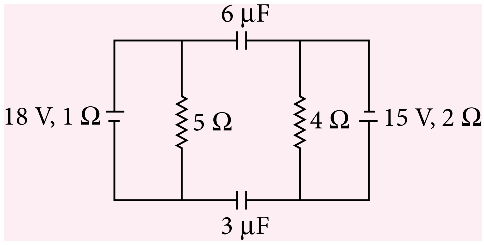
26. The maximum intensity in Young's double-slit experiment is I_0. Distance between the slits is $d = 5\lambda$, where λ is the wavelength of monochromatic light used in the experiment. What will be the intensity of light in front of one of the slits on a screen at a distance $D = 10d$?

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

27. If 2 mol of an ideal monatomic gas at temperature T_0 are mixed with 4 mol of another ideal monatomic gas at temperature $2T_0$, then the temperature of the mixture will be

(a) $\dfrac{5}{3}T_0$ (b) $\dfrac{3}{2}T_0$ (c) $\dfrac{4}{3}T_0$ (d) $\dfrac{5}{4}T_0$

28. Two batteries, two resistors and two capacitors are connected as shown in the figure. The charge on 3 μF capacitor is

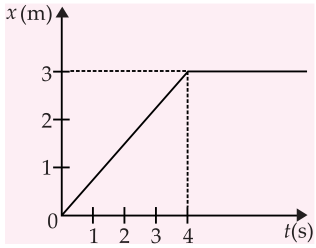


(a) 20 μC (b) 25 μC
(c) 50 μC (d) 40 μC

29. By increasing the temperature, what is the effect on the specific resistance of a conductor and a semiconductor ?

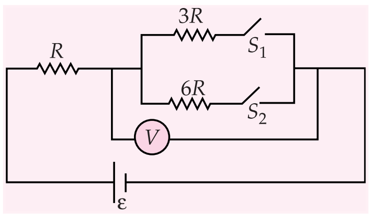
(a) increases for both (b) decreases for both
(c) increases for conductor and decreases for semiconductor
(d) decreases for conductor and increases for semiconductor

30. The position-time graph of a body of mass 2 kg is as shown in the figure. What is the impulse on the body at $t = 4$ s?



(a) $\dfrac{2}{3}$ kg m s^{-1}
(b) $-\dfrac{2}{3}$ kg m s^{-1}
(c) $\dfrac{3}{2}$ kg m s^{-1}
(d) $-\dfrac{3}{2}$ kg m s^{-1}

31. In the circuit shown in figure reading of voltmeter is V_1 when only S_1 is closed, reading of voltmeter is V_2 when only S_2 is closed and reading of voltmeter is V_3 when both S_1 and S_2 are closed. Then



(a) $V_3 > V_2 > V_1$ (b) $V_2 > V_1 > V_3$
(c) $V_3 > V_1 > V_2$ (d) $V_1 > V_2 > V_3$

32. The escape velocity for a planet is v_e. A tunnel is dug along a diameter of the planet and a small body is dropped into it at the surface. When the body reaches the centre of the planet, its speed will be

(a) Zero (b) $\dfrac{v_e}{2}$ (c) $\dfrac{v_e}{\sqrt{2}}$ (d) v_e

33. A ray of light from a denser medium strikes as rarer medium at an angle of incidence i. The reflected and refracted rays make an angle of $\pi/2$ with each other. If the angles of reflection and refraction are r and r', then the critical angle will be

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

34. An ideal gas heat engine operates in Carnot cycle between 227 °C and 127 °C. It absorbs 6×10^4 cal of heat at higher temperature. Amount of heat converted into work is

(a) 1.2×10^4 cal (b) 2.4×10^4 cal
(c) 6×10^4 cal (d) 4.8×10^4 cal.

35. Force between two identical charges placed at a distance r in vacuum is F. Now a slab of dielectric constant $K = 4$ is inserted between these two charges. The thickness of the slab is $r/2$. The force between the charges will now become

(a) $F/4$ (b) $F/2$ (c) $3F/5$ (d) $4F/9$

36. A constant voltage is applied between the two ends of a uniform metallic wire. Some heat is developed in it. The heat developed is doubled if

(a) both the length and the radius of the wire are halved.
(b) both the length and the radius of the wire are doubled.
(c) the radius of the wire is doubled.
(d) the length of the wire is doubled.

37. An ideal coil of 10 H is connected in series with a resistance of 5 Ω and a battery of 5 V. 2 s after the connection is made, the current flowing in ampere in the circuit is

(a) $(1 - e^{-1})$ (b) $(1 - e)$
(c) e (d) e^{-1}

38. Four particles of masses m, $2m$, $3m$ and $4m$ are arranged at the corners of a parallelogram with each side equal to a and one of the angle between two adjacent sides is 60°. The parallelogram lies in the x-y plane with mass m at the origin and $4m$ on the x-axis. The centre of mass of the arrangement will be located at

(a) $\left(\frac{\sqrt{3}}{2}a, 0.95a\right)$ (b) $\left(0.95a, \frac{\sqrt{3}}{4}a\right)$
(c) $\left(\frac{3a}{4}, \frac{a}{2}\right)$ (d) $\left(\frac{a}{2}, \frac{3a}{4}\right)$

39. A rigid spherical body is spinning around an axis without any external torque. Due to change in temperature, its volume increases by 1%. The angular speed:

(a) increase nearly by 1%
(b) decrease by 1%
(c) decreases by nearly 0.67%
(d) decreases nearly by 0.37%.

40. A radioactive substances is being consumed at a constant rate of 1 s^{-1}. After what time will the number of radioactive nuclei become 100. Initially, there were 200 nuclei present.

(a) 1 s (b) 1/ln 2 s
(c) ln 2 s (d) 2 s

SOLUTIONS

1. **(b) :** Let t_1 be the time taken by a body to fall through a height $(H - h)$ and t_2 be the time taken to fall through a vertical height h. Then

$$t_1 = \sqrt{\frac{2(H-h)}{g}} \text{ and } t_2 = \sqrt{\frac{2h}{g}}$$

$$\therefore \text{ Total time, } t = t_1 + t_2 = \sqrt{\frac{2(H-h)}{g}} + \sqrt{\frac{2h}{g}}$$

For maximum value of t, $\frac{dt}{dh} = 0$

$$\text{Then } \sqrt{\frac{2}{g}}\left[\frac{1}{2}(H-h)^{-1/2}(-1) + \frac{1}{2}h^{-1/2}\right] = 0$$

On solving we get, $H - h = h$ or $\frac{H}{h} = 2$

2. **(c) :** Applying law of conservation of energy, PE + KE = 0

$$-\frac{GMm}{(R+R)} + \frac{1}{2}m(nv)^2 = 0$$

$$\text{or } nv = \sqrt{\frac{GM}{R}} = \sqrt{gR} = \frac{v}{\sqrt{2}} \qquad (\text{as } v = \sqrt{2gR})$$

$\therefore$ $n = 1/\sqrt{2}$

3. **(b) :** Given wave equation

$$y = 10^{-6}\sin\left(100t + 20x + \frac{\pi}{4}\right) \text{ m}$$

Standard equation : $y = a \sin(\omega t + kx + \phi)$
Compare the two equations
$\therefore$ $\omega = 100\ s^{-1}$ and $k = 20\ m^{-1}$

wave speed, $v = \frac{\omega}{k} = \frac{100}{20} = 5\ m\ s^{-1}$

4. **(c) :** From $s = ut + \frac{1}{2}at^2$

$$h = 0 + \frac{1}{2} \times 9.8(2)^2 = 19.6$$

$$\frac{\Delta h}{h} = \pm 2\left(\frac{\Delta t}{t}\right) = \pm 2\left(\frac{0.1}{2}\right) = \pm\frac{1}{10}$$

$$\therefore \quad \Delta h = \pm\frac{h}{10} = \pm\frac{19.6}{10} = \pm 1.96 \text{ m}$$

5. (a) : Initial magnetic flux through the coil,

$\phi_i = BA\cos\theta = 3.0 \times 10^{-5} \times (\pi \times 10^{-2}) \times \cos 0°$

$= 3\pi \times 10^{-7}$ Wb

Final magnetic flux after the rotation

$\phi_f = BA\cos\theta = 3.0 \times 10^{-5} \times (\pi \times 10^{-2}) \times \cos 180°$

$= -3\pi \times 10^{-7}$ Wb

$$\text{Induced emf, } \varepsilon = -N\frac{\Delta\phi}{\Delta t} = -\frac{N(\phi_f - \phi_i)}{t}$$

$$= -\frac{50\ (-3\pi \times 10^{-7} - 3\pi \times 10^{-7})}{0.25}$$

$$= \frac{50 \times (6\pi \times 10^{-7})}{0.25} = 3.8 \times 10^{-3} \text{ V}$$

$$I = \frac{\varepsilon}{R} = \frac{3.8 \times 10^{-3}\text{ V}}{2\,\Omega} = 1.9 \times 10^{-3}\text{ A}$$

6. (b) : Here, KE = 100 eV = $100 \times 1.6 \times 10^{-19}$ J

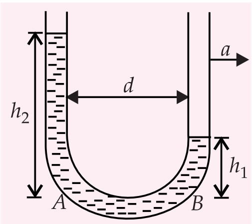
This KE is lost when electron moves through a distance (d) towards the negative plate.

$$\text{KE} = \text{work done} = F \times s = q\,E \times s = e\left(\frac{\sigma}{\varepsilon_0}\right)d$$

$$d = \frac{(\text{KE})\varepsilon_0}{e\sigma} = \frac{100 \times 1.6 \times 10^{-19} \times 8.86 \times 10^{-12}}{1.6 \times 10^{-19} \times 2 \times 10^{-6}}$$

$= 4.43 \times 10^{-4}$ m $= 0.443$ mm

7. (a) : Let A = area of cross-section of the tube, ρ = density of the liquid



Consider the section AB of the tube.

Mass of the liquid in $AB = Ad\rho$

Pressure at $A = P_0 + h_2\rho g$

where P_0 is the atmospheric pressure

Pressure at $B = P_0 + h_1\rho g$

Net force to the right on $AB = (h_2\rho g - h_1\rho g)A$

$\therefore \quad (h_2 - h_1)\rho gA = (Ad\rho)a$

$$\text{or} \quad (h_2 - h_1)g = da \quad \text{or} \quad h_2 - h_1 = \frac{ad}{g}$$

8. (a) : For the first line of Balmer series of hydrogen

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36} \Rightarrow \lambda = \frac{36}{5R}$$

For singly ionized helium ($Z = 2$),

$$\frac{1}{\lambda'} = 4R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Given $\lambda' = \lambda$

For $n_1 = 6$ to $n_2 = 4$

$$\frac{1}{\lambda'} = 4R\left(\frac{1}{4^2} - \frac{1}{6^2}\right) = \frac{20R}{144} = \frac{5R}{36}$$

Hence, it corresponds to transition from $n_1 = 6$ to $n_2 = 4$.

9. (d) : For a voltmeter,

$V = I_g(G + R)$ where R is connected in series with the galvanometer

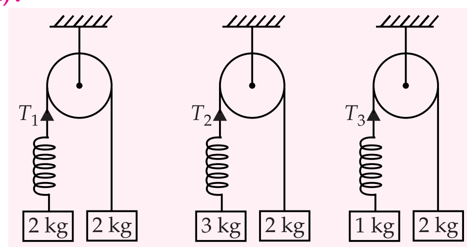
$\therefore \quad 50 = (100 + R) \times 10^{-3}$ or $50000 = 100 + R$

or $\quad R = 49900\ \Omega$

Again, total resistance of voltmeter $= G + R$

$= 100 + 49900 = 50000\ \Omega$

10. (d) :



If T_1, T_2, T_3 are the tensions in the strings in the three cases, we have

$$T_1 = \frac{2m_1m_2g}{m_1 + m_2} = \frac{2 \times 2 \times 2g}{(2+2)} = 2g$$

$$T_2 = \frac{2 \times 3 \times 2g}{(3+2)} = 2.4g; \quad T_3 = \frac{2 \times 1 \times 2g}{(1+2)} = 1.33g$$

As $x \propto T$ and $T_2 > T_1 > T_3 \quad \therefore \quad x_2 > x_1 > x_3$

11. (b) : Given : $m = 0.5$ kg, $v = kx^{3/2}$ where, $k = 5\text{ m}^{-1/2}\text{ s}^{-1}$

$$\text{Acceleration, } a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} = v\frac{dv}{dx}$$

As $v^2 = k^2x^3$

Differentiating both sides with respect to x, we get

$$2v\frac{dv}{dx} = 3k^2x^2$$

$$\therefore \quad \text{Acceleration, } a = \frac{3}{2}k^2x^2$$

$$\text{Force, } F = \text{mass} \times \text{acceleration} = \frac{3}{2}mk^2x^2$$

$$\text{Work done, } W = \int F\,dx = \int_0^2 \frac{3}{2}mk^2x^2\,dx$$

$$W = \frac{3}{2}mk^2\left[\frac{x^3}{3}\right]_0^2 = \frac{3}{6} \times 0.5 \times 5^2 \times [2^3 - 0] = 50\text{ J}$$

12. (a) : $W = -MB(\cos\theta_2 - \cos\theta_1)$

$$= -MB(\cos 60° - \cos 0°) = \frac{MB}{2}$$

$\therefore \quad MB = 2W$

Torque $= MB \sin 60° = (2W)\sin 60°$

$$= \frac{2W \times \sqrt{3}}{2} = \sqrt{3}\ W$$

13. (d) : Only convex lens can form a real as well as virtual image. So, the given lens is a convex lens.
Let f is the focal length of the lens and m is the magnitude of magnification.
In the first case, when the image is real

$u = -16$ cm, $v = -mu = (16\ m)$ cm

Using $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$; $\frac{1}{16m} + \frac{1}{16} = \frac{1}{f}$

or $\quad 1 + \frac{1}{m} = \frac{16}{f} \quad$ ...(i)

In the second case, when image is virtual

$u = -6$ cm, $v = mu = (-6\ m)$ cm

$\therefore \quad \frac{1}{-6m} + \frac{1}{6} = \frac{1}{f}$; $1 - \frac{1}{m} = \frac{6}{f} \quad$ ...(ii)

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

$$2 = \frac{22}{f} \quad \therefore f = 11 \text{ cm}$$

14. (a) : Rate of cooling, $\frac{\Delta\theta}{t} = \frac{Ae\sigma\left(T^4 - T_0^4\right)}{mc}$

As surface area, material and temperature difference are same, so rate of loss of heat is same in both the spheres.
Now in this case, rate of cooling depends on mass.

$\Rightarrow$ Rate of cooling, $\frac{\Delta\theta}{t} \propto \frac{1}{m}$

since $m_{solid} > m_{hollow}$, hollow sphere will cool at faster rate.

15. (c) : Since diode D_1 is reverse biased, therefore it will act like an open circuit.
Effective resistance of the circuit is $R = 4 + 2 = 6\ \Omega$
Current in the circuit is $I = V/R = 12/6 = 2$ A

16. (a)

17. (b) : For truck, $u = 0$, $a = 2$ m s^{-2}, $t = 10$ s

Let v be the velocity of the truck after 10 s.

As $\quad v = u + at$

$\therefore \quad v = 0 + (2 \text{ m s}^{-2})(10 \text{ s}) = 20 \text{ m s}^{-1}$

For stone,

When the stone is dropped from the moving truck it will possess a velocity along the horizontal equal to that of the truck at that time.

$\therefore \quad v_x = v = 20 \text{ m s}^{-1}$

Initial velocity of the stone along the vertical is zero.
Let v_y be the velocity of the stone along the vertical at $t = 11$ s *i.e.* after being dropped out of the truck.

$\therefore \quad v_y = 0 + (10 \text{ m s}^{-2})(1 \text{ s}) = 10 \text{ m s}^{-1}$

The resultant velocity of the stone at $t = 11$ s is

$$v_R = \sqrt{v_x^2 + v_y^2} = \sqrt{(20 \text{ m s}^{-1})^2 + (10 \text{ m s}^{-1})^2}$$

$$= \sqrt{500} \text{ m s}^{-1} = 10\sqrt{5} \text{ m s}^{-1}$$

18. (b) : Here, $P_1 = +6$ D, $P_2 = -4$ D

The power of the combination is

$P = P_1 + P_2 = 6 \text{ D} + (-4 \text{ D}) = +2 \text{ D}$

$$P(\text{in D}) = \frac{1}{f\ (\text{in metre})} \quad \text{or} \quad f = \frac{1}{+2 \text{ D}} = 0.5 \text{ m} = 50 \text{ cm}$$

The given combination will behave like a convergent lens of focal length 50 cm.

19. (c) : Young's modulus $Y = \frac{(F/A)}{\Delta l / l}$ or $\Delta l = \frac{(F/A)l}{Y}$

Also, $\Delta l = \alpha l \Delta\theta$

As per question

$$\frac{(F/A)l}{Y} = \alpha l \Delta\theta \quad \text{or} \quad \Delta\theta = \frac{F}{YA\alpha}$$

$$= \frac{\text{[illegible]} \quad \text{N}}{(3 \times 10^{1} \ \text{N m}^{-2}) \times (10^{-3} \text{ m}^2) \times (1.1 \times 10^{-5} \ °\text{C}^{-1})}$$

$\therefore \quad \Delta\theta = 10$ °C

20. (a) : Density of water is maximum at 4 °C, this is because of anomalous expansion of water.
Let volume of the sphere be V and ρ be its density, then buoyant force,

$F = V\rho g$

$\Rightarrow \quad F \propto \rho \qquad (\because V$ and g are almost constant$)$

$\Rightarrow \quad \frac{F_{4°C}}{F_{0°C}} = \frac{\rho_{4°C}}{\rho_{0°C}} > 1 \qquad (\because \rho_{4°C} > \rho_{0°C})$

$\therefore \quad F_{4°C} > F_{0°C}$

Hence, buoyancy will be less in water at 0 °C than that in water at 4 °C.

21. (d) : Range of the TV tower, $d = \sqrt{2hR}$

Population covered $= \pi d^2 \times$ population density

$= \pi \times 2hR \times$ population density

$$= \frac{3.14 \times 2 \times \text{[illegible]} \quad \times 6.37 \times 10^6 \times \text{[illegible]}}{\text{[illegible]}\ ^{6}} = 4 \times 10^6$$

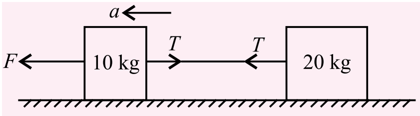
$= 40$ lakh

22. (d) : The frequency is a characteristic of source. It is independent of the medium.

23. (d) : Here, $m_1 = 10$ kg, $m_2 = 20$ kg, $F = 600$ N

Let T be tension of the string and a be common acceleration of the system.

$$\therefore \quad a = \frac{F}{m_1 + m_2} = \frac{600\text{ N}}{10\text{ kg} + 20\text{ kg}} = \frac{600}{30}\text{ m s}^{-2} = 20\text{ m s}^{-2}$$



When a force F is applied on 10 kg block, then the tension in the string is

$T = m_2 a = (20\text{ kg})(20\text{ m s}^{-2}) = 400$ N

24. (b) : In the steady state, the current in the coil is $I = \frac{\varepsilon}{R}$. The energy stored in it is $= \frac{1}{2}LI^2 = \frac{L\varepsilon^2}{2R^2}$.

When the switch is opened, this energy is shared equally between the two resistances.

25. (c) : $v_1 = \frac{d}{dt}(y_1) = (0.1 \times 100\pi)\cos\left(100\pi t + \frac{\pi}{3}\right)$

$$v_2 = \frac{d}{dt}(y_2) = (-0.1 \times \pi)\sin \pi t = (0.1 \times \pi)\cos\left(\pi t + \frac{\pi}{2}\right)$$

$$\therefore \quad \Delta\phi = \frac{\pi}{3} - \frac{\pi}{2} = -\frac{\pi}{6}$$

26. (a) : Path difference, $\Delta x = \frac{yd}{D}$

Here, $y = \frac{5\lambda}{2}$, $d = 5\lambda$, $D = 10d = 50\lambda$

$$\therefore \quad \Delta x = \left(\frac{5\lambda}{2}\right)\left(\frac{5\lambda}{50\lambda}\right) = \frac{\lambda}{4}$$

Corresponding phase difference will be

$$\phi = \left(\frac{2\pi}{\lambda}\right)(\Delta x) = \left(\frac{2\pi}{\lambda}\right)\left(\frac{\lambda}{4}\right) = \frac{\pi}{2}$$

$$\therefore \quad I = I_0\cos^2\left(\frac{\phi}{2}\right) = I_0\cos^2\left(\frac{\pi}{4}\right) = \frac{I_0}{2}$$

27. (a) : Let T be the temperature of the mixture.

Then $U = U_1 + U_2$

or $\quad \frac{f}{2}(n_1 + n_2)RT = \frac{f}{2}(n_1)(R)(T_0) + \frac{f}{2}(n_2)(R)(2T_0)$

or $\quad (2 + 4)T = 2T_0 + 8T_0 \qquad (\because n_1 = 2, n_2 = 4)$

$$\therefore \quad T = \frac{5}{3}T_0$$

28. (c) : Current in resistance 5 Ω is due to battery of 18 V alone.

$$\therefore \quad \text{Current, } I_1 = \frac{18}{5+1} = 3\text{ A}$$

Terminal potential difference of 18 V battery,

$V_1 = 18 - 3 \times 1 = 15$ V.

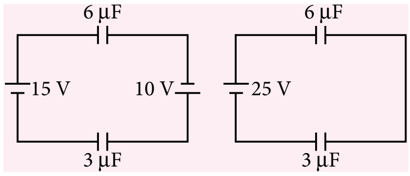
The current in 4 Ω is due to battery of 15 V alone.

$$\therefore \quad \text{Current, } I_2 = \frac{15}{2+4} = 2.5\text{A}$$

Terminal potential difference of 15 V battery,

$V_2 = 15 - 2 \times 2.5 = 10$ V

The equivalent circuit will become as shown in figure.



The two capacitors are in series, the charge on capacitor 3 μF = charge in circuit $= 25 \times \frac{3 \times 6}{3+6} = 50\,\mu\text{C}$

29. (c) : For conductor, specific resistance (ρ) increases as temperature rises. For semiconductor, specific resistance (ρ) decreases as temperature rises.

30. (d) : At $t = 4$ s, the body has constant velocity,

$$u = \frac{3}{4}\text{ m s}^{-1}.$$

After $t = 4$ s, the body is at rest *i.e.*, $v = 0$

$\therefore$ Impulse on the body $= m(v - u)$

$$= 2\text{ kg}\left(0 - \frac{3}{4}\text{ m s}^{-1}\right) = -\frac{3}{2}\text{ kg m s}^{-1}$$

31. (b) : In series, potential difference $\propto R$

When only S_1 is closed, $V_1 = \frac{3}{4}\varepsilon = 0.75\,\varepsilon$

When only S_2 is closed, $V_2 = \frac{6}{7}\varepsilon = 0.86\,\varepsilon$

When both S_1 and S_2 are closed, combined resistance of $6R$ and $3R$ is $2R$

$$\therefore \quad V_3 = \left(\frac{2}{3}\right)\varepsilon = 0.67\,\varepsilon \qquad \therefore \quad V_2 > V_1 > V_3$$

32. (c) : Potential energy of body on the surface of planet

$$U_S = -\frac{GMm}{R}$$

where M is the mass and R is the radius of the planet and m is the mass of the body.

Potential energy of body at the centre of planet,

$$U_C = -\frac{3GMm}{2R}$$

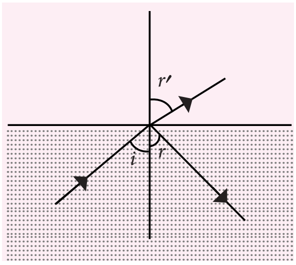
If v is the velocity acquired by body while reaching at the centre of planet then

$$\frac{1}{2}mv^2 = U_S - U_C = -\frac{GMm}{R} + \frac{3}{2}\frac{GMm}{R}$$

or $v^2 = \frac{GM}{R} = Rg = \frac{2Rg}{2}$ $\left(\because g = \frac{GM}{R^2}\right)$

or $v = \frac{\sqrt{2gR}}{\sqrt{2}} = \frac{v_e}{\sqrt{2}}$ $\left(\because v_e = \sqrt{2gR}\right)$

33. (c) : $\mu = \frac{\sin r'}{\sin i}$



But $r' + r = 90°$

or $r' = 90° - r$

$\therefore$ $\mu = \frac{\sin r'}{\sin i} = \frac{\cos i}{\sin i}$

or $\frac{1}{\sin i_c} = \frac{1}{\tan i}$

or $i_c = \sin^{-1}(\tan i)$

34. (a) : As $\frac{Q_2}{Q_1} = \frac{T_2}{T_1} \therefore \frac{Q_2}{6\times 10^4} = \frac{127+273}{227+273} = \frac{400}{500}$

$Q_2 = \frac{4}{5} \times 6 \times 10^4 = 4.8 \times 10^4$ cal

$\therefore$ $W = Q_1 - Q_2 = 6 \times 10^4 - 4.8 \times 10^4 = 1.2 \times 10^4$ cal.

35. (d) : According to Coulomb's law,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$$

Suppose force between the charges is same when charges are r' distance apart in dielectric

$\therefore$ $F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{Kr^2} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r'^2}$

Thus distance r' of dielectric is equivalent to $\sqrt{K}r$ distance of air.

In the given situation, force between the charge would be

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{\left(\frac{r}{2}+\sqrt{4}\frac{r}{2}\right)^2} = \frac{4}{9}\times\frac{q^2}{4\pi\varepsilon_0 r^2} \Rightarrow F' = \frac{4}{9}F$$

36. (b) : $Q = \frac{V^2}{R}$. But $R = \frac{\rho l}{\pi r^2}$. Therefore, $Q = \left(\frac{\pi V^2}{\rho}\right)\frac{r^2}{l}$

Q is doubled if both l and r are doubled.

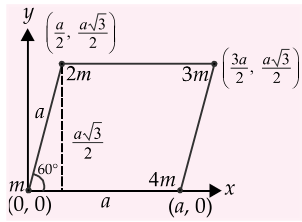
37. (a) : During the growth of current in LR circuit is given by,

$$I = \frac{\varepsilon_0}{R}\left(1 - e^{-\frac{R}{L}t}\right) = \frac{5}{5}\left(1 - e^{-\frac{5}{10}\times 2}\right) = (1 - e^{-1}).$$

38. (b) : $x_{CM} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + m_4x_4}{m_1 + m_2 + m_3 + m_4}$

$$= \frac{(m\times 0) + \left(2m\times\frac{a}{2}\right) + \left(3m\times\frac{3a}{2}\right) + (4m\times a)}{m + 2m + 3m + 4m}$$

$$= \frac{0 + ma + 4.5ma + 4ma}{10m} = \frac{9.5ma}{10m} = 0.95a$$



$$y_{CM} = \frac{m_1y_1 + m_2y_2 + m_3y_3 + m_4y_4}{m_1 + m_2 + m_3 + m_4}$$

$$= \frac{(m\times 0) + (2m\times\frac{a\sqrt{3}}{2}) + (3m\times\frac{a\sqrt{3}}{2}) + (4m\times 0)}{m + 2m + 3m + 4m}$$

$$= \frac{0 + \sqrt{3}am + \sqrt{3}\times 1.5ma + 0}{10m} = \frac{2.5\sqrt{3}am}{10m} = \frac{\sqrt{3}a}{4}$$

$\therefore$ Centre of mass is at $\left(0.95a, \frac{\sqrt{3}a}{4}\right)$.

39. (c) : $\frac{\Delta V}{V} = \frac{\Delta\left(\frac{4\pi}{3}R^3\right)}{\frac{4\pi}{3}R^3} = \frac{3R^2\Delta R}{R^3} = \frac{3\Delta R}{R}$

Thus, $\frac{\Delta R}{R} = \frac{1}{3}\left(\frac{\Delta V}{V}\right) = \frac{1}{3}\%$

As $I = \left(\frac{2}{5}MR^2\right), \frac{\Delta I}{I} = \frac{\Delta\left(\frac{2}{5}MR^2\right)}{\frac{2}{5}MR^2}$

$$= \frac{2R\Delta R}{R^2} = 2\left(\frac{\Delta R}{R}\right) = 2\times\frac{1}{3}\% = 0.67\%$$

Moment of inertia of the system increases by 0.67%. Now, as no external torque is acting on the system, angular momentum of the system will be conserved.

$\therefore$ Angular speed of the body decreases by 0.67%.

40. (c) : Let N be the number of nuclei at any time t.

Then, $\frac{dN}{dt} = 200 - \lambda N$

$\therefore$ $\int_0^N \frac{dN}{200 - \lambda N} = \int_0^t dt$ or $N = \frac{200}{\lambda}\left(1 - e^{-\lambda t}\right)$

Given : $N = 100$ and $\lambda = 1\ s^{-1}$

$\therefore$ $e^{-t} = \left(\frac{1}{2}\right)$ $\therefore t = \ln 2$ s

PRACTICE PAPER AIIMS

Exam on 28^{th} May

1. The diameter of a flywheel is increased by 1%. Increase in its moment of inertia about the central axis is
(a) 1% (b) 0.5% (c) 2% (d) 4%

2. A lamp in which 10 A current can flow at 15 V, is connected with an alternating source of peak voltage 220 V. The frequency of source is 50 Hz. The inductance of choke coil required to light the bulb is
(a) 0.07 H (b) 0.14 H (c) 0.28 H (d) 1.07 H

3. Two projectiles A and B are thrown with velocities v and $\frac{v}{2}$ respectively. They have the same range. If B is thrown at an angle of 15° to the horizontal, A must have been thrown at an angle
(a) $\sin^{-1}\left(\frac{1}{16}\right)$ (b) $\sin^{-1}\left(\frac{1}{4}\right)$
(c) $2\sin^{-1}\left(\frac{1}{4}\right)$ (d) $\frac{1}{2}\sin^{-1}\left(\frac{1}{8}\right)$

4. An electric dipole is placed at an angle of 60° with an electric field of intensity 10^5 N C^{-1}. It experiences a torque equal to $8\sqrt{3}$ N m. Calculate the charge on the dipole, if the dipole length is 2 cm.
(a) -8×10^3 C (b) 8.54×10^{-4} C
(c) 8×10^{-3} C (d) -0.85×10^{-6} C

5. If the radius of the earth were increased by a factor of 2 keeping the mass constant by what factor would its density have to be changed to keep the g same?
(a) $\frac{1}{8}$ (b) 4
(c) $\frac{1}{2}$ (d) $\frac{1}{4}$

6. In a container having water filled upto a height h, a hole is made in the bottom. The velocity of water flowing out of the hole is
(a) independent of h (b) proportional to h^3
(c) proportional to $\sqrt{h}$ (d) proportional to h^2

7. A fish looking up through the water sees the out side world contained in a circular horizon. If the refractive index of water is $\frac{4}{3}$ and the fish is 12 cm below the surface the radius of circle is
(a) $\frac{12 \times 3}{\sqrt{7}}$ cm (b) $12 \times \sqrt{\frac{5}{3}}$ cm
(c) $12 \times 3 \times \sqrt{7}$ cm (d) $12 \times 3 \times \sqrt{5}$ cm

8. If there is a positive error of 50% in the measurement of speed of a body due to fault in speedometer, then the error in the measurement of kinetic energy is
(a) 25% (b) 50% (c) 100% (d) 125%

9. 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 additional charge that flows now from battery to the capacitor is
(a) 120 μC (b) 600 μC
(c) 480 μC (d) 240 μC

10. The upper end of a wire of radius 4 mm and length 100 cm is clamped and its lower end is twisted through an angle of 30°. The angle of shear is
(a) 12° (b) 1.2° (c) 0.12° (d) 0.012°

11. The wavelength of X-rays lies between
(a) maximum to finite limits
(b) minimum to certain limits
(c) minimum to infinite limits
(d) infinite to finite limits.

12. An elevator and its load have a total mass of 800 kg. The elevator is originally moving downwards at 10 m s^{-1}, it slows down to stop with constant acceleration in a distance of 25 m. Find the tension T in the supporting cable while the elevator is being brought to rest. (Take g = 10 m s^{-2})

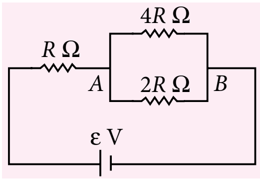
(a) 8000 N (b) 1600 N
(c) 9600 N (d) 6400 N

13. A circular copper disc 10 cm in diameter rotates at 1800 rev per min about an axis through its centre and at right angles to the disc. A uniform field of induction B of 1 Wb m^{-2} is perpendicular to disc. What potential difference is developed between the axis of the disc and the rim?
(a) 0.023 V (b) 0.23 V
(c) 23 V (d) 230 V

14. Let W be the work done when a bubble of volume V is formed in a given soap solution. Work required to be done to form a bubble of volume $2V$ is
(a) W (b) $2W$ (c) $2^{1/3}\,W$ (d) $4^{1/3}\,W$

15. If the magnitudes of scalar and vector products of two vectors are 6 and $6\sqrt{3}$ respectively, then the angle between two vectors is
(a) 15° (b) 30° (c) 60° (d) 75°

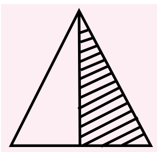
16. As shown in figure the current flowing through the $2R\ \Omega$ resistor is



(a) $2\varepsilon/R$
(b) $2\varepsilon/7R$
(c) $\varepsilon/7R$
(d) ε/R

17. Frequency of a particle executing SHM is 10 Hz. The particle is suspended from a vertical spring. At the highest point of its oscillation the spring is unstretched. Maximum speed of the particle is ($g = 10$ m s^{-2})
(a) 2π m s^{-1} (b) π m s^{-1}
(c) $\frac{1}{\pi}$ m s^{-1} (d) $\frac{1}{2\pi}$ m s^{-1}

18. A light ray is incident on a prism in minimum deviation position and suffers a deviation of 34°. If the shaded half of the prism is removed off, then the same ray will suffer a deviation of



(a) 0°
(b) 65°
(c) 17°
(d) 34°

19. A block of mass 10 kg slides down a rough slope which is inclined at 45° to the horizontal. The coefficient of sliding friction is 0.30. When the block has slide 5 m, the work done on the block by the force of friction is nearly
(a) 115 J (b) $-75\sqrt{2}$ J
(c) 321.4 J (d) −321.4 J

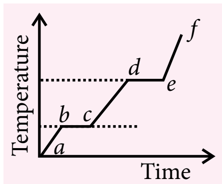
20. A vessel of depth $2d$ cm is half filled with a liquid of refractive index μ_1 and the upper half with a liquid of refractive index μ_2. The apparent depth of the vessel seen perpendicularly is
(a) $2d\left(\frac{1}{\mu_1/\mu_2}\right)$ (b) $2d\left(\frac{1}{\mu_1+\frac{1}{\mu_2}}\right)$
(c) $d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$ (d) $d\left(\frac{\mu_1\mu_2}{\mu+\mu_2}\right)$

21. Work function of a metal is 1 eV. Light of wavelength λ = 3000 Å falls on it. The photo electrons come out with a maximum velocity
(a) 10 m s^{-1} (b) 10^2 m s^{-1}
(c) 10^4 m s^{-1} (d) 10^6 m s^{-1}

22. A particle moves along x-axis as
$$x = 4(t-2) + a(t-2)^2$$
Which of the following is true?
(a) The initial velocity of particle is 4.
(b) The acceleration of particle is $2a$.
(c) The particle is at origin at $t = 0$.
(d) None of these.

23. An electron makes a transition from orbit $n = 4$ to the orbit $n = 2$ of a hydrogen atom. What is the wavelength of the emitted radiations?
(R = Rydberg's constant)
(a) $\frac{16}{4R}$ (b) $\frac{16}{5R}$
(c) $\frac{16}{2R}$ (d) $\frac{16}{3R}$.

24. The following figure represents the temperature versus time plot for a given amount of a substance when heat energy is supplied to it at a fixed rate and at a constant pressure. Which parts of the plot represent a phase change



(a) a to b and e to f
(b) b to c and c to d
(c) d to e and e to f
(d) b to c and d to e

25. A body of mass 4 kg is moving with momentum of 8 kg m s^{-1}. A force of 0.2 N acts on it in the direction of motion of the body for 10 s. The increase in kinetic energy in joule is
(a) 10 (b) 8.5 (c) 4.5 (d) 4

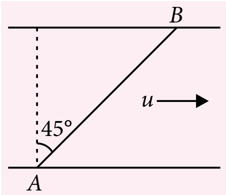
26. For a transistor $\frac{I_C}{I_E} = 0.96$, then current gain for common emitter is

(a) 12 (b) 6 (c) 48 (d) 24

27. A radioactive element has half life period 800 years. After 6400 years what amount of initial radioactive material will remain?

(a) 1/2 (b) 1/16 (c) 1/8 (d) 1/256

28. A man wants to reach point B on the opposite bank of a river flowing at a speed u as shown in figure. What minimum speed relative to water should the man have so that he can reach point B?



(a) $u\sqrt{2}$

(b) $u/\sqrt{2}$

(c) $2u$

(d) $u/2$

29. A magnetising field of 2×10^3 A m^{-1} produces a magnetic flux density of 8π T in an iron rod. The relative permeability of the rod will be

(a) 10^2 (b) 10^0 (c) 10^3 (d) 10^4

30. A train moves towards a stationary observer with speed 34 m s^{-1}. The train sounds a whistle and its frequency registered by the observer is υ_1. If the train's speed is reduced to 17 m s^{-1}, the frequency registered is υ_2. If the speed of sound is 340 m s^{-1} then the ratio υ_1/υ_2 is

(a) 18/19 (b) 1/2 (c) 2 (d) 19/18

31. A TV transmitting tower has height of 160 m. Its covering range, and the height raised to double its covering range, will be respectively

(a) 45 km and 640 m (b) 50 km and 700 m
(c) 40 km and 600 m (d) None of these

32. In an isobaric process of an ideal gas. The ratio of heat supplied and work done by the system is

(a) $\frac{\gamma - 1}{\gamma}$ (b) γ

(c) $\frac{\gamma}{\gamma - 1}$ (d) 1

33. The given truth table is for which logic gate

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

(a) NAND (b) XOR (c) NOR (d) OR.

34. From the top of a tower, a stone is thrown up and reaches the ground in time t_1 = 9 s. A second stone is thrown down with the same speed and reaches the ground in time t_2 = 4 s. A third stone is released from rest and reaches the ground in time t_3, which is equal to

(a) 6.5 s (b) 6.0 s (c) $\frac{5}{36}$ s (d) 65 s

35. A battery of internal resistance r having no load resistance, has an emf ε. What is the observed emf across the terminals of the battery when a load resistance $R = r$ is connected to its terminals?

(a) 2ε (b) ε (c) $\varepsilon/2$ (d) $\varepsilon/4$

36. A string of mass 0.2 kg m^{-1} and length l = 0.6 m is fixed at both ends and stretched such that it has a tension of 80 N. The string vibrates in 3 segments with maximum amplitude of 0.5 cm. The maximum transverse velocity is

(a) 1.57 m s^{-1} (b) 6.28 m s^{-1}
(c) 3.14 m s^{-1} (d) 9.42 m s^{-1}

37. An interference pattern is observed by Young's double slit experiment. If now, the separation between coherent sources is halved and the distance of screen from coherent sources be doubled. The new fringe width

(a) becomes four times (b) remains same
(c) become one fourth (d) becomes double

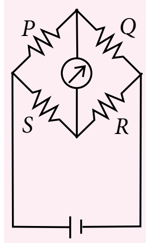
38. A block of mass 2 kg is placed on the floor. The coefficient of static friction is 0.4. If a force of 2.8 N is applied on the block parallel to the floor, the force of friction between the block and the floor is (Take g = 10 m s^{-2})

(a) 2.8 N (b) 8 N (c) 2 N (d) Zero

39. A long solenoid has 80 turns per cm. The current necessary to produce a magnetic field of 20 m T at the end of the solenoid on its axis will be approximately

(a) 4.0 A (b) 3.5 A (c) 3.0 A (d) 2.5 A

40. In the Wheatstone's bridge, P = 2 Ω, Q = 3 Ω, R = 6 Ω and S = 8 Ω. In order to balance the bridge, shunt resistance across S must be



(a) 2 Ω
(b) 3 Ω
(c) 8 Ω
(d) 6 Ω

Directions : In the following questions (41-60), a statement of assertion is followed by a statement of reason. Mark the correct choice as

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

41. Assertion : If dot product and cross product of $\vec{A}$ and $\vec{B}$ are zero, it imply that one of the vector $\vec{A}$ and $\vec{B}$ must be a null vector.
Reason : Null vector is a vector with zero magnitude.

42. Assertion : A safe turn by a cyclist should neither be fast nor sharp.
Reason : The bending angle from the vertical would decrease with increase in velocity.

43. Assertion : It is possible to eliminate dispersion by combining two prism of same refracting angles but of different materials.
Reason : The angular dispersion does not depends on refractive index of the material of the prism.

44. Assertion : Stopping potential depends upon the frequency of incident light but is independent of the intensity of the light.
Reason : The maximum kinetic energy of the photoelectrons is proportional to stopping potential.

45. Assertion : Number of significant figure in 0.005 is one and that in 0.500 is three.
Reason : Zeros are not significant figures.

46. Assertion : Friction is a self adjusting force.
Reason : Friction does not depend upon mass of the body.

47. Assertion : If the whole apparatus of Young's experiment is immersed in liquid, the fringe width will decrease.
Reason : The wavelength of light in water is more than that of air.

48. Assertion : Mean free path of gas molecules varies inversely as density of the gas.
Reason : Mean free path of gas molecules is defined as the average distance travelled by a molecule between two successive collisions.

49. Assertion : The current gain in common emitter transistor is always less than one.
Reason : In all kind of transistor, collector current is equal to sum of base current and emitter current.

50. Assertion : When height of a tube is less than liquid rise in the capillary tube, the liquid does not overflow.
Reason : Product of radius of meniscus and height of liquid in the capillary tube always remain constant.

51. Assertion : The coefficient of restitution for a perfectly elastic collision is equal to one.
Reason : In perfectly elastic collision, kinetic energy before and after the collision remains conserved.

52. Assertion : Anode of Coolidge tube gets heated up at the time of emission of X-rays.
Reason : The anode of Coolidge tube is made of a material of high melting point.

53. Assertion : Activity of 10^8 undecayed radioactive nuclei of half life of 50 days is equal to that of 1.2×10^8 number of undecayed nuclei of some other material with half life of 60 days.
Reason : Activity of radioactive material is proportional to half life.

54. Assertion : When a girl sitting on a swing stands up, the periodic time of the swing will increase.
Reason : In standing position of girl, the length of the swing will increase.

55. Assertion : Beats can also be observed by two light sources as in sound.
Reason : Light sources have constant phase difference.

56. Assertion : Capacity of a parallel plate capacitor increases when distance between the plates is decreased.
Reason : Capacitance of capacitor is inversely proportional to distance between them.

57. Assertion : The eye is most sensitive for the light of frequency 5.36×10^{14} Hz.
Reason : The frequency of light is directly proportional to wavelength of light.

58. Assertion : The ratio of specific heat of a gas at constant pressure and specific heat at constant volume for a diatomic gas is more than that for a monatomic gas.
Reason : The molecules of a monatomic gas have more degree of freedom than those of a diatomic gas.

59. **Assertion :** NAND or NOR gates are called digital building blocks.
Reason : The repeated use of NAND (or NOR) gates can produce all the basic or complicated gates.

60. **Assertion :** Identical springs of steel and copper are equally stretched. More work will be done on the steel spring.
Reason : Steel is more elastic than copper.

SOLUTIONS

1. **(c) :** Moment of inertia is given as
$I = MR^2$ $\therefore$ $\log I = \log M + 2\log R$.

Differentiating, we get $\dfrac{dI}{I} = 0 + 2\dfrac{dR}{R}$

$$\therefore \quad \frac{dI}{I}\times 100 = 2\left(\frac{dR}{R}\right)\times 100 = 2\times\frac{1}{100}\times 100 = 2\%$$

2. **(a) :** Here resistance R is given as

$$R = \frac{\varepsilon_v}{I} = \frac{15}{10} = 1.5\,\Omega$$

Impedance $Z = \dfrac{\varepsilon_v}{I_v} = \dfrac{220}{10} = 22\,\Omega$

As, $R^2 + X_L^2 = Z^2$

$$\therefore \quad X_L = \sqrt{Z^2 - R^2} = \sqrt{22^2 - 1.5^2} = 21.94\,\Omega$$

$$X_L = \omega L = 2\pi\upsilon L = 2\pi \times 50L = 100\pi L$$

$$L = \frac{X_L}{100\pi} = \frac{21.94}{100\pi} = 0.07\text{ H}$$

3. **(d):** Range is given as, $R = \dfrac{u^2 \sin 2\theta}{g}$

As range is same for A and B

$\therefore$ $R_A = R_B$

$$v^2 \sin 2\theta = \left(\frac{v}{2}\right)^2 \sin 30° = \frac{v^2}{8};\ \sin 2\theta = \frac{1}{8}$$

or $\quad 2\theta = \sin^{-1}\left(\dfrac{1}{8}\right)$; $\therefore$ $\theta = \dfrac{1}{2}\sin^{-1}\left(\dfrac{1}{8}\right)$

4. **(c) :** $\tau = pE\sin\theta = q\,(2a)\,E\sin\theta$

$$q = \frac{\tau}{2aE\sin\theta} = \frac{8\sqrt{3}}{2\times 10^{-2}\times 10^{5}\times \sin 60°}$$

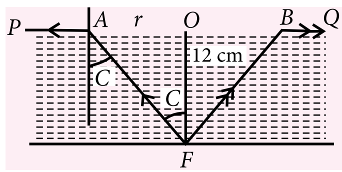
$$q = \frac{8\sqrt{3}}{2\times 10^{3}\times\sqrt{3}/2} = 8\times 10^{-3}\text{C}$$

5. **(c) :** $g = \dfrac{GM}{R^2} = \dfrac{G\left(\frac{4}{3}\pi R^3\rho\right)}{R^2} = \dfrac{4}{3}\pi G\rho R$

R is increased by a factor of 2 *i.e.*, to keep the value of g to be constant the value of density (ρ) has to be changed by a factor $\dfrac{1}{2}$.

6. **(c) :** From Torricelli's theorem, $v = \sqrt{2gh}$ or $v \propto \sqrt{h}$

7. **(a) :** The fish can see along FAP and FBQ to cover a circular horizon of radius $r = AO = BO$



Ray travels from water to air,

$\therefore$ ${}^a\mu_w = 4/3$

also ${}^a\mu_w = \dfrac{1}{\sin C}$

$\therefore$ $\sin C = \dfrac{3}{4}$ and $\tan C = \dfrac{3}{\sqrt{7}}$

By figure, $\dfrac{r}{12} = \tan C$

$\therefore$ $\dfrac{r}{12} = \dfrac{3}{\sqrt{7}}$ or $r = \dfrac{12\times 3}{\sqrt{7}}$ cm

8. **(d):** Kinetic energy, $\text{KE} = \dfrac{1}{2}mv^2$

$$\therefore \quad \frac{\Delta\text{KE}}{\text{KE}}\times 100 = \frac{v_f^2 - v_i^2}{v_i^2}\times 100$$

$$= [(1.5)^2 - 1] \times 100 = 125\%$$

9. **(c) :** $q_1 = C_1V = 10 \times 12 = 120\ \mu$C
$q_2 = C_2V = KC_1 \times V = 5 \times 10 \times 12 = 600\ \mu$C
The additional charge that flows from battery
$= q_2 - q_1$
$= 600\ \mu\text{C} - 120\ \mu\text{C} = 480\ \mu$C

10. **(c) :** $\theta = 30° = \dfrac{\pi}{6}$ rad

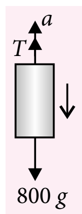
$\Delta x = r\theta = (0.4)\,(\pi/6)$ cm

Angle of shear = shearing strain = $\dfrac{\Delta x}{L}$

$$= \frac{(0.4)(\pi/6)}{100}\text{rad} == \frac{(0.4)(\pi/6)}{100}\times\frac{180°}{\pi} = 0.12°$$

11. **(b)**

12. **(c) :** As the elevator is going down with decreasing speed, so acceleration is upward direction.



$T - 800\,g = 800\,a$
$T = 800\,(g + a)$
From $v^2 = u^2 - 2as$; $0 = 10^2 - 50a$
$\therefore$ $a = 2\text{ m s}^{-2}$
So, $T = 800\,(10 + 2)$
$\therefore$ $T = 9600$ N

13. (b): Here, $l = r = 5$ cm $= 5 \times 10^{-2}$ m, $B = 1$ Wb m^{-2}

$$\omega = 2\pi\left(\frac{1800}{60}\right) \text{rad s}^{-1} = 60\pi \text{ rad s}^{-1}$$

Potential difference $= \frac{1}{2}Bl^2\omega =$

$$= \frac{1}{2} \times 1 \times (5 \times 10^{-2})^2 \times 60\pi = 0.23 \text{ V}$$

14. (d): $\frac{V'}{V} = \frac{(4\pi/3)R^3}{(4\pi/3)r^3} = \frac{2V}{V} = 2\,;\ \frac{R}{r} = 2^{1/3}$

Surface area of a bubble $= 2 \times 4\pi R^2 = 8\pi R^2$

or $\quad \frac{W'}{W} = \frac{T \times (8\pi R^2)}{T \times (8\pi r^2)} = \frac{R^2}{r^2} = (2^{1/3})^2$

or $\quad W' = 4^{1/3}\ W$

15. (c): Given, $\vec{A} \cdot \vec{B} = AB \cos\theta = 6$

and $|\vec{A} \times \vec{B}| = AB \sin\theta = 6\sqrt{3}$

or $\quad \frac{AB\sin\theta}{AB\cos\theta} = \frac{6\sqrt{3}}{6} = \sqrt{3}$

or $\quad \tan\theta = \sqrt{3} \Rightarrow \theta = 60°$

16. (b): Total resistance of circuit $= R + \frac{4R \times 2R}{4R + 2R}$

$$= R + \frac{4}{3}R = \frac{7}{3}R$$

Current in circuit, $I = \frac{\varepsilon}{(7/3)R} = \frac{3\varepsilon}{7R}$

Potential difference across A and B

$$= I \times \frac{4}{3}R = \frac{3\varepsilon}{7R} \times \frac{4}{3}R = \frac{4}{7}\varepsilon$$

$\therefore$ Current through resistance $2R = \frac{(4/7)\varepsilon}{2R} = \frac{2\varepsilon}{7R}$

17. (d): Mean position of the particle is $\frac{mg}{k}$ distance below the unstretched position of spring. Therefore, amplitude of oscillation is $A = \frac{mg}{k}$.

$$\omega = \sqrt{\frac{k}{m}} = 2\pi\upsilon = 20\pi \qquad (\upsilon = 10 \text{ Hz})$$

$\therefore \quad \frac{m}{k} = \frac{1}{400\pi^2}$

Therefore, the maximum speed of particle will be

$$v_{max} = A\omega = \left(\frac{g}{400\pi^2}\right)(20\pi) = \frac{1}{2\pi} \text{ m s}^{-1}$$

18. (c): For a prism, $\delta = A(\mu - 1)$

After removing the half portion, A is reduced to $A/2$.

$\therefore \quad \frac{\delta}{\delta'} = \frac{A\,(\mu - 1)}{A'\,(\mu - 1)} = \frac{A}{A'}$

or $\quad \delta' = \frac{A'}{A}\,\delta = \frac{A}{2A} \times 34° = \frac{34°}{2} = 17°$

19. (b): As, $F = \mu mg \cos\theta$

or $\quad F = 0.30 \times 10 \times 10 \cos 45° = \frac{30}{\sqrt{2}}$ N

$$W = F \times d \times \cos 180° = -\frac{30}{\sqrt{2}} \times 5 = -75\sqrt{2} \text{ J}$$

This work is negative because F and d are oppositely directed.

20. (c): Apparent depth $= \frac{\text{Real depth}}{\mu}$

$\therefore \quad$ For first liquid $d_1 = \frac{d}{\mu_1}$;

For second liquid $d_2 = \frac{d}{\mu_2}$

$\therefore \quad$ Total Apparent depth $= d_1 + d_2 = d\left(\frac{1}{\mu_1} + \frac{1}{\mu_2}\right)$

21. (d): $h\upsilon = \phi + \frac{1}{2}mv^2$ or $\frac{hc}{\lambda} = \phi + \frac{1}{2}mv^2$

$$\therefore \quad \frac{(6.6 \times 10^{-34})(3 \times 10^8)}{3000 \times 10^{-10}} = (1.6 \times 10^{-19}) + \frac{1}{2} \times (9.1 \times 10^{-31})v^2$$

On solving we get $v \cong 10^6$ m s^{-1}

22. (b): Given, $x = 4(t - 2) + a(t - 2)^2$

$$v = \frac{dx}{dt} = 4 + 2a(t - 2)$$

At $t = 0$, $\quad v = 4(1 - a)$

Acceleration $= \frac{d^2x}{dt^2} = 2a$

23. (d): Transition of hydrogen atom from orbit $n_2 = 4$ to $n_1 = 2$

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16}$$

$\Rightarrow \quad \lambda = 16/3R$

24. (d): During phase change, the temperature remains constant and the supplied heat is utilized in changing intramolecular distance in the substance. Hence b to c and d to e represent the phase change.

25. (c): Initially, $4u = 8 \Rightarrow u = 2$ m s^{-1}

Now, $mv - mu = Ft\,;\ mv - 8 = 0.2 \times 10$

or $\quad v = 5/2$ m s^{-1}

Increase in KE = $\frac{1}{2}m(v^2-u^2)$

$$=\frac{1}{2}\times 4\left[\left(\frac{5}{2}\right)^2-(2)^2\right]=4.5\text{ J}$$

26. (d): $\beta=\frac{I_C}{I_B}=\frac{I_C}{I_E-I_C}$

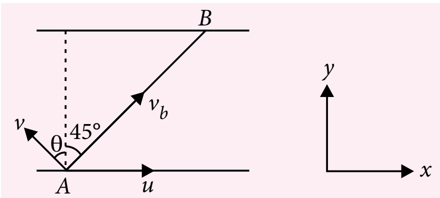
Now, $\frac{I_E}{I_C}=\frac{1}{0.96}$. $\therefore\ \frac{I_E-I_C}{I_C}=\frac{1}{0.96}-1=\frac{0.04}{0.96}$

$\therefore\quad \beta=\frac{0.96}{0.04}=24$

27. (d): Number of half lives, $n=\frac{t}{T}=\frac{6400}{800}=8$

$$\frac{N}{N_0}=\left(\frac{1}{2}\right)^8=\frac{1}{256}\Rightarrow N=\frac{N_0}{256}$$

28. (b): Let v be the speed of the man in still water.



Resultant of v and u should be along AB. Components of v_b along x and y directions are,

$v_x = u - v\sin\theta$ and $v_y = v\cos\theta$

Further, $\tan 45^\circ=\frac{v_y}{v_x}$ or $1=\frac{v\cos\theta}{u-v\sin\theta}$

$$v=\frac{u}{\sin\theta+\cos\theta}=\frac{u}{\sqrt{2}\sin(\theta+45^\circ)}$$

v is minimum if,

$\theta + 45^\circ = 90^\circ$ or $\theta = 45^\circ$ $\therefore$ $v_{min}=\frac{u}{\sqrt{2}}$

29. (d): $\mu_r=\frac{\mu}{\mu_0}=\frac{\mu H}{\mu_0 H}=\frac{B}{\mu_0 H}$

$$=\frac{8\pi}{(4\pi\times10^{-7})(2\times10^3)}=10^4$$

30. (d): $\upsilon_1=\upsilon\left(\frac{v}{v-v_s}\right)=\upsilon\left(\frac{340}{340-34}\right)=\upsilon\left(\frac{340}{306}\right)$

and $\upsilon_2=\upsilon\left(\frac{340}{340-17}\right)=\upsilon\left(\frac{340}{323}\right)$

$\therefore\quad \frac{\upsilon_1}{\upsilon_2}=\frac{323}{306}=\frac{19}{18}$

31. (a): Here R = radius of earth = 6.4×10^6 m

$\therefore$ Covering range $d=\sqrt{2\times160\times6.4\times10^6}$

$d = 45$ km

For double the covering range,

$$\frac{d}{2d}=\sqrt{\frac{160}{h_2}};\ \frac{d}{2d}=\sqrt{\frac{160}{h_2}}$$

or $h_2 = 4\times 160$ m or $h_2 = 640$ m

32. (c): An isobaric process is that in which pressure remains constant work done = PdV.

By first law of thermodynamics

$dQ = dU + dW$ or $\frac{dQ}{dW}=\frac{dU}{dW}+1$ ...(i)

dU = internal energy = $C_V\,dT$ ...(ii)

Since $C_P - C_V = R$ and $C_P/C_V = \gamma$

$\therefore\quad \gamma C_V - C_V = R$ or $C_V=\frac{R}{(\gamma-1)}$ ...(iii)

From (ii) and (iii),

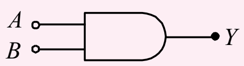
$\therefore\quad dU=\frac{R}{\gamma-1}dT$ ...(iv)

Also, $PV = RT$ or $PdV = RdT$

$\therefore\quad dU=\frac{PdV}{\gamma-1}=\frac{dW}{\gamma-1}$

So, $\frac{dQ}{dW}=\frac{dW}{(\gamma-1)}\frac{1}{dW}+1=\frac{1}{(\gamma-1)}+1=\frac{\gamma}{\gamma-1}$

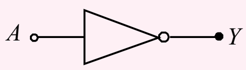
33. (a): NAND gate is a combination of AND and NOT gate.



AND gate

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

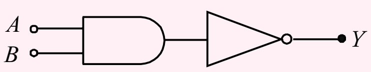
Truth table of AND gate



NOT gate

A	Y
0	1
1	0

Truth table of NOT gate



NAND gate

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

Truth table of NAND gate

Hence the given truth table is of a NAND gate.

34. (b): Let u be the initial upward velocity of the stone from the point A and h be the height of the tower. Taking the downward motion of the first stone from A to the ground, we have

$h=-ut_1+\frac{1}{2}gt_1^2$ ...(i)

Taking the downward motion of the second stone from A to the ground, we have

$h=ut_2+\frac{1}{2}gt_2^2$ ...(ii)

Multiplying eqn. (i) t_2 and eqn. (ii) by t_1 and adding, we get

$$h(t_1+t_2)=\frac{1}{2}gt_1t_2(t_1+t_2)$$

So, $h=\frac{1}{2}gt_1t_2$ ...(iii)

For falls under gravity from the top of the tower

$$h=\frac{1}{2}gt_3^2 \quad \text{...(iv)}$$

From eqs. (iii) and (iv),

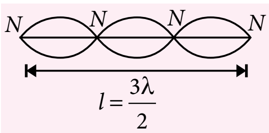
$$t_3^2=t_1t_2$$

or $t_3=\sqrt{t_1t_2}=\sqrt{9\times4}=6\text{ s}$

35. (c) : $V=\varepsilon-Ir=\varepsilon-\left(\frac{\varepsilon}{R+r}\right)r$

$$=\varepsilon-\frac{\varepsilon}{2}=\frac{\varepsilon}{2} \qquad (\because R=r)$$

36. (a) : $l=\frac{3\lambda}{2}$



$$\lambda=\frac{2l}{3}=\frac{(2)(0.6)}{3}\text{ m}=0.4\text{ m}$$

$$v=\sqrt{\frac{T}{\mu}}=\sqrt{\frac{80}{0.2}}=20\text{ m s}^{-1}$$

$$\upsilon=\frac{v}{\lambda}=\frac{20}{0.4}\text{ Hz}=50\text{ Hz}$$

$v_{max}=a_{max}\omega$

$$=(0.5\times10^{-2})\,(2\pi)\,(50)=\frac{\pi}{2}=1.57\text{ m s}^{-1}$$

37. (a) : Fringe width $\beta=\frac{D\lambda}{d}$

$$\therefore\ \frac{\beta_1}{\beta_2}=\frac{D_1}{d_1}\times\frac{d_2}{D_2}=\frac{D_1}{d_1}\times\frac{d_1}{2\times2D_1}=\frac{1}{4}$$

or $\beta_2=4\beta_1=4$ times original fringe width

38. (a) : Minimum force required to move the block

$=\mu f=\mu mg=0.4\times2\times10=8$ N

Since the force applied is only 2.8 N, the block fails to move and static friction = applied force = 2.8 N.

39. (a) : Here, $n=80\times100$ turns per metre;

$B=20\times10^{-3}$ T

$$B=\frac{\mu_0nI}{2}\ \text{ or }\ I=\frac{2B}{\mu_0n}$$

$$=\frac{2\times20\times10^{-3}}{(4\pi\times10^{-7})\times(80\times100)}\approx4\text{ A}$$

40. (c) : For balanced bridge,

$$\frac{P}{Q}=\frac{S'}{R}\quad\therefore\ \frac{2}{3}=\frac{S'}{6}\ \text{ or }\ S'=4\ \Omega$$

Let the shunt resistance across S is x

$$\therefore\ \frac{1}{S'}=\frac{1}{S}+\frac{1}{x}\ \text{ or }\ \frac{1}{4}=\frac{1}{8}+\frac{1}{x}\ \text{ or }\ x=8\ \Omega$$

41. (b): Both assertion and reason are true but reason is not the correct explanation of assertion.

$$\vec{A}\cdot\vec{B}=|\vec{A}||\vec{B}|\cos\theta=0$$

$$\vec{A}\times\vec{B}=|\vec{A}||\vec{B}|\sin\theta=0$$

If $\vec{A}$ and $\vec{B}$ are not null vectors than it follows that $\sin\theta$ and $\cos\theta$ both should be zero simultaneously. But it cannot be possible so it is essential either $\vec{A}=\vec{0}$ or $\vec{B}=\vec{0}$.

42. (c) : Assertion is true but reason is false.

During a turn $\tan\theta=\frac{v^2}{rg}$, where θ is angle of bending with vertical, when v is large and r is small, $\tan\theta$ increases. Therefore, as θ increases, so chances of skidding increase.

Thus for a safe turn, θ should be small, for which v should be small and r should be large, *i.e.*, turning should be at a slow speed and along a track of larger radius.

43. (d): Both assertion and reason are false.

For a prism of small angle A, the angular dispersion produced = $(\mu_v-\mu_R)A$. This can be cancelled by a second prism of angle A' made of different material such that $(\mu'_v-\mu'_R)A'=(\mu_v-\mu_R)A$

If only $A=A'$, then the dispersion produced by one prism cannot be cancelled by the dispersion produced by the other prism because, $(\mu'_v-\mu'_R)A'=(\mu_v-\mu_R)A$ for different materials. Therefore in order to eliminate dispersion by combining two prism they should have same refracting angle and made of same material.

44. (b): Both assertion and reason are true but reason is not the correct explanation of assertion.

Stopping potential is a measure of maximum kinetic energy of emitted photoelectron ($eV_0=\text{KE}_{max}$) and KE_{max} depends upon the frequency of incident light but is independent of intensity.

45. (c) : Assertion is true but reason is false.

In a number less than one, zeros between the decimal point and first non zero digit are not significant. But zeros to the right of last non zero digit are significant.

46. (d): Both assertion and reason are false.

Only static friction is a self adjusting force. This is because force of static friction is equal and opposite to applied force (so long as actual motion does not start). Frictional force = μmg, *i.e.*, friction depends on mass.

47. (c) : Assertion is true but reason is false.
On immersing the apparatus in water, the wavelength of light decreases $\left(\lambda' = \frac{\lambda}{\mu}\right)$, Hence it follows from the expression of fringe width $\left(\beta = \frac{D\lambda}{d}\right)$, that when apparatus is immersed in a liquid, the fringe width will decrease. As $\mu \propto 1/\lambda$ and refractive index of water is greater than air, therefore wavelength of light in water is smaller than wavelength in air.

48. (b): Both assertion and reason are true but reason is not the correct explanation of assertion.
Mean free path of molecules is given by $\lambda = \frac{1}{\sqrt{2}n\pi d^2}$,
where n is number of molecules per unit volume, d is diameter of molecules. From this $n = \frac{N}{V} = \frac{N}{m}\rho$.
Therefore $\lambda \propto 1/\rho$, mean free path is inversely proportional to the density of gas molecules.

49. (d): Both assertion and reason are false.

50. (a) : Both assertion and reason are true and reason is the correct explanation of assertion.

51. (b): Both assertion and reason are true but reason is not the correct explanation of assertion.
According to definition of coefficient of restitution,

$$e = -\frac{\text{velocity of separation}}{\text{velocity of approach}}$$

For an elastic collision,
velocity of separation = – velocity of approach
$\therefore$ $e = 1$

52. (b): Both assertion and reason are true but reason is not the correct explanation of assertion.
When fast moving electrons strike the atoms of the target, then most of their kinetic energy is used in increasing the thermal agitation of the atoms of the target and only a small part is radiated in the form of X-rays. So the temperature of the target rises.

53. (c) : Assertion is true but reason is false.

$$\text{Activity} = -\frac{dN}{dt} = \lambda N = \frac{0.693N}{T_{1/2}}$$

Here, $\frac{N_1}{T_{1/2}} = \frac{N_2}{T_{1/2}} = 2\times 10^6$ nuclei day^{-1}

Activity of radioactive material is proportional to $1/T_{1/2}$, and not to $T_{1/2}$.

54. (d): Both assertion and reason are false.
When a girl stands up on a swing, the position of centre of gravity of girl is raised up. Due to which the effective length of pendulum decreases, hence the time-period of swing decreases and becomes $T \propto \sqrt{l}$.

55. (d): Both assertion and reason are false.
As emission of light from atom is a random and rapid phenomenon. The phase at a point due to two independent light source will change rapidly and randomly. Therefore, instead of beats, we shall get uniform intensity. However if light sources are LASER beams of nearly equal frequencies, it may possible to observe the phenomenon of beats in light.

56. (a) : Both assertion and reason are true and reason is the correct explanation of assertion.

57. (c) : Assertion is true but reason is false.
Cones in the retina of the human eye are most sensitive for radiation of wavelength
$\lambda = 5600 \times 10^{-10}$ m. Therefore, its frequency

$$\nu = \frac{c}{\lambda} = \frac{3\times 10^8}{5600\times 10^{-10}} = 5.36\times 10^{14}\ \text{Hz}$$

Hence, eye is most sensitive for the light of frequency 5.36×10^{14} Hz.

58. (d): Both assertion and reason are false.
For a monatomic gas, number of degree of freedom, $f = 3$, and for a diatomic gas $f = 5$.

As, $\frac{C_P}{C_V} = \gamma = 1 + \frac{2}{f}$,

$\therefore$ for monoatomic gas, $\frac{C_P}{C_V} = \frac{5}{3} = 1.73$ and

for diatomic gas, $\frac{C_P}{C_V} = \frac{7}{5} = 1.4$,

or, $\left(\frac{C_P}{C_V}\right)_{\text{mono}} > \left(\frac{C_P}{C_V}\right)_{\text{di}}$

59. (a) : Both assertion and reason are true and reason is the correct explanation of assertion.

60. (a) : Both assertion and reason are true and reason is the correct explanation of assertion.

MPP CLASS XII ANSWER KEY

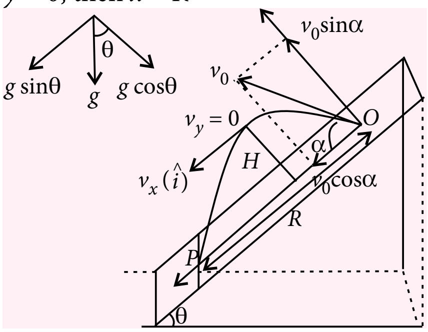
1.	(a)	2.	(d)	3.	(b)	4.	(d)	5.	(b)
6.	(a)	7.	(a)	8.	(b)	9.	(d)	10.	(b)
11.	(d)	12.	(a)	13.	(a)	14.	(c)	15.	(b)
16.	(c)	17.	(d)	18.	(a)	19.	(a)	20.	(c, d)
21.	(b, c, d)	22.	(a,d)	23.	(a,c)	24.	(4)	25.	(2)
26.	(7)	27.	(a)	28.	(b)	29.	(c)	30.	(d)

KEY CONCEPT on PROJECTILE MOTION ON INCLINED PLANE

Continued from last issue ....

Er. Sandip Prasad*

- **Range (R) :** Displacement covered by the projectile along x-axis during its time of flight is called range. It is equal to $OP = R$.
  When $y = 0$, then $x = R$



For the motion along x-axis in the interval O-P:

$u_x = v_0\cos\alpha$, $a_x = g\sin\theta$ and $t = T = \dfrac{2v_0\sin\alpha}{g\cos\theta}$

Applying kinematic equation along the x-axis:

As, $s_x = u_x t + \frac{1}{2}a_x t^2$ $\qquad(\because s_x = R)$

$$\therefore \quad R = v_0\cos\alpha T + \frac{1}{2}g\sin\theta\cdot T^2$$

$$\text{or} \quad R = T\left[v_0\cos\alpha + \frac{1}{2}g\sin\theta\cdot T\right]$$

$$= T\left[v_0\cos\alpha + \frac{1}{2}\cdot g\cdot\sin\theta\cdot\frac{2v_0\sin\alpha}{g\cos\theta}\right]$$

$$= v_0 T\left[\cos\alpha + \frac{\sin\alpha\cdot\sin\theta}{\cos\theta}\right]$$

$$\therefore \quad R = \frac{2v_0^2\sin\alpha\cdot\cos(\theta-\alpha)}{g\cos^2\theta}$$

Condition for the maximum range(R_{max}):

The range, $\quad R = \dfrac{2v_0^2\sin\alpha\cdot\cos(\theta-\alpha)}{g\cos^2\theta}$

For maximum value of R, $\dfrac{dR}{d\alpha} = 0$

$$\text{or} \quad \frac{d}{d\alpha}\left[\frac{2v_0^2}{g\cos^2\theta}\big(\sin\alpha\cdot\cos(\theta-\alpha)\big)\right] = 0$$

$$\text{or} \quad \frac{2v_0^2}{g\cos^2\theta}\cdot\frac{d}{d\alpha}[\sin\alpha\cdot\cos(\theta-\alpha)] = 0$$

$$\text{or} \quad \frac{d}{d\alpha}[\sin\alpha\cdot\cos(\theta-\alpha)] = 0$$

$$\sin(\theta-\alpha)\cdot\sin\alpha + \cos(\theta-\alpha)\cdot\cos\alpha = 0$$

$$\Rightarrow \cos(\theta - 2\alpha) = 0$$

$$\therefore \quad \theta - 2\alpha = \frac{\pi}{2} \quad\Rightarrow\quad \alpha = \frac{\theta}{2} - \frac{\pi}{4}$$

Hence, the range of the projectile is maximum when it is projected at an angle of $\alpha = \left(\dfrac{\theta}{2} - \dfrac{\pi}{4}\right)$ with the inclined.

The maximum value of the range is given by,

$$R_{max} = \frac{2v_0^2\sin\left(-\frac{\pi}{4}+\frac{\theta}{2}\right)\cdot\cos\left(\theta+\frac{\pi}{4}-\frac{\theta}{2}\right)}{g\cos^2\theta}$$

$$= \frac{v_0^2\left[2\sin\left(\frac{\theta}{2}-\frac{\pi}{4}\right)\cdot\cos\left(\frac{\theta}{2}+\frac{\pi}{4}\right)\right]}{g\cos^2\theta}$$

$$= \frac{v_0^2\left[\sin\left(\frac{\theta}{2}-\frac{\pi}{4}+\frac{\theta}{2}+\frac{\pi}{4}\right)+\sin\left(\frac{\theta}{2}-\frac{\pi}{4}-\frac{\theta}{2}-\frac{\pi}{4}\right)\right]}{g\cos^2\theta}$$

$$= \frac{v_0^2\left[\sin\theta - \sin\left(-\frac{\pi}{2}\right)\right]}{g\cos^2\theta} = \frac{v_0^2\left(\sin\theta + \sin\frac{\pi}{2}\right)}{g\cos^2\theta}$$

$$= \frac{v_0^2(1+\sin\theta)}{g\cos^2\theta} = \frac{v_0^2(1+\sin\theta)}{g(1-\sin^2\theta)}$$

$$= \frac{v_0^2(1+\sin\theta)}{g(1+\sin\theta)(1-\sin\theta)} = \frac{v_0^2}{g(1-\sin\theta)}$$

$$R_{max} = \frac{v_0^2}{g(1-\sin\theta)}$$

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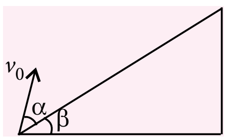
Problem solving steps for problem based on projectile motion in inclined plane

- **Step-I:** Imagine the situation of the problem, draw a picture which shows the object and its possible trajectory.
- **Step-II:** Choose a co-ordinate system. Choice of origin is arbitrary. Generally point of projection is assigned the origin. For calculating range along inclined plane, take positive x-axis parallel to it and y-axis normal to it.
- **Step-III:** Identify the initial position, initial velocity and acceleration. If initial velocity and acceleration are not assigned along x-axis and y-axis, then resolve them into x and y components. Decide on the time interval, for which projectile motion can only include motion under the effect of gravity alone, not throwing or landing. Time interval must be the same for motion along x and y axis.
- **Step-IV:** Examine the horizontal motion (motion along x-axis) and vertical motion (motion along y-axis) separately. Make the list for the known and unknown kinematical physical quantities, one for motion along x-axis and another for motion along y-axis. Make two sets of equations, one for motion along x-axis and another for motion along y-axis. After writing appropriate kinematical equations in component form, solve them. Think for a minute before jumping into the equations. A little planning goes a long way.

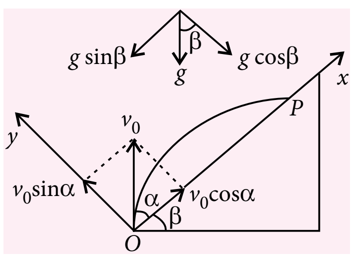
Example-1 : A projectile is thrown at an angle α with an inclined plane of inclination β as shown in figure. Find the relation between α and β if projectile strikes the inclined plane perpendicularly.



Soln.: The motion parallel to the plane (along x-axis)

$u_x = v_0 \cos\alpha$

$a_x = -g \sin\beta$



At the striking point P, it strikes perpendicularly,

$\therefore \; v_x = 0$

Applying kinematics equations along the x-axis:

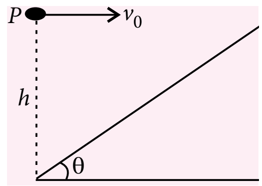
$v_x = u_x + a_x t$

or, $0 = v_0 \cos\alpha + (-g\sin\beta)\cdot T$

or, $v_0\cos\alpha = g\sin\beta \cdot \dfrac{2v_0\sin\alpha}{g\cos\beta}$

or, $2\tan\alpha = \cot\beta$

Example-2 : A stone must be projected horizontally from a point P, which is h meters above the foot of a plane inclined at an angle θ with horizontal as shown in figure. Calculate the velocity $\vec{v}_0$ of the stone so that it may hit the inclined plane perpendicularly.

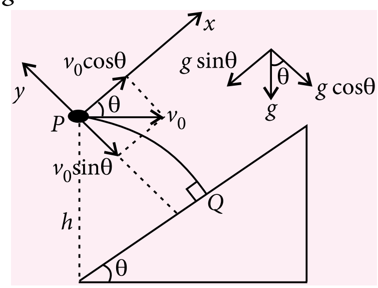


Soln.: In interval P-Q,

The motion parallel to the plane (along x-axis):

$u_x = v_0\cos\theta$

$a_x = -g\sin\theta$



At the striking point Q, it strikes perpendicularly,

$\therefore \; v_x = 0$

As, $v_x = u_x + a_x t$

$\therefore \; 0 = u_x + a_x t$

or, $0 = v_0\cos\theta + (-g\sin\theta).t$

or, $t = \dfrac{v_0\cos\theta}{g\sin\theta}$ ...(i)

The motion perpendicular to the plane (along y-axis)

$u_y = v_0\sin\theta$

$a_y = -g\cos\theta$

$\therefore \; s_y = -h\cos\theta$

As, $s_y = u_y t + \frac{1}{2}a_y t^2$

$\therefore \; -h\cos\theta = -v_0\sin\theta \; t + \frac{1}{2}(-g\cos\theta)t^2$

or $h\cos\theta = v_0\sin\theta t + \frac{1}{2}g\cos\theta t^2$

Putting the value of t, from eqn (i)

or, $h\cos\theta = v_0\sin\theta \times \dfrac{v_0\cos\theta}{g\sin\theta} + \dfrac{1}{2}\cdot g\cdot\cos\theta \times \dfrac{v_0^2\cos^2\theta}{g^2\sin^2\theta}$

or, $h\cos\theta = \dfrac{v_0^2 \cos\theta}{g} + \dfrac{v_0^2 \cos^3\theta}{2g\sin^2\theta}$

or, $h = \dfrac{v_0^2}{g} + \dfrac{v_0^2 \cos^2\theta}{2g\sin^2\theta}$ or, $h = \dfrac{v_0^2}{g}\left(1 + \dfrac{\cos^2\theta}{2\sin^2\theta}\right)$

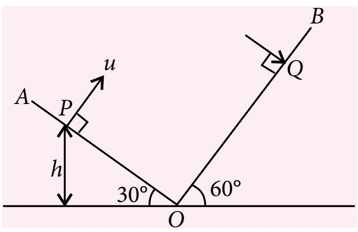
or, $h = \dfrac{v_0^2}{g}\left(1 + \dfrac{\cot^2\theta}{2}\right)$

or, $2gh = v_0^2\,(2 + \cot^2\theta)$

or, $v_0^2 = \dfrac{2gh}{2+\cot^2\theta}$

$\therefore\ v_0 = \sqrt{\dfrac{2gh}{2+\cot^2\theta}}$

Example-3 : Two inclined planes OA and OB having inclinations 30° and 60° respectively with the horizontal intersecting each other at O, as shown in figure. A particle is projected from point P with velocity $u = 10\sqrt{3}$ m s^{-1} along a direction perpendicular to plane OA. If the particle strikes plane OB perpendicular at Q. Calculate



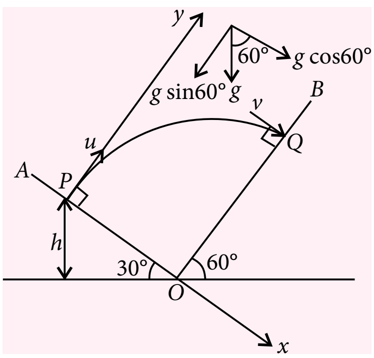
(a) time of flight
(b) velocity with which the particle strikes the plane OB
(c) height h of point P from point O
(d) distance PQ. (Take $g = 10$ m s^{-2})

Soln.: **For the motion along x-axis in interval P-Q,**

$u_x = 10\sqrt{3} = u$

$a_x = -g\sin\theta = -g\sin 60°$

$\therefore\ a_x = -\dfrac{\sqrt{3}}{2}g$



For the motion along y-axis in interval P-Q,

$u_y = 0$

$a_y = -g\cos\theta = -g\cos 60°$

$\therefore\ a_y = -\dfrac{1}{2}g$

At the striking point Q, it strikes perpendicularly,

$\therefore\ v_x = 0$

As, $v_x = u_x + a_x t$

$\therefore\ 0 = u_x + a_x t$

or $0 = 10\sqrt{3} - \dfrac{\sqrt{3}}{2}g\cdot t$

$\therefore\ t = 2$ s

As, $v_y = u_y + a_y t$

or $v_y = 0 + \left(-\dfrac{g}{2}\right)\times 2$

$\therefore\ v_y = -10$ m s^{-1}

Hence, at point Q, $v_x = 0$

$v_y = -10$ m s^{-1}

$\therefore\ v = \sqrt{v_x^2 + v_y^2} = 10$ m s^{-1}

Again, as, $s_y = u_y t + \dfrac{1}{2}a_y t^2$

or $s_y = 0 - \dfrac{1}{2}\times\dfrac{g}{2}\times(2)^2$ or, $s_y = -10$ m

$10\sin 30° = h$ or $h = \dfrac{10}{2} = 5$ m

Horizontal displacement

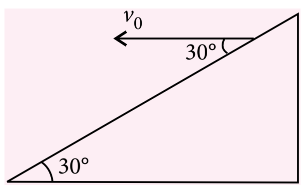
$s_x = u_x t + \dfrac{1}{2}a_x t^2$

or $s_x = 0 + \dfrac{1}{2}\left(-g\dfrac{\sqrt{3}}{2}\right)\times(2)^2$

$= -\dfrac{10\sqrt{3}}{4}\times 4 = -10\sqrt{3}$ m

$\therefore\ PQ = \sqrt{(10)^2 + (-10\sqrt{3})^2} = 20$ m

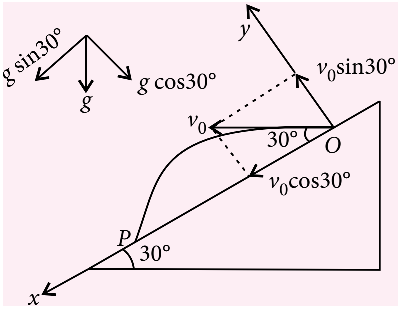
Example-4 : A projectile is projected horizontally at a speed of $v_0 = 20$ m s^{-1} on an inclined plane as shown in the figure. Find time of flight and range of the projectile. ($g = 10$ m s^{-2}).



Soln.: **For the motion along y-axis in interval O-P,**

$u_y = v_0 \sin 30°$

$a_y = -g \cos 30°$



As, $s_y = u_y t + \frac{1}{2} a_y t^2$

$\therefore \quad 0 = v_0 \sin 30° t - \frac{1}{2} g \cos 30° t^2$

Either, $t = 0$ or, $v_0 \sin 30° - \frac{1}{2} g \cos 30° t = 0$

or, $T = t = 2.31$ s

For the motion along x-axis in interval O-P,

$u_x = v_0 \cos 30°$

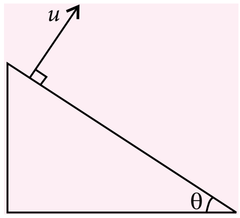
$a_x = g \sin 30°$

As, $s_x = u_x t + \frac{1}{2} a_x t^2$

$\therefore \quad R = v_0 \cos 30° T + \frac{1}{2} \times g \sin 30° \times T^2$

Putting the value of $t = T = 2.31$ s, the value of range, $R = 53.33$ m

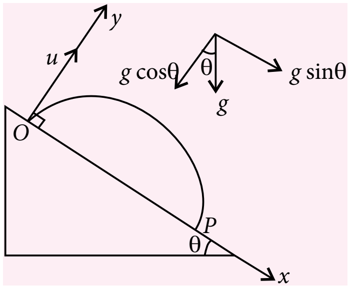
Example-5 : A projectile is fired with a velocity u at right angles to the slope, which is inclined at an angle θ with the horizontal. Derive an expression for the range 'R' a distance along inclined plane from point of projection to the point of impact.



Soln.: **For the motion along y-axis in interval O-P,**

$u_y = u \sin 90° = u$

$a_y = -g \cos\theta$



As, $s_y = u_y t + \frac{1}{2} a_y t^2$

$0 = ut - \frac{1}{2} g \cos\theta t^2$

Either, $t = 0$

or, $u - \frac{1}{2} g \cos\theta t = 0$

or, $t = \frac{2u}{g \cos\theta}$

For the motion along x-axis in interval O-P,

$u_x = u \cos 90° = 0$

$a_x = g \sin\theta$

As, $s_x = u_x t + \frac{1}{2} a_x t^2$

$\therefore \quad R = 0 + \frac{1}{2} g \sin\theta \left(\frac{2u}{g \cos\theta} \right)^2$

$= \frac{2u^2}{g} \sec\theta \tan\theta$

◇◇

MPP MONTHLY Practice Paper

This specially designed column enables students to self analyse their extent of understanding of complete syllabus. Give yourself four marks for correct answer and deduct one mark for wrong answer.

Self check table given at the end will help you to check your readiness.

Total Marks : 120 **Time Taken : 60 min**

NEET / AIIMS / PMTs

Only One Option Correct Type

1. A balloon rises from rest on the ground with constant acceleration $g/8$. A stone is dropped when the balloon has risen to a height H m. Then the time taken by the stone to reach the ground is
   (a) $2\sqrt{g/H}$ (b) $2\sqrt{gH}$
   (c) $2\sqrt{H/g}$ (d) $2\sqrt{2gH}$

2. A projectile is thrown with initial velocity $(a\hat{i}+b\hat{j})\,\text{m s}^{-1}$. Obtain a relation between a and b for its range of projection to be twice the maximum height reached by it.
   (a) $a = 2b$ (b) $b = a$
   (c) $3b = 2a$ (d) $b = 2a$

3. If two resistors of resistances $R_1 = (4 \pm 0.5)\ \Omega$ and $R_2 = (16 \pm 0.5)\ \Omega$ are connected in parallel. Then the equivalent resistance of the combination will be
   (a) $(3.2 \pm 0.34)\ \Omega$ (b) $(2.4 \pm 0.48)\ \Omega$
   (c) $(2.4 \pm 0.34)\ \Omega$ (d) $(3.2 \pm 0.48)\ \Omega$

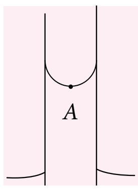
4. A solid cylinder of mass 3 kg is rolling on a horizontal surface with velocity 4 m s^{-1}. It collides with a horizontal spring of force constant 200 N m^{-1}. The maximum compression produced in the spring will be
   (a) 0.5 m (b) 0.6 m (c) 0.7 m (d) 0.2 m

5. A smooth block is released from rest on a 45° incline and then slides a distance d. If the time taken to slide on rough incline is n times as large as that to slide than on a smooth incline, find the coefficient of friction.
   (a) $1 - n^2$ (b) $1-\frac{1}{n^2}$
   (c) n (d) $1-\frac{1}{n}$

6. A body is projected vertically from the Earth with a velocity equal to half the escape velocity. What is the maximum height attained by the body?
   (a) $2R$ (b) $3R$ (c) $\frac{R}{3}$ (d) $\frac{R}{2}$

7. An air bubble of volume 1.0 cm^3 rises from the bottom of a lake 40 m deep at a temperature of 12 °C. To what volume does it grow, when it reaches the surface, which is at a temperature of 35 °C? Given 1 atm = 1.01×10^5 pa.
   (a) $5.275 \times 10^{-6}\,\text{m}^3$ (b) $4.345 \times 10^{-6}\,\text{m}^3$
   (c) $6.45 \times 10^{-5}\,\text{m}^3$ (d) $4.54 \times 10^{-5}\,\text{m}^3$

8. Figure shows a capillary tube of radius r dipped into water (surface tension = S). If the atmospheric pressure is P_0, the pressure at point A is



   (a) P_0 (b) $P_0+\frac{2S}{r}$
   (c) $P_0-\frac{2S}{r}$ (d) $P_0-\frac{4S}{r}$

9. A Carnot engine takes in 3000 kcal of heat from a reservoir at 627 °C and gives it to a sink at 27 °C. The work done by the engine is
   (a) 4.2×10^6 J (b) 8.4×10^6 J
   (c) 16.8×10^6 J (d) Zero

10. A sphere of diameter 7 cm and mass 266.5 g floats in a bath of a liquid. As the temperature is raised, the sphere just begins to sink at a temperature of 35 °C. If the density of the liquid at 0 °C is 1.527 g cm^{-3}, The coefficient of cubical expansion of the liquid will be. (Neglect the expansion of the sphere.)
(a) 0.0082 $°C^{-1}$ (b) 0.000082 $°C^{-1}$
(c) 0.00082 $°C^{-1}$ (d) 0.82 $°C^{-1}$

11. A 5 g body executes SHM with an amplitude of 3 cm and a period of 8 s. What is the force acting on the body 1 s after crossing its mean position?
(a) 6.55 dyne (b) 4.55 dyne
(c) 5.84 dyne (d) 7.21 dyne

12. Two particles are in SHM along same line with same amplitude a and same time period T. At time $t = 0$, particle 1 is at $+\frac{a}{2}$ and moving towards positive x-axis. At the same time particle 2 is at $-\frac{a}{2}$ and moving towards negative x-axis. Find the time when they will collide
(a) $\frac{2T}{3}$ (b) $\frac{5T}{12}$ (c) $\frac{4T}{3}$ (d) $\frac{2T}{5}$

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. **Assertion :** A hydrogen filled balloon stops rising after it has attained a certain height in the sky.
Reason : The atmospheric pressure decreases with height and becomes zero when maximum height is attained.

14. **Assertion :** Moment of inertia depends on mass and size of the body and also on axis of rotation.
Reason : Moment of inertia of a body is same, whatever be the axis of rotation.

15. **Assertion :** For a floating body to be in stable equilibrium, its centre of buoyancy must be located above the centre of gravity.
Reason : The torque formed by the weight of the body and the upthrust will restore the body back to its normal position, after the body is disturbed.

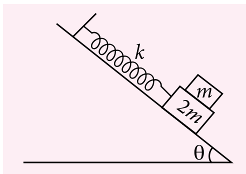
JEE MAIN / JEE ADVANCED / PETS

Only One Option Correct Type

16. An open umbrella is held upright and is twirled about the handle at a uniform rate of 21 revolutions is 44 s. If the rim of the umbrella is a circle of 1 m in diameter and the height of the rim above the floor is 1.5 m, find where the drops of water spun off the rim hit the floor with respect to the centre of rim?
(a) 0.67 m (b) 0.97 m
(c) 0.45 m (d) 0.81 m

17. There is a horizontal film of soap solution. On it a thread is placed in the form of a loop. The film is pierced inside the loop and the thread becomes a circular loop of radius R. If the surface tension of the loop be S, then tension in the thread will be
(a) $\pi R^2 S$ (b) $2RS$ (c) RS (d) $\frac{\pi R^2}{S}$

18. The coefficient of friction between two blocks of masses m and $2m$ is $\mu = 2 \tan\theta$. There is no friction between block of mass $2m$ and inclined plane.



The maximum amplitude of the two blocks and spring system for which there is no relative motion between both the blocks is
(a) $g\sin\theta\sqrt{\frac{k}{m}}$ (b) $\frac{mg\sin\theta}{k}$
(c) $\frac{3mg\sin\theta}{k}$ (d) None of these

19. Two cars A and B cross a point P with velocities 10 m s^{-1} and 15 m s^{-1} . After that they move with different uniform accelerations and the car A overtakes B with a speed of 25 m s^{-1}. What is velocity of B at that instant?
(a) 20 m s^{-1} (b) 25 m s^{-1}
(c) 30 m s^{-1} (d) 40 m s^{-1}

More than One Options Correct Type

20. Which of the following statements are correct regarding base and derived quantities? Choose the correct statements.

(a) All quantities may be represented dimensionally in terms of the base quantities.

(b) A base quantity cannot be represented dimensionally in terms of the rest of the base quantities.

(c) The dimension of a base quantity in other base quantities is always zero.

(d) The dimension of a derived quantity is never zero in any base quantity.

21. A particle of mass m is attached to a light string of length l, the other end of which is fixed. Initially the string is kept horizontal and the particle is given an upward velocity v. The particle is just able to complete a circle.

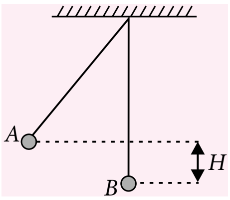
(a) The string becomes slack when the particle reaches its highest point.

(b) The velocity of the particle becomes zero at the highest point.

(c) The kinetic energy of the ball in initial position was $\frac{1}{2}mv^2 = mgl$.

(d) The particle again passes through the initial position.

22. Two small balls A and B of mass M and 3 M hang from the ceiling by strings of equal length. The ball A is drawn aside so that it is raised to a height H. It is then released and collides with ball B. Select the correct statements regarding collision of balls.



(a) If collision is elastic, ball B will rise to a height $H/4$.

(b) If the collision is elastic, ball A will rise upto a height $H/4$.

(c) If the collision is perfectly inelastic, the combined mass will rise to a height $H/16$.

(d) If the collision is perfectly inelastic, the combined mass will rise to a height $H/4$.

23. A particle is projected from a point P with a velocity v at an angle θ with horizontal. At a certain point Q it moves at right angles to its initial direction. Then,

(a) Velocity of particle at Q is $v \sin\theta$

(b) Velocity of particle at Q is $v \cot\theta$

(c) Time of flight from P to Q (v/g) cosecθ

(d) Time of flight from P to Q (v/g) secθ

Integer Answer Type

24. Gravitational acceleration on the surface of a planet is $\frac{\sqrt{6}}{11}g$, where g is the gravitational acceleration on the surface of the earth. The average mass density of the planet is $\frac{2}{3}$ times that of the earth. If the escape speed on the surface of the earth is taken to be 11 km s^{-1}, the escape speed on the surface of the planet (in km s^{-1}) will be

SOLUTION OF FEBRUARY 2017 CROSSWORD

	[1]C	H	R	O	N	O	N		[2]D	E	C	O	U	P	L	I	N	G		[3]P
	O				[4]R	A	Y	L	E	I	G	H	D	I	S	C		[5]I		Y
	N								N									N		R
	T		[6]C	R	I	T	I	C	A	L	M	A	S	S				T		O
	R			[7]S	E	N	S	A	T	I	O	N	L	E	V	E	L	E		E
	A								U								[8]R	R		L
[9]I	S	[10]O	D	I	A	P	H	E	R	E	S						A	F		E
	T	P							A								D	E		C
		A					[11]J	A	N	S	K	Y					I	R		T
		C		[12]C	[13]G	I	A	N	T	S	T	A	R				A	O		R
		I		O	[14]E	L	E	C	T	R	O	N	V	O	L	T	N	M		I
[15]D	A	T	I	N	G		[16]C	H	L	A	D	N	I	P	L	A	T	E	S	C
	[17]M	Y		V				P								[18]F	I	T		I
	E			E		[19]C		E								U	N	E		T
	C	[20]M	I	C	R	O	G	R	A	V	I	T	Y			G	T	R		Y
	H			T		R		I								A	E			
	A			R		E		S			[21]K					C	N			
	N			O		L		C			E					I	S			
	I			N		O		O			R					T	I			
	C					S		[22]P	E	R	M	A	L	L	O	Y	T			
	S					S		E			A						Y			

Winner (February 2017)

- Saloni Porwal, Alwar

Solution Senders (January 2017)

- Anindita Chatterjee, Hasimara
- Chinmay Aggarwal, Shahdol

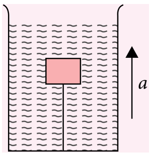
Solution Senders of Physics Musing

SET-43

1. Neha Sharma, Mumbai
2. Ruchika Singh, Lucknow
3. Vijayan Pillai, Trivendrum

25. A block of mass 1 kg lies on a horizontal surface in a truck, the coefficient of static friction between the block and the surface is 0.6. The force of friction on the block (in N) if acceleration of truck is 5 m s^{-2} is

26. A tank containing water, accelerates upwards with acceleration $a = 2$ m s^{-2}. A block of mass 1 kg and density 0.6 g cm^{-3} is held stationary inside the tank with the help of a string as shown in figure. The tension (in N) in the string is (use, density of water = 1000 kg m^{-3}, g = 10 m s^{-2})



Comprehension Type

A boat is travelling in a river with a speed 10 m s^{-1} along the stream flowing with a speed 2 m s^{-1}. From this boat, a sound transmitter is lowered into the river through a rigid support. The wavelength of the sound emitted from the transmitter inside the water is 14.45 mm. Assume that attenuation of sound in water and air is negligible.

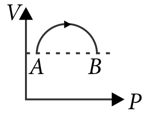
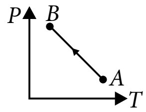
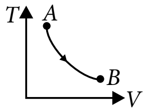
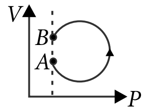
Temperature of the air and water = 20° C; Density of river water = 10^3 kg m^{-3}; Bulk modulus of the water = 2.088 × 10^9 Pa; Gas constant R = 8.31 J mol^{-1} K^{-1}; Mean molecular mass of air = 28.8 × 10^{-3} kg mol^{-1}; C_P/C_V for air = 1.4.

27. What will be the frequency detected by a receiver kept inside the river downstream?
(a) 1.005×10^5 Hz (b) 1.007×10^5 Hz
(c) 1.009×10^5 Hz (d) 1.002×10^5 Hz

28. The transmitter and the receiver are now pulled up into air. The air is blowing with a speed 5 m s^{-1} in the direction opposite the river stream. Determine the frequency of the sound detected by the receiver.
(a) 1.06×10^5 Hz (b) 1.01×10^5 Hz
(c) 1.09×10^5 Hz (d) 1.03×10^5 Hz

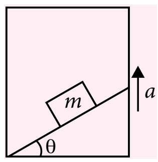
Matrix Match Type

29. A sample of gas goes from state A to state B in four different manners, as shown by the graphs. Let W be the work done by the gas and ΔU be change in internal energy along the path AB. Correctly match the graphs in Column I with the statements provided in column II.

	Column I		Column II
(A)		(P)	Both W and ΔU are positive
(B)		(Q)	Both W and ΔU are negative
(C)		(R)	W is positive whereas ΔU is negative
(D)		(S)	W is negative whereas ΔU is positive

	A	B	C	D
(a)	Q	R	S	P
(b)	P	Q	S	R
(c)	S	Q	R	P
(d)	S	R	P	Q

30. A block of mass m is stationary with respect to a rough wedge as shown in figure. Starting from rest in time t, (m = 1 kg, θ = 30°, a = 2 m s^{-2}, t = 4 s) Match the column I with column II for the work done by different forces acting on the block.



Column-I	Column-II
(A) By gravity	(P) 144 J
(B) By normal reaction	(Q) 32 J
(C) By friction	(R) 48 J
(D) By all the forces	(S) −160 J

	A	B	C	D
(a)	P	Q	S	R
(b)	S	Q	R	P
(c)	S	P	R	Q
(d)	R	P	S	Q

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted ......
No. of questions correct ......
Marks scored in percentage ......

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

CLASS XII

ACE YOUR WAY CBSE

Exam date : 15^{th} March 2017

Practice Paper

Time Allowed : 3 hours
Maximum Marks : 70

GENERAL INSTRUCTIONS

(i) All questions are compulsory. There are 26 questions in all.
(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.
(iv) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.

SECTION-A

1. Under what condition, can we draw maximum current from a cell? What is the value of maximum current?

2. What should be the length of dipole antenna for a carrier wave of frequency 6×10^8 Hz?

3. An infinite line charge produces a field of 9×10^4 N C^{-1} at a distance of 2 cm. Calculate the linear charge density.

4. On what factors does the magnitude of the emf induced in the circuit due to magnetic flux depend?

5. When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.

SECTION-B

6. (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

(ii) Draw a plot showing the variation of photo-electric current versus the intensity of incident radiation on a given photosensitive surface.

7. In the ground state of hydrogen atom, its Bohr radius is given as 5.3×10^{-11} m. The atom is excited such that the radius becomes 21.2×10^{-11} m. Find (i) the value of the principal quantum number and (ii) the total energy of the atom in this excited state.

8. Derive an expression for the resistivity of a good conductor, in terms of the relaxation time of electrons.

9. A conductor of length l is connected to a dc source of potential V. If the length of the conductor is tripled by gradually stretching it keeping V constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected? Justify your answer.

OR

The sequence of coloured bands in two carbon resistors R_1 and R_2 is

(i) brown, green, blue

(ii) orange, black, green

Find the ratio of their resistances.

10. The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.

SECTION-C

11. An electron and a photon each have a wavelength 1.00 nm. Find

(i) their momenta,

(ii) the energy of the photon and

(iii) the kinetic energy of electron.

12. (i) Deduce the expression, $N = N_0\, e^{-\lambda t}$, for the law of radioactive decay.

(ii) (a) Write symbolically the process expressing the β^+ decay of $^{22}_{11}\text{Na}$. Also write the basic nuclear process underlying this decay.

(b) Is the nucleus formed in the decay of $^{22}_{11}\text{Na}$, an isotope or isobar?

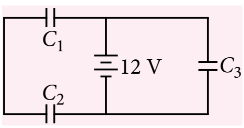
13. Draw *V-I* characteristics of a *p-n* junction diode. Answer the following questions, giving reasons.

(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?

(ii) Why does the reverse current show a sudden increase at the critical voltage?

Name any semiconductor device which operates under the reverse bias in the breakdown region.

14. Three identical capacitors C_1, C_2 and C_3 of capacitance 6 μF each are connected to a 12 V battery as shown. Find



(i) charge on each capacitor

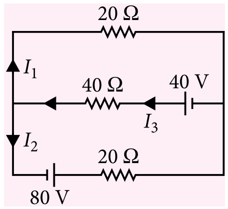
(ii) equivalent capacitance of the network

(iii) energy stored in the network of capacitors.

15. Mention three different modes of propagation used in communication system. Explain with the help of a diagram how long distance communication can be achieved by ionospheric reflection of radio waves.

16. (i) State Kirchhoff's rules of current distribution in an electrical network.

(ii) Using these rules determine the value of the current I_1 in the electric circuit given in figure.



17. (i) Define the current sensitivity of a galvanometer.

(ii) The coil area of a galvanometer is 16×10^{-4} m^2. It consists of 200 turns of a wire and is in a magnetic field of 0.2 T. The restoring torque constant of the suspension fibre is 10^{-6} N m per degree. Assuming the magnetic field to be radial, calculate the maximum current that can be measured by the galvanometer if the scale can accommodate 30° deflection.

18. The current flowing in the two coils of self-inductance L_1 = 16 mH and L_2 = 12 mH are increasing at the same rate. If the power supplied to the two coils are equal, find the ratio of (i) induced voltages, (ii) the currents and (iii) the energies stored in the two coils at a given instant.

19. Write any four characteristics of electromagnetic waves. State clearly how a microwave oven works to heat up a food item containing water molecules.

Why are microwaves found useful for the radar systems in aircraft navigation?.

20. A ray of light passing through an equilateral triangular glass prism from air undergoes minimum deviation when angle of incidence is 3/4$^{\text{th}}$ of the angle of prism. Calculate the speed of light in the prism.

OR

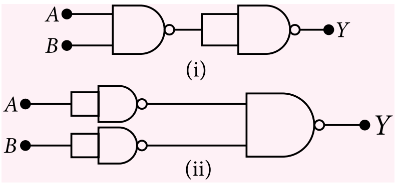
(i) The ratio of the widths of two slits in Young's double slit experiment is 4 : 1.

Evaluate the ratio of intensities at maxima and minima in the interference pattern.

(ii) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy? Explain.

21. The second line of Lyman series in hydrogen spectrum has wavelength 5400 Å. Find the wavelength of the first line.

22. You are given two circuits as shown in figure which consist of NAND gates. Identify the logic operation carried out by the two circuits.



SECTION-D

23. Mr. Khanna, a retired Physics teacher, was working in his field with his grandson. There was a big high tension tower carrying thick wires in their field. Grandson asked Mr. Khanna why could not the tower be removed from their field, so that they might get more space for crops. Mr. Khanna explained him the necessity of high tension tower, and said it was very high voltage ac transmission line and is a lifeline of their town.
(i) What are the values being displayed by Mr. Khanna?
(ii) Give two disadvantages of transmitting the electrical power at low voltage.

SECTION-E

24. How will a dia, para and a ferromagnetic material behave when kept in a non-uniform external magnetic field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide its suitability for making (i) a permanent magnet, (ii) an electromagnet. Which of these two characteristics should have high or low values for each of these two types of magnets?

OR

Draw a schematic diagram of a cyclotron. Explain its underlying principle and working stating clearly the function of the electric and magnetic fields applied on a charged particle.
Deduce an expression for the period of revolution and show that it does not depend on the speed of the charge particle.

25. What is meant by diffraction? Draw a graph to show the relative intensity distribution for a single slit diffraction pattern. Obtain an expression for the diffraction of the first minimum and first maximum in the diffraction pattern.

OR

Draw a ray diagram to show the formation of the image of an object placed between F and $2F$ of a thin convex lens. Using this diagram, derive the relation between object distance u, image distance v and focal length f of the convex lens. Draw the graph showing the variation of v and u. Also find its magnification.

26. An electric dipole is held in a uniform electric field.
(i) Show that no translatory force acts on it.
(ii) Derive an expression for the torque acting on it.
(iii) The dipole is aligned parallel to the field. Calculate the work done in rotating it through 180°.

OR

(i) Write the five important results regarding electrostatics of conductors.
(ii) Derive an expression for electric field due to hollow charged shell at different points. Also draw the variation of electric field.

SOLUTIONS

1. We can draw maximum current from a cell when the cell is short-circuited, *i.e.*, there is no external resistance present in the circuit. The maximum value of current,

$$I_{\text{max}} = \frac{\varepsilon}{r}$$

Where ε = emf of the cell and,
r = internal resistance of the cell

2. As, $\lambda = \frac{c}{\upsilon} = \frac{3\times10^8}{6\times10^8} = 0.5\text{ m}$

$\therefore$ Length of dipole antenna, $l = \frac{\lambda}{4} = 0.125\text{ m}$

3. Here, $E = 9\times10^4\text{ N C}^{-1}$, $r = 2\text{ cm} = 2\times10^{-2}\text{ m}$

As, $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

So, $\lambda = 2\pi\varepsilon_0 r\cdot E = \frac{1}{2\times9\times10^9}\times9\times10^4\times2\times10^{-2}$

or $\lambda = 1\times10^{-7}\text{ C m}^{-1} = 0.1\ \mu\text{C m}^{-1}$

4. The magnitude of the emf induced in the circuit due to magnetic flux depends on the time rate of change of magnetic flux through the circuit.

$$|\varepsilon| = \frac{\Delta\phi}{\Delta t}$$

5. Frequency being a characteristic of source of light, does not change with change of medium.
Refractive index μ of medium is defined as,

$$\mu = \frac{c}{v} = \frac{\text{(speed of light in vacuum)}}{\text{(speed of light in medium)}}$$

As, $v = \upsilon\lambda$

$\therefore\ \mu \propto \frac{1}{\lambda}$ $\quad$ ($\because$ υ is same in different media)

Hence, wavelength of light is different in different media.

6. (i) Given, $\upsilon = 6.0 \times 10^{14}$ Hz, $P = 2.0 \times 10^{-3}$ W

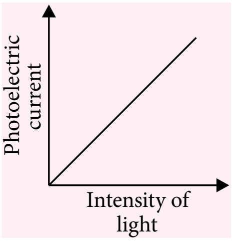
Let n be the number of photons emitted by the source per second.

$$n = \frac{P}{E} = \frac{P}{h\upsilon}$$

$$= \frac{2\times10^{-3}}{6.63\times10^{-34}\times6.0\times10^{14}} = 0.0502 \times 10^{17}$$

$= 5 \times 10^{15}$ photons per second

(ii) Variation of photo-electric current with intensity of light for a given frequency of incident radiation is given as in figure.



7. (i) Since, $r \propto n^2$; $\frac{r}{r_1} = \left(\frac{n}{n_1}\right)^2$

or $\frac{n^2}{1} = \frac{21.2\times10^{-11}}{5.3\times10^{-11}}$

$\frac{212}{53} = n^2 \Rightarrow n^2 = 4$ or $n = \sqrt{4} = 2$

(ii) We know that $E = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4$ eV

8. We know that drift velocity of electron is given by

$$|v_d| = \frac{eE}{m}\tau \text{ but } E = \frac{V}{l}$$

$$\therefore \quad |v_d| = \frac{e}{m}\cdot\frac{V}{l}\cdot\tau \Rightarrow V = \frac{|v_d|\cdot ml}{e\tau}$$

$\therefore$ According to ohm's law

$$R = \frac{V}{I} = \frac{|v_d|ml/e\tau}{I} = \frac{|v_d|ml/e\tau}{neAv_d}$$

$$R = \frac{|v_d|ml}{e\tau.neAv_d} = \frac{m}{ne^2\tau}\cdot\frac{l}{A} \quad \text{...(i)}$$

But the resistivity is given by

$$R = \rho\frac{l}{A} \quad \text{...(ii)}$$

Comparing (i) and (ii), we get

$$\rho = \frac{m}{ne^2\tau}$$

which is the required relationship between resistivity and relaxation time of electrons.

9. (i) We know that $v_d = -\frac{eV\tau}{ml} \Rightarrow v_d \propto \frac{1}{l}$

When length is tripled, the drift velocity becomes one-third.

(ii) $R = \rho\frac{l}{A} = \rho\frac{l\times l}{A\times l} = \rho\frac{l^2}{V}$, Given $l' = 3l$

$\therefore$ New resistance

$$R' = \rho\frac{l'^2}{V'} = \rho\times\frac{(3l)^2}{V} = 9R \quad \Rightarrow R' = 9R$$

Hence, the new resistance will be 9 times the original.

OR

(i) We know that the numbers for brown, green and blue are 1, 5 and 6 respectively

$\therefore$ $R_1 = 15 \times 10^6\ \Omega$

(ii) We know that the numbers for orange, black and green are 3, 0 and 5 respectively.

$R_2 = 30 \times 10^5\ \Omega$

$\therefore$ Ratio of their resistances is

$$\frac{R_1}{R_2} = \frac{15\times10^6}{30\times10^5} = \frac{10}{2} = \frac{5}{1} = 5:1$$

10. Here, $R_1 = 10$ cm, $R_2 = -15$ cm, $f = 12$ cm, $\mu = ?$

Using lens formula, we have

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{12} = (\mu-1)\left(\frac{1}{10} - \frac{1}{-15}\right)$$

$$= (\mu-1)\left(\frac{3+2}{30}\right) = (\mu-1)\left(\frac{5}{30}\right)$$

$$\Rightarrow \quad (\mu-1) = \frac{1}{12}\times\frac{30}{5} \quad \Rightarrow \quad \mu - 1 = 0.5$$

$\mu = 1 + 0.5 \quad \therefore \quad \mu = 1.5$

11. Here, $\lambda = 1.00$ nm $= 1.00 \times 10^{-9}$ m

(i) Momentum of photon

$$p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{1\times10^{-9}} = 6.6\times10^{-25} \text{ kg m s}^{-1}$$

Momentum of electron

$$p = \frac{6.6\times10^{-34}}{1\times10^{-9}} = 6.6\times10^{-25} \text{ kg m s}^{-1}$$

(ii) Energy of photon

$$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^8}{1\times10^{-9}} = 1.98\times10^{-16} \text{ J}$$

(iii) Kinetic energy of electron

$$K = \frac{p^2}{2m} = \frac{(6.6\times10^{-25})^2}{2\times9.1\times10^{-31}} = 2.39 \times 10^{-19} \text{ J}$$

12. (i) The number of radioactive nuclei disintegrating per second of a radioactive sample at any time is directly proportional to the number of undecayed nuclei present in the sample at that time.

i.e., $\frac{dN}{dt} \propto N$ or $\frac{dN}{dt} = -\lambda N$ ...(i)

where N is number of active nuclei in a radioactive sample at time t and λ is called disintegration constant or decay constant of radioactive substance. The negative sign indicates that the rate of

disintegration $\frac{dN}{dt}$ decreases with time.

From equation (i), $\frac{dN}{N} = -\lambda dt$

Integrating above equation on both sides, using the limits that initially at time $t = 0$, number of active nuclei are N_0, and at time t, number of active nuclei are N. Hence,

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt \quad \text{or} \quad \left[\ln N\right]_{N_0}^{N} = -\lambda [t]_0^t$$

or $\ln N - \ln N_0 = -\lambda[t - 0]$

or $\ln \frac{N}{N_0} = -\lambda t$ or $\frac{N}{N_0} = e^{-\lambda t}$

or $N = N_0 e^{-\lambda t}$ ...(ii)

(ii) (a) The β^+ decay of ${}^{22}_{11}\text{Na}$ is given by

$${}^{22}_{11}\text{Na} \longrightarrow {}^{22}_{10}\text{Ne} + e^+ + \nu$$

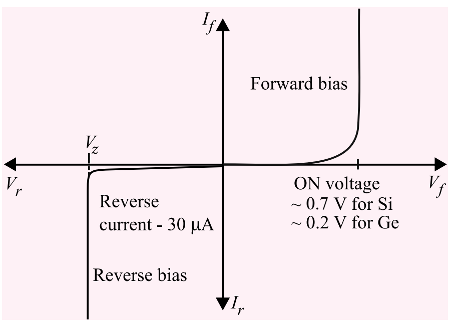
If the unstable nucleus has excess protons than that needed for stability, a proton converts itself into a neutron.

$p \longrightarrow n + e^+ + \nu$

where e^+ is a positron and ν is a neutrino created during the process.

(b) A nucleus ${}^{22}_{10}\text{Ne}$ is formed in the decay of the nucleus ${}^{22}_{11}\text{Na}$. Both the nuclei are isobar because they have same mass number.

13.



(i) The reverse current is due to minority charge carriers and even a small voltage is sufficient to sweep the minority carriers from one side of the junction to the other side of the junction. Here the current is not limited by the magnitude of the applied voltage but is limited due to the concentration of the minority carriers on either side of the junction.

(ii) At breakdown voltage, a large number of covalent bonds break, resulting in availability of large number of charge carriers.

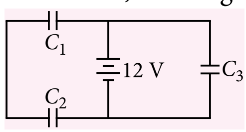
Zener diode operates under the reverse bias in the breakdown region.

14. (i) Since C_1 and C_2 are in series, so

$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{6} + \frac{1}{6} = \frac{1}{3}$$

or $C' = 3\ \mu\text{F}$

As potential difference across C' is 12 V, so charge stored on it is



$Q' = C'V = 3 \times 10^{-6} \times 12$
$= 36\ \mu\text{C}$

C_1 and C_2 are in series, so

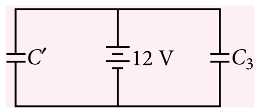
$Q_1 = Q_2 = Q'$

or $Q_1 = Q_2 = 36\ \mu\text{C}$

Also, the potential difference across C_3 is 12 V, so charge stored on it is

$Q_3 = C_3 V = 6 \times 10^{-6} \times 12 = 72\ \mu\text{C}$

(ii) As C' and C_3 are in parallel, so net capacitance of the network is



$C = C' + C_3 = 3 + 6 = 9\ \mu\text{F}$

(iii) Net energy stored in network of capacitors is

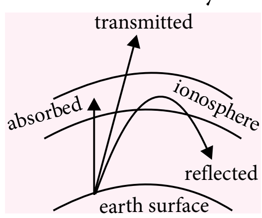
$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 9 \times 10^{-6} \times 12^2 = 648 \times 10^{-6}\ \text{J}$$
$$= 6.48 \times 10^{-4}\ \text{J}$$

15. (i) Ground wave or surface wave propagation

(ii) Sky wave propagation or ionospheric propagation

(iii) Space wave propagation or line of sight propagation.

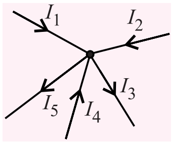
In sky wave propagation, radio waves transmitted by transmitting antenna are directed towards the ionosphere. The radiowaves having frequency range 2 MHz to 30 MHz are reflected back by the ionosphere.



In sky wave propagation, radio signals can be transmitted to the stations which otherwise become inaccessible to the ground due to curvature of earth.

Thus due to reflection by ionosphere, radio wave signals can be transmitted virtually from one place to the other on surface of earth. So it is useful for very long distance radio communication. Thus for long distance radio broadcasts through sky wave propagation, we use short wave bands.

16. (i) Kirchhoff's first rule : The algebraic sum of all the currents passing through a junction of an electric circuit is zero.



Here, I_1, I_2, I_3, I_4 and I_5 are currents in different branches of a circuit which meet at a junction.

$I_1 + I_2 - I_3 + I_4 - I_5 = 0$

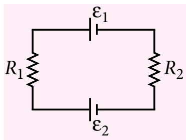
This rule is based on the principle of conservation of charge.

Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.

Mathematically,

$\Sigma\varepsilon = \Sigma IR$

This is based on energy conservation principle



Using this rule,

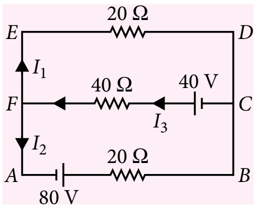
$\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2$

(ii) $I_3 = I_1 + I_2$ ...(i)

Taking loop *FEDCF*

$20I_1 + 40I_3 = 40$

$\Rightarrow\ I_1 + 2I_3 = 2 \quad \Rightarrow \quad 2I_1 + 4I_3 = 4$ ...(ii)



Taking loop *FCBAF*

$-40I_3 - 20I_2 = -40 - 80$

$\Rightarrow\ 4I_3 + 2I_2 = 12 \quad \Rightarrow \quad 2I_3 + I_2 = 6$ ...(iii)

Substituting value of I_2 from equation (i) in equation (iii)

$2I_3 + (I_3 - I_1) = 6 \quad \Rightarrow \quad 3I_3 - I_1 = 6$ ...(iv)

On solving equations (ii) and (iv), we get

$I_1 = -1.2$ A

17. (i) Current sensitivity : It is defined as the deflection of coil per unit current flowing in it, *i.e.*,

$$S = \frac{\theta}{I} = \frac{NAB}{k}$$

(ii) $A = 16 \times 10^{-4}$ m^2, $N = 200$, $B = 0.2$ T, $k = 10^{-6}$ N m per degree, $\theta = 30°$,

$$I = \frac{k}{NBA}\theta$$

$$= \frac{10^{-6} \times 30}{200 \times 0.2 \times 16 \times 10^{-4}} = 4.69 \times 10^{-4}\,\text{A}$$

18. (i) Induced voltage $V = L\dfrac{dI}{dt}$

$$\frac{V_1}{V_2} = \frac{L_1}{L_2}\ \left(\text{as } \frac{dI}{dt} \text{ is same}\right) \quad \Rightarrow \quad \frac{V_1}{V_2} = \frac{16}{12} = \frac{4}{3}$$

(ii) Power $P = IV$

$$\frac{I_1}{I_2} = \frac{V_2}{V_1} = \frac{3}{4}\ (\text{as } P \text{ is same}) \quad \Rightarrow \quad \frac{I_1}{I_2} = \frac{3}{4}$$

(iii) Energy stored $E = \dfrac{1}{2}LI^2$

$$\frac{E_1}{E_2} = \frac{L_1 I_1^2}{L_2 I_2^2} = \frac{16}{12} \times \frac{9}{16} = \frac{3}{4} \quad \Rightarrow \quad \frac{E_1}{E_2} = \frac{3}{4}$$

19. Four characteristics of electromagnetic waves are :

1. Electromagnetic waves do not require any medium for their propagation.
2. These waves travel in free space with speed 3×10^8 m s^{-1}. It is given by the relation
$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$
3. The energy in electromagnetic waves is divided equally between electric field and magnetic field.
4. Electromagnetic waves are produced by accelerated charged particles.

In microwave oven, frequency of the microwave is selected to match the resonant frequency of water molecule so that energy from the waves get transferred efficiently to the kinetic energy of the molecules. This kinetic energy raises the temperature of any food containing water.

Microwaves are short wavelength radio waves, with frequency of order of GHz. Due to short wavelength, they have high penetrating power with respect to atmosphere and less diffraction in the atmospheric layers. So these waves are suitable for the radar systems used in aircraft navigation.

20. Here, $A = 60°$

and $i = \dfrac{3}{4}$ of $A \ \Rightarrow\ i = \dfrac{3}{4} \times 60 = 45°$

Using prism formula, we have

$$\mu = \frac{\sin\left(\dfrac{A + \delta_m}{2}\right)}{\sin\dfrac{A}{2}} = \frac{\sin i}{\sin A/2} \qquad \left(\because\ i = \frac{A + \delta_m}{2}\right)$$

But $\mu = \frac{c}{v}$ $\quad \therefore \quad \frac{c}{v} = \frac{\sin i}{\sin A/2}$

$$\frac{3\times10^8}{v} = \frac{\sin 45^\circ}{\sin 60^\circ/2} \Rightarrow v = \frac{3\times10^8 \times \sin 30^\circ}{\sin 45^\circ}$$

$$\therefore \quad v = \frac{3\times10^8 \times \frac{1}{2}}{\frac{1}{\sqrt{2}}} \Rightarrow v = 3\times10^8 \times \frac{1}{2}\times\sqrt{2}$$

$\therefore \quad v = 1.5 \times 1.41 \times 10^8 = 2.115 \times 10^8$ m s^{-1}

OR

(i) The intensity of light due to slit is directly proportional to width of slit.

$$\therefore \quad \frac{I_1}{I_2} = \frac{w_1}{w_2} = \frac{4}{1}$$

$$\Rightarrow \frac{a_1^2}{a_2^2} = \frac{4}{1} \text{ or } \frac{a_1}{a_2} = \frac{2}{1} \text{ or } a_1 = 2a_2$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{(2a_2+a_2)^2}{(2a_2-a_2)^2} = \frac{9a_2^2}{a_2^2} = 9:1$$

(ii) No, the appearance of bright and dark fringes in the interference pattern does not violate the law of conservation of energy.

When interference takes place, the light energy which disappears at the regions of destructive interference appears at regions of constructive interference so that the average intensity of light remains the same. Hence, the law of conservation of energy is obeyed in the phenomenon of interference of light.

21. For Lyman series,

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right) \qquad (\therefore n = 2, 3, 4, ...)$$

Let λ_1 and λ_2 be the wavelengths of the first and second line respectively, then

$$\frac{1}{\lambda_1} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = R\left(1-\frac{1}{4}\right) = \frac{3}{4}R \qquad ...(i)$$

$$\text{and } \frac{1}{\lambda_2} = R\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = R\left(1-\frac{1}{9}\right) = \frac{8}{9}R \qquad ...(ii)$$

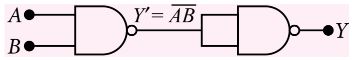
Dividing (ii) by (i), we get

$$\frac{\frac{1}{\lambda_2}}{\frac{1}{\lambda_1}} = \frac{\frac{8}{9}R}{\frac{3}{4}R} \Rightarrow \frac{1}{\lambda_2}\times\frac{\lambda_1}{1} = \frac{8}{9}\times\frac{4}{3}$$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{32}{27}$$

As $\lambda_2 = 5400$ Å

$$\therefore \quad \lambda_1 = \frac{32}{27}\times\lambda_2 = \frac{32}{27}\times 5400 = 6400 \text{ Å}$$

22. (i) 

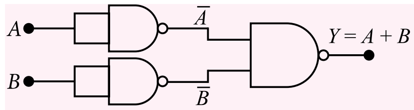
Here, $Y' = \overline{AB}$

Final output, $Y = \overline{Y'\cdot Y'} = \overline{Y'} = \overline{\overline{AB}} = AB$

hence logic circuit operates as AND gate.

(ii) By De-Morgan's theorem

$$\left(\overline{\bar{A}\bar{B}}\right) = \bar{\bar{A}} + \bar{\bar{B}} = A + B$$



So, the given logic circuit acts as OR gate.

23. (i) Social awareness and sense of responsibility.

(ii) (a) Large length of transmission cables have appreciable resistance. Hence a large amount of energy (I^2Rt) will be lost as heat during transmission. (b) Large voltage drop (IR) occurs along the live wire. Hence the voltage at the receiving station will be much smaller than that at the generating station.

24. Refer to point 3.8 (8, 11) page no. 180, 181 (MTG Excel in Physics)

OR

Refer to point 3.3 (5) page no. 173 (MTG Excel in Physics)

25. Refer to point 6.14 (1, 3, 4) page no. 449 (MTG Excel in Physics)

OR

Refer to point 6.6 (4, 5, 6) page no. 376 (MTG Excel in Physics)

26. Refer to point 1.4 (5, 6) page no. 6 (MTG Excel in Physics)

OR

(i) Refer to point 1.9 page no. 13 (MTG Excel in Physics)

(ii) Refer to point 1.8 (4) page no. 13 (MTG Excel in Physics)

MPP CLASS XI ANSWER KEY

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

MPP MONTHLY Practice Paper

Class XII

This specially designed column enables students to self analyse their extent of understanding of complete syllabus. Give yourself four marks for correct answer and deduct one mark for wrong answer.

Self check table given at the end will help you to check your readiness.

Total Marks : 120 **Time Taken : 60 min**

NEET / AIIMS / PMTs

Only One Option Correct Type

1. A pithball covered with tinfoil having a mass of m kg hangs by a fine silk thread l metre long in an electric field E. When the ball is given an electric charge of q, it stands out at a distance d from the vertical line. Then electric field is

(a) $\dfrac{mgd}{q\sqrt{l^2-d^2}}$ (b) $\dfrac{mgd}{q\sqrt{l^2+d^2}}$

(c) $\dfrac{mg\sqrt{l^2-d^2}}{q.d}$ (d) $\dfrac{mg\sqrt{l^2+d^2}}{q.d}$

2. A condenser of capacity C is charged to a potential difference of V_1. The plates of the condenser are then connected to an ideal inductor of inductance L. The current through the inductor when the potential difference across the condenser reduces to V_2 is

(a) $\left(\dfrac{C(V_1-V_2)^2}{L}\right)^{\frac{1}{2}}$ (b) $\dfrac{C(V_1^2-V_2^2)}{L}$

(c) $\dfrac{C(V_1^2+V_2^2)}{L}$ (d) $\left(\dfrac{C(V_1^2-V_2^2)}{L}\right)^{\frac{1}{2}}$.

3. Let the x-z plane be the boundary between two transparent media. Medium 1 in $z \geq 0$ has a refractive index of $\sqrt{2}$ and medium 2 with $z < 0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{3}\,\hat{i} + 8\sqrt{3}\,\hat{j} - 10\hat{k}$ is incident on the plane of separation. The angle of refraction in medium 2 is

(a) 30° (b) 45° (c) 60° (d) 75°.

4. In a Young's double-slit experiment, bichromatic light of wavelengths 400 nm and 560 nm is used. The distance between the slits is 0.1 nm and the distance between the plane of the slits and the screen is 1 m. The minimum distance between two successive regions of complete darkness is

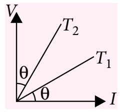
(a) 4 mm (b) 5.6 mm (c) 14 mm (d) 28 mm

5. Consider a magnetic dipole kept in the north to south direction. Let P_1, P_2, Q_1, Q_2 be four points at the same distance from the dipole towards north, south, east and west of the dipole respectively. The direction of the magnetic field due to the dipole are the same at

(a) P_1 and P_2 (b) Q_1 and Q_2

(c) P_1 and Q_1 (d) P_2 and Q_2

6. The V-I graph for a conductor at temperatures T_1 and T_2 are as shown in figure. $(T_2 - T_1)$ is proportional to



(a) $\dfrac{\cos 2\theta}{\sin^2\theta}$ (b) $\dfrac{\sin 2\theta}{\sin^2\theta}$ (c) $\dfrac{\tan 2\theta}{\sin^2\theta}$ (d) $\dfrac{\cot 2\theta}{\sin^2\theta}$

7. If the binding energy of the electron in hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is

(a) 30.6 eV (b) 13.6 eV (c) 3.4 eV (d) 6.8 eV

8. In a transformer, number of turns in the primary coil are 140 and that in the secondary coil are 280. If current in primary coil is 4 A, then that in the secondary coil is

(a) 4 A (b) 2 A (c) 6 A (d) 10 A.

9. In a photoemissive cell, with exciting wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be

(a) less than $v\left(\dfrac{4}{3}\right)^{1/2}$ (b) $v\left(\dfrac{4}{3}\right)^{1/2}$

(c) $v\left(\dfrac{3}{4}\right)^{1/2}$ (d) greater than $v\left(\dfrac{4}{3}\right)^{1/2}$

10. There is a non-uniform magnetic field in a region given by $\vec{B} = B_0(1 + x/l)\hat{k}$. A square loop of edge l and carrying current I is placed with its edges parallel to the x-y axis. The magnitude of the net magnetic force experienced by the loop is

(a) BIl (b) $B_0 I l$ (c) $2B_0 I l$ (d) $B_0 I l/2$

11. Two radioactive nuclei P and Q in a given sample decay into a stable nucleus R. At time $t = 0$, number of P species are $4N_0$ and that of Q are N_0. Half-life of P (for conversion to R) is 1 minute whereas that of Q is 2 minutes. Initially there are no nuclei of R present in the sample. When number of nuclei of P and Q are equal, the number of nuclei of R present in the sample would be

(a) $\frac{5N_0}{2}$ (b) $2N_0$ (c) $3N_0$ (d) $\frac{9N_0}{2}$

12. A radio station has two channels. One is AM at 1020 kHz and the other is FM at 89.5 MHz. For good results, you will use
(a) longer antenna for the AM channel and shorter for the FM
(b) shorter antenna for the AM channel and longer for the FM
(c) same antenna length will work for both
(d) insufficient data

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

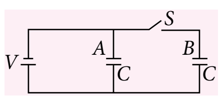
13. Assertion : χ_m - T graph for a diamagnetic material is a straight line parallel to T-axis.
Reason : Susceptibility of a diamagnetic material is not affected by temperature.

14. Assertion : A combination of a convex lens and a concave lens forms a real image when focal length of convex lens is less than the focal length of concave lens.
Reason : Real image is formed only when the combination of lenses behaves as a concave lens.

15. Assertion : If the accelerating potential in an X-ray tube is increased, the wavelength of the characteristic X-rays does not change.
Reason : When an electron beam strikes the target in an X-ray tube, part of the kinetic energy is converted into X-ray energy.

Only One Option Correct Type

16. Figure shows two identical parallel plate capacitors connected to a battery through a switch S. Initially, the switch is closed so that the capacitors are completely charged. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant 3. Find the ratio of the initial total energy stored in the capacitors to the final total energy stored.



(a) 2 : 3 (b) 3 : 2 (c) 3 : 5 (d) 5 : 3.

17. A compass needle is placed in the gap of a parallel plate capacitor. The capacitor is connected to a battery through a resistance. The compass needle
(a) does not deflect
(b) deflects for a very short time and then comes back to the original position
(c) deflects and remains deflected as long as the battery is connected
(d) deflects and gradually comes to the original position in a time which is large compared to the time constant.

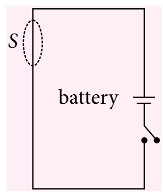
18. When modulation percentage is 75, an AM transmitter produces power of 10 kW. What would be percentage power saving if the carrier and one of the side bands were suppressed before transmission took place?
(a) 89.1% (b) 9.1% (c) 7.81% (d) 100%

19. A wire of resistance R carries a current I. The power lost to the surroundings is $\lambda(\theta - \theta_0)$. Here, λ is a constant, θ is temperature of the resistance and θ_0 is the temperature of the atmosphere. If the coefficient of linear expansion of the wire is α. The strain in the wire is

(a) $\frac{\alpha I^2 R}{\lambda}$ (b) $\frac{\alpha I^2 R}{2\lambda}$ (c) $\alpha\lambda IR$ (d) $2\alpha\lambda IR$

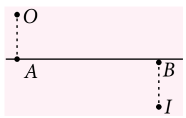
More than One Options Correct Type

20. A closed surface S is constructed around a conducting wire connected to a battery and a switch. As the switch is closed, the free electrons in the wire start moving along the wire. In any time interval, the number of electrons entering the closed surface S is equal to the number of electrons leaving it. On closing the switch, the flux of the electric field through the closed surface



(a) is increased (b) is decreased
(c) remains unchanged (d) remains zero.

21. A luminous point object is placed at O, whose image is formed at I as shown in figure. Line AB is the optical axis. Which of the following statements are correct?



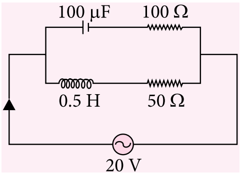
(a) If a lens is used to obtain the image, then it must be a diverging lens and its optical center will be the intersection point of line AB and OI
(b) If a lens is used to obtain the image, then it must be a converging lens and its optical center will be the intersection point of line AB and OI
(c) If a mirror is used to obtain the image, then the mirror must be concave and the object and image subtend equal angles at the pole of the mirror
(d) I is a real image

22. The breakdown in a reverse biased p–n junction diode is more likely to occur due to
(a) large velocity of the minority charge carriers if the doping concentration is small.
(b) large velocity of the minority charge carriers if the doping concentration is large.

(c) strong electric field in a depletion region if the doping concentration is small.

(d) strong electric field in the depletion region if the doping concentration is large.

23. In the given circuit, the AC source has ω = 100 rad s^{-1}. Considering the inductor and capacitor to be ideal, the correct choice(s) is/are



(a) the current through the circuit, I is 0.3 A.

(b) the current through the circuit, I is $0.3\sqrt{2}$ A.

(c) the voltage across 100 Ω resistor = $10\sqrt{2}$V.

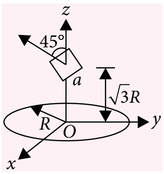
(d) the voltage across 50 Ω resistor = 10 V.

Integer Answer Type

24. When two identical batteries of internal resistance 1 Ω each are connected in series across a resistor R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25\ J_2$ then the value of R in Ω is

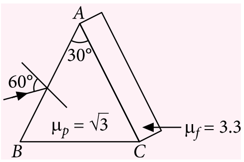
25. The radioactivity of a sample is R_1 at a time T_1 and R_2 at a time T_2. If the half-life of the specimen is T, the number of atoms that have disintegrated in the time $(T_2 - T_1)$ is equal to $\dfrac{n(R_1 - R_2)T}{\ln 4}$. What is the value of n?

26. A circular wire loop of radius R is placed in the x-y plane centered at the origin O. A square loop of side a $(a << R)$ having two turns is placed with its center at $z = \sqrt{3}R$ along the axis of the circular wire loop, as shown in figure. The plane of the square loop makes an angle of 45° with respect to the z-axis. If the mutual inductance between the loops is given by $\dfrac{\mu_0 a^2}{2^{p/2} R}$, then the value of p is



Comprehension Type

A prism of an angle 30° and refractive index $\mu_p = \sqrt{3}$ is shown in the figure.



Face AC of the prism is covered with a thin film of refractive index μ_f = 2.2. A monochromatic light of wavelength λ = 550 nm falls on the face AB at an angle of incidence of 60°. Calculate:

27. The angle of emergence of light will be

(a) 0° (b) 30° (c) 45° (d) 60°

28. The minimum value of thickness t so that intensity of emergent ray is maximum is

(a) 100 nm (b) 125 nm (c) 75 nm (d) 50 nm

Matrix Match Type

29. Match the entries in column I with column II.

Column I	Column II
(A) Dielectric ring uniformly charged	(P) Constant electrostatic field out of system
(B) Dielectric ring uniformly charged rotating with angular velocity ω	(Q) Magnetic field strength
(C) Constant current	(R) Induced electric field in ring I_0
(D) A variable current in a ring, $I = I_0 \cos \omega t$	(S) Magnetic moment

	A	B	C	D
(a)	P, S	P, Q, R S	P, S	R
(b)	P, Q	Q, R	P	P, R
(c)	P	P, Q, S	Q, S	Q, R, S
(d)	P, R	Q, R, S	Q	P, Q, R, S

30. Some laws/processes are given in column I. Match these with the physical phenomena given in column II.

Column I	Column II
(A) Transition between two atomic energy levels	(P) Characteristic X-rays
(B) Electron emission from a material	(Q) Photoelectric effect
(C) Mosley's law	(R) Hydrogen spectrum
(D) Change of photon energy into kinetic energy of electrons	(S) β-decay

	A	B	C	D
(a)	P, Q	R	R, S	Q
(b)	R	Q, R	P	P, Q
(c)	P, R, S	Q, S	P, Q	R, S
(d)	P, R	P, Q, S	P	Q

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted ......

No. of questions correct ......

Marks scored in percentage ......

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.