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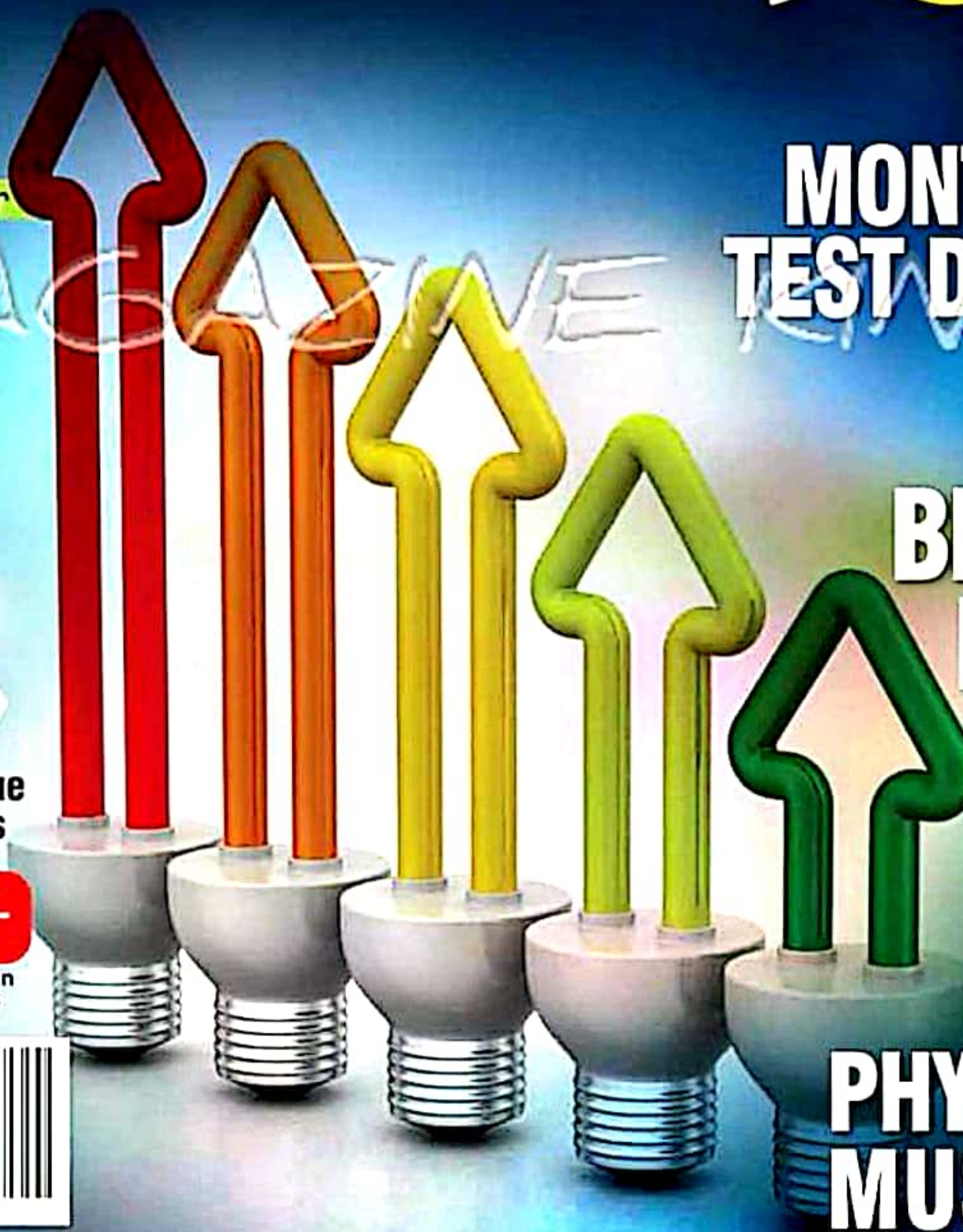

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PHYSICS
for you

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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) / NEET with additional study material.

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

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

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

PROBLEM Set 81

SINGLE OPTION CORRECT TYPE

1. A long horizontal wire AB, which is free to move in a vertical plane and carries a steady current of 20 A, is in equilibrium at a height of 0.01 m over another parallel long wire CD which is fixed in a horizontal plane and carries a steady current of 30 A, as shown in figure. When AB is slightly depressed, it executes simple harmonic motion. Find the period of oscillations.

(a) 0.01 s (b) 0.02 s
(c) 0.1 s (d) 0.2 s

2. A solid conducting sphere having a charge Q is surrounded by an uncharged concentric conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of hollow shell be V. What will be the new potential difference between the same two surfaces if the shell is given a charge $-3Q$?

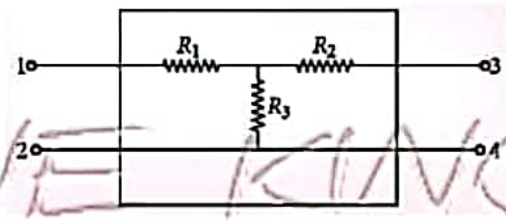
(a) V (b) $2V$
(c) $3V$ (d) $4V$

3. A ball is projected with velocity u, at an angle β to the horizontal towards a smooth wall which approach the ball with velocity v. Find the time of impact.

(a) $\dfrac{\cos\beta+2v}{g(4\cos\beta+v)}$ (b) $\dfrac{(u\cos\beta+2v)u\sin\beta}{g(u\cos\beta+v)}$

(c) $\dfrac{2vu\sin\beta}{g(u\cos\beta+v)}$ (d) $\dfrac{(u\cos\beta+2v)u\sin\beta}{g}$

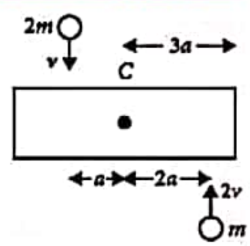
4. If voltage is applied between terminals 1 and 2 when terminals 3 and 4 are open, the power liberated is $P_1 = 40$ W and when terminals 3 and 4 are connected to each other, the power liberated is $P_2 = 80$ W. If the same source is connected to the terminals 3 and 4, the power liberated in the circuit when terminals 1 and 2 are open is $P_3 = 20$ W. Determine the power P_4 consumed in the circuit when the terminals 1 and 2 are connected and the same voltage is applied between the terminals 3 and 4.



(a) 20 W (b) 40 W
(c) 60 W (d) 80 W

MORE THAN ONE OPTION CORRECT TYPE

5. 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) $\omega = \dfrac{3v}{5a}$

(c) $\omega = \dfrac{v}{5a}$ (d) $E = \dfrac{3mv^2}{5}$.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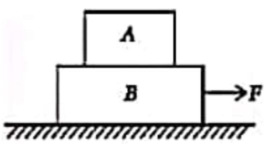
6. A particle of mass m moves in a certain plane due to a force F whose vector rotates in that place with a constant angular velocity ω. Assuming the particle to be stationary at the moment $t = 0$, then
   (a) its velocity as a function of time is $\left(\frac{F}{m\omega}\right)\sin\left(\frac{\omega t}{2}\right)$
   (b) its velocity as a function of time is $\left(\frac{2F}{m\omega}\right)\sin\left(\frac{\omega t}{2}\right)$
   (c) the distance covered by the particle between two successive stops is $\frac{8F}{m\omega^2}$
   (d) the mean velocity over two successive stops is $\frac{4F}{\pi m\omega}$.

7. Two point charges $+q$ and $-q$ are held fixed at $(-d, 0)$ and $(d, 0)$ respectively of a x-y coordinate system. Which of the following statements are correct?
   (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.

8. 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 is/are correct?



   (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 $F = 0.1\ mg$.

COMPREHENSION TYPE

A projectile is fired with speed v_0 at $t = 0$ on a planet named 'Increasing Gravity'. This planet is strange one, in the sense that the acceleration due to gravity increase linearly with time t as $g(t) = bt$, where b is a positive constant.

9. If angle of projection with horizontal is θ, then the time of flight is
   (a) $\sqrt{\frac{6v_0\sin\theta}{b}}$ (b) $\sqrt{\frac{2v_0\sin\theta}{b}}$
   (c) $\sqrt{\frac{3v_0\sin\theta}{b}}$ (d) $\sqrt{\frac{2v_0}{b}}$

10. If angle of projection with horizontal is θ, then the maximum height attained is
   (a) $\frac{1}{3}\frac{(v_0\sin\theta)^{3/2}}{\sqrt{b}}$ (b) $\frac{4}{3}\frac{(v_0\sin\theta)^{3/2}}{\sqrt{b}}$
   (c) $\frac{1}{3}\frac{(2v_0\sin\theta)^{3/2}}{\sqrt{b}}$ (d) None of these

All we need to know about BS-VI Fuel

Studies show that vehicles are a major source of pollutants that cause climate change. Cutting down on vehicular emission will also result in better air quality in cities. In a bid to bring down pollution levels, the Central government has announced that from April 1, 2020, all vehicles sold in India should comply with Bharat Stage-VI, or BS-VI emission standards.

The Bharat Stage emission standards are the legal limits on the amount of air pollutants like carbon monoxide and particulate matter that a vehicle in India can emit. These standards are targeted at making improvements in three areas-emission control, fuel efficiency and engine design.

India is currently operating on the BS-IV emission norms. In 2016, the government made a decision to jump BS-V and implement BS-VI in the country. While automobile manufactures are making available vehicles that comply with the new norms, oil companies will have to provide fuel that meet these standards. BS-VI standard fuel is said to be the world's cleanest fuel.

What makes BS-VI fuel better ?

Sulphur content in fuel is a major cause for concern. Sulphur dioxide released by fuel burning is a major pollutant that affects health as well. BS-VI fuel's sulphur content is much lower than BS-IV fuel. It is reduced to 10 mg kg^{-1} max in BS-VI from 50 mg kg^{-1} under BS-IV.

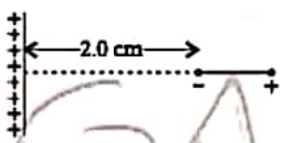
This reduction makes it possible to equip vehicles with better catalytic converters that capture pollutants. However, BS-VI fuel is expected to be costlier than BS-IV fuel. Vehicles that are compliant with BS-VI will also be more expensive.

GEAR UP FOR JEE MAIN 2020

with Numerical Value Type Questions

1. In a double slit pattern ($\lambda = 6000$ Å), the 1st order and 10th order maxima fall at 12.50 mm and 14.75 mm from a particular reference point. If λ is changed to 5500 Å, other arrangements remaining the same, position of 10th order maxima will be
   (a) 12.25 mm (b) 14.55 mm
   (c) 15.50 mm (d) 16.55 mm

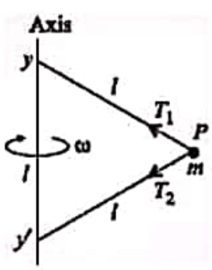
2. An electric dipole consists of charges $\pm 2.0 \times 10^{-8}$ C separated by a distance of 2.0×10^{-3} m. It is placed near a long line charge of linear charge density 4.0×10^{-4} C m^{-1} as shown in the figure, such that the negative charge is at a distance of 2.0 cm from the line charge. The force acting on the dipole will be



   (a) 7.2 N towards the line charge
   (b) 6.6 N away from the line charge
   (c) 0.6 N away from the line charge
   (d) 0.6 N towards the line charge.

3. A stone is allowed to fall from the top of a tower and cover half the height of the tower in the last second of its journey. Find the time taken by the stone to reach the foot of the tower.
   (a) 5.3 s (b) 4.3 s
   (c) 3.41 s (d) 2 s

4. A particle P of mass m is attached to a vertical axis by two strings each of length l. The particle rotates with angular velocity ω. The tension in the two strings are T_1 and T_2. Which of the following options is incorrect?

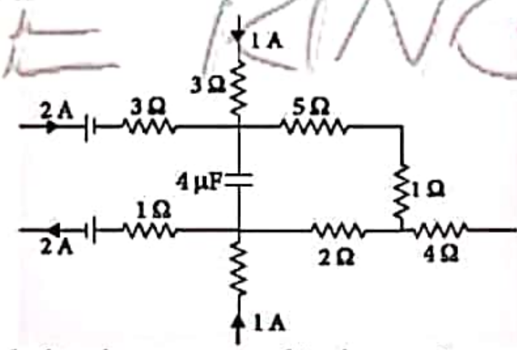


   (a) $T_1 = T_2$
   (b) $T_1 + T_2 = m\omega^2 l$
   (c) $T_1 - T_2 = 2mg$
   (d) Lower string will remain taut only if $\omega > \sqrt{\frac{2g}{l}}$

5. A body cools from a temperature $3T$ to $2T$ in 10 minutes. The room temperature is T. Assume that Newton's law of cooling is applicable. The temperature of the body at the end of next 10 minutes will be
   (a) $\frac{7}{4}T$ (b) $\frac{3}{2}T$ (c) $\frac{4}{3}T$ (d) T

6. For CE transistor amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 4 V. If the current amplification factor of the transistor is 100 and the base resistance is 1 kΩ, then the input signal voltage is
   (a) 10 mV (b) 20 mV (c) 30 mV (d) 15 mV

7. A part of circuit in steady state along with the current flowing in the branches, with value of each resistance is shown in figure.



   Calculate the energy stored in the capacitor.
   (a) 03.51 mJ (b) 0.59 mJ
   (c) 0.80 mJ (d) 0.1 mJ

8. In LCR series circuit, an alternating e.m.f. ε and current i are given by the equations $\varepsilon = 100 \sin(100t)$ volt, $i = 100 \sin\left(100t + \frac{\pi}{3}\right)$ mA.
   The average power dissipated in the circuit will be
   (a) 100 W (b) 10 W (c) 5 W (d) 2.5 W

9. A beaker contains a fluid of density ρ kg m^{-3}, specific heat S J kg^{-1} °C^{-1} and viscosity η. The beaker is filled up to height h. To estimate the rate of heat transfer per unit area ($\dot{Q}/A$) by convection when beaker is

put on a hot plate, a student proposes that it should depend on η, $\left(\frac{S\Delta\theta}{h}\right)$ and $\left(\frac{1}{\rho g}\right)$, where $\Delta\theta$ (in °C) is the difference in the temperature between the bottom and top of the fluid. In this situation the correct option for $(\dot{Q}/A)$ is

(a) $\eta\frac{S\Delta\theta}{h}$ (b) $\eta\left(\frac{S\Delta\theta}{h}\right)\left(\frac{1}{\rho g}\right)$

(c) $\frac{S\Delta\theta}{\eta h}$ (d) $\left(\frac{S\Delta\theta}{\eta h}\right)\left(\frac{1}{\rho g}\right)$

10. Silver has a work function of 4.7 eV. When ultraviolet light of wavelength 100 nm is incident upon it, a potential of 7.7 volt is required to stop the photoelectrons from reaching the collector plate. How much potential will be required to stop the photoelectrons when light of wavelength 200 nm is incident upon silver?
(Given hc = 12375 eV Å)

(a) 0.5 V (b) 1.5 V (c) 2.35 V (d) 3.85 V

11. In a plane electromagnetic wave, the electric field of amplitude 1 V m^{-1} varies with time in free space. The average energy density of magnetic field is (in J m^{-3})

(a) 8.86×10^{-12} (b) 4.43×10^{-12}

(c) 17.72×10^{-12} (d) 2.21×10^{-12}

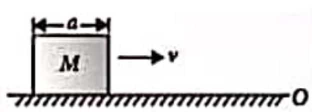
12. If an electron in a hydrogen atom jumps from the 3rd orbit to the 2nd orbit, it emits a photon of wavelength λ. When it jumps from the 4th orbit to the 3rd orbit, the corresponding wavelength of the photon will be

(a) $\frac{16}{25}\lambda$ (b) $\frac{9}{16}\lambda$ (c) $\frac{20}{7}\lambda$ (d) $\frac{20}{13}\lambda$

13. For a damped harmonic oscillator of mass 200 gm, the values of spring constant and damping constant are respectively, 90 N m^{-1} and 0.04 kg s^{-1}. The time taken for its amplitude of vibration to drop half of its initial value is (Take $\log_e 2 = 0.693$.)

(a) 7.0 s (b) 14.2 s (c) 15.9 s (d) 26.6 s

14. A cubical block of side a is moving with velocity v on a horizontal smooth plane as shown in figure. It hits a ridge at point O. The angular speed of the block after it hits O is

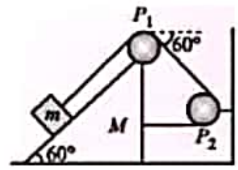


(a) $\frac{3v}{4a}$ (b) $\frac{3v}{2a}$ (c) $\frac{\sqrt{3}v}{\sqrt{2}a}$ (d) zero

15. A satellite is moving in a circular orbit at a certain height above the earth's surface. It takes 5.26×10^3 s to complete one revolution with a centripetal acceleration equal to 9.32 m s^{-2}. The height of the satellite orbit above the earth's surface is (Take radius of earth = 6.37×10^6 m)

(a) 70 km (b) 160 km (c) 190 km (d) 220 km

16. In the arrangement shown in figure, the block of mass m = 2 kg lies on the wedge of mass M = 8 kg. The initial acceleration of the wedge, if the surfaces are smooth, is



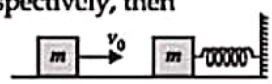
(a) $\frac{\sqrt{3}g}{23}$ m s^{-2} (b) $\frac{3\sqrt{3}g}{23}$ m s^{-2}

(c) $\frac{3g}{23}$ m s^{-2} (d) $\frac{g}{23}$ m s^{-2}

17. A ray incident at a point at an angle of incidence of 60° enters a glass sphere of $\mu = \sqrt{3}$ and is reflected and refracted at the farther surface of the sphere. The angle between the reflected and refracted rays at this surface is

(a) 50° (b) 90° (c) 60° (d) 40°

18. In the figure shown, surface is frictionless and spring is in natural condition. If x_1, x_2 and x_3 are the maximum compression in spring for elastic, completely inelastic and inelastic (e = 0.5) collisions respectively, then



(a) $x_1 > x_2 > x_3$ (b) $x_2 > x_3 > x_1$

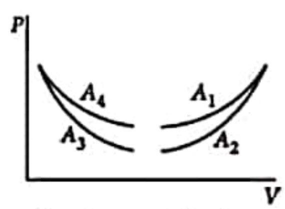
(c) $x_1 > x_3 > x_2$ (d) $x_2 > x_1 > x_3$

19. Two co-axial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area A = 10 cm^2 and length = 20 cm. If one of the solenoids has 300 turns and the other 400 turns, their mutual inductance is

(a) $2.4\pi \times 10^{-4}$ H (b) $2.4\pi \times 10^{-5}$ H

(c) $4.8\pi \times 10^{-4}$ H (d) $4.8\pi \times 10^{-5}$ H

20. The four curves A_1, A_2, A_3 and A_4 are shown on pV diagram. Which of the curves represents adiabatic process?

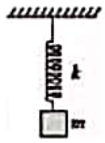


(a) A_3 (b) A_4 (c) A_1 (d) A_2

21. The equation of motion of a projectile is $y = 12x - \frac{3}{4}x^2$. If the horizontal component of velocity is 3 m s^{-1}, the range of the projectile (in m) is______.
(a) 18 m (b) 16 m (c) 12 m (d) 21.6 m

22. A disk of radius R = 4.8 cm carries a total charge q = +2.5 nC that is uniformly distributed over its surface and held in fixed location (Consider the surface to behave like an insulator.) An electron is initially at rest at a distance of d = 3.0 cm from the disk along its axis. When the electron is released, it is attracted toward the disk. The speed of the electron when it strikes the centre of the disk is $x \times 10^7$ m s^{-1}. The value of x (upto two decimal point) is______.

23. In the spring-mass system shown here, spring of spring constant 100 N m^{-1} is in its natural length initially. If the block of mass 1 kg is released from rest, the maximum power of the weight of the block (in watt) is______.



24. A straight horizontal conducting rod of length 50 cm and mass 50 g is suspended by two vertical wires at its ends. A current of 5.0 A is set up in the rod through the wires. The magnetic field (in tesla) one should set normal to the conductor such that the tension in the wires is zero, is______. (Take g = 10 m s^{-2})

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

SOLUTIONS

1. (b): Here, λ = 6000 Å
Between 1st order and 10th order maxima, there are 9 fringes.
Therefore, $9\beta = 14.75 - 12.50 = 2.25$ mm

$\beta = \frac{2.25}{9} = 0.25$ mm

When wavelength is changed to 5500 Å, the new fringe width becomes,

$\beta' = \frac{5500}{6000} \times \beta = 0.92 \times 0.25 \text{ mm} = 0.23 \text{ mm}$

The position of central maxima or zero order maxima remains the same, which was earlier at $12.50 - 0.25 = 12.25$ mm

$\therefore$ New position of 10th order maxima would be
$y = 12.25 + 10\beta' = 12.25 + 10 \times 0.23 = 14.55$ mm

2. (d): The electric field at a distance r from the line charge of linear density λ is given by

$E = \frac{\lambda}{2\pi\varepsilon_0 r}$

Hence the field at the negative charge,

$E_1 = \frac{(4.0 \times 10^{-4})(2 \times 9 \times 10^9)}{0.02} = 3.6 \times 10^8 \text{ N C}^{-1}$

The force on the negative charge

$F_1 = (3.6 \times 10^8)(2.0 \times 10^{-8})$
$= 7.2$ N towards the line charge

Similarly, the field at the positive charge, *i.e.*, at r = 0.022 m is

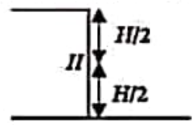
$E_2 = 3.3 \times 10^8 \text{ N C}^{-1}$.

The force on the positive charge,

$F_2 = (3.3 \times 10^8) \times (2.0 \times 10^{-8})$
$= 6.6$ N away from the line charge.

Hence, the net force on the dipole = 7.2 N – 6.6 N
= 0.6 N towards the line charge

3. (c) : Let the total time taken be n seconds.



$-\frac{H}{2} = -\frac{1}{2}g(n-1)^2$ ...(i)

$-H = -\frac{1}{2}gn^2$ ...(ii)

Using (i) and (ii), we get

$\frac{1}{2} = \frac{(n-1)^2}{n^2}$

$\Rightarrow n^2 = 2(n^2 + 1 - 2n) \Rightarrow n^2 - 4n + 2 = 0$

$\Rightarrow n = \frac{+4 \pm \sqrt{16-8}}{2} = (2 \pm \sqrt{2})$ s

Since time is greater than 1 s, therefore

$n = (2 + \sqrt{2})\text{ s} = 3.41\text{ s}$

4. (a): $T_1 \cos 30° + T_2 \cos 30° = m\omega^2\left(\frac{\sqrt{3}}{2}l\right)$

$T_1 + T_2 = m\omega^2 l$ ...(i)

$T_1 \sin 30° - T_2 \sin 30° = mg$

$T_1 - T_2 = 2\,mg$ ...(ii)

Solving eqns. (i) and (ii),

$2T_2 = m\omega^2 l - 2\,mg$

As $T_2 > 0$

$\therefore\ m\omega^2 l - 2\,mg > 0$

$\omega^2 > \frac{2g}{l} \Rightarrow \omega > \sqrt{\frac{2g}{l}}$

5. **(b):** According to Newton's law of cooling,

$$\frac{dT}{dt} = K(T - T_s)$$

For two cases, $\frac{dT_1}{dt} = K(T_1 - T_s)$ and

$$\frac{dT_2}{dt} = K(T_2 - T_s)$$

Here, $T_s = T$, $T_1 = \frac{3T + 2T}{2} = 2.5\,T$

so $\frac{dT_1}{dt} = \frac{3T - 2T}{10} = \frac{T}{10}$ (Given)

and $T_2 = \frac{2T + T'}{2} \Rightarrow \frac{dT_2}{dt} = \frac{2T - T'}{10}$

So, $\frac{T}{10} = K(2.5T - T)$ ...(i)

and $\frac{2T - T'}{10} = K\left(\frac{2T + T'}{2} - T\right)$ ...(ii)

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

$$\frac{T}{2T - T'} = \frac{(2.5T - T)}{\left(\frac{2T + T'}{2} - T\right)}$$

$$\frac{2T + T'}{2} - T = (2T - T') \times \frac{3}{2}$$

$T' = 3(2T - T')$ or, $4T' = 6T$

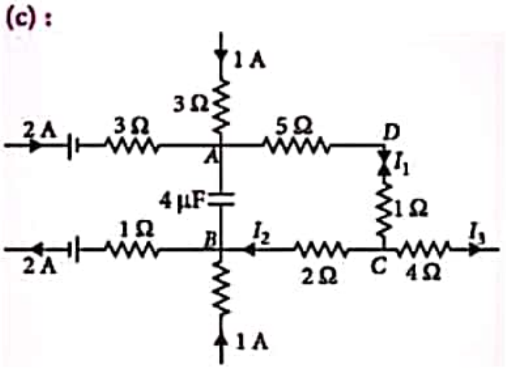
$\therefore\ T' = \frac{3}{2}T$

6. **(b):** Here, $R_C = 2\ \text{k}\Omega = 2000\ \Omega$, $V_0 = 4$ V
$\beta = 100$, $R_B = 1\ \text{k}\Omega = 1000\ \Omega$, $V_i = ?$

Voltage gain, $A = \beta\frac{R_C}{R_B} = 100 \times \frac{2000}{1000} = 200$

Also, $A = \frac{V_0}{V_i}$ or $V_i = \frac{V_0}{A} = \frac{4}{200} = \frac{2}{100}\text{V} = 20$ mV

7. **(c):**



Applying KCL at junctions A and B respectively, we have,

$2 + 1 - I_1 = 0$ or $I_1 = 3$ A

and $I_2 + 1 - 2 = 0$ or $I_2 = 1$ A.

Let potential at points A and B be V_A and V_B respectively.

From figure, $V_A - 3 \times 5 - 3 \times 1 - 1 \times 2 = V_B$

or $V_A - V_B = V = 20$ V

So, energy stored in the capacitor,

$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times (4 \times 10^{-6}) \times (20)^2 = 8 \times 10^{-4}\ \text{J}$$

8. **(d)**

9. **(a):** Let $\left(\frac{\dot{Q}}{A}\right)$ is derived quantity which is derived from three fundamental quantities η, $\left(\frac{S\Delta\theta}{h}\right)$ and $\left(\frac{1}{\rho g}\right)$.

By using principle of homogeneity of dimensions,

$$\left[\frac{\dot{Q}}{A}\right] = [\eta]^x \left[\frac{S\Delta\theta}{h}\right]^y \left[\frac{1}{\rho g}\right]^z$$

$$\left[\frac{\dot{Q}}{A}\right] = [\text{M}^1\text{T}^{-3}];\ [\eta] = [\text{M}^1\text{L}^{-1}\text{T}^{-1}]$$

$$\left[\frac{S\Delta\theta}{h}\right] = [\text{L}^1\text{T}^{-2}];\ \left[\frac{1}{\rho g}\right] = [\text{M}^{-1}\text{L}^2\text{T}^2]$$

$\therefore\ [\text{M}^1\text{L}^0\text{T}^{-3}] = [\text{M}^1\text{L}^{-1}\text{T}^{-1}]^x[\text{M}^0\text{L}^1\text{T}^{-2}]^y[\text{M}^{-1}\text{L}^2\text{T}^2]^z$

On comparing both sides

$x + 0 - z = 1, -x + y + 2z = 0$ and $-x - 2y + 2z = -3$

On solving these eqns, we get, $x = 1, y = 1\ z = 0$

so, $\frac{\dot{Q}}{A} = \eta\left(\frac{S\Delta\theta}{h}\right)$

10. **(b):** Here, $\lambda_1 = 100$ nm $= 1000$ Å and $\lambda_2 = 200$ nm $= 2000$ Å

Now, $E_1 = \frac{hc}{\lambda_1} = \frac{12375\ \text{eVÅ}}{1000\text{Å}} = 12.375$ eV and $E_2 = \frac{12375}{2000} = 6.1875$ eV

As $eV_s = E_1 - \phi_0$

$\therefore \quad e(7.7\text{ V}) = 12.375 - \phi_0$ ...(i)

and $eV_s' = 6.1875 - \phi_0$ ...(ii)

Subracting (ii) from (i), we get

$(7.7 - V_s')e = 6.1875$ eV

$7.7 - V_s' = 6.1875$ V

or $V_s' = 7.7 - 6.1875 = 1.51$ V

11. (c)

12. (c) : When electron jumps from higher orbit to lower orbit, then wavelength of emitted photon is given by $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

For transition $3 \rightarrow 2$,

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$$

and for transition $4 \rightarrow 3$,

$$\frac{1}{\lambda'} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{7R}{144}$$

$$\therefore \quad \lambda' = \frac{144}{7} \times \frac{5\lambda}{36} = \frac{20\lambda}{7}$$

13. (a) : Here, $m = 200$ gm $= 200 \times 10^{-3}$ kg $= 0.2$ kg

$k = 90$ N m^{-1}, $b = 0.04$ kg s^{-1}

The amplitude of the damped oscillator at any instant t is

$A(t) = A_0 e^{-bt/2m}$ ...(i)

where, A_0 is its initial amplitude and b is the damping constant.

At any instant $t = t_{1/2}$, the amplitude drop to half of its initial value.

From equation (i), we get

$$\frac{A_0}{2} = A_0 e^{-bt_{1/2}/2m} \quad \text{or} \quad \frac{1}{2} = e^{-bt_{1/2}/2m}$$

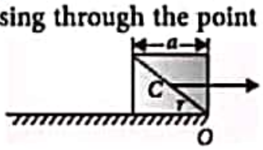
or $e^{bt_{1/2}/2m} = 2$

Taking natural logarithms on both sides, we get

$$\frac{bt_{1/2}}{2m} = \ln 2$$

$$t_{1/2} = \frac{2m \ln 2}{b} = \frac{2 \times 0.2 \times 0.693}{0.04} = 6.93 \text{ s} \approx 7 \text{ s}$$

14. (a) : The block would start rotating about an axis passing through the point O.



Since no external torque acts on the block, its angular momentum is conserved.

Angular momentum of the block before hitting the ridge $= mv\left(\frac{a}{2}\right)$

Angular momentum of the block after hitting the ridge $= I_o\omega$

The moment of inertia, I_o of the block about the axis passing through the point O is $I_o = I_C + mr^2$

$$= \frac{ma^2}{6} + m\left(\frac{a^2}{4} + \frac{a^2}{4}\right) = \frac{ma^2}{6} + \frac{ma^2}{2} = \frac{2}{3}ma^2$$

Hence the conservation of angular momentum gives

$$mv\left(\frac{a}{2}\right) = \left(\frac{2}{3}ma^2\right)\omega \quad \text{or} \quad \omega = \frac{3v}{4a}$$

15. (b): As, $T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$

or $\frac{T^2}{4\pi^2} = \frac{(R+h)^3}{GM}$ ...(i)

Centripetal acceleration, $a = \frac{GM}{(R+h)^2}$ ...(ii)

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

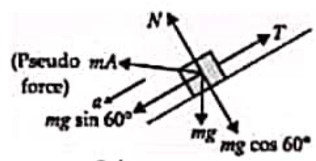
$$R + h = \frac{T^2}{4\pi^2} \times a = \left(5.26 \times \frac{10^3}{2\pi}\right)^2 \times 9.32$$

$\Rightarrow R + h = 6.53 \times 10^6$ m

$\therefore \quad h = 6.53 \times 10^6 - R = 6.53 \times 10^6 - 6.37 \times 10^6$

$= 0.16 \times 10^6$ m $= 160$ km

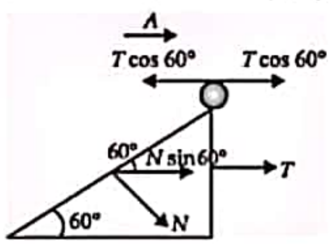
16. (b): If initial acceleration of M towards right is A, then acceleration of m with respect to M down the incline is



$a = A(1 + \cos\theta) = \frac{3A}{2} \quad (\because \theta = 60°)$

Equations of motion:

For m, $mg\frac{\sqrt{3}}{2} + mA \times \frac{1}{2} - T = m\left(\frac{3}{2}A\right)$ ...(i)



$$N + mA\frac{\sqrt{3}}{2} = mg\frac{1}{2} \quad \text{...(ii)}$$

For M, $T + N\frac{\sqrt{3}}{2} = MA$ ...(iii)

From equations (i), (ii) and (iii), $A = \frac{3\sqrt{3}\,g}{23}\ \text{m s}^{-2}$

17. (b)

18. (c) : For elastic collision velocity is interchanged.

$$\therefore\ \frac{1}{2}mv_0^2 = \frac{1}{2}kx_1^2 \Rightarrow x_1 = v_0\sqrt{\frac{m}{k}}$$

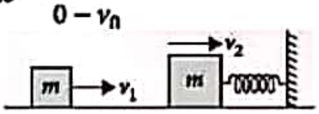
For completely inelastic collision,

$$mv_0 = 2mv \Rightarrow v = \frac{v_0}{2}$$

Now, $\frac{1}{2}kx_2^2 = \frac{1}{2}\times(2m)\times v^2 \Rightarrow x_2 = v_0\sqrt{\frac{m}{2k}}$

For inelastic collision,

$$e = 0.5,\ -0.5 = \frac{v_2 - v_1}{0 - v_0}$$



$$v_2 - v_1 = \frac{v_0}{2} \quad \text{...(i)}$$

Also, $mv_2 + mv_1 = mv_0$ ...(ii)

From eqns. (i) and (ii), $v_2 = \frac{3}{4}v_0$

$$\therefore\ \frac{1}{2}kx_3^2 = \frac{1}{2}mv_2^2 \Rightarrow x_3 = v_2\sqrt{\frac{m}{k}} = \sqrt{\frac{m}{k}}\left(\frac{3}{4}v_0\right)$$

Hence, $x_1 > x_3 > x_2$

19. (a) : Here, $A = 10\ \text{cm}^2 = 10\times10^{-4}\ \text{m}^2 = 10^{-3}\ \text{m}^2$

$l = 20\ \text{cm} = 0.2\ \text{m}$, $N_1 = 300$, $N_2 = 400$

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

$$= \frac{(4\pi\times10^{-7})\times300\times400\times10^{-3}}{0.2}$$

$$= 2.4\pi\times10^{-4}\ \text{H}$$

20. (a)

21. (16) : Given, $y = 12x - \frac{3}{4}x^2$, $u_x = 3\ \text{m s}^{-1}$

So, $v_y = \frac{dy}{dt} = 12\frac{dx}{dt} - \frac{3}{2}x\frac{dx}{dt} = 12u_x - \frac{3}{2}xu_x$

At $x = 0$, $v_y = u_y$ and $v_y = 12u_x = 12\times3 = 36\ \text{m s}^{-1}$

$$\Rightarrow\ a_y = \frac{d}{dt}\left(\frac{dy}{dt}\right) = 12\frac{d^2x}{dt^2} - \frac{3}{2}\left[\left(\frac{dx}{dt}\right)^2 + x\frac{d^2x}{dt^2}\right]$$

But $\frac{d^2x}{dt^2} = a_x = 0.$

Hence $a_y = -\frac{3}{2}\left(\frac{dx}{dt}\right)^2 = -\frac{3}{2}u_x^2 = -\frac{3}{2}\times(3^2)$

$$= -\frac{27}{2}\ \text{m s}^{-2}$$

Range, $R = \frac{2u_xu_y}{a_y} = \frac{2\times3\times36}{27/2} = 16\ \text{m}$

22. (1.21)

23. (10) : Maximum power, $P_{max} = mg\,v_{max}$

For v_{max}, $mg = kx_0 \Rightarrow x_0 = \frac{mg}{k}$ ...(i)

$\because\ U_i + T_i = U_f + T_f$

$$0 = -mgx_0 + \frac{1}{2}kx_0^2 + \frac{1}{2}mv_{max}^2$$

$$\therefore\ v_{max} = \frac{mg}{k}\sqrt{\frac{k}{m}} = g\sqrt{\frac{m}{k}} \quad \text{[Using (i)]}$$

$$\therefore\ P_{max} = mg\times g\sqrt{\frac{m}{k}} = mg^2\sqrt{\frac{m}{k}}$$

$$= 1\times100\sqrt{\frac{1}{100}} = \frac{100}{10} = 10\ \text{W}$$

24. (0.2) : Here, $l = 50\ \text{cm} = 50\times10^{-2}\ \text{m}$

$m = 50\ \text{g} = 50\times10^{-3}\ \text{kg}$, $I = 5.0\ \text{A}$

Tension in the wires is zero if the force on the rod due to magnetic field is equal and opposite to the weight of the rod.

i.e., $mg = BIl \Rightarrow B = \frac{mg}{Il}$

Substituting the given values, we get

$$B = \frac{50\times10^{-3}\times10}{5\times50\times10^{-2}} = 0.2\ \text{T}$$

25. (12) : Let safe level activity be A.

Initial activity = $64A$.

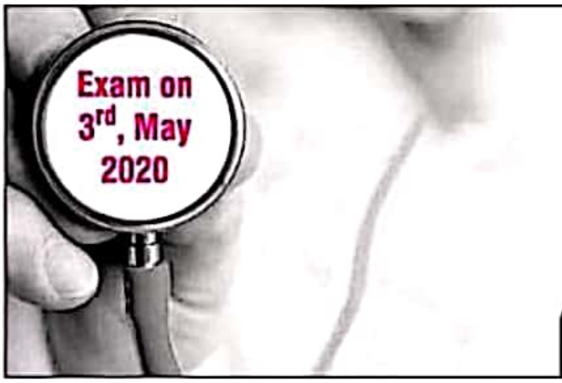
Since, $\frac{N}{N_0} = \frac{A}{A_0} = \frac{A}{64A} = \frac{1}{64}$

or $\left(\frac{1}{2}\right)^n = \frac{1}{64}$ or $n = 6$

Hence, $\frac{t}{T} = n = 6$

As $T = 2\ \text{h}$, $\therefore\ t = 12\ \text{h}$

&&&



Get Ready for NEET

PRACTICE PAPER 2020

1. A bank of overhead arc lamps can produce a light intensity of 2500 W m^{-2} in the 25 ft space stimulator facility at NASA. Find the average momentum density of a total absorbing surface.
   (a) 8.33×10^{-6} kg m^{-2} s^{-1}
   (b) 8.33×10^{-14} kg m^{-2} s^{-1}
   (c) 2.78 kg m^{-2} s^{-1}
   (d) 2.78×10^{-14} kg m^{-2} s^{-1}

2. At room temperature, the rms speed of the molecules of a certain diatomic gas is found to be 1930 m s^{-1}. The gas is
   (a) H_2 (b) F_2 (c) O_2 (d) Cl_2

3. In a galvanometer there is a deflection of 10 divisions per mA. The internal resistance of the galvanometer is 60 Ω. If a shunt of 2.5 Ω is connected to the galvanometer and there are 50 divisions in all, on the scale of galvanometer, what maximum current can this galvanometer read?
   (a) 125 mA (b) 100 mA
   (c) 25 mA (d) 250 mA

4. The focal length of a convex lens of refractive index 1.5 is f when it is placed in air. When it is immersed in a liquid it behaves as a converging lens and its focal length becomes xf $(x > 1)$. The refractive index of the liquid is
   (a) > 3/2 (b) < 3/2 and > 1
   (c) < 3/2 (d) all of these

5. Three concentric spherical shells have radii r, $2r$ and $3r$ with charges q_1, q_2 and q_3 respectively. Innermost and outermost shells are earthed. Which of the following is incorrect?
   (a) $q_1 + q_3 = -q_2$ (b) $q_1 = -\frac{q_2}{4}$
   (c) $\frac{q_3}{q_1} = 3$ (d) $\frac{q_3}{q_2} = -\frac{1}{3}$

6. If a magnetic material is having magnetic susceptibility $(\chi) = -1$, then the relative magnetic permeability (μ_r) and type of magnetic material is
   (a) 0, diamagnetic (b) 2, ferromagnetic
   (c) 1, paramagnetic (d) −1, diamagnetic

7. In the formula $X = 3YZ^2$, X and Z have dimensions of capacitance and magnetic induction respectively. What are the dimensions of Y in MKSQ system?
   (a) $[M^{-3}L^{-1}T^3Q^4]$ (b) $[M^{-3}L^{-2}T^4Q^4]$
   (c) $[M^{-2}L^{-2}T^4Q^4]$ (d) $[M^{-3}L^{-2}T^4Q^1]$

8. A boat crosses a river of width D from port A to port B, which are just on the opposite side. The speed of the water is v_W and that of boat is v_B relative to water. Assume $v_B = 2v_W$. What is the time taken by the boat, if it has to cross the river directly on the AB line?
   (a) $\frac{2D}{v_B\sqrt{3}}$ (b) $\frac{\sqrt{3}D}{2v_B}$
   (c) $\frac{D}{v_B\sqrt{2}}$ (d) $\frac{D\sqrt{2}}{v_B}$

9. 5 mole of an ideal gas with $\gamma = 7/5$ initially at STP are compressed adiabatically so that its temperature becomes 400°C. The increase in the internal energy of gas in kJ is
   (a) 21.55 (b) 41.55 (c) 65.55 (d) 50.55

10. When a wire of length 10 m is subjected to a force of 100 N along its length, the lateral strain produced is 0.01×10^{-3}. The Poisson's ratio was found to be 0.4. If the area of cross-section of wire is 0.025 m^2, its Young's modulus is
    (a) 1.6×10^8 N m^{-2} (b) 2.5×10^{10} N m^{-2}
    (c) 1.25×10^{11} N m^{-2} (d) 16×10^9 N m^{-2}

11. A mass of 0.2 kg is attached to the lower end of a massless spring of force constant 200 N m^{-1}, the upper end of which is fixed to a rigid support. Which of the following statements is not true?
    (a) The frequency of oscillation will be nearly 5 Hz.
    (b) In equilibrium, the spring will be stretched by 2 cm.

(c) If the mass is raised till the spring is unstretched state and then released, it will go down by 2 cm before moving upward.

(d) If the system is taken to a planet, the frequency of oscillation will be the same as on the earth.

12. A physicist works in a laboratory where the magnetic field is 2 T. She wears a necklace enclosing area $0.01\ m^2$ in such a way that the plane of the necklace is normal to the field and is having a resistance $R = 0.01\ \Omega$. Due to power failure, the field decays to 1 T in time 10^{-3} s, then the total heat produced in her necklace is

(a) 10 J (b) 20 J (c) 30 J (d) 40 J

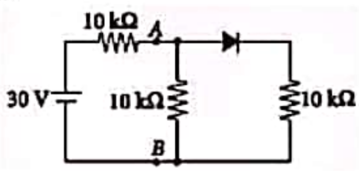
13. Two radioactive sources A and B of half lives 1 h and 2 h respectively initially contain the same number of radioactive atoms. At the end of two hours, their rates of disintegration are in the ratio of

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

14. An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz than the fundamental frequency of the open pipe. The fundamental frequency of the open pipe is

(a) 200 Hz (b) 300 Hz
(c) 240 Hz (d) 480 Hz

15. In the given circuit, the potential difference between A and B is



(a) 0 (b) 5 V (c) 10 V (d) 15 V

16. In Young's double slit experiment of equal width slits, if intensity at the centre of screen is I_0, then intensity at a distance of $\beta/4$ from the central maxima is (β is the fringe width)

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

17. Two satellites S_1 and S_2 revolve around a planet in coplanar circular orbits in the same sense. Their periods of revolution are 1 h and 8 h respectively. The radius of orbit of S_1 is 10^4 km. When S_2 is closest to S_1, the speed of S_2 relative to S_1 is

(a) $\pi \times 10^4$ km h^{-1} (b) $2\pi \times 10^4$ km h^{-1}
(c) $3\pi \times 10^4$ km h^{-1} (d) $4\pi \times 10^4$ km h^{-1}

18. A large plane sheet of charge having surface charge density $5.0 \times 10^{-16}\ C\ m^{-2}$ lies in the X-Y plane. The electric flux through a circular area of radius 0.1 m, if the normal to the circular area makes an angle of 60° with the Z-axis is
[Given : $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$]

(a) $4.44 \times 10^{-7}\ N\ m^2\ C^{-1}$
(b) $3.33 \times 10^{-7}\ N\ m^2\ C^{-1}$
(c) $2.22 \times 10^{-7}\ N\ m^2\ C^{-1}$
(d) $1.11 \times 10^{-7}\ N\ m^2\ C^{-1}$

19. A block of mass 10 kg is moving in x-direction with a constant speed of 10 m s^{-1}. It is subjected to a retarding force $F = -0.1x$ J m^{-1} during its travel from $x = 20$ m to $x = 30$ m. Its final kinetic energy will be

(a) 475 J (b) 450 J (c) 275 J (d) 250 J

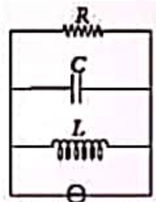
20. When a light of photons of energy 4.2 eV is incident on a metallic sphere of radius 10 cm and work function 2.4 eV, photoelectrons are emitted. The number of photoelectrons liberated before the emission is stopped, is
($e = 1.6 \times 10^{-19}$ C and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ N\ m^2\ C^{-2}$)

(a) 6.25×10^8 (b) 1.25×10^{18}
(c) 1.25×10^8 (d) 6.25×10^{18}

21. A force F acting on a body depends on its displacement S as $F \propto S^{-1/3}$. The power delivered by F will depend on displacement as

(a) $S^{2/3}$ (b) $S^{1/2}$ (c) S^0 (d) $S^{-5/3}$

22. In the circuit shown in figure $X_L = \frac{X_C}{2} = R$, the peak value of current I_0 is



(a) $\frac{\sqrt{5}V_0}{2R}$ (b) $\frac{V_0}{2\sqrt{2}R}$
(c) $\frac{V_0}{2R}$ (d) $\frac{V_0}{2\sqrt{3}R}$

23. A man in a balloon rising vertically with an acceleration of 4.9 m s^{-2} releases a stone 2 seconds after the balloon is let go from the ground. The greatest height above the ground reached by the stone is (Take $g = 9.8$ m s^{-2})

(a) 14.7 m (b) 19.6 m
(c) 9.8 m (d) 24.5 m

24. The twisting couple per unit twist for a solid cylinder of radius 3 cm is 0.1 N m. The twisting couple per unit twist, for a hollow cylinder of same material with outer and inner radius 5 cm and 4 cm respectively will be

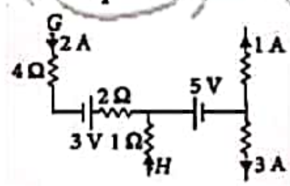
(a) 0.1 N m (b) 0.455 N m
(c) 0.91 N m (d) 1.82 N m

25. Water is in streamline flow along a horizontal pipe with nonuniform cross-section. At a point in the pipe where the area of cross-section is 10 cm^2, the velocity of water is 1 m s^{-1} and the pressure is 2000 Pa. The pressure at another point where the cross-sectional area is 5 cm^2 is
(a) 4000 Pa (b) 2000 Pa
(c) 1000 Pa (d) 500 Pa

26. Assuming the sun to have a spherical outer surface of radius R, radiating like a black body at temperature t°C, the power received by a unit surface (normal to the incident rays) at a distance r from the centre of the sun is
(a) $\frac{4\pi R^2 \sigma t^4}{r^2}$ (b) $\frac{R^2\sigma(t+273)^4}{4\pi r^2}$
(c) $\frac{16\pi R^2 \sigma t^4}{r^2}$ (d) $\frac{R^2\sigma(t+273)^4}{r^2}$

27. Excitation energy of a hydrogen like ion in its first excitation state is 40.8 eV. Energy needed to remove the electron from the ion in ground state is
(a) 54.4 eV (b) 13.6 eV
(c) 40.8 eV (d) 27.2 eV

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

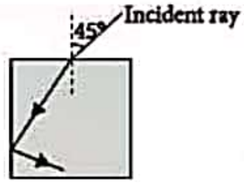


(a) 0 V (b) 12 V (c) 7 V (d) 3 V

29. If wavelength of photon emitted due to transition of an electron from the third orbit to the first orbit in a hydrogen atom is λ, then the wavelength of photon emitted due to transition of electron from the fourth orbit to the second orbit will be
(a) $\frac{128}{27}\lambda$ (b) $\frac{25}{9}\lambda$ (c) $\frac{36}{7}\lambda$ (d) $\frac{125}{11}\lambda$

30. A beam of cathode rays is subjected to crossed electric field E and magnetic field B. The fields are adjusted such that the beam is not deflected. The specific charge of the cathode rays is given by (Take, V = potential difference between anode and cathode)
(a) $\frac{B^2}{2VE^2}$ (b) $\frac{2VB^2}{E^2}$ (c) $\frac{2VE^2}{B^2}$ (d) $\frac{E^2}{2VB^2}$

31. For the given incident ray as shown in figure, the condition of total internal reflection of ray will be satisfied if the refractive index of block will be



(a) $\frac{\sqrt{3}+1}{2}$ (b) $\frac{\sqrt{2}+1}{2}$ (c) $\sqrt{\frac{3}{2}}$ (d) $\sqrt{\frac{7}{6}}$

32. A body of mass M is dropped from a height h on a sand floor. If the body penetrates a distance x into the sand, the average resistance offered by the sand to the body is
(a) $Mg\left(\frac{h}{x}\right)$ (b) $Mg\left(1+\frac{h}{x}\right)$
(c) $Mgh + Mgx$ (d) $Mg\left(1-\frac{h}{x}\right)$

33. If the charge on a capacitor is increased by 2 C, the energy stored in it increases by 21%. The original charge on the capacitor is
(a) 10 C (b) 20 C (c) 30 C (d) 40 C

34. A cylindrical metallic rod in thermal contact with two reservoirs of heat at its two ends conducts an amount of heat Q in time t. The metallic rod is melted and the material is formed into a rod of half the radius of the original rod. What is the amount of heat conducted by the new rod, when placed in thermal contact with the two reservoirs in time t?
(a) $\frac{Q}{4}$ (b) $\frac{Q}{16}$ (c) $2Q$ (d) $\frac{Q}{2}$

35. A metal sphere of radius r and specific heat s is rotated about an axis passing through its centre at a speed of υ rotations per second. It is suddenly stopped and 50% of its energy is used in increasing its temperature. Then the rise in temperature of the sphere is
(a) $\frac{2\pi^2\upsilon^2 r^2}{5s}$ (b) $\frac{\pi^2\upsilon^2}{10r^2 s}$
(c) $\frac{7}{8}\pi r^2\upsilon^2 s$ (d) $\frac{5(\pi r\upsilon)^2}{14s}$

36. The side of a cubical block when measured with a vernier callipers is 2.50 cm. The vernier constant is 0.01 cm. The maximum possible error in the area of the side of the block is
(a) ± 0.01 cm^2 (b) ± 0.02 cm^2
(c) ± 0.05 cm^2 (d) ± 0.10 cm^2

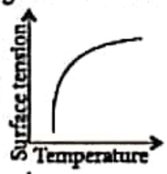
37. When the angle of projection is 75°, a ball falls 10 m short of the target. When the angle of projection is 45°, it falls 10 m ahead of the target. Both are projected from the same point with the same speed in the same direction, the distance of the target from the point of projection is

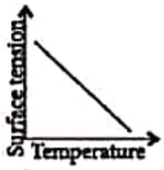
(a) 15 m (b) 30 m (c) 45 m (d) 10 m

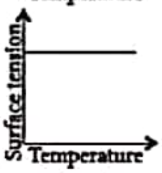
38. If the pressure of an ideal gas contained in a closed vessel increased by 0.5%, the increase in temperature is 2 K. The initial temperature of the gas is

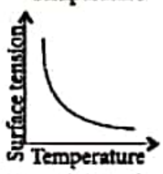
(a) 27 °C (b) 127 °C (c) 300 °C (d) 400 °C

39. Which graph represents the variation of surface tension with temperature over small temperature ranges for water?

(a)


(b)


(c)


(d)


40. The work done by electric field during the displacement of a negatively charged particle towards a fixed positively charged particle is 9 J. As a result the distance between the charges has been decreased by half. What work is done by the electric field over the first half of this distance?

(a) 3 J (b) 6 J (c) 1.5 J (d) 9 J

41. Two long parallel wires carry equal current I flowing in the same direction are at a distance $2d$ apart. The magnetic field B at a point lying on the perpendicular line joining the wires and at a distance x from the midpoint is

(a) $\frac{\mu_0 Id}{\pi(d^2+x^2)}$ (b) $\frac{\mu_0 Ix}{\pi(d^2-x^2)}$

(c) $\frac{\mu_0 Ix}{(d^2+x^2)}$ (d) $\frac{\mu_0 Id}{(d^2-x^2)}$

42. The nucleus $_{10}Ne^{23}$ decay by β^- emission. The maximum kinetic energy of the electrons emitted is

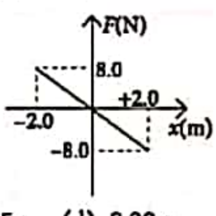
Given : $m(_{10}Ne^{23}) = 22.994466$ amu,

$m(_{11}Na^{23}) = 22.989770$ amu

(a) 4.372 MeV (b) 2.472 MeV

(c) 5.732 MeV (d) 1.341 MeV

43. A body of mass 0.01 kg executes simple harmonic motion (SHM) about $x = 0$ under the influence of a force shown below. The period of the SHM is



(a) 1.05 s (b) 0.52 s (c) 0.25 s (d) 0.30 s

44. Two coils, a primary of 400 turns and a secondary of 20 turns are wound over an iron core of length 20π m and cross-section of 2 cm radius. If $\mu_r = 800$, then coefficient of mutual induction is approximately

(a) 1.6×10^7 H (b) 1.6×10^{-4} H

(c) 1.6×10^3 H (d) 1.6 H

45. In the Young's double slit experiment at a point P on the central bright fringe is such that the intensity of the point P is $= \frac{1}{4}$ time the maximum intensity. Distance between the slits is d and wavelength is λ. Then angular separation of point P is

(a) $\sin^{-1}\left(\frac{\lambda}{d}\right)$ (b) $\sin^{-1}\left(\frac{\lambda}{2d}\right)$

(c) $\sin^{-1}\left(\frac{\lambda}{3d}\right)$ (d) $\sin^{-1}\left(\frac{\lambda}{4d}\right)$

SOLUTIONS

1. (d) : Energy density $= \frac{I}{c}$,

Momentum density $= \frac{I}{c^2} = \frac{2500}{9 \times 10^{16}}$

$= 2.78 \times 10^{-14}$ kg m^{-2} s^{-1}

2. (a) : Mass of the gas molecule

$m = \frac{3KT}{v^2} = \frac{3RT}{Nv^2}$

$= \frac{3 \times 8.31 \times 300}{6.023 \times 10^{23} \times (1930)^2} = 3.3 \times 10^{-27}$ kg

Mass of H_2 molecule $= 1.66 \times 10^{-27} \times 2 = 3.32 \times 10^{-27}$ kg

Thus the gas is hydrogen.

3. (a) : As the galvanometer has 50 divisions, current required to produce full scale deflection is

$I_g = \frac{1}{10} \times 50$ mA $= 5$ mA $= 0.005$ A

$R_g = 60\ \Omega$ and $R_s = 2.5\ \Omega$

Let I be the maximum current that the galvanometer can read.

Then $I_g = \frac{R_s}{R_g + R_s} \times I$

&&&

Monthly Test Drive CLASS XII ANSWER KEY

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

or $I = \frac{(R_g + R_s)I_g}{R_s} = \frac{(60+2.5)5}{2.5} = 125\,\text{mA}$

4. (b) : According to lens maker's formula.

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

when the lens is placed in air

$$\frac{1}{f} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad ...(i)$$

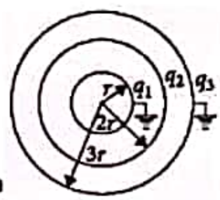
When the lens is placed in the liquid

$$\frac{1}{xf} = \left(\frac{1.5}{y} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad ...(ii)$$

where, y = refractive index of the liquid.

Solving eqn (i) and (ii), we get $y = \frac{3}{2 + (1/x)}$

5. (d) : Potential on innermost shell is zero.



$\therefore V_{inner} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r} + \frac{q_2}{2r} + \frac{q_3}{3r}\right] = 0$

$\Rightarrow 6q_1 + 3q_2 + 2q_3 = 0 \quad ...(i)$

Potential on outermost shell is zero

$\therefore V_{outer} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{3r} + \frac{q_2}{3r} + \frac{q_3}{3r}\right] = 0$

$\Rightarrow q_1 + q_2 + q_3 = 0 \quad ...(ii)$

From eqn. (ii), $q_1 + q_3 = -q_2$

Substituting the value of q_3 from (ii) in (i), we get

$6q_1 + 3q_2 + 2(-q_1 - q_2) = 0; q_1 = -q_2/4$

Substituting the value of q_2 from (ii) in (i), we get

$6q_1 + 3(-q_1 - q_3) + 2q_3 = 0; q_3/q_1 = 3$

Substituting the value of q_1 from (ii) in (i), we get

$6(-q_2 - q_3) + 3q_2 + 2q_3 = 0; \frac{q_2}{q_3} = -\frac{4}{3}$

Option (d) is incorrect.

6. (a) : Here, $\chi = -1$

then $\mu_r = 1 + \chi$ or $\mu_r = 1 + (-1) = 1 - 1 = 0$

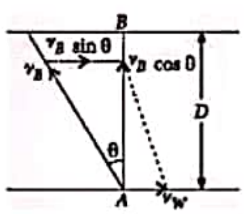
Since, magnetic susceptibility of given material is less than one, given magnetic material is a diamagnetic material.

7. (b) : $[X] = [C] = [M^{-1}L^{-2}T^2Q^2]$

$[Z] = [B] = [MT^{-1}Q^{-1}]$

$\therefore [Y] = \frac{[X]}{[Z^2]} = \frac{[M^{-1}L^{-2}T^2Q^2]}{[MT^{-1}Q^{-1}]^2} = [M^{-3}L^{-2}T^4Q^4]$

8. (a): To move straight along AB, $v_B \sin\theta = v_W$



$\sin\theta = \frac{v_W}{v_B} = \frac{v_W}{2v_W} = \frac{1}{2}$

$\therefore \theta = 30°$

Time taken to cross the river,

$t = \frac{D}{v_B\cos\theta} = \frac{D}{v_B\cos 30°} = \frac{2D}{v_B\sqrt{3}}$

9. (b) : Here, $n = 5, \gamma = 7/5, T_1 = 0°C, T_2 = 400°C$

$dU = \frac{nRdT}{\gamma - 1} = \frac{5\times 8.31\times(400-0)}{(7/5)-1} = 41550\text{ J} = 41.55\text{ kJ}$

10. (a)

11. (b) : $\upsilon = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{200}{0.2}} = 5\text{ Hz}$

In equilibrium, $kx = mg$

or $x = \frac{mg}{k} = \frac{0.2\times 10}{200} = 0.01\text{ m}$

When mass is raised till the spring is unstretched, the work $= \frac{1}{2}kx^2 = mgx$

When the mass is released from the unstretched position of spring, then total work done

$mgx' = (mgx) + \frac{1}{2}kx^2 = 2mgx$

or $x' = 2x = 2\times 0.01 = 0.02\text{ m}$

As υ of spring is independent of g so that the frequency of oscillation will be the same as that on the Earth.

12. (a) : As $\varepsilon = -\frac{d\phi}{dt} = -A\frac{dB}{dt}$

$= -0.01\times\frac{(1-2)}{10^{-3}} = 10\text{ V}$

Heat produced $= \frac{\varepsilon^2 t}{R} = \frac{(10)^2\times 10^{-3}}{0.01} = 10\text{ J}$

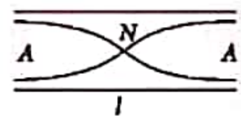
13. (c) : Rate of disintegration $\propto$ number of atoms left

In case of source A, $\frac{N}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

In case of source B, $\frac{N}{N_0} = \left(\frac{1}{2}\right)^1 = \frac{1}{2}$

$\therefore \frac{R_A}{R_B} = \frac{N_0/4}{N_0/2} = \frac{1}{2}$

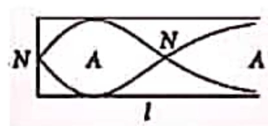
14. (a) : For open pipe, in fundamental mode,



$l = \frac{\lambda_1}{2}$

$\therefore$ Frequency $= \frac{v}{\lambda_1} = \frac{v}{2l} \quad \therefore \upsilon_1 = \frac{v}{2l} \quad ...(i)$

For closed pipe, vibration in third harmonic,



$l = \frac{3\lambda_2}{4}$

$\therefore$ Frequency $= \frac{v}{\lambda_2} = \frac{3v}{4l}$

or $\upsilon_2 = \frac{3v}{4l}$ ... (ii)

$\upsilon_2 - \upsilon_1 = 100$ (given)

$\therefore \frac{3v}{4l} - \frac{v}{2l} = 100$ or $\frac{v}{4l} = 100$ or $v = 400l$

$\therefore \upsilon_1 = \frac{v}{2l} = \frac{400l}{2l} = 200$ Hz

$\therefore$ Fundamental frequency of open pipe = 200 Hz.

15. (c) : The forward biased p-n junction does not offer any resistance.

$\therefore R_{AB} = \frac{10 \times 10}{10+10} = 5\ k\Omega$

Total resistance, $R = 10 + 5 = 15\ k\Omega$

Current in the circuit, $I = \frac{V}{R} = \frac{30}{15 \times 10^3} = 2 \times 10^{-3}$ A

Current through each arm $= \frac{I}{2} = 10^{-3}$ A

$\therefore V_{AB} = 10 \times 10^3 \times 10^{-3} = 10$ V

16. (b) : Let the intensity of individual waves be I, then

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

Also, $\Delta x = d\sin\theta = \frac{dy}{D}$

$\Delta x = \frac{d}{D} \times \frac{\beta}{4} = \frac{d}{D} \times \frac{\lambda D}{4d} = \frac{\lambda}{4};\ \Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$

So required intensity

$I' = I + I + 2\sqrt{I^2}\cos\frac{\pi}{2} = 2I = \frac{I_0}{2}$

17. (a) : $\frac{mv^2}{R} = \frac{GMm}{R^2} \Rightarrow v^2 = \frac{GM}{R}$

Also, $v = \frac{2\pi R}{T} \Rightarrow v^2 = \frac{4\pi^2 R^2}{T^2} = \frac{GM}{R}$

$\therefore T^2 = \frac{4\pi^2 R^3}{GM}$

If T_1 and T_2 are the time periods for satellite S_1 and S_2 respectively

$$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^3 \Rightarrow R_2 = \left(\frac{T_2}{T_1}\right)^{2/3} \times R_1$$

Here, $T_1 = 1$ h, $T_2 = 8$ h, $R_1 = 10^4$ km

$\therefore R_2 = \left(\frac{8}{1}\right)^{2/3} \times 10^4\ \text{km} = 4 \times 10^4\ \text{km}$

$$v_1 = \frac{2\pi R_1}{T_1} = \frac{2\pi \times 10^4}{1} = 2\pi \times 10^4\ \text{km h}^{-1}$$

$$v_2 = \frac{2\pi R_2}{T_2} = \frac{2\pi \times 4 \times 10^4}{8} = \pi \times 10^4\ \text{km h}^{-1}$$

Relative velocity of S_2 with respect to S_1 is

$v = v_2 - v_1 = (\pi \times 10^4 - 2\pi \times 10^4)$ km h^{-1}

$|v| = \pi \times 10^4$ km h^{-1}

18. (a) : Here, $\sigma = 5.0 \times 10^{-16}$ C m^{-2}, $r = 0.1$ m, $\theta = 60°$

Field due to a plane sheet of charge,

$E = \frac{\sigma}{2\varepsilon_0}$

Flux through circular area,

$\phi_E = E\Delta S\cos\theta = \frac{\sigma}{2\varepsilon_0} \times \pi r^2 \cos\theta$

$= \frac{5.0 \times 10^{-16} \times 3.14 \times (0.1)^2 \cos 60°}{2 \times 8.85 \times 10^{-12}}$

$= 4.44 \times 10^{-7}$ N m^2 C^{-1}

19. (a): According to work energy theorem,

$W = \Delta K.E.;\ W = K.E_F - K.E_I$

$Fdx = K.E_F - \frac{1}{2} \times m \times v^2$

$Fdx = K.E._F - \frac{1}{2} \times 10 \times 10^2;\ Fdx = K.E._F - 500$

How does WiFi work on planes ?

The central government has permitted airlines operating in India to provide in flight WiFi services to passengers.

WiFi in airplanes let you use your gadgets with an internet connection just like on ground, but with the flight mode turned on.

As inflight WiFi becomes available in more and more airlines, ever wondered how it works at 40,000 feet?

There are two systems of connectivity for inflight WiFi-Air-to-ground and satellite.

Air-to-ground system is a ground based system that works similar to mobile data network on cell phones. There are towers that project signals upwards unlike mobile data towers that projects downwards. Antennae fitted beneath the airplanes receive signals from these towers and send them to an onboard server. The server has a modem that converts these signals, thereby providing WiFi to passengers. These towers are connected to operation centres run by service providers.

In Satellite based WiFi system, antennae are fitted on the top of airplanes. Antennae receive signals from satellites orbiting the earth. The antennae need to constantly adjust their positions to receive signals as both the satellite and the airplane are constantly moving. These satellites are linked to ground stations that are connected to operation centres run by service providers.

The air-to-ground system works seamlessly, unless the airplane is flying over a space with no towers. In that case, satellite WiFi systems can be utilised.

Even though airlines all over the world are rushing to provide inflight WiFi services, WiFi in airplanes are slower and expensive than on the ground.

$$\int_{20}^{30} -0.1x\,dx = K.E._F - 500;\ -0.1\left[\frac{x^2}{2}\right]_{20}^{30} = K.E._F - 500$$

$$-0.1\left[\frac{900-400}{2}\right] = K.E._F - 500$$

$K.E._F = 500 - 25 = 475$ J

20. (c) : Here,
Radius of the sphere, $r = 10$ cm $= 10 \times 10^{-2}$ m
Work function, $\phi_0 = 2.4$ eV
Energy of a photon, $E = h\upsilon = 4.2$ eV
According to Einstein's photoelectric equation

$$K_{max} = h\upsilon - \phi_0$$

But $K_{max} = eV_0$
where V_0 is the stopping potential.

$\therefore\ eV_0 = h\upsilon - \phi_0$

$eV_0 = 4.2\text{ eV} - 2.4\text{ eV} = 1.8$ eV

or $V_0 = 1.8$ V

The sphere will stop emitting photoelectrons, when the potential on its surface becomes 1.8 V.
Let n be the number of photoelectrons emitted from the sphere. Then charge on the sphere is $q = ne$
Potential on the surface of the sphere is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\frac{ne}{r}$$

$$\therefore\ n = \frac{Vr}{\frac{1}{4\pi\varepsilon_0}e} = \frac{(1.8\text{ V})(10\times10^{-2}\text{ m})}{(9\times10^9\text{ N m}^2\text{ C}^{-2})(1.6\times10^{-19}\text{ C})}$$

$= 1.25 \times 10^8$

21. (c) : As $F \propto S^{-1/3}$, therefore, acceleration, $a \propto S^{-1/3}$

$$a = \frac{dv}{dt} = \frac{dv}{dS}\cdot\frac{dS}{dt} = \frac{dv}{dS}v \ \text{ i.e. } v\frac{dv}{dS} \propto S^{-1/3}$$

Integrating both sides, we get

$v^2 \propto S^{2/3}$ or $v \propto S^{1/3}$

As $P = Fv$

$\therefore\ P \propto S^{-1/3}S^{1/3}$ or $P \propto S^0$.

i.e. Power is independent of S.

22. (a) : $\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$

Substituting the given values, we get

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{2R} - \frac{1}{R}\right)^2};\ \frac{1}{Z} = \sqrt{\frac{1}{R^2} + \frac{1}{4R^2}};\ \frac{1}{Z} = \frac{\sqrt{5}}{2R}$$

or $Z = \frac{2R}{\sqrt{5}}\ \therefore\ I_0 = \frac{V_0}{Z} = \frac{\sqrt{5}V_0}{2R}$

23. (a): Here, $a = 4.9$ m s^{-2}, $t = 2$ s, $u = 0$,

$$s = ut + \frac{1}{2}at^2;\ s = 0 + \frac{1}{2}\times4.9\times(2)^2 = 9.8\text{ m}$$

This is the height from where stone is dropped.
Upward velocity of stone when released,
$v = u + at = 0 + 4.9 \times 2 = 9.8$ m s^{-1}
The stone will move up till its velocity become zero.
From, $v^2 - u^2 = 2as$

$0 - (9.8)^2 = 2(-9.8)s'\ \therefore\ s' = 4.9$ m

Maximum height above the ground

$= s + s' = 9.8\text{ m} + 4.9\text{ m} = 14.7$ m

24. (b) : Twisting couple per unit twist for solid cylinder,

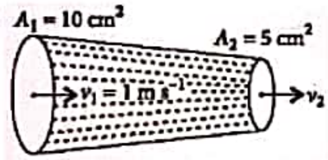
$$\tau_1 = \frac{\pi\eta R^4}{2l} \quad \text{...(i)}$$

for hollow cylinder, $\tau_2 = \frac{\pi\eta(r_2^4 - r_1^4)}{2l}$

$\therefore\ \tau_2 = \tau_1\frac{r_2^4 - r_1^4}{R^4}$ using (i),

$$= \frac{0.1\times(5^4 - 4^4)}{3^4} = \frac{36.9}{81} = 0.455\text{ N m}$$

25. (d) :



According to equation of continuity,
$A_1v_1 = A_2v_2$

$$\therefore\ v_2 = \frac{A_1v_1}{A_2} = \frac{10\text{ cm}^2\times1\text{ m s}^{-1}}{5\text{ cm}^2} = 2\text{ m s}^{-1}$$

For a horizontal pipe, according to Bernoulli's theorem

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

$$= 2000 + \frac{1}{2}\times10^3\times(1^2 - 2^2)$$

($\because$ Density of water, $\rho = 10^3$ kg m^{-3})

$$= 2000 - \frac{1}{2}\times10^3\times3 = 2000 - 1500 = 500\text{ Pa}$$

26. (d) : From Stefan's law, energy radiated by the sun per second, $E = \sigma AT^4 = \sigma\times4\pi R^2T^4$
Power received per unit area at distance r from the sun,

$$I = \frac{E}{4\pi r^2} = \frac{\sigma\times4\pi R^2\times T^4}{4\pi r^2} = \frac{\sigma R^2(t+273)^4}{r^2}$$

27. (a) : Excitation energy

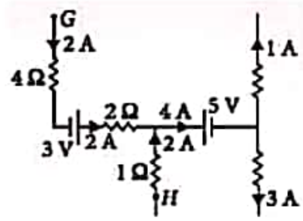
$$\Delta E = E_2 - E_1 = 13.6Z^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right];\ 40.8 = 13.6Z^2\times\frac{3}{4}$$

or $Z = 2$

So, energy required to remove the electron from ground state

$$= +\frac{13.6Z^2}{(1)^2} = 13.6(2)^2 = 54.4\text{ eV}$$

28. (c) : The current distribution in a circuit is as shown in the figure.



Let V_G and V_H be the potentials at points G and H respectively.

$\therefore \quad V_G - (2\text{ A})(4\ \Omega) +$

$$3\text{ V} - (2\text{ A})(2\ \Omega) + (2\text{ A})(1\ \Omega) = V_H$$

$V_G - 8\text{ V} + 3\text{ V} - 4\text{ V} + 2\text{ V} = V_H$

$V_G - V_H = 7\text{ V}$

29. (a) : $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \Rightarrow \lambda = \frac{9}{8R}$

Again, $\frac{1}{\lambda'} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] \Rightarrow \lambda' = \frac{16}{3R}$

Now, $\frac{\lambda'}{\lambda} = \frac{16}{3R} \times \frac{8R}{9}$ or $\lambda' = \frac{128}{27}\lambda$

30. (d) : As the electron beam is not deflected, then, $F_m = F_e$

or $Bev = Ee$; or $v = \frac{E}{B}$ ...(i)

As the electron moves from cathode to anode, its potential energy at the cathode appears as its kinetic energy at the anode. As V is the potential difference between the anode and cathode, then potential energy of the electron at cathode $= eV$. Also, kinetic energy of the electron at anode $= \frac{1}{2}mv^2$

According to law of conservation of energy $\frac{1}{2}mv^2 = eV$

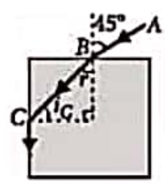
or $v = \sqrt{\frac{2eV}{m}}$ ...(ii)

From equations (i) and (ii), we have $\sqrt{\frac{2eV}{m}} = \frac{E}{B}$

or $\frac{e}{m} = \frac{E^2}{2VB^2}$

31. (c) : As $r + i_C = 90°$, $r = (90° - i_C)$

$\mu = \frac{\sin i}{\sin r} = \frac{\sin 45°}{\sin(90° - i_C)} = \frac{1}{\sqrt{2}\cos i_C}$



As $\mu = \frac{1}{\sin i_C}$, $\sin i_C = \sqrt{2}\cos i_C$

or $\tan i_C = \sqrt{2}$, $\Rightarrow \sin i_C = \sqrt{\frac{2}{3}}$

or $\mu = \frac{1}{\sin i_C} = \sqrt{\frac{3}{2}}$

32. (b) : If the body strikes the sand floor with a velocity v, then

$Mgh = \frac{1}{2}Mv^2$

With this velocity v, when body passes through the sand floor it comes to rest after travelling a distance x.

Let F be the resisting force acting on the body. Net force in downwards direction $= Mg - F$

Work done by all the forces is equal to change in kinetic energy

$\therefore \quad (Mg - F)x = 0 - \frac{1}{2}Mv^2$

$(Mg - F)x = -Mgh$ or $Fx = Mgh + Mgx$

$\therefore \quad F = Mg\left(1 + \frac{h}{x}\right)$

33. (b) : Energy stored in the capacitor

$U = \frac{1}{2}\frac{Q^2}{C}$ ...(i)

Here, $U' = U + 21\%$ of $U = U + \frac{21U}{100} = 1.21U$

$\therefore \quad 1.21U = \frac{1}{2}\frac{(Q+2)^2}{C}$ ...(ii)

Divide (ii) by (i) we get

$\frac{1.21}{1} = \frac{(Q+2)^2}{Q^2}$ or $\sqrt{\frac{1.21}{1}} = \frac{Q+2}{Q}$

or $1.1Q = Q + 2$ or $(1.1 - 1)Q = 2$

or $0.1Q = 2$ or $Q = \frac{2}{(1/10)} = 20\text{ C}$

34. (b)

35. (a) : Moment of inertia of a sphere,

$I = \frac{2}{5}mr^2$; $\omega = 2\pi\upsilon$ rad s^{-1}

$\therefore$ Kinetic energy $= \frac{1}{2}I\omega^2 = \frac{1}{2} \times \frac{2}{5}mr^2 \times (2\pi\upsilon)^2$

$= \frac{4}{5}m\pi^2r^2\upsilon^2$

Half of this energy is converted into heat.

$\therefore \quad \Delta Q = \frac{1}{2} \times \frac{4}{5}m\pi^2r^2\upsilon^2 = \frac{2}{5}m\pi^2r^2\upsilon^2$ ...(i)

Specific heat, $s = \frac{1}{m}\frac{\Delta Q}{\Delta T}$

or $\Delta T = \frac{\Delta Q}{ms} = \frac{\frac{2}{5}m\pi^2r^2\upsilon^2}{ms}$ (Using (i))

$\Delta T = \frac{2\pi^2r^2\upsilon^2}{5s}$

36. (c) : Here $l = 2.50$ cm and $\Delta l = 0.01$ cm

Since $A = l^2 = (2.50\text{ cm})^2$

$\therefore \quad \frac{\Delta A}{A} = 2 \cdot \frac{\Delta l}{l}$; $\frac{\Delta A}{A} = 2 \times \frac{0.01\text{ cm}}{2.50\text{ cm}}$

$\therefore \quad \Delta A = \frac{2 \times 0.01\text{ cm}}{2.50\text{ cm}} \times (2.50\text{ cm})^2$

$= 2 \times 0.01 \times 2.50\text{ cm}^2$; $= 0.01 \times 5\text{ cm}^2$

or $\Delta A = \pm 0.05\text{ cm}^2$

37. (b)

38. (b) : Closed vessel means volume remains constant.

$\therefore \quad \frac{P}{T} = \text{constant}$ or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ or $\frac{P_1}{P_2} = \frac{T_1}{T_2}$

Let P and T be initial pressure and temperature of the gas. Then

$$\frac{P}{P + \frac{0.5}{100}P} = \frac{T}{T+2}$$

On solving, we get $T = 400\text{ K} = 127°\text{C}$

39. (b) : As $S_T = S_0(1 - \alpha T)$, *i.e.*, surface tension decreases with increase in temperature.

40. (a) : Here, $U_1 = \frac{Q(-q)}{4\pi\varepsilon_0 r}$, $U_2 = \frac{Q(-q)}{4\pi\varepsilon_0 (r/2)}$

$\therefore \quad U_1 - U_2 = \frac{Q(-q)}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{2}{r}\right] = \frac{Qq}{4\pi\varepsilon_0 r} = 9 \qquad \text{...(i)}$

When negative charge travels first half of distance, *i.e.*, $r/4$, potential energy of the system

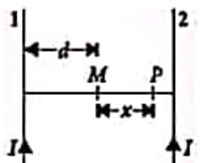
$$U_3 = \frac{Q(-q)}{4\pi\varepsilon_0(3r/4)} = \frac{-Qq}{4\pi\varepsilon_0 r} \times \frac{4}{3}$$

$\therefore$ Work done $= U_1 - U_3$

$$= \frac{Q(-q)}{4\pi\varepsilon_0 r} + \frac{Qq}{4\pi\varepsilon_0 r} \times \frac{4}{3}; = \frac{Qq}{4\pi\varepsilon_0 r} \times \frac{1}{3} = \frac{9}{3} = 3\text{ J}$$

41. (b) : The magnetic field due to first wire

$$B_1 = \frac{\mu_0 I}{2\pi(d+x)}$$



Due to second wire

$$B_2 = \frac{\mu_0 I}{2\pi(d-x)}$$

Both the magnetic fields act in opposite directions.

$$\therefore \quad B = B_2 - B_1 = \frac{\mu_0 I}{2\pi}\left[\frac{1}{d-x} - \frac{1}{d+x}\right]$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{d+x-d+x}{d^2 - x^2}\right] = \frac{\mu_0 I x}{\pi(d^2 - x^2)}$$

42. (a) : The β^- decay of ${}_{10}Ne^{23}$ may be represented as

${}_{10}Ne^{23} \rightarrow {}_{11}Na^{23} + {}_{-1}e^0 + \upsilon^- + Q$

Ignoring the rest mass of anti neutrino υ^- and electron are neglected.

Mass defect, $\Delta m = m\,({}_{10}Ne^{23}) - m\,({}_{11}Na^{23})$

$= 22.994466 - 22.989770$

$= 0.004696$ amu

The disintegration energy Q appears in the form of kinetic energy,

$Q = 0.004696 \times 931\text{ MeV} = 4.372\text{ MeV}$

43. (d) : Here, $m = 0.01$ kg

The slope of the $F - x$ graph will give the force constant k.

$\therefore$ From graph,

$\text{Slope} = k = \frac{8}{2} = 4\text{ N m}^{-1}$

Time period, $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.01}{4}} = 0.3\text{ s}$

44. (b) : As, $M = \frac{\mu_0\mu_r N_1 N_2 A}{l}$

$$= \frac{4\pi \times 10^{-7} \times 800 \times 400 \times 20 \times \pi(2 \times 10^{-2})^2}{20\pi}$$

$= 1.6 \times 10^{-4}$ H

45. (c) : Resultant intensity at any point P on the screen in YDSE is

$I = I_{max}\cos^2(\phi/2)$

According to question,

$\frac{I_{max}}{4} = I_{max}\cos^2(\phi/2)$

$\cos\frac{\phi}{2} = \frac{1}{2} = \cos\frac{\pi}{3} \quad \therefore \quad \phi = \frac{2\pi}{3}$

Also $\frac{\phi}{2\pi} = \frac{\Delta x}{\lambda}$ or $\Delta x = \frac{(2\pi/3)}{2\pi} \times \lambda = \frac{\lambda}{3}$

or $d\sin\theta = \frac{\lambda}{3}$ or $\theta = \sin^{-1}\left(\frac{\lambda}{3d}\right)$

EXAM CORNER 2020

Exam	Date
VITEEE	13th to 19th April
SRMJEEE	12th to 20th April
J & K CET	26th April (Revised)
Kerala PET	20th & 21st April
Karnataka CET	22nd & 23rd April
NEET	3rd May
COMEDK (Engg.)	10th May
UPSEE	10th May
AMU (Engg.)	31st May (Revised)
BITSAT	16th to 25th May
MHT CET	20th to 23rd April (Revised)
JEE Advanced	17th May

JEE Main

NUMERICAL VALUE TYPE QUESTIONS

1. 0.1 m^3 of water at 80°C is mixed with 0.3 m^3 of water at 60 °C. The final temperature (in °C) of the mixture is ________.

2. The electron in the hydrogen atom jumps from excited state ($n = 3$) to its ground state ($n = 1$) and the photons thus emitted irradiate a photosensitive material. If the work function of the material is 5.1 eV, the stopping potential (in V) is estimated to be ________. (The energy of the electron in n^{th} state $E_n = -\frac{13.6}{n^2}$ eV)

3. The horizontal range of a projectile fired at an angle of 15° is 50 m. If it is fired with the same speed at an angle of 45°, its range (in m) will be ________.

4. A 220 V input is supplied to a transformer. The output circuit draws a current of 2.0 A at 440 V. If the efficiency of the transformer is 80%, the current (in A) drawn by the primary windings of the transformer is ________.

5. A body is moving forward and backward. Change in frequency observed by the body of a source is 2%. The velocity (in m s^{-1}) of the body is ________. (Speed of sound is 300 m s^{-1})

6. An engine pumps water through a hose pipe. Water passes through the pipe and leaves it with a velocity of 2 m s^{-1}. The mass per unit length of water in the pipe is 100 kg m^{-1}. The power (in W) of the engine is ________.

7. In Millikan's oil drop experiment, a charged oil drop of mass 3.2×10^{-14} kg is held stationary between two parallel plates 6 mm apart, by applying a potential difference of 1200 V between them. The number of electrons the oil drop carry is ________. (Take $g = 10$ m s^{-2})

8. If the value of g at the surface of the earth is 9.8 m s^{-2}, then the value of g (in m s^{-2}) at a place 480 km above the surface of the earth will be ________. (Radius of the earth is 6400 km)

9. A transistor is operated in common emitter configuration at $V_C = 2$ V such that a change in the base current from 100 μA to 300 μA produces a change in the collector current from 10 mA to 20 mA. The current gain is ________.

10. A proton travelling at 23° with respect to the direction of a magnetic field of strength 2.6 mT experiences a magnetic force of 6.5×10^{-17} N. The speed of the proton is $x \times 10^5$ m s^{-1}. The value of 'x' is ________.

11. If $|\vec{a} \cdot \vec{b}| = |\vec{a} \times \vec{b}|$, then angle (in degree) between $\vec{a}$ and $\vec{b}$ will be ________.

12. A steel wire with cross-section 3 cm^2 has elastic limit 2.4×10^8 N m^{-2}. The maximum upward acceleration (in m s^{-2}) that can be given to a 1200 kg elevator supported by this cable wire if the stress is not to exceed one-third of the elastic limit is ________. (Take $g = 10$ m s^{-2})

13. If a simple pendulum is taken to a place where g decreases by 2%, then the percentage increase in time period is ________.

14. If a current of 5 A in a coil of self inductance 2 mH is cut off in time 0.1 s, the induced emf (in V) in the coil is ________.

15. A potential difference of 20 kV is applied across an X-ray tube. The minimum wavelength of X-rays generated (in angstrom) is ________.

SOLUTIONS

1. **(65) :** Let T°C be final temperature of the mixture. According to principle of calorimetry
Heat lost = Heat gained
$\therefore \quad 0.1 \times 10^3 \times s_{water} \times (80 - T)$
$= 0.3 \times 10^3 \times s_{water} \times (T - 60) \Rightarrow T = 65°C$

2. **(7) :** If υ is the frequency of the emitted photon when electron in an atom jumps from excited state ($n = 3$) to ground state ($n = 1$) is
$$E = h\upsilon = E_3 - E_1 = \frac{-13.6}{3^2} - \left(\frac{-13.6}{1^2}\right) = 12.1 \text{ eV}$$
If V_0 is the stopping potential, then
$eV_0 = h\upsilon - \phi_0 = 12.1 \text{ eV} - 5.1 \text{ eV} = 7 \text{ eV}$ or $V_0 = 7$ V

3. **(100) :** Horizontal range, $R = \frac{u^2 \sin 2\theta}{g}$

For the same speed, $R \propto \sin 2\theta$

$\therefore \quad \frac{R_1}{R_2} = \frac{\sin 2\times 15^\circ}{\sin 2\times 45^\circ} = \frac{\sin 30^\circ}{\sin 90^\circ}$

or $\quad R_2 = R_1 \frac{\sin 90^\circ}{\sin 30^\circ} = 50\,\text{m} \times \frac{1}{\left(\frac{1}{2}\right)} = 100\,\text{m}$

4. (5) : Here, $V_p = 220$ V, $I_s = 2$ A, $V_s = 440$ V

$\eta = 80\%$, $I_p = ?$

$\eta = \frac{V_s I_s}{V_p I_p}$ or $I_p = \frac{V_s I_s}{\eta V_p}$

Substituting the given values, we get $I_P = 5$A

5. (3) : Here, body is acting as an observer. According to the given case, let u be the velocity of the body.

Then, $\upsilon_1 = \upsilon\left(\frac{v-u}{v}\right)$ and $\upsilon_2 = \upsilon\left(\frac{v+u}{v}\right)$

$\therefore \quad \Delta\upsilon = \upsilon_2 - \upsilon_1 = \upsilon\frac{2u}{v}$

So, $\quad \frac{\Delta\upsilon}{\upsilon}\times 100 = \frac{2u}{v}\times 100 = 2$

$\Rightarrow \quad u = \frac{v}{100} = \frac{300}{100} = 3\text{ m s}^{-1}$

6. (400): $\frac{\text{Mass}}{\text{Length}} = 100\text{ kg m}^{-1}$

Velocity $= \frac{\text{Length}}{\text{Time}} = 2\text{ m s}^{-1}$

$\therefore \frac{\text{Mass}}{\text{Time}} = m = (100\text{ kg m}^{-1})\times(2\text{ m s}^{-1}) = 200\text{ kg s}^{-1}$

Power of engine = KE of water flowing per second

$= \frac{1}{2}mv^2 = \frac{1}{2}\times 200\times 2^2 = 400$ W

7. (10) : Since the drop is held stationary,

$\therefore$ Force on the drop due to electric field

= Weight of the drop

$qE = mg$ or $ne\frac{V}{d} = mg$

$\therefore n \times 1.6\times 10^{-19}\times \frac{1200}{6\times 10^{-3}} = 3.2\times 10^{-14}\times 10$

or $n = \frac{3.2\times 10^{-13}\times 6\times 10^{-3}}{1.6\times 10^{-19}\times 1200} = 10$

8. (8.4) : The value of g on the surface of the earth is

$g = \frac{GM}{R^2}$ where R is the radius of the earth.

The value of g at height h above the surface of the earth is

$g' = \frac{GM}{(R+h)^2} \Rightarrow g' = g\frac{R^2}{(R+h)^2}$

$= \frac{9.8\text{ m s}^{-2}\times(6400\text{ km})^2}{(6400\text{ km}+480\text{ km})^2} = 8.4\text{ m s}^{-2}$

9. (50) : Current gain,

$\beta = \frac{\Delta I_c}{\Delta I_b} = \frac{(20-10)\text{ mA}}{(300-100)\,\mu\text{A}} = \frac{10\times 10^{-3}\text{ A}}{200\times 10^{-6}\text{ A}} = 50$

10. (4) : Given : $\theta = 23^\circ$, $B = 2.6$ mT $= 2.6\times 10^{-3}$ T

$F = 6.5\times 10^{-17}$ N

$F = qvB\sin\theta$

$6.5\times 10^{-17} = 1.6\times 10^{-19}\times v\times 2.6\times 10^{-3}\times \sin 23^\circ$

$\Rightarrow v = 4\times 10^5\text{ m s}^{-1}$

11. (45) : Let θ be the angle between $\vec{a}$ and $\vec{b}$.

As $|\vec{a}\cdot\vec{b}| = |\vec{a}\times\vec{b}|$ $\therefore \quad ab\cos\theta = ab\sin\theta$

or $\tan\theta = 1$ or $\theta = \tan^{-1}(1) = 45^\circ$

12. (10) : Maximum tension in the wire is

$T = \frac{1}{3}\times\text{stress}\times\text{area of cross-section}$

$= \frac{1}{3}\times(2.4\times 10^8)\times(3\times 10^{-4}) = 2.4\times 10^4$ N

If a is the maximum upward acceleration of elevator, then $T = m(g+a)$ or $2.4\times 10^4 = 1200(10+a)$

On solving, we get $a = 10\text{ m s}^{-2}$

13. (1) : Time period of a simple pendulum is,

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

Taking logarithm on both sides, we get

$\log T = \log(2\pi) + \frac{1}{2}\log l - \frac{1}{2}\log g$

Differentiating it, we get

$\frac{\Delta T}{T} = 0 + 0 - \frac{1}{2}\frac{\Delta g}{g}$ $\quad (\because l$ is a constant)

$= -\frac{1}{2}\left(-\frac{2}{100}\right) = \frac{1}{100}$

% increase in time period $\frac{\Delta T}{T}\times 100 = \frac{1}{100}\times 100 = 1\%$

14. (0.1) : Induced emf, $\varepsilon = -\frac{LdI}{dt}$

Here, $L = 2$ mH $= 2\times 10^{-3}$ H

$\Rightarrow \quad \varepsilon = -L\frac{(\text{final current} - \text{initial current})}{\Delta t}$

$= -\frac{2\times 10^{-3}(0-5)}{0.1} = 0.1$ V

15. (0.62) : For X-rays production, $\frac{hc}{\lambda_{min}} = eV$

$\lambda_{min} = \frac{hc}{eV} = \frac{6.63\times 10^{-34}\times 3\times 10^8}{1.6\times 10^{-19}\times 20\times 10^3} = 0.62$ Å

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JEE ADVANCED 2020 PRACTICE PAPER

Exam on 17^{th} May

PAPER - I

SECTION 1 (Maximum Marks : 12)

- *This section contains FOUR (04) questions.*
- *Each question has FOUR options. ONLY ONE of these four options is the correct answer.*
- *For each question, choose the correct option corresponding to the correct answer.*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks :	*+3*	*If ONLY the correct option is chosen.*
Zero Marks :	*0*	*If none of the options is chosen i.e. the question is unanswered).*
Negative Marks :	*–1*	*In all other cases.*

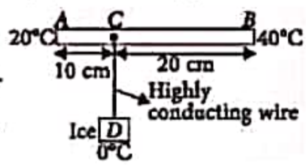
1. A block of mass 1 kg is attached to one end of spring of force constant $k = 20$ N m^{-1}. The other end of the spring is attached to a fixed rigid support. This spring block system is made to oscillate on a rough horizontal surface ($\mu = 0.04$). The initial displacement of the block from the equilibirum position is $a = 30$ cm. How many times the block passes from the mean position before coming to rest? (Take $g = 10$ m s^{-2})

(a) 11 (b) 7 (c) 6 (d) 15

2. A system consists of a uniform charged sphere of radius R and a surrounding medium filled by a charge with charge density $\rho = \frac{\alpha}{r}$, where α is a positive constant and r is the distance from the centre of the charge. The charge of the sphere for which the electric field intensity E outside the sphere is independent of r is

(a) $\pi R^2\alpha$ (b) $4\pi R^2\alpha$ (c) $2\pi R^2\alpha$ (d) $3\pi R^2\alpha/4$

3. In the figure shown, AB is a rod of length 30 cm and area of cross-section 1 cm^2 and thermal conductivity



336 SI units. The ends A and B are maintained at temperatures 20°C and 40°C respectively. A point C of this rod is connected to a box D, containing ice at 0°C, through a highly conducting wire of negligible heat capacity. The rate at which ice melts in the box is

[Assume latent heat of fusion for ice, $L_f = 80$ cal g^{-1}]

(a) 84 mg s^{-1} (b) 84 g s^{-1}
(c) 20 mg s^{-1} (d) 40 mg s^{-1}

4. 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}

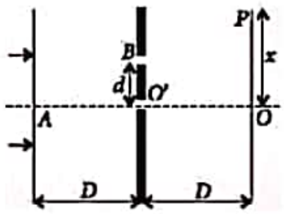
Section 2 (Maximum Marks : 32)

- *This section contains EIGHT (08) questions.*
- *Each question has FOUR options. ONE OR MORE THAN ONE of these four option(s) is (are) correct answer(s).*
- *For each question, choose the option(s) corresponding to (all) the correct answer(s).*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks :	*+4*	*If only (all) the correct option(s) is (are) chosen.*
Partial Marks :	*+3*	*If all the four options are correct but ONLY three options are chosen.*
Partial Marks :	*+2*	*If three or more options are correct but ONLY two options are chosen and both of which are correct.*
Partial Marks :	*+1*	*If two or more options are correct but ONLY one option is chosen and it is a correct option.*
Zero Marks :	*0*	*If none of the options is chosen (i.e. the question is unanswered).*
Negative Marks :	*–1*	*In all other cases.*

- *For example, in a question, if (a), (b) and (d) are the ONLY three options corresponding to correct answers, then choosing ONLY (a), (b) and (d) will get +4 marks; choosing ONLY (a) and (b) will get +2 marks; choosing ONLY (a) and (d) will get +2 marks; choosing ONLY (b) and (d) will get +2 marks; choosing ONLY (a) will get +1 mark; choosing ONLY (b) will get +1 mark; choosing ONLY (d) will get +1 mark; choosing no option (i.e. the question is unanswered) will get 0 marks ; and choosing any other combination of options will get –1 mark.*

5. The minimum value of d so that there is a dark fringe at O is d_{min}, the distance at which the next bright fringe is formed is x. Then



(a) $d_{min} = \sqrt{\lambda D}$ (b) $d_{min} = \sqrt{\frac{\lambda D}{2}}$

(c) $x = \frac{d_{min}}{2}$ (d) $x = d_{min}$

6. A steel rod of length $2l$, cross-sectional area A and mass M is set rotating (with angular speed ω) in a horizontal plane about an axis passing through the centre. If Y is the Young's modulus for steel, then the extension in the length of the rod will be (Assume the rod is uniform)

(a) $\frac{M\omega^2 l^2}{2YA}$ (b) $\frac{M\omega^2 l^2}{6YA}$

(c) $\frac{M\omega^2 l^2}{4YA}$ (d) $\frac{M\omega^2 l^2}{3YA}$

7. A straight copper wire of length 1000 m and cross-sectional area 1.0 mm^2 carries a current 4.5 A. Assuming that one free electron corresponds to each copper atom, (Density of copper = 8.96×10^3 kg m^{-3}, Atomic mass of copper = 63.5 g, Resistivity of copper wire = 1.69×10^{-8} Ω m)

Which of the following statements is/are correct?

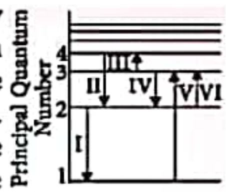
(a) The time taken by an electron to displace from one end of the wire to the other is 4×10^6 s.

(b) The sum of electric force acting on all free electrons in the given wire is 1×10^6 N.

(c) The time taken by an electron to displace from one end of the wire to the other is 3×10^6 s.

(d) The sum of electric force acting on all free electrons in the given wire is 2×10^6 N.

8. The figure shows an energy level diagram for the hydrogen atom. Several transitions are marked as I, II, III, ... The diagram is only indicative and not to scale. Which of the following statements is/are correct?



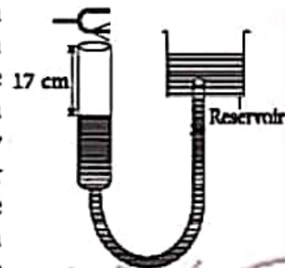
(a) The transition in which a Balmer series photon absorbed is VI.

(b) The wavelength of the radiation involved in transition II is 486 nm.

(c) Transition IV will occur when a hydrogen atom is irradiated with radiation of wavelength 103 nm.

(d) Transition IV will emit the longest wavelength line in the visible portion of the hydrogen spectrum.

9. A tuning fork vibrating with a frequency of 512 Hz is kept close to the open end of a tube filled with water, as shown in the figure. The water level in the tube is gradually lowered. When the water level is 17 cm below the open end, maximum intensity of sound is heard. The room temperature is 20°C. Which of the following statements is/are correct?



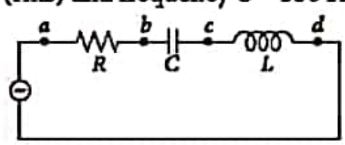
(a) Speed of sound in air at room temperature is 360 m s^{-1}.

(b) Speed of sound in air at 0°C is 336 m s^{-1}.

(c) If the water in the tube is replaced with mercury, then the intensity of reflected sound increases.

(d) If the water in the tube is replaced with mercury, then the intensity of reflected sound decreases.

10. 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.



Which of the following statements is/are correct?

(a) The rms value of current is 2.49A.

(b) The rms voltages ΔV_{ab}, ΔV_{bd} are 65 V and 37.4 V respectively.

(c) Average power dissipated in the circuit is 93.3 W .

(d) The rms voltage between points b and c, $\Delta V_{bc} = 153$ V.

11. If a planet revolving around the Sun with time period T, is suddenly stopped in its orbit supposed to be circular. It would fall onto the Sun in a time

(a) $t=\left(\frac{2}{7}\right)T$ (b) $t=\left(\frac{\sqrt{2}}{8}\right)T$

(c) $t=\left(\frac{2\pi}{7}\right)T$ (d) $t=\left(\frac{\pi}{2}\right)T$

12. The coordinates of a particle moving in a plane are given by $x(t) = a\cos(pt)$ and $y(t) = b\sin(pt)$ where a, b and p are positive constants of appropriate dimensions. Then,

(a) the path of the particle is an ellipse.

(b) the velocity and acceleration of the particle are normal to each other at $t = \pi/(2p)$.

(c) the acceleration of the particle is always directed towards the origin.

(d) the distance travelled by the particle in time interval $t = 0$ to $t = \pi/(2p)$ is a.

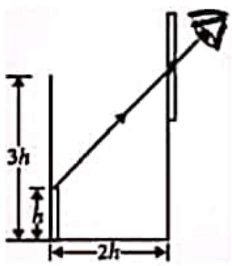
SECTION 3 (Maximum Marks : 18)

- *This section contains SIX (06) questions. The answer to each question is a NUMERICAL VALUE.*
- *For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer. If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks : +3 *If ONLY the correct numerical value is entered.*

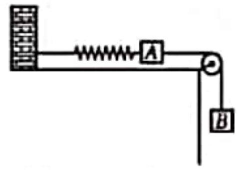
Zero Marks : 0 *In all other cases.*

13. An observer can see the top of a thin rod of height h through a pinhole situated at the top of beaker 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 ______.



14. There is a stream of neutrons with a kinetic energy of 0.0327 eV. The half life of neutrons is 700 s. Fraction of neutrons that decay before they travel distance of 10 m is 3.9×10^{-p}, then the value of p is ______. (mass of neutron = 1.675×10^{-27} kg)

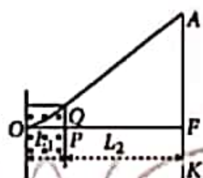
15. Consider the situation shown in the figure. Mass of block A is 6 kg and that of block B is 12 kg. The force constant of spring is 50 N m^{-1}. Friction is absent everywhere. System is released from rest with the spring unstretched. When the extension in the spring is $x = \frac{x_m}{2}$, x_m = maximum extension of spring, the speed of block A (in m s^{-1}) is ______.



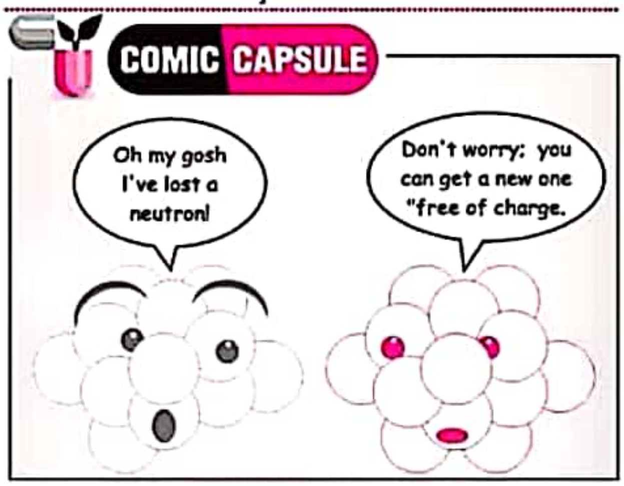
16. A steel wire of length 2 m and diameter 0.8 mm is stretched horizontally between a rigid support attached at its ends. When a load is hung from midpoint of wire, it is found that a depression of 1.0 cm is produced. If Young's modulus for steel is 2×10^{12} dyne cm^{-2}, the load (in gm-wt) on the wire is ______.

17. A man stands at top of a tower and throws a ball at a speed of v at an angle θ to the horizontal. The height of the tower is v^2/g and the ball strikes the ground at a distance of d from the foot of the tower. The value of θ (in degrees) for which d is maximum if $v = 10$ m s^{-1} is ______. (Take $g = 10$ m s^{-2})

18. A beam of particle accelerated by a potential difference of V flies into a homogeneous magnetic field applied perpendicular to the plane of the paper and towards the observer. The width of the magnetic field is OP. In the absence of magnetic field, the electron beam produces a spot at a point F on fluorescent screen AK, which is at a distance of L_2 from the edge of the magnetic field. When the magnetic field is switched on, the spot moves on to A along the path OQA. If the induction of the magnetic field is B the displacement FA (in m) of the spot is ______.



(Take $B = 1$ T, $\frac{2Vm}{q} = 1$, $L_1 = \frac{\sqrt{3}}{2}$ m, $L_2 = 3\frac{\sqrt{3}}{2}$ m)



SECTION 1 (Maximum Marks : 32)

- *This section contains EIGHT (08) questions.*
- *Each question has FOUR options. ONE OR MORE THAN ONE of these four option(s) is (are) correct answer(s).*
- *For each question, choose the option(s) corresponding to (all) the correct answer (s).*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks : +4 *If only (all) the correct option(s) is (are) chosen.*

Partial Marks : +3 *If all the four options are correct but ONLY three options are chosen.*

Partial Marks : +2 *If three or more options are correct but ONLY two options are chosen and both of which are correct.*

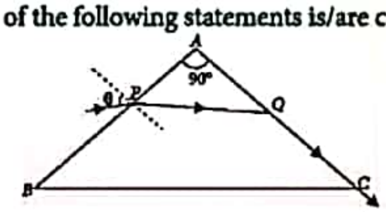
Partial Marks : +1 *If two or more options are correct but ONLY one option is chosen and it is a correct option.*

Zero Marks : 0 *If none of the options is chosen (i.e. the question is unanswered).*

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

- *For example, in a question, if (a), (b) and (d) are the ONLY three options corresponding to correct answers, then choosing ONLY (a), (b) and (d) will get +4 marks; choosing ONLY (a) and (b) will get +2 marks; choosing ONLY (a) and (d) will get +2 marks; choosing ONLY (b) and (d) will get +2 marks; choosing ONLY (a) will get +1 mark; choosing ONLY (b) will get +1 mark; choosing ONLY (d) will get +1 mark; choosing no option (i.e. the question is unanswered) will get 0 marks ; and choosing any other combination of options will get –1 mark.*

1. 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°. Which of the following statements is/are correct?



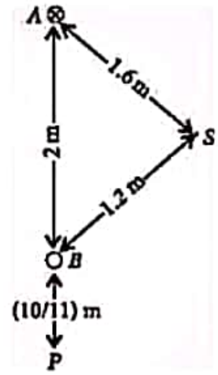
(a) The refractive index of the prism is $\sqrt{1+\sin^2\theta}$.

(b) The maximum value of the refractive index is $\sqrt{2}$.

(c) The light at Q emerges into air if the incident angle θ is increased slightly.

(d) The light at Q emerges into air if the incident angle θ is decreased slightly.

2. 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 3A and is 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}.

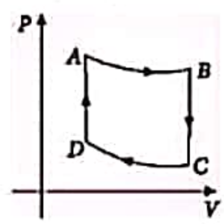
(d) The magnitude of the magnetic field of induction at point S is 2.4×10^{-6} T.

3. The gap between the plates of a parallel-plate capacitor is filled with isotropic dielectric whose permittivity ε varies linearly from ε_1 to $\varepsilon_2(\varepsilon_2 > \varepsilon_1)$ in the direction perpendicular to the plates. The area of each plate equals A, the separation between the plates is equal to d. Then the capacitance of the capacitor will be given by

(a) $\dfrac{(\varepsilon_2-\varepsilon_1)\varepsilon_0 A}{d\ln(\varepsilon_2/\varepsilon_1)}$ (b) $\dfrac{(\varepsilon_2-\varepsilon_1)\varepsilon_0 A}{d}$

(c) $\dfrac{\varepsilon_2\varepsilon_0 A}{d}$ (d) $\dfrac{(\varepsilon_1+\varepsilon_2)\varepsilon_0 A}{d\ln(\varepsilon_2/\varepsilon_1)}$

4. One mole of a monatomic ideal gas is taken through the cycle as 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 $A \rightarrow B$ is 870 J.
(b) the heat lost by the gas in the process $B \rightarrow C$ is 5298 J.
(c) the temperature T_B is 850 K.
(d) the temperature T_C is 250 K.

5. An external magnetic field is decreased to zero, due to which a current is induced in a circular wire loop of radius r and resistance R placed in the field. This current will not become zero,
(a) at the instant when external magnetic field stops changing ($t = 0$), the current in the loop as a function of time for $t > 0$ is given by $I_0 e^{-2Rt/\mu_0 \pi r}$.
(b) at the instant when B stops changing ($t = 0$), the current in the loop as a function of time $t > 0$ is given by $\frac{\mu_0 IR}{2r}$.
(c) the time in which current in loop decreases to $10^{-3} I_0$ (from $t = 0$) for $R = 100\ \Omega$ and $r = 5$ cm is given by $\frac{3\pi^2 \ln 10}{10^{10}}$ s.
(d) the time in which current in loop decreases to $10^{-3} I_0$ (from $t = 0$) for $R = 100\ \Omega$ and $r = 5$ cm is given by $\frac{3\pi^2}{10^6}$ s.

6. A tube of length l and radius R carries a steady flow of fluid whose density is ρ and viscosity is η. The fluid flow velocity depends on the distance r from the axis of the tube as $v = v_0\left(1 - \frac{r^2}{R^2}\right)$. Which of the following statements is/are correct?
(a) The volume of the fluid flowing across the section of the tube per unit time is $\frac{1}{2}\pi^2 v_0 R^2$.
(b) The kinetic energy of the fluid within the tube's volume is $\frac{1}{6}\pi l R^2 \rho v_0^2$.
(c) The frictional force exerted on the tube by the fluid is $4\pi\eta l v_0$.
(d) The pressure difference at the ends of the tube is $\frac{4\eta l v_0}{R^2}$.

7. An ideal gas enclosed in a vertical cylindrical container supports a freely moving piston of mass M. The piston and the cylinder have equal cross sectional area A. When the piston is in equilibrium, the volume of the gas is V_0 and its pressure is P_0. The piston is slightly displaced from the equilibrium position and released. Assuming that the system is completely isolated from its surrounding, the piston executes a simple harmonic motion with frequency
(a) $\frac{1}{2\pi}\sqrt{\frac{MV_0}{A\gamma P_0}}$
(b) $\frac{1}{2\pi}\frac{A\gamma P_0}{V_0 M}$
(c) $\frac{1}{2\pi}\frac{V_0 M P_0}{A^2\gamma}$
(d) $\frac{1}{2\pi}\sqrt{\frac{A^2\gamma P_0}{MV_0}}$

8. Consider three quantities; $x = \frac{E}{B}$, $y = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ and $z = \frac{l}{CR}$. Here l is the length of a wire, C is the capacitance and R is the resistance. All other symbols have standard meanings. Which of the following statements is/are correct?
(a) x, y have the same dimensions.
(b) x, z have the same dimensions.
(c) y, z have the same dimensions.
(d) None of the three pairs have the same dimensions.

SECTION 2 (Maximum Marks : 18)

- *This section contains SIX (06) questions. The answer to each question is a NUMERICAL VALUE.*
- *For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numerical keypad in the place designated to enter the answer. If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.*
- *Answer to each question will be evaluated according to the following marking scheme:*

Full Marks : *+3 If ONLY the correct numerical value is entered.*

Zero Marks : *0 In all other cases.*

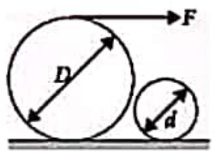
9. Four point charges $+8\ \mu C$, $-1\ \mu C$, $-1\ \mu C$, and $+8\ \mu C$ are fixed at the points $-\sqrt{\frac{27}{2}}$ m, $-\sqrt{\frac{3}{2}}$ m, $+\sqrt{\frac{3}{2}}$ m, and $+\sqrt{\frac{27}{2}}$ m respectively on the y-axis. A particle of mass 6×10^{-4} kg and charge $+0.1\ \mu C$ moves along the x-direction. Its speed at $x = +\infty$ is v_0. The least value of v_0 (in m s^{-1}) for which the particle will cross the origin is ______. Assume that space is gravity free.
Given $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}.

10. An ice cube of mass 0.1 kg at 0°C is placed in an isolated container which is at 227°C. The specific heat s of the container varies with temperature T

according to the empirical relation $s = A + BT$, where $A = 100$ cal kg^{-1} K^{-1} and $B = 2 \times 10^{-2}$ cal kg^{-1} K^{-2}. The final temperature of the container is 27°C and the mass of the container is $x \times 10^{-1}$ kg. Then the value of x is _____. (Latent heat of fusion of water $= 8 \times 10^4$ cal kg^{-1}, Specific heat of water $= 10^3$ cal kg^{-1} K^{-1}).

11. A screw gauge having 100 equal divisions and a pitch of length 1 mm is used to measure the diameter of a wire of length 5.6 cm. The main scale reading is 1 mm and 47th circular division coincides with the main scale. The curved surface area of wire (in cm^2) to appropriate significant figure is _____.

12. Two cylindrical rollers of diameters D and d respectively rest on a horizontal plane as shown in figure. The diameter of the larger roller is four times that of smaller one. The larger roller wound round with a string is pulled with a horizontal force F. Assuming that the coefficient of friction is μ for all surfaces of contact, the larger value of μ (in 10^{-1}) such that the larger roller can be pulled over the smaller one is _____.



13. A beam of light has three wavelengths 4144 Å, 4972 Å and 6216 Å with a total intensity of 3.6×10^{-3} W m^{-2} equally distributed amongst the three wavelengths. The beam falls normally on an area 1.0 cm^2 of a clean metallic surface of work function 2.3 eV. Assuming that there is no loss of light by reflection and that each energetically capable photon ejects one electron, the number of photo electrons liberated in two second is $x \times 10^{12}$. Then the value of x is _____.

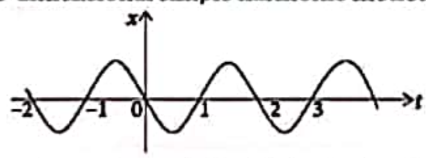
14. A prism of angle 60° deviates a ray of light through 40° for two angles of incidence which differ by 11°. The refractive index of the glass of the prism is _____.

Section 3 (Maximum Marks : 12)

- *This section contains FOUR (04) questions.*
- *Each question has TWO (02) matching lists: LIST-I and LIST-II.*
- *FOUR options are given representing matching of elements from LIST-I and LIST-II. ONLY ONE of these four options corresponds to a correct matching.*
- *For each question, choose the option corresponding to the correct matching.*
- *For each question, marks will be awarded according to the following marking scheme:*

Full Marks :	+3	*If ONLY the option corresponding to the correct matching is chosen.*
Zero Marks :	0	*If none of the options is chosen (i.e. the question is unanswered).*
Negative Marks :	-1	*In all other cases.*

15. Figure gives the x-t plots of a particle executing one-dimensional simple harmonic motion.

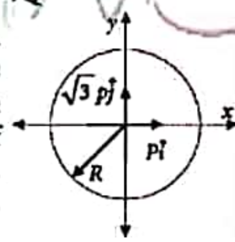


Match the statements in List-I with the statements in List-II.

List - I Time		List - II Signs of position (x), velocity (v) and acceleration (a)	
(I)	At $t = -1.2$ s	(P)	$x < 0, v < 0, a > 0$
(II)	At $t = -0.3$ s	(Q)	$x > 0, v > 0, a < 0$
(III)	At $t = 0.3$ s	(R)	$x > 0, v < 0, a < 0$
(IV)	At $t = 1.2$ s	(S)	$x < 0, v > 0, a > 0$

(a) I→S, II→R, III→P, IV→Q
(b) I→R, II→P, III→Q, IV→S
(c) I→S, II→R, III→Q, IV→P
(d) I→R, II→S, III→P, IV→Q

16. List I gives a situation in which two dipoles of dipole moment $p\hat{i}$ and $\sqrt{3}p\hat{j}$ are placed at origin. A circle of radius R with centre at origin is drawn as shown in figure. List II gives coordinates of certain positions on the circle. Match the statements in List I with the statements in List II.

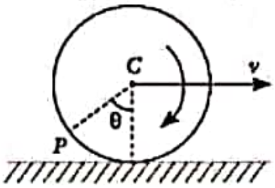


List I		List II	
(I)	The coordinate(s) of point on circle where potential is maximum	(P)	$\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$
(II)	The coordinate(s) of point on circle where potential is zero	(Q)	$\left(-\frac{R}{2}, -\frac{\sqrt{3}R}{2}\right)$
(III)	The coordinate(s) of point on circle where magnitude of electric field intensity is $\left\lvert\frac{1}{4\pi\varepsilon_0}\frac{4p}{R^3}\right\rvert$	(R)	$\left(-\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$

(IV)	The coordinate(s) of point on circle where magnitude of electric field intensity is $\left\lvert\frac{1}{4\pi\varepsilon_0}\frac{2p}{R^3}\right\rvert$	(S)	$\left(\frac{\sqrt{3}R}{2}, -\frac{R}{2}\right)$

(a) I→P, II→R,S, III→P, Q, IV→R,S
(b) I→Q, II→R, S, III→Q, IV→R,S
(c) I→P,Q, II→R, S III→Q, IV→R
(d) I→P, II→R, III→P, Q, IV→S

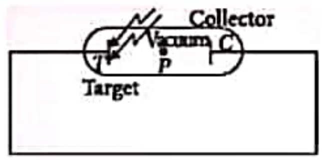
17. A disc rolls on ground without slipping. Velocity of centre of mass is v. There is a point P on circumference of disc at angle θ. Suppose v_P is the speed of this point. Match the statments in List I with the statements in List II.



List I		List II	
(I)	If $\theta = 60°$	(P)	$v_P = \sqrt{2}v$
(II)	If $\theta = 90°$	(Q)	$v_P = v$
(III)	If $\theta = 120°$	(R)	$v_P = 2v$
(IV)	If $\theta = 180°$	(S)	$v_P = \sqrt{3}v$

(a) I→P, II→P, III→S, IV→Q
(b) I→S, II→R, III→R, IV→S
(c) I→Q, II→P, III→S, IV→R
(d) I→R, II→S, III→Q, IV→P

18. In a photoelectric experimental arrangement, light of frequency f is incident on a metal target whose work function is $\phi = hf/3$ as shown. In List I, KE of photoelectron is mentioned at various locations/instant and in List II, the corresponding values. Match the statements in List I with the statements in List II.



List I		List II	
(I)	Maximum KE of photoelectrons just after emission from target	(P)	zero
(II)	KE of photoelectrons just after emission from target	(Q)	$hf/3$
(III)	KE of photoelectron when they are halfway between the target and collector	(R)	$hf/2$
(IV)	KE of photoelectrons as they reach the collector	(S)	$2hf/3$

(a) I→P, II→Q, III→S, IV→R
(b) I→S, II→P,Q, III→Q,R, IV→S,R
(c) I→P, II→P,Q,R,S, III→P,Q,R,S, IV→P,Q,R,S
(d) I→S, II→P,Q,R,S, III→P,Q,R,S, IV→P,Q,R,S

SOLUTIONS

PAPER-I

1. (b) : Let the initial amplitude decreases to a_1 to the other side *i.e.*, after the first sweep,
decrease in elastic potential energy
= work done against friction

or $\frac{1}{2}ka^2 - \frac{1}{2}ka_1^2 = \mu mg(a + a_1)$

or $\frac{1}{2}k(a + a_1)(a - a_1) = \mu mg(a + a_1)$

or $a - a_1 = \frac{2\mu mg}{k}$ ...(i)

Similarly, $a_1 - a_2 = \frac{2\mu mg}{k}$ ...(ii)

....

$a_{n-1} - a_n = \frac{2\mu mg}{k}$ ...(iii)

Adding all the above equations

$a - a_n = \frac{2n\mu mg}{k}$ ...(iv)

The block stops when, $\mu mg = ka_n$ or $a_n = \frac{\mu mg}{k}$

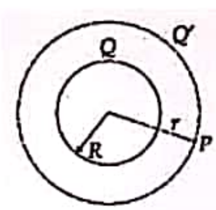
Substituting in equation (iv) we get, $(2n+1)\left(\frac{\mu mg}{k}\right) = a$

or $(2n+1) = \frac{ka}{\mu mg} = \frac{20 \times 0.3}{0.04 \times 1 \times 10} = 15$

or $2n = 15 - 1$ ∴ $n = 7$

2. (c) : $\oint E_P dS = \frac{Q + Q'}{\varepsilon_0}$ ...(i)

where Q' is the charge outside the sphere.



$Q' = \int_R^r \rho dV = \int_R^r \frac{\alpha}{r} \times 4\pi r^2 dr$

$= 4\pi\alpha\left(\frac{r^2}{2}\right)_R^r = 4\pi\alpha\left(\frac{r^2}{2} - \frac{R^2}{2}\right) = 2\pi\alpha(r^2 - R^2)$

From equation (i), $E_P \times 4\pi r^2 = \frac{Q + 2\pi\alpha(r^2 - R^2)}{\varepsilon_0}$

$$E_P = \frac{Q}{4\pi r^2 \varepsilon_0} + \frac{\alpha}{2\varepsilon_0} - \frac{\alpha R^2}{2r^2 \varepsilon_0}$$

E is independent of r if $\frac{Q}{4\pi r^2 \varepsilon_0} - \frac{\alpha R^2}{2r^2 \varepsilon_0} = 0$; $Q = 2\pi R^2 \alpha$

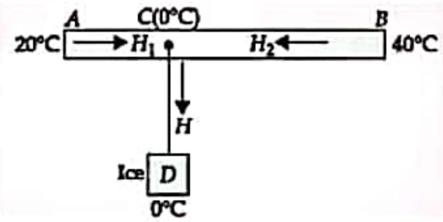
3. (d) : Thermal resistance of $AC = \frac{L}{KA}$

$$= \frac{0.1}{336 \times 1 \times 10^{-4}} = \frac{10^3}{336} = R(\text{suppose})$$

Thermal resistance of $BC = \frac{0.2}{336 \times 10^{-4}} = 2R$

Temperature of $C = 0°C$

$$\therefore \quad H_1 = \frac{20}{R}; H_2 = \frac{40}{2R} = \frac{20}{R}$$



$$\therefore \quad H = H_1 + H_2 = \frac{40}{R} = \frac{40 \times 336}{10^3}$$

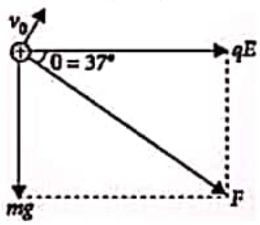
$$= \frac{13440}{10^3} = 13.44 \text{ W}$$

Rate of melting of ice

$$= \frac{H}{L_f} = \frac{13.44}{4.2 \times 80} \text{ g s}^{-1} = 40 \text{ mg s}^{-1}$$

4. (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.

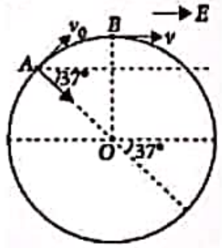
Considering free body diagram of sphere at A,

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

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

or $\quad 2v_0^2 = 10$

or $\quad v_0 = \sqrt{5}$ 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.

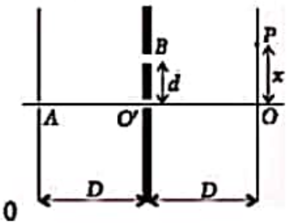
$W_{\text{total}} = \Delta K$

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

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

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

5. (b, d) : There is a dark fringe at O if the path difference $\Delta x = ABO - AO'O = \frac{(n+1)\lambda}{2}$, where $n = 0, 1, 2, 3$ ....



$$\Delta x = 2D\left(1 + \frac{d^2}{D^2}\right)^{1/2} - 2D$$

$$= 2D\left(1 + \frac{1}{2}\frac{d^2}{D^2}\right) - 2D = \frac{d^2}{D}$$

For minimum value of d, $n = 0$

$$\therefore \quad \frac{\lambda}{2} = \frac{d_{\min}^2}{D} \quad \text{or,} \quad d_{\min} = \sqrt{\frac{\lambda D}{2}}$$

The next bright fringe is formed at P if the path difference

$$= AO'P - ABP = 0$$

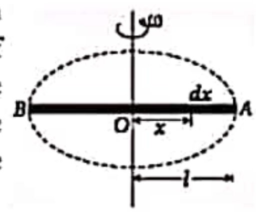
$$\Rightarrow \quad D + \sqrt{D^2 + x^2} - \sqrt{D^2 + d^2} - \sqrt{D^2 + (x - d)^2} = 0$$

$$\Rightarrow \quad \frac{x^2}{2D} - \frac{d^2}{2D} - \frac{(x^2 + d^2 - 2xd)}{2D} = 0$$

Given $d = d_{\min}$

On solving, $x = d_{\min} = \sqrt{\frac{\lambda D}{2}}$

6. (d) : Let us consider an element of length dx on half portion OA of the rod at a distance x from the axis of rotation, Since the rod is uniform, mass of the element



$$dx = (\text{mass/unit length})dx = \left(\frac{M}{2l}\right)dx$$

Centripetal force acting on this element,

$$dF = \left(\frac{M}{2l}dx\right)x\omega^2 = \left(\frac{M}{2l}\right)\omega^2 x\, dx$$

Here, dF is provided by the tension in the rod due to elasticity.

The tension (F) in half of the portion OA of the rod at a distance x from its axis of rotation is due to the centripetal force acting on all the elements from x to l, i.e.,

$$F = \frac{M\omega^2}{2l}\int_x^l x\,dx = \frac{M\omega^2}{4l}(l^2 - x^2)$$

If $d\delta$ is the extension in the element of length dx at position x, then

$$d\delta = \frac{Fdx}{YA} \qquad \left[\text{as } Y = \frac{\text{stress}}{\text{longitudinal strain}}\right]$$

Extension in half the portion OA (of length l) of the rod, *i.e.*,

$$\delta = \int_0^l \frac{Fdx}{YA} = \frac{M\omega^2}{4YAl}\int_0^l (l^2 - x^2)dx$$

$$= \frac{M\omega^2}{4YAl}\left[l^3 - \frac{l^3}{3}\right] = \left(\frac{M\omega^2}{4YAl}\right)\left(\frac{2l^3}{3}\right) = \left(\frac{M\omega^2 l^2}{6YA}\right)$$

Extension in the entire rod of length $2l$, *i.e.*,

$$2\delta = \frac{M\omega^2 l^2}{3YA}$$

7. (b,c) : Every copper atom has one free electron.
So, number of electrons per unit volume = number of atoms per unit volume.

$n = \frac{N_A d}{M}$, where d = density of copper

$= \frac{6.02\times10^{23}\times8.96\times10^3}{63.5\times10^{-3}} = 8.49\times10^{28}$ electron per m^3

We know, $I = neAv_d = neA\frac{l}{t}$

$$t = \frac{neAl}{I} = \frac{8.49\times10^{28}\times1.6\times10^{-19}\times10^{-4}\times10^3}{4.5} = 3\times10^6\text{ s}$$

Sum of electric forces

$$F = |(nV)e\vec{E}| = |nAle\rho\vec{J}| = nAle\rho\frac{I}{A} = nlerI$$

$= 8.49\times10^{28}\times10^3\times1.6\times10^{-19}\times1.69\times10^{-8}\times4.5$
$= 1.03\times10^6\text{ N} \simeq 1\times10^6\text{ N}$

8. (a,b,d) : For Balmer series, $n_1 = 2$ (lower), $n_2 = 3, 4, \ldots$ (higher)

$\therefore$ In transition (VI), photon of Balmer series is absorbed.

In transition II

$E_2 = -3.4$ eV, $E_4 = -0.85$ eV, $\Delta E = 2.55$ eV

$\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$; $\lambda = 486$ nm

Wavelength of radiation = 103 nm = 1030 Å

$\therefore \quad \Delta E = \frac{12400\text{ eV Å}}{1030\text{ Å}} \simeq 12.0\text{ eV}$

So difference of energy should be 12.0 eV (approx)

Hence $n_1 = 1$ and $n_2 = 3$
(–13.6 eV) (–1.51 eV)

$\therefore$ Transition is (V).

For longest wavelength, energy difference should be minimum.
So in visible portion of hydrogen atom, minimum energy emitted is in transition IV.

9. (b, c) : The tube filled with water behaves as a closed organ pipe of length, $L = 17$ cm $= 0.17$ m

As $\upsilon = \frac{v_{20}}{4L}$

$v_{20} = 4\upsilon L = 4\times512\times0.17 = 348.16\text{ m s}^{-1}$

As $\frac{v_{20}}{v_0} = \sqrt{\frac{T}{T_0}} = \sqrt{\frac{273+20}{273}}$

$v_0 = 348.16\times\sqrt{\frac{273}{293}} = 336\text{ m s}^{-1}$

The resonance will still be observed for 17cm length of air column above mercury. However, due to more complete reflection of sound waves at mercury surface, the intensity of reflected sound increases.

10. (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. 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

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

11. (b) : If the mass of the Sun is M and radius of the planet's orbit is r, then as $v_0 = \sqrt{(GM/r)}$,

$$T = \frac{2\pi r}{v_0} = 2\pi r\sqrt{\frac{r}{GM}}$$

i.e., $T^2 = \dfrac{4\pi^2 r^3}{GM}$ ...(i)

Now, if the planet (when stopped in the orbit) has velocity v when it is at a distance x from the sun, by conservation of mechanical energy,

$$\frac{1}{2}m(-v)^2 + \left(-\frac{GMm}{x}\right) = 0 - \frac{GMm}{r}$$

or $\left(-\dfrac{dx}{dt}\right)^2 = \dfrac{2GM}{r}\left[\dfrac{r-x}{x}\right]$,

i.e., $-\dfrac{dx}{dt} = \sqrt{\dfrac{2GM}{r}}\sqrt{\dfrac{(r-x)}{x}}$

or $\int_0^t dt = -\sqrt{\dfrac{r}{2GM}}\int_r^0\left[\sqrt{\dfrac{x}{(r-x)}}\right]dx$

Substituting $x = r\sin^2\theta$ and solving the RHS.

$$-\int_r^0\sqrt{\frac{x}{(r-x)}}dx = -\int_{\pi/2}^0\left(\frac{r\sin^2\theta}{r - r\sin^2\theta}\right)^{1/2} r\cdot 2\cdot\sin\theta\cos\theta\, d\theta$$

$$= -r\int_{\pi/2}^0 (1-\cos 2\theta)d\theta = -r\left[\theta - \frac{1}{2}\sin 2\theta\right]_{\pi/2}^0 = \frac{\pi r}{2}$$

$t = \sqrt{\dfrac{r}{2GM}} \times \left(\dfrac{\pi r}{2}\right)$ ...(ii)

From eqn. (i) and (ii), $t = \dfrac{1}{4\sqrt{2}}T$ *i.e.*, $t = \left(\dfrac{\sqrt{2}}{8}\right)T$

12. (a, b, c) : $x = a\cos pt,\ y = b\sin pt$

$$\therefore \cos^2 pt + \sin^2 pt = \left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2$$

or $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 1$ It is an equation of ellipse.

$\because\ x = a\cos pt$

$\therefore\ \dfrac{dx}{dt} = -ap\sin pt \Rightarrow v_x = -ap\sin pt$

$\dfrac{d^2x}{dt^2} = -ap^2\cos pt \Rightarrow a_x = -ap^2\cos pt$

$\because\ y = b\sin pt$

$\therefore\ \dfrac{dy}{dt} = bp\cos pt \Rightarrow v_y = bp\cos pt$

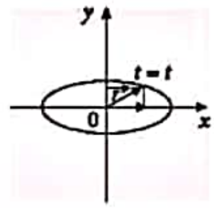
$\dfrac{d^2y}{dt^2} = -bp^2\sin pt \Rightarrow a_y = -bp^2\sin pt.$

When $t = \pi/2p$, $a_x = 0$ and $v_y = 0$; $a_y = -bp^2$, $v_x = -ap$

Thus velocity is along negative x-axis.

Acceleration is along negative y-axis.

At $t = t$,



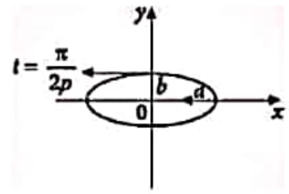
$\vec{r}(t) = x\hat{i} + y\hat{j}$

$= a\cos pt\,\hat{i} + b\sin pt\,\hat{j}$

$\vec{a}(t) = a_x\hat{i} + a_y\hat{j}$

$= -p^2[a\cos pt\,\hat{i} + b\sin pt\,\hat{j}]$

$= -p^2[x\hat{i} + y\hat{j}] = -p^2\vec{r}(t)$



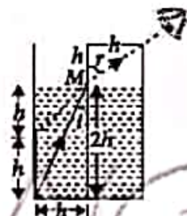
Hence acceleration is always directed towards origin.

At $t = 0$, the particle is at $(a, 0)$

At $t = \pi/(2p)$, the particle is at $(0, b)$

Therefore distance covered is one-fourth of elliptical path. It is not equal to a.

13. (1.58) : When $2h$ column of liquid is made available, then



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

From the figure, $\sin r = \dfrac{h}{\sqrt{2}h}$

$\sin i = \dfrac{h}{\sqrt{5}h}$ $\therefore\ \mu = \sqrt{\dfrac{5}{2}} = 1.58$

14. (6) : Kinetic energy of neutrons = 0.0327 eV

or $K = 0.0327 \times 1.6 \times 10^{-19}$ J

or $\dfrac{1}{2}mv^2 = 0.0327 \times 1.6 \times 10^{-19}$

or $v^2 = \dfrac{2\times 0.0327\times 1.6\times 10^{-19}}{1.675\times 10^{-27}}$

or $v^2 = 0.0625 \times 10^8$ or $v = 0.25 \times 10^4$ m s^{-1}

$\therefore$ time taken $= \dfrac{\text{distance}}{\text{velocity}} = \dfrac{10}{0.25\times 10^4}$

or $t = 4 \times 10^{-3}$ s

$\therefore$ Fraction that decays $= \dfrac{N_0 - N}{N_0} = (1 - e^{-\lambda t})$

$$= 1 - \left\{e^{-\left(\frac{0.693}{700}\times 4\times 10^{-3}\right)}\right\} = 3.96\times 10^{-6} = 3.96\times 10^{-p} \text{ (Given)}$$

$\therefore\ p = 6.$

15. (4) : Let mass of block A be m, then mass of block $B = 2m$

At maximum extension in the spring

$v_A = v_B = 0$ (momentarily)

Therefore, applying conservation of mechanical energy, Decrease in gravitational potential energy of block B = increase in elastic potential energy of spring.

or $m_B g x_m = \frac{1}{2}kx_m^2$

or $2mgx_m = \frac{1}{2}kx_m^2 \quad \therefore x_m = \frac{4mg}{k}$

At $x = \frac{x_m}{2} = \frac{2mg}{k}$

Let $v_A = v_B = v$(say)

Then, decrease in gravitational potential energy of block B = increase in elastic potential energy of spring + increase in kinetic energy of both the blocks.

$\therefore \quad m_B g x = \frac{1}{2}kx^2 + \frac{1}{2}(m_A + m_B)v^2$

or $(2m)(g)\left(\frac{2mg}{k}\right) = \frac{1}{2}k\left(\frac{2mg}{k}\right)^2 + \frac{1}{2}(m + 2m)v^2$

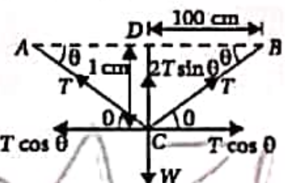
$\therefore \quad v = 2g\sqrt{\frac{m}{3k}} = 2\times10\sqrt{\frac{6}{3\times50}} = 4\ \text{m s}^{-1}$

16. (10.25) : Length of steel wire (l) = 2 m

Diameter (d) = 0.8 mm

Depression produced in wire on hanging a load at mid point = 1.0 cm

Young's modulus of steel (Y) = 2×10^{12} dyne cm^{-2}



Let W be the load hung at mid point and T be the tension in the string.

Let depressed wire make an angle θ with the horizontal.

Using geometry,

$AC = BC = \sqrt{BD^2 + CD^2} = \sqrt{100^2 + 1^2} = 100\times1.00005\,\text{cm}$

$\therefore$ Extension of wire $BD = (CB - BD)$

$= (100 \times 1.00005 - 100) = 0.005$ cm.

From figure, resolving tension T in the wire in to vertical and horizontal components, the horizontal components balance each other and in vertical direction,

$W = 2T\sin\theta$

$\therefore \quad T = \frac{W}{2\sin\theta} = \frac{W}{2\times1/\sqrt{100^2+1}} = \frac{W\times100.005}{2}$

Strain in the wire $= \frac{\Delta l}{l} = \frac{0.005}{100} = 5\times10^{-5}$ cm

Cross sectional area of the wire

$A = \pi r^2 = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.08)^2\ \text{cm}^2$

Now, by definition of Young's modulus,

$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{T/A}{\Delta l/l} = \frac{Tl}{A\Delta l} = \frac{Wl}{2\sin\theta A\Delta l}$

$\Rightarrow \quad W = \frac{2A\sin\theta\Delta lY}{l} = \frac{2\pi(0.08)^2\times0.005\times2\times10^{12}}{4\times100.005\times100\times980}$

= 10.25 gm-wt

17. (30)

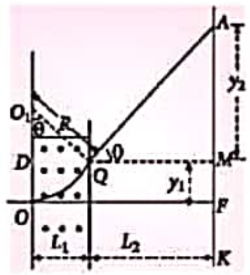
18. (5) : The path OQ of the particle travelled in the magnetic field B is an arc of the circle of radius R is given by

$R = \frac{mv}{qB}$ ...(i)

where m and q are mass and charge of a particle and v its velocity.

The velocity gained by the accelerated electron

$v = \sqrt{\frac{2qV}{m}}$ ...(ii)



where V is the accelerating potential difference.

From equations (i) and (ii),

$R = \frac{1}{B}\sqrt{\frac{2Vm}{q}}$ ...(iii)

The centre of curvature of the arc OQ lies at O_1 and $OO_1 = QO_1 = R$

QA is a straight line and tangent to the curve at Q.

Displacement $FA = FM + MA = y_1 + y_2$.

To find y_1,

$y_1 = FM = OD = OO_1 - O_1D$

$= R - \sqrt{R^2 - DQ^2} = R - \sqrt{R^2 - L_1^2}$ ...(iv)

To find y_2,

Triangles AQM and O_1DQ are similar.

$\frac{AM}{QM} = \frac{DQ}{O_1D} \Rightarrow \frac{y_2}{L_2} = \frac{L_1}{\sqrt{R^2 - L_1^2}}$ or $y_2 = \frac{L_1L_2}{\sqrt{R^2 - L_1^2}}$

Total displacement

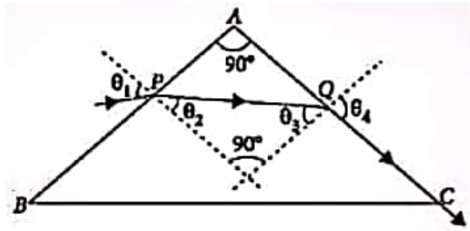
$FA = y_1 + y_2 = \left(R - \sqrt{R^2 - L_1^2}\right) + \frac{L_1L_2}{\sqrt{R^2 - L_1^2}}$ ...(v)

$R = \frac{1}{B}\sqrt{\frac{2Vm}{q}} = 1\ \text{m}$

Now, $FA = 1 - \sqrt{1 - \frac{3}{4}} + \frac{\frac{\sqrt{3}}{2}\,\frac{3\sqrt{3}}{2}}{\sqrt{1 - \frac{3}{4}}} = 5$ m

PAPER-II

1. (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 $\theta_3 = 90° - \theta_2$

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

From Snell's law at face AC,

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

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

From Snell's law at face AB,

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

$$\sin\theta_2 = \frac{\sin\theta_1}{\mu} \quad \text{...(iii)}$$

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

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

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

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

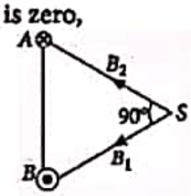
$$\mu_{max} = \sqrt{2} = 1.414$$

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.

2. (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, 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 $\quad I_B = I_A \times \frac{10}{32}$ 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 $I_A = B_1$

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

$$\text{or} \quad B_1 = \frac{(2\times10^{-7})(9.6)}{(1.6)} = 12\times10^{-7}\text{ T}$$

Magnetic field due to $I_B = B_2$

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

$$\text{or} \quad B_2 = \frac{(2\times10^{-7})(3)}{1.2} = 5\times10^{-7}\text{ T}$$

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

$$B^2 = B_1^2 + B_2^2$$

$$\therefore \quad B^2 = (12\times10^{-7})^2 + (5\times10^{-7})^2$$

or $\quad B^2 = 169\times(10^{-7})^2$ or $B = 13\times10^{-7}$ T

or $\quad B = 1.3\times10^{-6}$ T

Force per unit length on the wire B

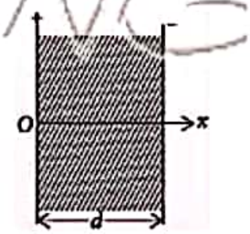
$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_AI_B}{r}, \quad \text{where } r = AB = 2\text{ m}$$

$$= \frac{(2\times10^{-7})(9.6)(3)}{2} = 2.88\times10^{-6}\text{ N m}^{-1}$$

3. (a) : We point the x-axis towards right and place the origin on the left hand side plate. The left plate is assumed to be positively charged.

Since ε varies linearly, we can write,

$$\varepsilon = a + bx$$



where a and b can be determined from the boundary conditions.

We have,

$\varepsilon = \varepsilon_1$ at $x = 0$ and $\varepsilon = \varepsilon_2$ at $x = d$,

$$\text{Thus, } \varepsilon = \varepsilon_1 + \left(\frac{\varepsilon_2-\varepsilon_1}{d}\right)x$$

Now potential difference between the plates

$$V_+ - V_- = \int_0^d \vec{E}\cdot d\vec{r} = \int_0^d \frac{\sigma}{\varepsilon_0\varepsilon}dx$$

$$= \int_0^d \frac{\sigma}{\varepsilon_0\left(\varepsilon_1+\left(\frac{\varepsilon_2-\varepsilon_1}{d}\right)x\right)}dx = \frac{\sigma d}{(\varepsilon_2-\varepsilon_1)\varepsilon_0}\ln\frac{\varepsilon_2}{\varepsilon_1}$$

Hence, the required capacitance,

$$C = \frac{\sigma A}{V_+-V_-} = \frac{(\varepsilon_2-\varepsilon_1)\varepsilon_0 A}{\left(\ln\frac{\varepsilon_2}{\varepsilon_1}\right)d}$$

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

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

Along $A \to B$

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

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

or $T_B = 1000 \times 0.85 = 850\text{ K}$

$$W_{AB} = \frac{R}{1-\gamma}(T_B - T_A) = \frac{8.31}{\left(1-\frac{5}{3}\right)}(850 - 1000) \approx 1870\text{ J}$$

Along $B \to C$; $\frac{T_B}{T_C} = \frac{P_B}{P_C}$

$\therefore\ T_C = \left(\frac{P_C}{P_B}\right)T_B = \left(\frac{P_A}{3} \times \frac{3}{2P_A}\right)850\text{ K}$ or $T_C = 425\text{ K}$

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

$$Q_{BC} = \frac{3}{2} \times 8.31 \times (425 - 850) \approx -5298\text{ J}$$

5. (a, c) : Flux linked with loop due to its own magnetic field,

$$\phi = \frac{\mu_0 I}{2r}(\pi r^2) = \frac{\mu_0 \pi r I}{2}$$

emf induced $= -\frac{d\phi}{dt} = \varepsilon = -\frac{\mu_0 \pi r}{2}\frac{dI}{dt}$; $I = \frac{\varepsilon}{R} = -\frac{\mu_0 \pi r}{2R}\frac{dI}{dt}$

$$\int_{I_0}^{I}\frac{dI}{I} = -\int_0^t \frac{2R}{\mu_0 \pi r}dt;\ I = I_0 e^{-2Rt/\mu_0 \pi r}$$

Now, $10^{-3}I_0 = I_0 e^{-\frac{2Rt}{\mu_0 \pi r}}$

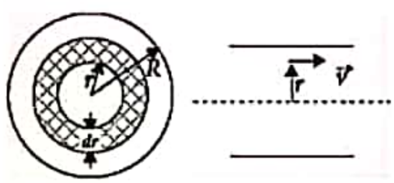
which gives $t = \frac{3\pi^2 \ln 10}{10^{10}}$ s.

6. (b, c, d) : Let dV be the volume flowing per second through the cylindrical shell of thickness dr then,

$$dV = (2\pi r\, dr)v_0\left(1 - \frac{r^2}{R^2}\right) = 2\pi v_0\left(r - \frac{r^3}{R^2}\right)dr$$

and the total volume,

$$V = 2\pi v_0 \int_0^R \left(r - \frac{r^3}{R^2}\right)dr = 2\pi v_0 \frac{R^2}{4} = \frac{\pi}{2}R^2 v_0$$



Let, dK be the kinetic energy, within the above cylindrical shell. Then

$$dK = \frac{1}{2}(dm)v^2 = \frac{1}{2}(2\pi r l \rho)v^2 dr$$

$$= \frac{1}{2}(2\pi l \rho)r\, v_0^2\left(1 - \frac{r^2}{R^2}\right)^2 dr = \pi l \rho v_0^2\left[r - \frac{2r^3}{R^2} + \frac{r^5}{R^4}\right]dr$$

Hence, kinetic energy of the fluid

$$K = \pi l \rho v_0^2 \int_0^R \left(r - \frac{2r^3}{R^2} + \frac{r^5}{R^4}\right)dr = \frac{l\pi R^2 \rho v_0^2}{6}$$

Here frictional force is the shearing force on the tube, exerted by the fluid, which equals $-\eta A\frac{dv}{dr}$, where A is the surface area of tube.

Given, $v = v_0\left(1 - \frac{r^2}{R^2}\right)$, So $\frac{dv}{dr} = -2v_0\frac{r}{R^2}$

and at $r = R$, $\frac{dv}{dr} = -\frac{2v_0}{R}$

Then, viscous force is given by

$$dF = -\eta(2\pi Rl)\left(\frac{dv}{dr}\right)_{r=R} = -2\pi R\eta l\left(-\frac{2v_0}{R}\right) = 4\pi\eta l v_0$$

Taking a cylindrical shell of thickness dr and radius r

Viscous force, $F = -\eta(2\pi r l)\frac{dv}{dr}$

Let, ΔP be the pressure difference, then net force on the element $= \Delta P \pi r^2 + 2\pi\eta l r\frac{dv}{dr}$

But, since the flow is steady, $F_{net} = 0$

or $$\Delta P = \frac{-2\pi l \eta r\frac{dv}{dr}}{\pi r^2} = \frac{2\pi l \eta r\left(2v_0\frac{r}{R^2}\right)}{\pi r^2} = \frac{4\eta l v_0}{R^2}$$

7. (d)

8. (a, b, c) : Unit of $x = \frac{\text{unit of } E}{\text{unit of } B} = \frac{\frac{\text{volt}}{\text{metre}}}{\frac{\text{volt/metre}}{\text{metre/sec}}}$

$= \frac{\text{metre}}{\text{second}} =$ unit of velocity

$y = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c =$ velocity of light

and unit of $\frac{l}{CR} = \frac{\text{metre}}{\text{farad} \times \text{ohm}}$

$$= \frac{\text{metre}}{\frac{\text{coulomb}}{\text{volt}} \times \frac{\text{volt}}{\text{ampere}}} = \frac{\text{metre}}{\frac{\text{ampere} \times \text{sec}}{\text{ampere}}}$$

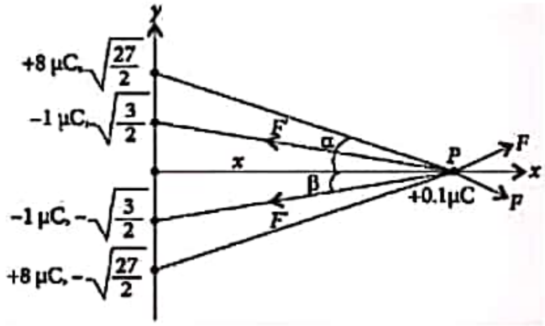
$= \frac{\text{metre}}{\text{sec}} =$ unit of velocity

9. **(3) :** Let the particle be, at some instant, at a point P distant x from the origin. At this point electric field will be zero.

Net force towards origin = $2F' \cos\beta$

Net force away from origin = $2F\cos\alpha$

For net force at point P to become zero,



$2F\cos\alpha = 2F'\cos\beta$

$$\therefore \frac{2k\times(8\times10^{-6})\times(0.1\times10^{-6})\cos\alpha}{\left(x^2+\frac{27}{2}\right)}$$

$$= \frac{2k\times(1\times10^{-6})\times(0.1\times10^{-6})\cos\beta}{\left(x^2+\frac{3}{2}\right)} \text{ where } k=\frac{1}{4\pi\varepsilon_0}$$

$$\Rightarrow x = \pm\sqrt{\frac{5}{2}}\text{ m}$$

The least value of kinetic energy of the particle at infinity should be enough so that particle can reach at $x=+\sqrt{\frac{5}{2}}$ m because at $x=+\sqrt{\frac{5}{2}}$ m net force on it is zero.

For $x>\sqrt{\frac{5}{2}}$ m, net force on the particle is repulsive (towards positive x-axis).

For $x<\sqrt{\frac{5}{2}}$ m, net force on the particle is attractive (towards negative x-axis).

Let electric potential at $x=\sqrt{\frac{5}{2}}$ m be V.

$$\therefore V=\frac{2\times(9\times10^9)\times(8\times10^{-6})}{\sqrt{\frac{5}{2}+\frac{27}{2}}} - \frac{2\times(9\times10^9)\times(1\times10^{-6})}{\sqrt{\frac{5}{2}+\frac{3}{2}}}$$

or $V = 2.7\times10^4$ V

Using energy conservation at $x=\sqrt{\frac{5}{2}}$ m and $x=\infty$,

$$q\times V+0 = 0+\frac{1}{2}mv_0^2$$

or $(0.1\times10^{-6})\times(2.7\times10^4) = \frac{1}{2}(6\times10^{-4})v_0^2$

or $v_0^2 = 9$ ... $v_0 = 3\text{ m s}^{-1}$

10. **(5)**

11. **(2.6) :** Least count of screw gauge

$$= \frac{\text{pitch}}{N} = \frac{1\text{ mm}}{100} = 0.01\text{ mm}$$

Diameter $= D = 1+(47\times0.01) = 1.47$ mm $= 0.147$ cm

Area of curved surface, $S=\pi Dl$

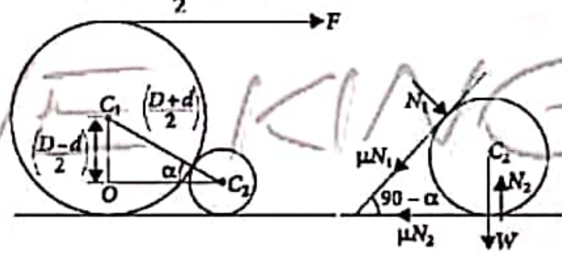
$$\therefore S=\frac{22}{7}\times0.147\times5.6 = 2.5872\text{ cm}^2$$

Round off to two significant digits = 2.6 cm^2.

12. **(5) :** Here C_1 and C_2 are the centres of the rollers. OC_1 is the perpendicular difference between the heights of centers of cylindrical roller from the ground.

$$\therefore C_1C_2 = R+r = \frac{1}{2}(D+d)$$

$$OC_1 = R-r = \frac{1}{2}(D-d)$$



$$\Rightarrow \sin\alpha = \left(\frac{D-d}{D+d}\right) \text{ or } \cos\alpha=\frac{2\sqrt{dD}}{D+d} \quad ...(i)$$

Let N_1 be the normal reaction between the two rollers and N_2 between the smaller cylinder and the horizontal plane.

The larger cylinder can be pulled over the smaller one provided the latter neither rolls nor slides.

There will be no rolling provided the sum of the moments of forces about C_2 is zero

$\mu N_1 d = \mu N_2 d;\ N_1 = N_2$

There will be no sliding provided the sum of resolved parts of the forces in horizontal direction is zero

$\mu N_2 + \mu N_1\cos(90-\alpha) = N_1\cos\alpha$

$\mu N_1 + \mu N_1 \sin\alpha = N_1\cos\alpha$ (As $N_1 = N_2$)

$$\mu = \frac{\cos\alpha}{1+\sin\alpha} \quad ...(ii)$$

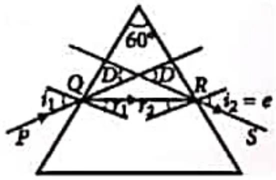
$$\mu = \sqrt{\frac{d}{D}} \quad \text{(using eqns. (i) and (ii))}$$

Hence the necessary condition is that

$$\mu \geq \sqrt{\frac{d}{D}} \quad \text{or} \quad \mu \geq \sqrt{\frac{1}{4}} \Rightarrow \mu \geq 5 \times 10^{-1}$$

13. (1.1)

14. (1.52) : The incident PQ is deviated through 40° and the principle of irreversibility of ray, through optical system, shows that the SR would also suffer the same deviation of 40°.



∴ The other angle of incidence causing same deviation = 40°

i.e. $e = i_2$, where $i_1 - i_2 = 11°$ (given)

Also $i_1 + i_2 = 100°$

∴ $i_1 = 55°\,30'$ and $i_2 = 44°\,30'$

Now, $\mu = \dfrac{\sin i_1}{\sin r_1} = \dfrac{\sin i_2}{\sin r_2}$, where $r_2 = (60° - r_1)$

$$\therefore \mu = \frac{\sin 55°30'}{\sin r_1} = \frac{\sin 44°30'}{\sin(60° - r_1)}$$

we first solve this equation for r_1 and hence find μ

$$\frac{0.8241}{\sin r_1} = \frac{0.7009}{\frac{\sqrt{3}}{2}\cos r_1 - \frac{1}{2}\sin r_1}$$

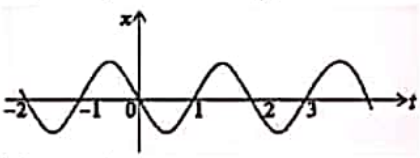
Dividing both sides in denominator by $\sin r_1$, we get

$$\frac{\frac{0.8241}{\sin r_1}}{\frac{\sin r_1}{\sin r_1}} = \frac{0.709}{\frac{\sqrt{3}}{2}\cot r_1 - \frac{1}{2}}; \therefore \frac{1}{2}(\sqrt{3}\cot r_1 - 1) = \frac{0.7009}{0.8241}$$

$$\therefore \cot r_1 = 1.559 \Rightarrow r_1 = 32°40'$$

$$\therefore \mu = \frac{\sin 55°30'}{\sin 32°40'} = \frac{0.8241}{0.5400} = 1.526.$$

15. (a) : In SHM, acceleration, $a = -\omega^2 x$ where ω is (*i.e* angular frequency) constant.



At $t = -1.2$ s, $x < 0$

The slope of x-t is positive, hence v is positive.

Since $a = -\omega^2 x$, hence a is positive.

∴ At $t = -1.2$ s, $x < 0$, $v > 0$, $a > 0$

I $\rightarrow$ S

At $t = -0.3$ s, $x > 0$

The slope of x-t is negative, hence v is negative.

Since $a = -\omega^2 x$, hence $a < 0$

∴ At $t = -0.3$ s, $x > 0$, $v < 0$, $a < 0$

II $\rightarrow$ R

At $t = 0.3$ s, $x < 0$

The slope of x-t is negative, hence v is negative.

Since $a = -\omega^2 x$, hence $a > 0$

∴ At $t = 0.3$ s, $x < 0$, $v < 0$, $a > 0$

III $\rightarrow$ P

At $t = 1.2$ s, $x > 0$

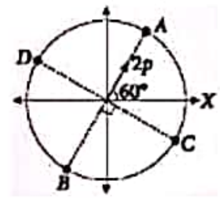
The slope of x-t is positive, hence v is positive.

Since $a = -\omega^2 x$, hence $a < 0$

∴ At $t = 1.2$, $x > 0$, $v > 0$, $a < 0$

IV $\rightarrow$ Q

16. (a) : The resultant dipole moment has magnitude $\sqrt{(\sqrt{3}p)^2 + p^2} = 2p$. At an angle $\theta = \tan^{-1}\dfrac{\sqrt{3}P}{P} = 60°$ with positivex-direction. Diameter AB is along net dipole moment and diameter CD is normal to net dipole moment.



Potential at $A\left(\dfrac{R}{2}, \dfrac{\sqrt{3}R}{2}\right)$ is maximum

I $\rightarrow$ P

Potential is zero at $C\left(\dfrac{\sqrt{3}R}{2}, -\dfrac{R}{2}\right)$ and $D\left(-\dfrac{\sqrt{3}R}{2}, \dfrac{R}{2}\right)$

II $\rightarrow$ R,S

Magnitude of electric field is $\dfrac{1}{4\pi\varepsilon_0}\dfrac{4p}{R^3}$

at $A\left(\dfrac{R}{2}, \dfrac{\sqrt{3}R}{2}\right)$ and $B\left(-\dfrac{R}{2}, -\dfrac{\sqrt{3}R}{2}\right)$

III $\rightarrow$ P,Q

Magnitude of electric field is $\dfrac{1}{4\pi\varepsilon_0}\dfrac{2p}{R^3}$

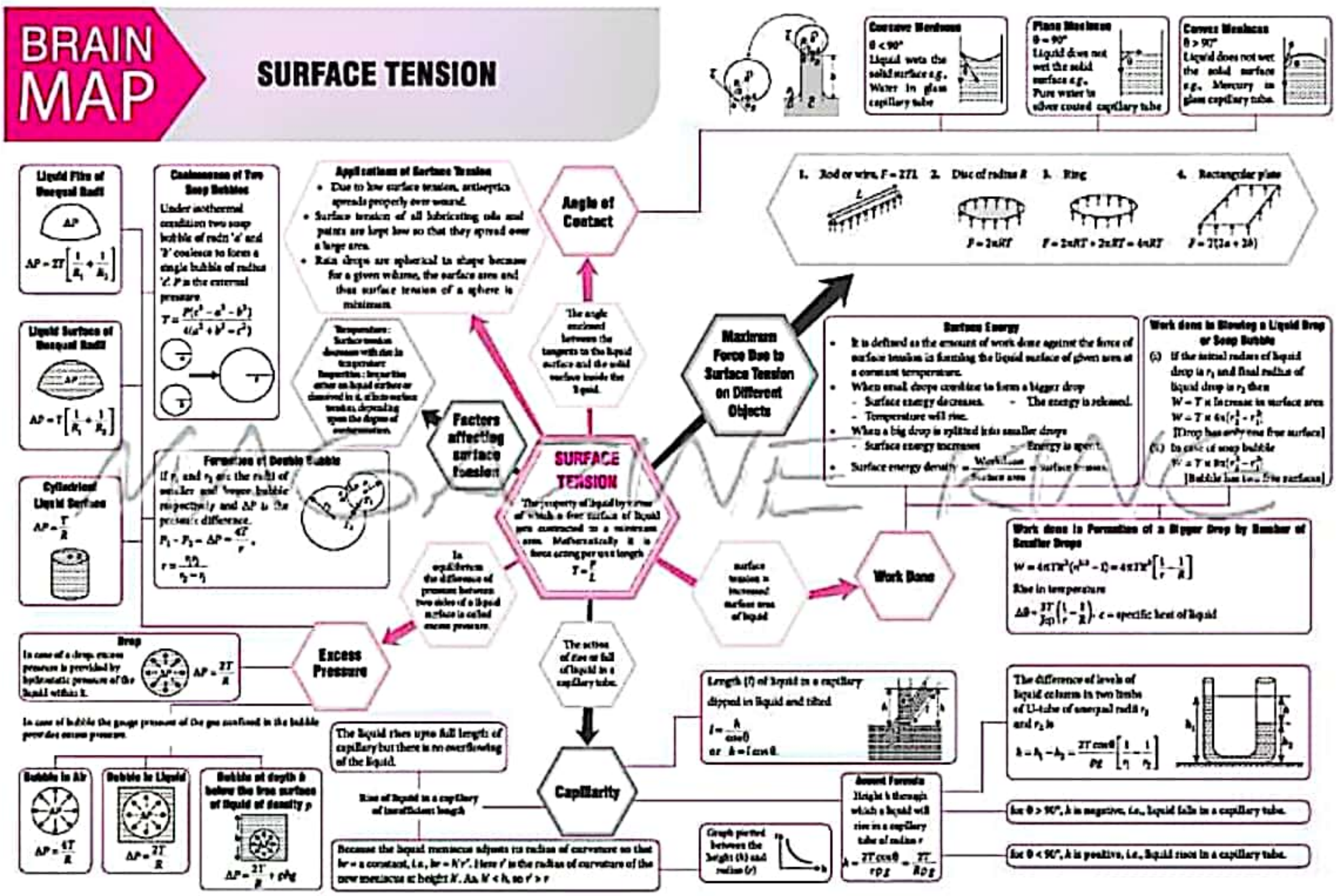
at $C\left(\dfrac{\sqrt{3}R}{2}, -\dfrac{R}{2}\right)$ and $D\left(-\dfrac{\sqrt{3}R}{2}, \dfrac{R}{2}\right)$

IV $\rightarrow$ R,S

17. (c)

18. (d) : Maximum kinetic energy of ejected electron is given by Einstein's photoelectric equation $K_{max} = hf - (hf/3) = 2hf/3$. As no potential difference is applied across target and collector and vacuum is there in the tube, so this maximum KE remains same at all locations.

For (II), (III) and (IV), kinetic energy of ejected photoelectrons can be anything from 0 to K_{max} (as found for (I)). It remains the same at all locations (reasoning is same as for above).



BRAIN MAP
SURFACE TENSION
SURFACE TENSION
The property of liquid by virtue of which a free surface of liquid gets contracted to a minimum area. Mathematically it is force acting per unit length. T = F/L
Angle of Contact
The angle enclosed between the tangents to the liquid surface and the solid surface inside the liquid.
Concave Meniscus
θ < 90°
Liquid wets the solid surface e.g. Water in glass capillary tube
Plane Meniscus
θ = 90°
Liquid does not wet the solid surface e.g. Pure water in silver coated capillary tube
Convex Meniscus
θ > 90°
Liquid does not wet the solid surface e.g. Mercury in glass capillary tube.
Maximum Force Due to Surface Tension on Different Objects
1. Rod or wire, F = 2Tl
2. Disc of radius R
3. Ring
4. Rectangular plate
F = 2πRT
F = 2πRT + 2πRT = 4πRT
F = T(2a + 2b)
Applications of Surface Tension
Due to low surface tension, antiseptics spreads properly over wound.
Surface tension of all lubricating oils and paints are kept low so that they spread over a large area.
Rain drops are spherical in shape because for a given volume, the surface area and thus surface tension of a sphere is minimum.
Factors affecting surface tension
Temperature : Surface tension decreases with rise in temperature
Impurities : Impurities either on liquid surface or dissolved in it, affects surface tension, depending upon the degree of contamination.
Surface Energy
It is defined as the amount of work done against the force of surface tension in forming the liquid surface of given area at a constant temperature.
When small drops combine to form a bigger drop
- Surface energy decreases.
- The energy is released.
- Temperature will rise.
When a big drop is splitted into smaller drops
- Surface energy increases
- Energy is spent.
Surface energy density = Work done / Surface area = surface tension
Work done in Blowing a Liquid Drop or Soap Bubble
(i) If the initial radius of liquid drop is r_1 and final radius of liquid drop is r_2 then
W = T × Increase in surface area
$W = T \times 4\pi(r_2^2 - r_1^2)$
[Drop has only one free surface]
(ii) In case of soap bubble
$W = T \times 8\pi(r_2^2 - r_1^2)$
[Bubble has two free surfaces]
Work Done
surface tension × increased surface area of liquid
Work done in Formation of a Bigger Drop by Number of Smaller Drops
$W = 4\pi TR^2(n^{1/3} - 1) = 4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$
Rise in temperature
$\Delta\theta = \frac{3T}{J\rho}\left(\frac{1}{r} - \frac{1}{R}\right)$; c = specific heat of liquid
Liquid Film of Unequal Radii
$\Delta P = 2T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$
Liquid Surface of Unequal Radii
$\Delta P = T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$
Cylindrical Liquid Surface
$\Delta P = \frac{T}{R}$
Coalescence of Two Soap Bubbles
Under isothermal condition two soap bubble of radii 'a' and 'b' coalesce to form a single bubble of radius 'c'. P is the external pressure
$T = \frac{P(c^3 - a^3 - b^3)}{4(a^2 + b^2 - c^2)}$
Formation of Double Bubble
If r_1 and r_2 are the radii of smaller and larger bubble respectively and ΔP is the pressure difference.
$P_1 - P_2 = \Delta P = \frac{4T}{r}$,
$r = \frac{r_1 r_2}{r_2 - r_1}$
In equilibrium the difference of pressure between two sides of a liquid surface is called excess pressure.
Excess Pressure
Drop
In case of a drop, excess pressure is provided by hydrostatic pressure of the liquid within it.
$\Delta P = \frac{2T}{R}$
In case of bubble the gauge pressure of the gas confined in the bubble provides excess pressure.
Bubble in Air
$\Delta P = \frac{4T}{R}$
Bubble in Liquid
$\Delta P = \frac{2T}{R}$
Bubble at depth h below the free surface of liquid of density ρ
$\Delta P = \frac{2T}{R} + \rho hg$
The action of rise or fall of liquid in a capillary tube.
Capillarity
The liquid rises upto full length of capillary but there is no overflowing of the liquid.
Rise of liquid in a capillary of insufficient length
Because the liquid meniscus adjusts its radius of curvature so that hr = a constant, i.e., hr = h'r'. Here r' is the radius of curvature of the new meniscus at height h'. As h' < h, so r' > r
Length (l) of liquid in a capillary dipped in liquid and tilted
$l = \frac{h}{\cos\theta}$
or $h = l\cos\theta$
Graph plotted between the height (h) and radius (r)
Ascent Formula
Height h through which a liquid will rise in a capillary tube of radius r
$h = \frac{2T\cos\theta}{r\rho g} = \frac{2T}{R\rho g}$
The difference of levels of liquid column in two limbs of U-tube of unequal radii r_1 and r_2 is
$h = h_1 - h_2 = \frac{2T\cos\theta}{\rho g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$
for θ > 90°, h is negative, i.e., liquid falls in a capillary tube.
for θ < 90°, h is positive, i.e., liquid rises in a capillary tube.

PRACTICE PAPER

BITSAT

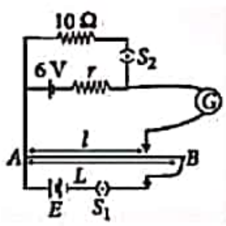
Exam date: 16th to 25th May 2020

1. The rate of cooling at 600 K, if surrounding temperature is 300 K is R. Assume that the Stefan's law holds. The rate of cooling at 900 K is
(a) $\frac{16}{3}R$ (b) $2R$ (c) $3R$ (d) $\frac{2}{3}R$

2. A racing car moving towards a cliff sounds its horn. The driver observes that the sound reflected from the cliff has a pitch one octave higher than the actual sound of the horn. If v be the velocity of sound, the velocity of the car is
(a) $v/\sqrt{2}$ (b) $v/2$ (c) $v/3$ (d) $v/4$

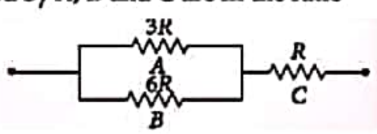
3. Two particles A and B describe S.H.M. of same amplitude a and frequency υ along the same straight line. The maximum distance between two particles is $\sqrt{3}\,a$. The initial phase difference between the particles is
(a) $2\pi/3$ (b) $\pi/6$ (c) $\pi/2$ (d) $\pi/3$

4. In the arrangement shown in figure when the switch S_2 is open, the galvanometer shows no deflection for $\ell = \frac{L}{2}$. When the switch S_2 is closed, the galvanometer shows no deflection for $\ell = \frac{5L}{12}$. The internal resistance (r) of 6 V cell, and the emf E of the other battery are respectively



(a) 3Ω, 8V (b) 2Ω, 12V (c) 2Ω, 24V (d) 3Ω, 12V

5. The three resistances A, B and C have values $3R$, $6R$ and R respectively. When some potential difference is applied across the network, the thermal powers dissipated by A, B and C are in the ratio

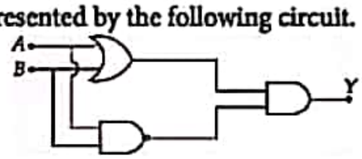


(a) 2 : 3 : 4 (b) 2 : 4 : 3
(c) 4 : 2 : 3 (d) 3 : 2 : 4

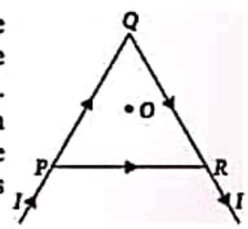
6. A boy throws a ball upwards with velocity u = 15 m s^{-1}. The wind imparts a horizontal acceleration of 3 m s^{-2} to the left. The angle θ with vertical at which the ball must be thrown so that the ball returns to the boy's hand is
(Take g = 10 m s^{-2})
(a) $\tan^{-1}(0.4)$ (b) $\tan^{-1}(0.2)$
(c) $\tan^{-1}(0.3)$ (d) $\tan^{-1}(0.15)$

7. 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) $\left(\frac{3g}{L}\right)^{1/2}$

8. Name the gate represented by the following circuit.
(a) OR gate
(b) XOR gate
(c) AND gate
(d) NAND gate

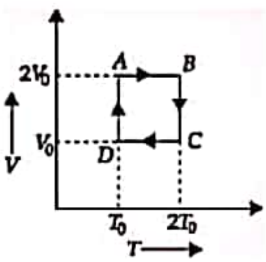


9. An equilateral triangle of side length l is formed from a piece of wire of uniform resistance. The current I is fed as shown in the figure. The magnitude of the magnetic field at its centre O is



(a) $\frac{\sqrt{3}\mu_0 I}{2\pi l}$ (b) $\frac{3\sqrt{3}\mu_0 I}{2\pi l}$
(c) $\frac{\mu_0 I}{2\pi l}$ (d) zero

10. One mole of an ideal gas is taken through a cyclic process as shown in the V-T diagram. Which of the following statements is true?



(a) The magnitude of work done by the gas is $RT_0\ln 2$.
(b) Work done by gas is V_0T_0.
(c) Net work done by the gas is zero.
(d) Work done by the gas is $2RT_0\ln 2$.

11. A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60°. What is the torque needed to maintain the needle in this position?

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

12. In an interference experiment using waves of same amplitude, path difference between the waves at a point on the screen is $\lambda/4$. The ratio of intensity at this point with that at the central bright fringe is
(a) 1 (b) 0.5 (c) 1.5 (d) 2.0

13. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m while applying the force and the ball goes up to 2 m height further, find the magnitude of the force. (Take $g = 10\ m\ s^{-2}$)
(a) 16 N (b) 20 N (c) 22 N (d) 4 N

14. A slab of material of dielectric constant K has the same area as the plates of a parallel plate capacitor but has a thickness $\left(\frac{3}{4}\right)d$, where d is the separation of the plates. The ratio of the capacitance C (in the presence of the dielectric) to the capacitance C_0 (in the absence of the dielectric) is

(a) $\frac{3K}{K+4}$ (b) $\frac{3}{4}K$ (c) $\frac{4K}{K+3}$ (d) $\frac{4}{3}K$

15. A pure inductor of 25 mH is connected to a source of 220 V. Given the frequency of the source as 50 Hz, the rms current in the circuit is
(a) 7 A (b) 14 A (c) 28 A (d) 42 A

16. When light of wavelength 400 nm is incident on the cathode of a photocell, the stopping potential recorded is 6 V. If the wave of the incident light is increased to 600 nm, then the new stopping potential is
(a) 1.03 V (b) 2.42 V (c) 4.97 V (d) 3.58 V

17. Suppose speed of light (c), force (F) and kinetic energy (K) are taken as the fundamental units, then the dimensional formula for mass will be
(a) $[Kc^{-2}]$ (b) $[KF^{-2}]$ (c) $[cK^{-2}]$ (d) $[Fc^{-2}]$

18. A gas bubble from an explosion under water oscillates with a time period T, depends upon static pressure p, density of water ρ and the total energy of explosion E. Find the expression for the time period T. k is a dimensionless constant.
(a) $T = kp^{-5/6}\rho^{1/2}E^{1/3}$ (b) $T = kp^{-4/7}\rho^{1/2}E^{1/3}$
(c) $T = kp^{-5/6}\rho^{1/2}E^{1/2}$ (d) $T = kp^{-4/7}\rho^{1/3}E^{1/2}$

19. A vessel contains oil (density = 0.8 g cm^{-3}) over mercury (density = 13.6 g cm^{-3}). A uniform sphere floats with half its volume immersed in mercury and the other half in oil. The density of the material of sphere in g cm^{-3} is
(a) 3.3 (b) 6.4 (c) 7.2 (d) 12.8

20. A sand bag of mass M is suspended by a rope. A bullet of mass m is fired at it with speed v and gets embeded in it. The loss of kinetic energy of the system is

(a) $\frac{Mmv^2}{2(M+m)}$ (b) $\frac{Mv^2}{2(M+m)}$

(c) $\frac{m^2v^2}{2(M+m)}$ (d) $\frac{1}{2}(M+m)v^2$

21. Consider two containers A and B containing identical gases at the same pressure, volume and temperature. The gas in container A is compressed to half of its original volume isothermally while the gas in container B is compressed to half of its original volume adiabatically. The ratio of final pressure of gas in B to that of gas in A is

(a) $2^{\gamma-1}$ (b) $\left(\frac{1}{2}\right)^{\gamma-1}$

(c) $\left(\frac{1}{1-\gamma}\right)^2$ (d) $\left(\frac{1}{\gamma-1}\right)^2$

22. Soap water drips from a capillary. When the drop breaks away, the diameter of its neck is 1 mm. The mass of the drop is 0.0129 g. Find the surface tension of soapy water. (Take $g = 9.8\ m\ s^{-2}$)
(a) $12.9 \times 10^{-3}\ N\ m^{-1}$ (b) $31.2 \times 10^{-3}\ N\ m^{-1}$
(c) $40.3 \times 10^{-3}\ N\ m^{-1}$ (d) $58.6 \times 10^{-3}\ N\ m^{-1}$

23. In a galvanometer 5% of the total current in the circuit passes through it. If the resistance of the galvanometer is G, the shunt resistance S connected to the galvanometer is

(a) $19G$ (b) $\frac{G}{19}$ (c) $20G$ (d) $\frac{G}{20}$

24. A uniform chain of mass m and length l is lying on a table with $\frac{l}{4}$ of its length hanging freely from the edge of the table. The amount of work done in dragging the chain on the table completely is

(a) $\frac{mgl}{4}$ (b) $\frac{mgl}{8}$ (c) $\frac{mgl}{32}$ (d) $\frac{mgl}{16}$

25. A needle placed 45 cm from a lens forms an image on a screen placed 90 cm on the other side of the lens. Its focal length and the size of image if the size of the needle is 5 cm are respectively

(a) – 30 cm, 10 cm (b) + 30 cm, – 10 cm
(c) – 20 cm, 15 cm (d) + 20 cm, – 15 cm

26. The three stable isotopes of neon $_{10}Ne^{20}$, $_{10}Ne^{21}$ and $_{10}Ne^{22}$ have respective abundances of 90.51%, 0.27% and 9.22%. The atomic masses of the three isotopes are 19.99 u, 20.99 u and 21.99 u respectively. The average atomic mass of neon is

(a) 11.18 u (b) 15.18 u (c) 20.18 u (d) 10.18 u

27. The electric field (in N C^{-1}) in an electromagnetic wave is given by $E = 50 \sin \omega(t - x/c)$. The energy stored in a cylinder of cross-section 10 cm^2 and length 100 cm along the x-axis will be

(a) 5.5×10^{-12} J (b) 1.1×10^{-11} J
(c) 2.2×10^{-11} J (d) 3.3×10^{-11} J

28. A fork A has frequency 2% more than the standard fork and B has a frequency 3% less than the frequency of same standard fork. The forks A and B when sounded together produced 6 beats s^{-1}. The frequency of fork A is

(a) 116.4 Hz (b) 120 Hz
(c) 122.4 Hz (d) 238.8 Hz

29. The plane face of a planoconvex lens is silvered. If μ be the refractive index and R, the radius of curvature of curved surface, then the system will behave like a concave mirror of radius of curvature

(a) μR (b) $\frac{R}{(\mu-1)}$ (c) $\frac{R}{\mu}$ (d) $\left(\frac{\mu+1}{\mu-1}\right)R$

30. The work function of a certain metal is 3.31×10^{-19} J. Then, the maximum kinetic energy of photoelectrons emitted by incident radiation of wavelength 5000 Å is

(a) 2.48 eV (b) 0.42 eV (c) 2.07 eV (d) 0.82 eV

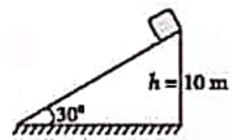
31. A diode having potential difference 0.5 V across its junction which does not depend on current, is connected in series with resistance of 20 Ω across source. If 0.1 A current passes through resistance, then what is the voltage of the source?

(a) 1.5 V (b) 2.0 V (c) 2.5 V (d) 5 V

32. An object initially at rest explodes into three fragments A, B and C. The momentum of A is $P\hat{i}$ and that of B is $\sqrt{3}P\hat{j}$ where P is positive number. The momentum of C is

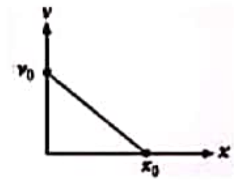
(a) $(1 + \sqrt{3})P$ in a direction making 120° with A
(b) $2P$ in a direction making 150° with A
(c) $2P$ in a direction making 150° with B
(d) $(1 + \sqrt{3})P$ in a direction making 150° with B.

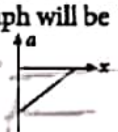
33. A block of mass 5 kg slides down on an inclined plane of inclination 30° from a height of 10 m from ground. The coefficient of friction between the block and the inclined plane is 0.5. Find the work done by friction on the block.

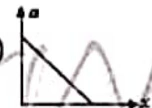


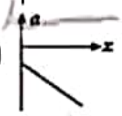
(a) $250\sqrt{3}$ J (b) $-250\sqrt{3}$ J
(c) 500 J (d) – 500 J

34. The velocity displacement graph of a particle moving along a straight line is shown. The most suitable acceleration-displacement graph will be



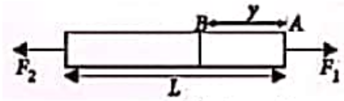
(a)


(b)


(c)


(d)


35. What is the tension in a rod of length L and mass M at a distance y from F_1, when the rod is acted on by two unequal forces F_1 and F_2 ($<F_1$) as shown in figure.



(a) F_1 (b) $F_1 - F_2$
(c) $F_1\left(\frac{y}{L}\right)+F_2\left(1-\frac{y}{L}\right)$ (d) $F_1\left(1-\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$

36. Imagine a light planet revolving around a massive star in a circular orbit of radius r with a period of revolution T. If the gravitational force of attraction between planet and the star is proportional to $r^{-5/2}$, then the relation between T and r will be

(a) $T \propto r^{-2}$ (b) $T^2 \propto r^{7/2}$ (c) $T^3 \propto r^4$ (d) $T \propto r^{3/2}$

37. If the shear modulus of a wire material is 5.9×10^{11} dyne cm^{-2} then the potential energy of a wire of 4×10^{-3} cm in diameter and 5 cm long twisted through an angle of 10′, is

(a) 1.253×10^{-12} J (b) 2×10^{-12} J
(c) 1.00×10^{-12} J (d) 0.8×10^{-12} J

38. A lift is moving down with acceleration a. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground are respectively
(a) g, g (b) $a, g-a$ (c) $g-a, g$ (d) a, g

39. The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is
(a) 120 cm (b) 140 cm (c) 80 cm (d) 100 cm

40. On observing light from three different stars P, Q and R, it was found that intensity of violet colour is maximum in the spectrum of P, the intensity of green colour is maximum in the spectrum of R and the intensity of red colour is maximum in the spectrum of Q. If T_P, T_Q and T_R are the respective absolute temperatures of P, Q and R, then it can be concluded from the above observations that
(a) $T_P < T_R < T_Q$ (b) $T_P < T_Q < T_R$
(c) $T_P > T_Q > T_R$ (d) $T_P > T_R > T_Q$

SOLUTIONS

1. **(a)** : Rate of cooling is proportional to $(T^4 - T_0^4)$, as per Stefan's law.

$\therefore \frac{R'}{R} = \frac{900^4 - 300^4}{600^4 - 300^4}$

$= \frac{9^4 - 3^4}{6^4 - 3^4} = \frac{3^4(3^4-1)}{3^4(2^4-1)} = \frac{80}{15} = \frac{16}{3}$ or $R' = \frac{16}{3}R.$

2. **(c)**

3. **(a)** : $y_1 = a \sin \omega t$ and $y_2 = a \sin(\omega t + \theta)$

$y_2 - y_1 = a\sqrt{3} = a\sin(\omega t + \theta) - a \sin \omega t$

or $\sqrt{3}a = 2a\cos\frac{(\omega t+\theta)+\omega t}{2}\sin\frac{(\omega t+\theta)-\omega t}{2}$

$= 2a\cos(\omega t + \theta/2)\sin\theta/2$

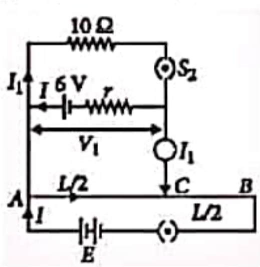
For maximum value, $\cos(\omega t + \theta/2) = 1$

$\therefore \sqrt{3}a = 2a\sin\theta/2$

or $\sin\theta/2 = \frac{\sqrt{3}}{2} = \sin\frac{\pi}{3}$ or $\frac{\theta}{2} = \frac{\pi}{3}$ or $\theta = \frac{2\pi}{3}$

4. **(b)** : When S_2 is open :
Assume resistance of $AB = R$
Resistance of wire per unit length.

$x = \frac{R}{L}$; $i = \frac{E}{R}$



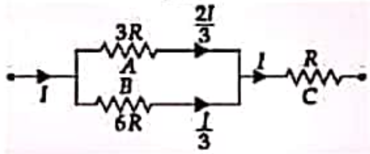
Now in AC, $\frac{E}{R}\times\frac{R}{L}\times\frac{L}{2} = 6\text{ V}$
$E = 12$ V

When S_2 is closed :

$V_1 = \frac{E}{R}\times\frac{R}{L}\times\frac{5L}{12} = \frac{5E}{12} = \frac{5\times12}{12} = 5\text{V}$

$\Rightarrow 6 - I_1 r = 5; \Rightarrow 6 - \left(\frac{5}{10}\right)r = 5 \Rightarrow r = 2\,\Omega$

5. **(c)** :



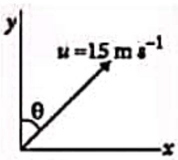
Thermal power in A, $P_A = \left(\frac{2I}{3}\right)^2 3R = \frac{4}{3}I^2R$

Thermal power in B, $P_B = \left(\frac{I}{3}\right)^2 6R = \frac{2}{3}I^2R$

Thermal power in C, $P_C = I^2R$.

$P_A : P_B : P_C = \frac{4}{3}I^2R : \frac{2}{3}I^2R : I^2R = 4:2:3$

6. **(c)** : Here, $u_y = u\cos\theta = 15\cos\theta$
$u_x = u\sin\theta = 15\sin\theta$



Time of flight of the ball is

$T = \frac{2u_y}{g} = \frac{2\times15\cos\theta}{10} = 3\cos\theta$ ...(i)

The boy will catch the ball if in time T, displacement of the ball in horizontal direction should also be zero. So

$0 = u_xT - \frac{1}{2}a_xT^2$

or $T = \frac{2u_x}{a_x} = \frac{2(15\sin\theta)}{3} = 10\sin\theta$ ...(ii)

From eqns. (i) and (ii), $3\cos\theta = 10\sin\theta$

or $\tan\theta = \frac{3}{10} = 0.3$ or $\theta = \tan^{-1}(0.3)$

7. **(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

$0 + \frac{MgL}{2} = \frac{1}{2}I\omega^2 + 0 = \frac{1}{2}\frac{ML^2}{3}\omega^2$

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

8. **(b)** : Output of OR gate is $A + B$. Output of NAND gate is $\overline{A\cdot B}$

Now, $Y = (A+B)\cdot\overline{A\cdot B} = (A+B)\cdot(\bar{A}+\bar{B})$

If $A = 1$ and $B = 1$, then $A + B = 1$ and $\bar{A}+\bar{B} = 0$

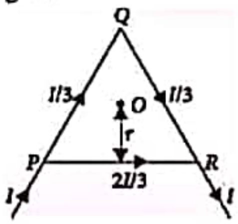
So, $Y = 0$

If $A = 0$ and $B = 0$, then $Y = 0$

If $A = 1$ and $B = 0$, then $A + B = 1$; $\bar{A}+\bar{B} = 1$

So, $Y = 1$
If $A = 0$ and $B = 1$, then $Y = 1$
So, the given combination is XOR gate.

9. **(d) :** The magnetic field induction at O due to current through PR is



$$B_1 = \frac{\mu_0}{4\pi}\frac{2I/3}{r}[\sin 30^\circ + \sin 30^\circ]$$

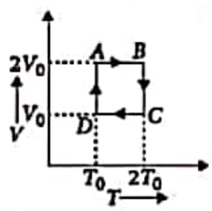
$$= \frac{\mu_0}{4\pi}\frac{2}{3}\frac{I}{r}$$

It is directed outside the paper.
The magnetic field induction at O due to current through PQR is

$$B_2 = 2\times\frac{\mu_0}{4\pi}\frac{(I/3)}{r}[\sin 30^\circ + \sin 30^\circ] = \frac{\mu_0}{4\pi}\frac{2I}{3r}.$$

It is directed inside the paper.
$\therefore$ Resultant magnetic field induction at O is $B_1 - B_2 = 0$

10. **(a) :** In the process AB and CD, volume is constant, Therefore, no work is done.



$$W_{DA} = RT_0 \ln\left(\frac{2V_0}{V_0}\right)$$

$$\Rightarrow W_{DA} = RT_0 \ln 2$$

$$W_{BC} = R(2T_0)\ln\left(\frac{V_0}{2V_0}\right) = -2RT_0 \ln 2$$

Total work done by the gas
$W = W_{DA} + W_{BC} = RT_0 \ln 2 - 2RT_0 \ln 2 = -RT_0 \ln 2$
$|W| = RT_0 \ln 2$

11. **(a) :** In case of a dipole in a magnetic field,
Workdone, $W = MB(\cos\theta_1 - \cos\theta_2)$
Torque, $\tau = MB \sin\theta$; $\theta_1 = 0^\circ$ and $\theta_2 = 60^\circ$

$$\therefore W = MB(1 - \cos\theta) = 2MB\sin^2\frac{\theta}{2}$$

$$\tau = MB\sin\theta = 2MB\sin\frac{\theta}{2}\cos\frac{\theta}{2}$$

$$\frac{\tau}{W} = \cot\left(\frac{\theta}{2}\right), \text{ or } \tau = W\cot 30^\circ = \sqrt{3}W$$

12. **(b) :** As $I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

Here, $\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{4} = \frac{\pi}{2}$, $I_1 = I_2 = I$

$$\therefore I_R = I + I + 2I\cos\frac{\pi}{2} = 2I$$

At the central bright fringe, $I' = 4I$

$$\therefore \frac{I_R}{I'} = \frac{2I}{4I} = 0.5$$

13. **(b) :** Let v be the velocity given by hand and h be the height to which the ball goes.

$$\therefore \frac{1}{2}mv^2 = mgh \qquad ...(i)$$

If F is the force applied by the hand as it moves through 0.2 m, then $\frac{1}{2}mv^2 + F\times 0.2 = mg(h+2)$ ...(ii)

Using eqn. (i); $mgh + F \times 0.2 = mgh + mg \times 2$

$$F = \frac{mg\times 2}{0.2} = 10mg = 10\times 0.2\times 10 = 20 \text{ N}$$

14. **(c)**

15. **(c) :** Here, $L = 25$ mH $= 25\times 10^{-3}$ H
$\upsilon = 50$ Hz, $V_{rms} = 220$ V
The inductive reactance is

$$X_L = 2\pi\upsilon L = 2\times\frac{22}{7}\times 50\times 25\times 10^{-3}\ \Omega$$

The rms current in the circuit is

$$I_{rms} = \frac{V_{rms}}{X_L} = \frac{220}{2\times\frac{22}{7}\times 50\times 25\times 10^{-3}} = 28 \text{ A}$$

16. **(c) :** As $K_{max} = h\upsilon - \phi_0$

or $eV_0 = \frac{hc}{\lambda} - \phi_0$ or $V_0 = \frac{hc}{e\lambda} - \frac{\phi_0}{e}$

$\therefore \Delta V_0 = (V_0)_1 - (V_0)_2$

$$= \left[\frac{hc}{e\lambda_1} - \frac{\phi_0}{e}\right] - \left[\frac{hc}{e\lambda_2} - \frac{\phi_0}{e}\right] = \frac{hc}{e}\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$$

$$= \frac{6.6\times 10^{-34}\times 3\times 10^8}{1.6\times 10^{-19}}\left[\frac{1}{4\times 10^{-7}} - \frac{1}{6\times 10^{-7}}\right] = 1.03 \text{ V}$$

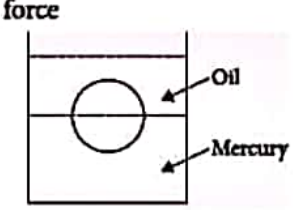
$\therefore (V_0)_2 = (V_0)_1 - 1.03 = 6 - 1.03 = 4.97$ V

17. **(a)**

18. **(a) :** Time period, $T \propto p^a\rho^b E^c$ or $T = kp^a\rho^b E^c$
k is a dimensionless constant.
According to homogeneity of dimensions,
LHS = RHS $\Rightarrow [T] = [ML^{-1}T^{-2}]^a[ML^{-3}]^b[ML^2T^{-2}]^c$
$[T] = [M^{a+b+c}][L^{-a-3b+2c}][T^{-2a-2c}]$
Comparing the powers, we obtain
$a + b + c = 0$; $-a - 3b + 2c = 0$; $-2a - 2c = 1$

On solving, we get $a = -\frac{5}{6}$, $b = \frac{1}{2}$, $c = \frac{1}{3}$

19. **(c) :** Weight = Buoyant force



$$V\rho_m g = \frac{V}{2}\rho_{Hg}g + \frac{V}{2}\rho_{oil}g$$

$$\rho_m = \frac{\rho_{Hg} + \rho_{oil}}{2}$$

$$= \frac{13.6 + 0.8}{2} = \frac{14.4}{2} = 7.2$$

20. **(a) :** According to law of conservation of linear momentum, $mv = (M + m)V$

or $V = mv/(M+m)$

Initial KE of the system $= \frac{1}{2}mv^2$

Final KE of the system $= \frac{1}{2}(M+m)V^2$

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

Loss of KE $= \frac{1}{2}mv^2 - \frac{1}{2}\frac{(mv)^2}{(M+m)} = \frac{mMv^2}{2(M+m)}$

21. (a) : For isothermal compression of gas A,

$P_f = \frac{P_iV_i}{V_f} = 2P_i \qquad (\because V_f = \frac{1}{2}V_i)$

For adiabatic compression of gas B,

$P_f' = P_i\left(\frac{V_i}{V_f}\right)^{\gamma} = 2^{\gamma}P_i \Rightarrow \frac{P_f'}{P_f} = \frac{2^{\gamma}P_i}{2P_i} = 2^{\gamma-1}$

22. (c) : When the drop breaks away from the capillary, weight of the drop = force of surface tension acting on it due to capillary, *i.e.*,

$$mg = (\pi D)\times T \text{ or } T = \frac{mg}{\pi D} \qquad ...(i)$$

Here, $m = 0.0129\text{ g} = 1.29\times10^{-5}\text{ kg}$, $g = 9.8\text{ m s}^{-2}$, $D = 1\text{ mm} = 10^{-3}\text{ m}$

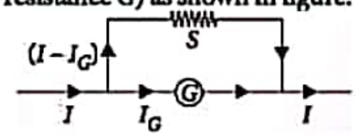
From eqn. (i),

$T = \frac{(1.29\times10^{-5}\text{ kg})(9.8\text{ m s}^{-2})}{3.14\times10^{-3}\text{ m}} = 40.3\times10^{-3}\text{ N m}^{-1}$

23. (b) : As shunt is a small resistance S in parallel with a galvanometer (of resistance G) as shown in figure.

$(I - I_G)S = I_GG$

$S = \frac{I_GG}{(I - I_G)}$



Here, $I_G = \frac{5}{100}I \quad \therefore \quad S = \frac{\frac{5}{100}IG}{I - \frac{5}{100}I} = \frac{G}{19}$

24. (c) : Mass of $\left(\frac{l}{4}\right)$ length of the chain $= \frac{m}{4}$

The weight of this part of the chain acts as its CG which is at a distance $\left(\frac{l}{8}\right)$ from the edge of the table.

Work done $= \left(\frac{m}{4}\right)g\left(\frac{l}{8}\right) = \frac{mgl}{32}$

25. (b) : Here, $u = -45$ cm, $v = +90$ cm

Using thin lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{90} + \frac{1}{45} = \frac{1+2}{90}$

$\therefore \quad f = +30$ cm

Magnification, $m = \frac{h_2}{h_1} = \frac{v}{u}$ or $\frac{h_2}{5} = \frac{90}{-45}$

$[\because h_1 = 5\text{ cm}]$

$\therefore$ Size of image, $h_2 = -10$ cm

26. (c) : The masses of three isotopes are 19.99 u, 20.99 u, 21.99 u.

Their relative abundances are 90.51%, 0.27% and 9.22%.

$\therefore$ Average atomic mass of neon is

$$m = \frac{90.51\times19.99 + 0.27\times20.99 + 9.22\times21.99}{(90.51 + 0.27 + 9.22)} = 20.18\text{ u}$$

27. (b) : Energy contained in a cylinder

U = average energy density × volume

$= \frac{1}{2}\epsilon_0E_0^2 \times Al$

$= \frac{1}{2}\times(8.85\times10^{-12})\times(50)^2\times(10\times10^{-4})\times1 = 1.1\times10^{-11}\text{ J}$

28. (c) : Let υ be frequency of standard fork. The frequency of A, $\upsilon_A = \upsilon + \frac{2}{100}\upsilon$

and the frequency of B, $\upsilon_B = \upsilon - \frac{3}{100}\upsilon$

According to question, $\upsilon_A - \upsilon_B = 6$

$\therefore \left(\upsilon + \frac{2}{100}\upsilon\right) - \left(\upsilon - \frac{3}{100}\upsilon\right) = 6 \Rightarrow \upsilon = 120\text{ Hz}$

The frequency of A

$\upsilon_A = \left(\upsilon + \frac{2}{100}\upsilon\right) = 120 + \frac{2}{100}\times120 = 122.4\text{ Hz}$

29. (b) : For planoconvex lens (without its plane surface silvered)

$\frac{1}{f_L} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) = \frac{\mu - 1}{R}$ or $f_L = \frac{R}{(\mu - 1)}$

When an object is placed in front of the planoconvex lens with its plane face silvered, light rays are : (i) refracted at the convex surface (ii) reflected at the silvered surface and (iii) refracted again at convex surface. If F is the effective focal length of the combination, then

$$\frac{1}{F} = \frac{1}{f_L} + \frac{1}{f_M} + \frac{1}{f_L} = \frac{2}{f_L} \qquad (\text{as } f_M = \infty)$$

or $F = \frac{f_L}{2} = \frac{R}{2(\mu - 1)}$

Radius of curvature of the concave mirror $= 2F = \frac{R}{(\mu - 1)}$

30. (b) : Here, work function, $\phi_0 = 3.31\times10^{-19}$ J

Wavelength, $\lambda = 5000\text{ Å} = 5000\times10^{-10}$ m

Energy of the incident photon,

$$E=\frac{hc}{\lambda}=\frac{6.63\times10^{-34}\times3\times10^{8}}{5000\times10^{-10}}=3.98\times10^{-19}\text{ J}$$

According to Einstein's photoelectric equation
$K_{max}=h\upsilon-\phi_0=3.98\times10^{-19}\text{ J}-3.31\times10^{-19}\text{ J}$

$$=0.67\times10^{-19}\text{ J}=\frac{0.67\times10^{-19}}{1.6\times10^{-19}}\text{ eV}=0.42\text{ eV}$$

31. (c)

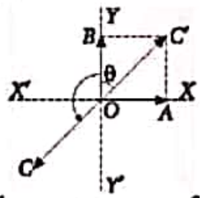
32. (c) : Here $P_x=P$ and $P_y=\sqrt{3}P$

$\therefore$ Resultant momentum of A and B

$$P=\sqrt{P_x^2+P_y^2}=\sqrt{P^2+(\sqrt{3}P)^2}=2P$$

It is along OC'.

As is clear from figure



$$\tan\theta=\frac{BC'}{OB}=\frac{OA}{OB}=\frac{P}{\sqrt{3}P}=\frac{1}{\sqrt{3}}$$

or $\theta=30°$

As the object was initially at rest, the vector sum of linear momenta of A, B and C must be zero. Therefore, momentum of $C=2P$ along OC opposite to OC'. It makes an angle with $B=\angle YOC$

$=\angle YOX'+\angle X'OC=90°+60°=150°$

33. (b) : In ΔABC, $\sin30°=\frac{BC}{AC}$

$\Rightarrow\frac{1}{2}=\frac{10}{AC}$ or $AC=20$ m

Frictional force is acting on the block.

$f=\mu mg\cos30°$

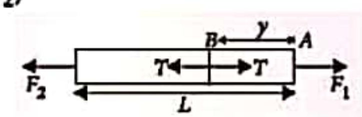
$$=0.5\times5\times10\times\frac{\sqrt{3}}{2}=\frac{50\sqrt{3}}{4}$$

Work done by frictional force on the block, $W_f=f\times AC\times\cos180°$

$$=\frac{-50\sqrt{3}}{4}\times20=-250\sqrt{3}\text{ J}$$

34. (a)

35. (d) : Here, as it is clear in figure, net force on the rod $F=(F_1-F_2)$



$\therefore$ Acceleration of rod, along F_1

$$a=\frac{F}{M}=\frac{(F_1-F_2)}{M}\quad\text{...(i)}$$

Mass of part AB of the rod $=\left(\frac{M}{L}\right)y$

Let T be the tension in the rod at B.

Equation of motion of part AB of the rod is

$$F_1-T=ma=\frac{M}{L}y\cdot\left(\frac{F_1-F_2}{M}\right)$$

$$F_1-T=(F_1-F_2)\frac{y}{L}\quad\text{or}\quad T=F_1-(F_1-F_2)\frac{y}{L}$$

$$T=F_1(1-y/L)+F_2(y/L)$$

36. (b) : Force of gravitation on the planet = Centripetal force

$$kr^{-5/2}=mr\omega^2=mr\left(\frac{2\pi}{T}\right)^2$$

or $$T^2=\frac{4\pi^2mr}{kr^{-5/2}}=\frac{4\pi^2m}{k}\cdot r^{7/2}\quad\therefore\ T^2\propto r^{7/2}$$

37. (a) : To twist wire through the angle $d\theta$, it is necessary to do the work $dW=\tau d\theta$

and $\theta=10'=\frac{10}{60}\times\frac{\pi}{180}=\frac{\pi}{1080}$ rad

$$W=\int_0^\theta\tau\,d\theta=\int_0^\theta\frac{\eta\pi r^4\theta\,d\theta}{2l}=\frac{\eta\pi r^4\theta^2}{4l}=1.253\times10^{-12}\text{ J}$$

38. (c) : When the ball dropped, its acceleration is g as is observed by a man standing stationary on the ground. Now the man inside the lift has downward acceleration a, the acceleration of the ball as observed by this man will be $g-a$.

39. (a) : For closed organ pipe, fundamental frequency is given by $\upsilon_c=\frac{v}{4l}$

For open organ pipe, fundamental frequency is given by

$$\upsilon_o=\frac{v}{2l'}$$

2^{nd} overtone of open organ pipe

$$\upsilon'=3\upsilon_o\ \Rightarrow\ \upsilon'=\frac{3v}{2l'}$$

According to question, $\upsilon_c=\upsilon'$

$$\frac{v}{4l}=\frac{3v}{2l'}\ \Rightarrow\ l'=6l=120\text{ cm}$$

40. (d) : According to Wein's displacement law

$\lambda_mT=$ constant ...(i)

For star P, intensity of violet colour is maximum.

For star Q, intensity of red colour is maximum.

For star R, intensity of green colour is maximum.

Also, $\lambda_r>\lambda_g>\lambda_v$

Using equation (i), $T_r<T_g<T_v$; $T_Q<T_R<T_P$

Solution Senders of Physics Musing

SET-80

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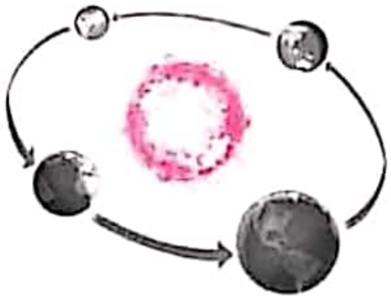

SCIENCE BEHIND LEAP YEAR

Why it's a Leap Year and why Our Great-grandparents Skipped One of Them

February 29 is a date that comes approximately once every four years. Approximately, not exactly, for there are exceptions to the leap year's cycle of four years.

Rules and exceptions

Leap years are always multiples of four - 2016, 2020, 2024 - but a year that is a multiple of four is not always a leap year. There are exceptions, such as 1900 and 2100, both multiples of four, yet neither a leap year.

A year ending with 00 is obviously a multiple of four, but is usually not a leap year. These are the exceptions. But again, there are exceptions to such exceptions. For example, 2000 ended with 00 but remained a leap year. As a result, many people alive today - except some who are very young - are likely to spend their lifetimes without skipping a leap year. Our ancestors skipped a leap year in 1900, while our descendants will skip one in 2100. What is the reasoning behind the rule for leap years, the exceptions to the rule, and the exceptions to the exceptions?

Why have leap years

Our solar calendar is supposed to reflect one orbit of Earth around the Sun. This helps in anticipating the seasons, maintaining crop cycles, setting school schedules, etc.

Earth takes 365 days and a few hours to orbit the Sun, which is why a year is usually 365 days long. The actual period of the orbit is close to (not exactly) 365 days and 6 hours, which means that the calendar year is about 6 hours shorter than the actual solar year. To compensate, we have leap years.

The leap year was introduced by scholars engaged by Julius Caesar in 46 BC, and made more precise from 12 AD. The reasoning went thus: if the calendar year is 365 days long, it is missing 6 hours. These 6 hours keep adding up, year after year. By the end of 4 years, the calendar years will have missed a total of 24 hours, or one full day. So, why not add an extra day once every four years, the scholars reasoned.

Thus, the Julian calendar had a year that was usually 365 days long, with a 366th day added once every four years. It appeared to make sense. Only, it was never going to work in the long run.

This is because 365 days and 6 hours is an approximation. It is a very small approximation, but even these tiny errors were going to add up one day.

The errors pile up

To be more precise than earlier, Earth completes one orbit in 365 days, 5 hours, 48 minutes and 46 seconds. However, with three years of 365 days and one leap year of 366 days, the average length of a year in the Julian calendar was 365 days and 6 hours. This was longer, if ever slightly so, than 365 days, 5 hours, 48 minutes and 46 seconds.

In effect, the leap year formula was an overcompensation. Leap years were introduced because the calendar year was short, but they ended up making the average calendar year longer than the solar year. The difference: a small matter of 11 minutes and 14 seconds. Minute by minute, second by second, the errors piled up, year after year, century after century. In the 16th century, it was calculated that the calendar years until then had accumulated 10 extra days. In 1582, Pope Gregory XIII ordered a drastic compensation by dropping 10 days from the calendar, and October 4 that year was followed by October 15 the very next day.

The need was for further reform, so that the minutes and seconds would not accumulate again in the future. The obvious thing to do was to reduce some leap years-about one leap year every century. And the obvious candidates were the years ending with 00. But if all "00 years" ceased to be leap years, calculations showed, it would result in another over-compensation. Therefore, some "00 years" needed to remain leap years.

Eventually, the reform led to the Gregorian calendar, which we follow today. The formula:

- A year that is a multiple of 4 is a leap year; except:
- A year ending with 00 is not a leap year; except:
- A "00 year" in which 00 is preceded by a multiple of 4 (1600, 2000, 2400 etc) remains a leap year.

That is why 1900 and 2100 are not leap years, but 2000 is one.

Is that it, finally?

It can never be perfect. We try to clock the Earth's orbit precisely down to the last second, yet we follow a calendar with a whole number of days. The calendar today is about 26 seconds off from Earth's orbital period, which adds up to one full day in 3,320 years.

There have been proposals for a future correction - remove a leap year once every 4,000 years, or once every 3,200 years. Years 3200 and 4000, however, are still a long way away. As of 2020, not everyone is bothered.

Courtesy : The Indian Express

CBSE BOARD SOLVED PAPER 2020*

Time allowed : 3 hours | Maximum Marks : 70

GENERAL INSTRUCTIONS

(i) This question paper comprises four sections-A, B, C and D.
(ii) There are 37 questions in the question paper. All questions are compulsory.
(iii) Section A : Q. no. 1 to 20 are very short-answer type questions carrying 1 mark each.
(iv) Section B : Q. no. 21 to 27 are short-answer type questions carrying 2 marks each.
(v) Section C : Q. no. 28 to 34 are long-answer type questions carrying 3 marks each.
(vi) Section D : Q. no. 35 to 37 are also long answer type questions carrying 5 marks each.
(vii) There is no overall choice in the question paper. However, an internal choice has been provided in two questions of one mark, two questions of two marks, one question of three marks and all the three questions of five marks. You have to attempt only one of the choices in such questions.

(viii) However, separate instructions are given with each section and question, wherever necessary.
(ix) Use of calculators and log tables is not permitted.
(x) You may use the following values of physical constants wherever necessary.

$c = 3 \times 10^8$ m s^{-1} ; $h = 6.63 \times 10^{-34}$ J s ; $e = 1.6 \times 10^{-19}$ C ; $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1} ; $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2} ; Mass of electron (m_e) $= 9.1 \times 10^{-31}$ kg ; Mass of neutron $= 1.675 \times 10^{-27}$ kg ;

Mass of proton $= 1.673 \times 10^{-27}$ kg ; Avogadro's number $= 6.023 \times 10^{23}$ per gram mole ; Boltzmann constant $= 1.38 \times 10^{-23}$ J K^{-1}

SECTION-A

Note : Select the most appropriate option from those given below each question.

1. Photons of energies 1 eV and 2 eV are successively incident on a metallic surface of work function 0.5 eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be
(a) 1 : 2 (b) 1 : 1 (c) 1 : 3 (d) 1 : 4

2. Which of the following statements is not correct according to Rutherford model?
(a) Most of the space inside an atom is empty.
(b) The electrons revolve around the nucleus under the influence of coulomb force acting on them.
(c) Most part of the mass of the atom and its positive charge are concentrated at its centre.
(d) The stability of atom was established by the model.

3. The resolving power of a telescope can be increased by increasing
(a) wavelength of light (b) diameter of objective
(c) length of the tube
(d) focal length of eyepiece.

4. The magnetic dipole moment of a current carrying coil does not depend upon
(a) number of turns of the coil
(b) cross-sectional area of the coil
(c) current flowing in the coil
(d) material of the turns of the coil.

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5. For a glass prism, the angle of minimum deviation will be smallest for the light of
(a) red colour (b) blue colour
(c) yellow colour (d) green colour

6. A biconvex lens of glass having refractive index 1.47 is immersed in a liquid. It becomes invisible and behaves as a plane glass plate. The refractive index of the liquid is
(a) 1.47 (b) 1.62
(c) 1.33 (d) 1.51

7. The resistance of a metal wire increases with increasing temperature on account of
(a) decrease in free electron density
(b) decrease in relaxation time
(c) increase in mean free path
(d) increase in the mass of electron

8. An electric dipole placed in a non-uniform electric field can experience
(a) a force but not a torque
(b) a torque but not a force
(c) always a force and a torque
(d) neither a force nor a torque

9. If the net electric flux through a closed surface is zero, then we can infer
(a) no net charge is enclosed by the surface
(b) uniform electric field exists within the surface
(c) electric potential varies from point to point inside the surface
(d) charge is present inside the surface

10. Kirchhoff's first rule at a junction in an electrical network, deals with conservation of
(a) energy (b) charge
(c) momentum (d) both energy and charge

Note : Fill in the blanks with appropriate answer.

11. A ray of light on passing through an equilateral glass prism, suffers a minimum deviation equal to the angle of the prism. The value of refractive index of the material of the prism is ______.

12. According to Bohr's atomic model, the circumference of the electron orbit is always an ______ multiple of de Broglie wavelength.

OR

In β-decay, the parent and daughter nuclei have the same number of ______.

13. The number of turns of a solenoid are doubled without changing its length and area of cross-section. The self-inductance of the solenoid will become ______ times.

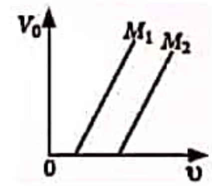
14. Laminated iron sheets are used to minimize ______ currents in the core of a transformer.

15. The magnetic field lines are ______ by a diamagnetic substance.

Note : Answer the following.

16. Why cannot we use Si and Ge in fabrication of visible LEDs?

17. The variation of the stopping potential (V_0) with the frequency (υ) of the light incident on two different photosensitive surfaces M_1 and M_2 is shown in the figure.



Identify the surface which has greater value of the work function.

18. How does an increase in doping concentration affect the width of depletion layer of a *p-n* junction diode?

19. The nuclear radius of $^{27}_{13}Al$ is 3.6 fermi. Find the nuclear radius of $^{64}_{29}Cu$.

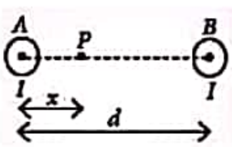
OR

A proton and an electron have equal speeds. Find the ratio of de Broglie wavelengths associated with them.

20. How is displacement current produced between the plates of a parallel plate capacitor during charging?

SECTION-B

21. Two long straight parallel wires A and B separated by a distance d, carry equal current I flowing in same direction as shown in the figure.



(a) Find the magnetic field at a point P situated between them at a distance x from one wire.
(b) Show graphically the variation of the magnetic field with distance x for $0 < x < d$.

22. Using Bohr's atomic model, derive the expression for the radius of n^{th} orbit of the revolving electron in a hydrogen atom.

OR

(a) Write two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation.

(b) Draw a graph showing variation of photocurrent with the anode potential of a photocell.

23. Define wavefront of a travelling wave. Using Huygens principle, obtain the law of refraction at a plane interface when light passes from a rarer to a denser medium.

OR

Using lens maker's formula, derive the thin lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a biconvex lens.

24. Explain the principle of working of a meter bridge. Draw the circuit diagram for determination of an unknown resistance using it.

25. Explain the term 'depletion layer' and 'potential barrier' in a *p-n* junction diode. How are the (a) width of depletion layer, and (b) value of potential barrier affected when the *p-n* junction is forward biased?

26. N small conducting liquid droplets, each of radius r, are charged to a potential V each. These droplets coalesce to form a single large drop without any charge leakage. Find the potential of the large drop.

27. Define activity of a sample of a radioactive substance. The value of the disintegration constant of a radioactive substance is 0.0693 h^{-1}. Find the time after which the activity of a sample of this substance reduces to one-half that of its present value.

SECTION-C

28. In a single slit diffraction experiment, light of wavelength λ illuminates the slit of width 'a' and the diffraction pattern is observed on a screen.

(a) Show the intensity distribution in the pattern with the angular position θ

(b) How are the intensity and angular width of central maxima affected when

(i) width of slit is increased, and

(ii) separation between slit and screen is decreased?

29. With the help of a simple diagram, explain the working of a silicon solar cell giving all three basic processes involved. Draw its *I–V* characteristic.

30. A resistor R and an inductor L are connected in series to a source $V = V_0 \sin \omega t$. Find the

(a) peak value of the voltage drops across R and across L

(b) phase difference between the applied voltage and current. Which of them is ahead?

31. (a) Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r.

(b) Write the wavelength range and name of the electromagnetic waves which are used in

(i) radar systems for aircraft navigation, and

(ii) Earth satellites to observe the growth of the crops.

32. (a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2, respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.

(b) In case the two cells are identical, each of emf $E = 5$ V and internal resistance $r = 2\ \Omega$, calculate voltage across the external resistance $R = 10\ \Omega$.

33. (a) Write an expression of magnetic moment associated with a current (I) carrying circular coil of radius r having N turns.

(b) Consider the above mentioned coil placed in YZ plane with its centre at the origin. Derive expression for the value of magnetic field due to it at point $(x, 0, 0)$.

OR

(a) Define current sensitivity of a galvanometer. Write its expression.

(b) A galvanometer has resistance G and shows full scale deflection for current I_g.

(i) How can it be converted into an ammeter to measure current upto $I_0 (I_0 > I_g)$?

(ii) What is the effective resistance of this ammeter?

34. The nucleus $^{235}_{92}Y$, initially at rest, decays into $^{231}_{90}X$ by emitting an α-particle

$$^{235}_{92}Y \longrightarrow {}^{231}_{90}X + {}^{4}_{2}He + \text{energy}.$$

The binding energies per nucleon of the parent, nucleus, the daughter nucleus and α-particle are 7.8 MeV, 7.835 MeV and 7.07 MeV, respectively.

Assuming the daughter nucleus to be formed in the unexcited state and neglecting its share in the energy of the reaction, find the speed of the emitted α-particle. (Mass of α-particle $= 6.68 \times 10^{-27}$ kg)

SECTION-D

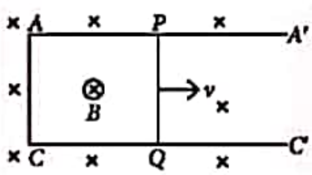
35. **(a)** Derive the expression for the torque acting on the rectangular current carrying coil of a galvanometer. Why is the magnetic field made radial?

(b) An α-particle is accelerated through a potential difference of 10 kV and moves along x-axis. It enters in a region of uniform magnetic field $B = 2 \times 10^{-3}$ T acting along y-axis. Find the radius of its path.
(Take mass of α-particle $= 6.4 \times 10^{-27}$ kg)

OR

(a) With the help of a labelled diagram, explain the working of a step-up transformer. Give reasons to explain the following :
(i) The core of the transformer is laminated.
(ii) Thick copper wire is used in windings.

(b) A conducting rod PQ of length 20 cm and resistance 0.1 Ω rests on two smooth parallel rails of negligible resistance AA' and CC'. It can slide on the rails and the arrangement is positioned between the poles of a permanent magnet producing uniform magnetic field $B = 0.4$ T. The rails, the rod and the magnetic field are in three mutually perpendicular directions as shown in the figure. If the ends A and C of the rails are short circuited, find the
(i) external force required to move the rod with uniform velocity $v = 10$ cm s^{-1} and
(ii) power required to do so.



36. **(a)** Draw the ray diagram of an astronomical telescope when the final image is formed at infinity. Write the expression for the resolving power of the telescope.

(b) An astronomical telescope has an objective lens of focal length 20 m and eyepiece of focal length 1 cm.
(i) Find the angular magnification of the telescope.
(ii) If this telescope is used to view the Moon, find the diameter of the image formed by the objective lens. Given the diameter of the Moon is 3.5×10^6 m and radius of lunar orbit is 3.8×10^8 m.

OR

(a) An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the miror equation $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.

(b) An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

37. **(a)** Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance x from the centre of shell, such that
(i) $0 < x < R$, and
(ii) $x > R$

(b) An electric field is uniform and acts along $+x$ direction in the region of positive x. It is also uniform with the same magnitude but acts in $-x$ direction in the region of negative x. The value of the field is $E = 200$ N C^{-1} for $x > 0$ and $E = -200$ N C^{-1} for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at $x = +10$ cm and the other is at $x = -10$ cm. Find :
(i) The net outward flux through the cylinder.
(ii) The net charge present inside the cylinder.

OR

(a) Find the expression for the potential energy of a system of two point charges q_1 and q_2 located at $\vec{r}_1$ and $\vec{r}_2$, respectively in an external electric field $\vec{E}$.

(b) Draw equipotential surfaces due to an isolated point charge $(-q)$ and depict the electric field lines.

(c) Three point charges +1 μC, –1 μC and +2 μC are initially infinite distance apart. Calculate the work done in assembling these charges at the vertices of an equilateral triangle of side 10 cm.

SOLUTIONS

1. **(c) :** Given $\phi = 0.5$ eV
$\because$ $h\upsilon = K_{max} + \phi$
$\therefore$ $K_{max_1} = 1\text{ eV} - 0.5\text{ eV} = 0.5\text{ eV}$ ...(i)
$K_{max_2} = 2\text{eV} - 0.5\text{ eV} = 1.5\text{ eV}$ ...(ii)
From (i) and (i)
$$\frac{K_{max_1}}{K_{max_2}} = \frac{1}{3}$$

2. **(d) :** The stability of atom was not established by this model.

3. **(b) :** As resolving power $= \frac{D}{1.22\lambda}$, where D is the diameter or aperture of the objective lens. Increasing D increases the resolving power.

4. **(d) :** Magnetic dipole moment of a current carrying coil does not depend upon the material of the coil.

5. **(a) :** As $\delta_m = (\mu - 1)A$
$\because$ $\mu_{blue} > \mu_{yellow} > \mu_{green} > \mu_{red}$
$\delta_{m_{blue}} > \delta_{m_{yellow}} > \delta_{m_{green}} > \delta_{m_{red}}$

6. **(a)**

7. **(b) :** In metals, decrease in the value of relaxation time τ with rise in temperature causes resistivity and thus resistance to increase.

8. **(c) :** Since the electric dipole is placed in a non-uniform electric field it experiences both force and torque.

9. **(a) :** If the net electric flux through a closed surface is zero, then it can be concluded that there is no net charge enclosed by the surface.

10. **(b) :** The junction rule states that, at any junction, the sum of currents entering the junction is equal to the sum of currents leaving the junction. It represents the conservation of charge.

11. As angle of prism is equal to angle of minimum deviation.
$A = \delta_m$
$$\therefore\ \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60+60}{2}\right)}{\sin\left(\frac{60}{2}\right)}$$
[$\because$ $A = 60°$ for equilateral prism]
$$= \frac{\sin 60°}{\sin 30°} = \sqrt{3}$$

12. According to Bohr's postulate,
angular momentum, $L = \frac{nh}{2\pi} \Rightarrow mvr = \frac{nh}{2\pi}$
or $2\pi r = \frac{nh}{mv} = n\lambda$ [$\because$ $h/p = \lambda$]
Thus the circumference of the electron orbit is always an integral multiple of de Broglie wavelength.

OR

In β-decay, the parent and daughter nuclei have the same number of nucleons.
$${}^A_Z X \longrightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \bar{\nu}$$

13. Initially, self inductance, $L = \mu_0 n^2 Al$ ...(i)
Given, $n = 2n$, $l = l$ and $A = A$
$\therefore$ $L' = \mu_0(2n)^2 Al$ ...(ii)
From (i) and (ii),
$L' = 4L$
Thus self inductance increases by four times.

14. Laminated iron sheets are used to minimize eddy currents in the core of a transformer.

15. The magnetic field lines are repelled by a diamagnetic substance.

16. The semiconductor used for fabrication of visible LEDs must have at least a band gap of 1.8 eV because spectral range of visible light is about 0.4 mm to 0.7 mm, *i.e.*, about 3 eV to 1.8 eV. But Si and Ge have band gaps less than 1.8 eV.

17. Here surface M_2 has greater value of work function.
Work function, $\phi = h\upsilon_0$
Here $\upsilon_{0M_2} > \upsilon_{0M_1}$, thus $\phi_{M_2} > \phi_{M_1}$

18. Increasing the doping concentration decreases the width of the depletion region of a *p-n* junction diode.

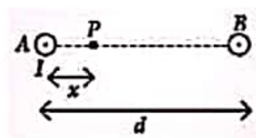
19. As nuclear radius, $R = R_0 A^{1/3}$
For ${}^{27}_{13}$Al, 3.6 fermi $= R_0(27)^{1/3} \Rightarrow R_0 = 1.2$ fermi
$\therefore$ For ${}^{64}_{29}$Cu, $R = 1.2 \times (64)^{1/3} = 4.8$ fermi

OR

$$\because\ \lambda = \frac{h}{p} = \frac{h}{mv} \quad \therefore\ \lambda_p = \frac{h}{m_p v_p} \text{ and } \lambda_e = \frac{h}{m_e v_e}$$
Given $v_p = v_e$; $\frac{\lambda_p}{\lambda_e} = \frac{m_e}{m_p} = \frac{m_e}{1836\, m_e} = \frac{1}{1836}$

20. Displacement current is produced due to time-varying electric field across the capacitor and is given by
$$I_d = \varepsilon_0 \frac{d\phi_E}{dt}$$

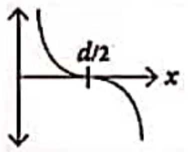
21. **(a) :** At P, according to right hand thumb rule, field due to A is upwards and due to B is downwards



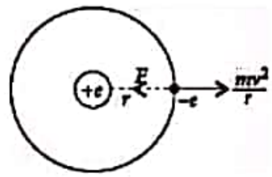
$$B_P = \frac{\mu_0 I}{2\pi}\left[\frac{1}{x} - \frac{1}{(d-x)}\right]$$

$$= \frac{\mu_0 I}{2\pi x}\left[\frac{d-2x}{d-x}\right]$$

(b) The variation of magnetic field with distance x is shown in graph.



22. Radius of n^{th} orbit of hydrogen atom : In H-atom, an electron having charge $-e$ revolves around the nucleus of charge $+e$ in a circular orbit of radius r, such that necessary centripetal force is provided by the electrostatic force of attraction between the electron and nucleus.



i.e., $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e.e}{r^2}$ or $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$ ...(i)

From Bohr's quantization condition

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

Using equation (ii) in (i), we get

$m\cdot\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$ or $\frac{m\cdot n^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

or $r = \frac{n^2h^2\varepsilon_0}{\pi me^2}$ ...(iii)

where $n = 1, 2, 3, ...$ is principal quantum number.

Equation (iii), gives the radius of n^{th} orbit of H-atom.

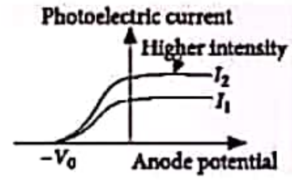
OR

(a) On the basis of experiments on photoelectric effect, three observed features are :

(i) The emission of photoelectrons takes place only when the frequency of the incident radiations is above a certain critical value called threshold frequency υ_0, which is characteristic of that metal emitting electrons. Above threshold frequency υ_0, maximum kinetic energy with which photoelectrons are emitted is directly proportional to frequency υ of incident radiation.

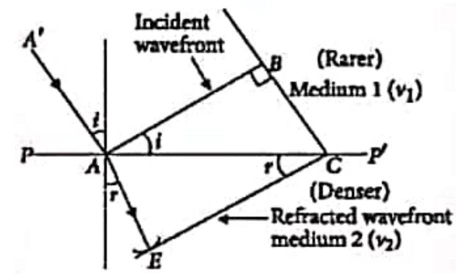
(ii) The maximum kinetic energy with which a photoelectron is emitted from a metallic surface is independent of the intensity of light and depends only upon its frequency.

(b) For a given frequency, Photoelectric current varies with anode potential is as shown in graph.



23. Wavefront : The continuous locus of all the particles of a medium, which are vibrating in the same phase is called a wavefront.

Snell's law of refraction : Let PP' represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and medium 2 respectively. We assume a plane wavefront AB propagating in the direction $A'A$ incident on the interface at an angle i. Let t be the time taken by the wavefront to travel the distance BC.

$\therefore\ BC = v_1 t$ [$\because$ distance = speed × time]

In order to determine the shape of the refracted wavefront, we draw a sphere of radius $v_2 t$ from the point A in the second medium (the speed of the wave in second medium is v_2).

Let CE represents a tangent plane drawn from the point C. Then, $AE = v_2 t$

$\therefore$ CE would represent the refracted wavefront.

In ΔABC and ΔAEC, we have

$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$ and $\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$

where i and r are the angles of incident and refraction respectively.

$\therefore\ \frac{\sin i}{\sin r} = \frac{v_1 t}{AC}\cdot\frac{AC}{v_2 t};\ \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$

If c represents the speed of light in vacuum, then

$\mu_1 = \frac{c}{v_1}$ and $\mu_2 = \frac{c}{v_2}$ $\Rightarrow$ $v_1 = \frac{c}{\mu_1}$ and $v_2 = \frac{c}{\mu_2}$

where μ_1 and μ_2 are the refractive indices of medium 1 and medium 2.

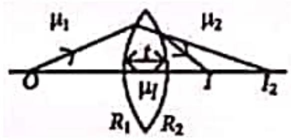
$\therefore\ \frac{\sin i}{\sin r} = \frac{c/\mu_1}{c/\mu_2} \Rightarrow \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$

This is the Snell's law of refraction.

OR

Medium on two sides of lens is different.

Image I_1 formed by the first refractory surface behaves as object for the second refracting surface.



For 1st refractory surface

$$\frac{\mu_l}{v_1}-\frac{\mu_1}{u}=\frac{\mu_l-\mu_1}{R_1} \quad \text{...(i)}$$

For 2nd refractory surface $\frac{\mu_2}{v}-\frac{\mu_l}{v_1-t}=\frac{\mu_2-\mu_l}{R_2}$

Neglecting t for thin lenses,

$$\frac{\mu_2}{v}-\frac{\mu_l}{v_1}=\frac{\mu_2-\mu_l}{R_2} \quad \text{...(ii)}$$

From eqn. (i) and (ii),

$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{(\mu_l-\mu_1)}{R_1}-\frac{(\mu_l-\mu_2)}{R_2}$$

If medium on both sides of lens is same,

$\mu_1=\mu_2=\mu_s$ (Refractive index of surroundings)

$$\frac{1}{v}-\frac{1}{u}=\left(\frac{\mu_l}{\mu_s}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

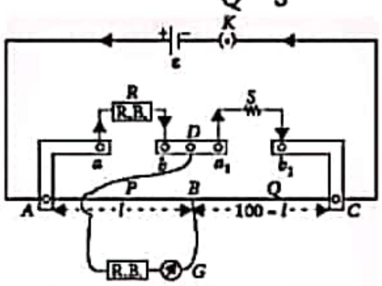
But, $\frac{1}{f}=\left(\frac{\mu_l}{\mu_s}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ (Lens makers formula)

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

24. Metre bridge : It is the simplest practical application of the Wheatstone bridge that is used to measure an unknown resistance.

Principle : Its working is based on the principle of Wheatstone bridge.

When the bridge is balanced, $\frac{P}{Q}=\frac{R}{S}$



Measurement of unknown resistance by a metre bridge.

Where unknown resistance, $S=\frac{R(100-l)}{l}$

25. Depletion layer : The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called the depletion layer.

Potential barrier : Due to accumulation of negative charges in the p-region and positive charges in the n-region, a potential difference sets up across the junction. This acts as a barrier and is called potential barrier V_B which opposes the further diffusion of electrons and holes across the junction.

(a) In forward biasing the width of depletion layer is reduced and

(b) the external applied field is able to overcome the strong electric field of depletion layer.

26. Let q be the charge on each droplet.

Then $V=\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ ...(i)

Volume of big drop = $N\times$ volume of small drop

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

where R is the radius of the big drop.

$\Rightarrow R=N^{1/3}r$ ...(ii)

and $Q=Nq$, where Q is the charge of bigger drop

$\therefore$ Potential of larger drop,

$$V'=\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}=\frac{1}{4\pi\varepsilon_0}\frac{Nq}{N^{1/3}r}=\frac{N}{N^{1/3}}V=N^{2/3}V$$

27. The rate of decay of a radioactive substance is called the activity of that substance.

$$R=-\frac{dN}{dt}$$

Its SI unit is becquerel (Bq) or disintegrations per second.

Given $\lambda=0.0693\ h^{-1}$

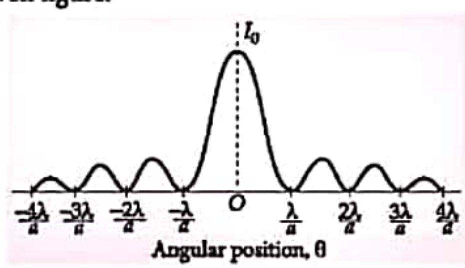
Let at time t, the activity of the sample of this substance reduce to half of its present value, then $R=R_0e^{-\lambda t}$

or $\frac{R_0}{2}=R_0e^{-\lambda t} \Rightarrow 2=e^{\lambda t}$

Taking natural logarithm on both sides

$$\ln 2=\lambda t \Rightarrow t=\frac{\ln 2}{\lambda}=\frac{0.693}{0.0693}=10\ \text{h}.$$

28. **(a)** : The intensity pattern on the screen is shown in the given figure.



Width of central maximum $=\frac{2D\lambda}{a}$

(b) The angular width of central maximum is given by

$$2\theta_0 = \frac{2\lambda}{a}, \quad \text{...(i)}$$

where a is the slit width and r_1 is the wavelength of light.

(i) From equation (i), it follows that $2\theta_0 \propto \frac{1}{a}$.

Therefore, as the slit width is increased, the width of the central maximum will decrease and the intensity of central maxima will increase.

(ii) From equation (i), it follows that $2\theta_0$ is independent of D. So the angular width will remain same when the separation between slit and screen is decreased and the intensity will increases.

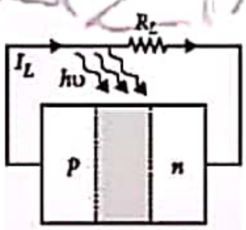
29. Principle : A solar cell works on the principle of photo voltaic effect according to which when light photons of energy greater than energy band gap of a semiconductor are incident on p-n junction of that semiconductor, electron-hole pairs are generated which give rise to an emf.

Generation of emf : Three basic processes are involved in the generation of emf by a solar cell when solar radiations are incident on it. These are:

(i) The generation of electron-hole pairs close to the junction due to incidence of light with photo energy $h\nu \geq E_g$.

(ii) The separation of electrons and holes due to the electric field of the depletion region. So, electrons are swept to n-side and holes to p-side.

(iii) The electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus, p-side becomes positive and n-side become negative giving rise to a photovoltage.



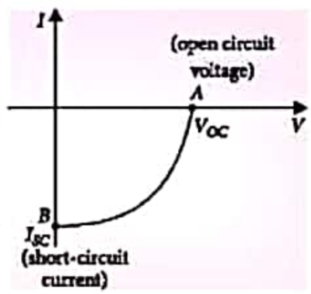
Depletion layer

When an external load R_L is connected as shown in figure, a photocurrent I_L begins to flow through the load.

V-I characteristics of solar cell

(i) *V-I* curve is drawn in the forth quadrant, because a solar cell does not draws current but supply current to the load.

(ii) In *V-I* curve, the point A indicates the maximum voltage V_{OC} being supplied by the given solar cell when no current is being drawn from it. V_{OC} is called the open circuit voltage.



(iii) In *V-I* curve, the point B indicates the maximum current I_{SC} which can be obtained by short circuiting the solar cell without any load resistance. I_{SC} is called the short circuit current.

30. (a) : Peak value of voltage drop across R,

$$V_R = I_R$$

where $I = \frac{V_0}{\sqrt{R^2 + X_L^2}} = \frac{V_0}{\sqrt{R^2 + \omega^2 L^2}}$

$$\therefore V_R = \frac{V_0 R}{\sqrt{R^2 + \omega^2 L^2}} = \frac{V_0}{\sqrt{1 + \omega^2 L^2 / R^2}}$$

Peak value of voltage drop across L

$$V_L = IX_L = \frac{V_0}{\sqrt{R^2 + \omega^2 L^2}} \omega L = \frac{V_0 \omega L}{\sqrt{R^2 + \omega^2 L^2}}$$

(b) Phase difference, $\tan\phi = \frac{\omega L}{R} \Rightarrow \phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

Here the voltage exceeds the current.

31. (a) The speed of electromagnetic wave in a medium is $v = \frac{1}{\sqrt{\mu\varepsilon}}$

where μ and ε are permeability and permittivity of the medium respectively.

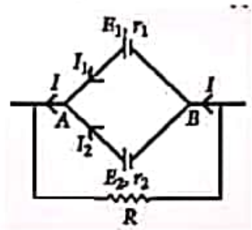
$$v = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$$

(b) (i) Microwaves ($\lambda = 0.1$ m to 1 mm) are suitable for radar system used in aircraft navigation.

(ii) Infrared waves (λ = 1 mm to 700 nm) are used in Earth Satellites to observe growth of crops.

32. (a) : Here, $I = I_1 + I_2$

Let V = Potential difference between A and B



For cell E_1,

$$V = E_1 - I_1 r_1$$

$$\Rightarrow I_1 = \frac{E_1 - V}{r_1}$$

Similarly, for cell E_2, $I_2 = \frac{E_2 - V}{r_2}$

Putting these values in equation (i)

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

or $I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

or $V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ ...(ii)

Comparing the above equation with the equivalent circuit of emf 'E_{eq}' and internal resistance 'r_{eq}' then,

$V = E_{eq} - Ir_{eq}$ ...(iii)

Then

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \text{ and } r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

(b) Given $E_1 = E_2 = E = 5$ V

and $r_1 = r_2 = r = 2\ \Omega$, and $R = 10\ \Omega$

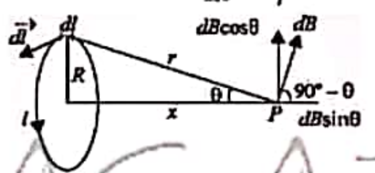
Then current, $I = \frac{E_{eq}}{R + r_{eq}} = \frac{5}{10 + 2/2} = \frac{5}{11}$ A

$\therefore$ Voltage across the external resistance,

$$V = IR = \frac{5}{11} \times 10 = \frac{50}{11} = 4.55 \text{ A}$$

33. (a) The magnetic moment associated with a current (I) carrying circular coil of radius r having N turns, is given by, $M = NIA = NI\pi r^2$.

(b) Magnetic field at a distance x from the centre of the ring due to element dl, $dB = \frac{\mu_0}{4\pi} \frac{idl \sin 90°}{r^2}$



Since, angle between $d\vec{l}$ and $\vec{r}$ is 90°. The component $dB\cos\theta$ will get cancelled due to symmetry

$$B = \int dB \sin\theta = \int \left(\frac{\mu_0}{4\pi} \frac{idl}{r^2}\right)(\sin\theta)$$

Here, r and θ are constants and $\sin\theta = \frac{R}{r}$

$$B = \int \frac{\mu_0}{4\pi} \frac{idl}{r^2}\left(\frac{R}{r}\right) = \int \frac{\mu_0}{4\pi} \frac{idl}{r^3}$$

$$= \frac{\mu_0}{4\pi} \frac{iR}{r^3} \int dl = \frac{\mu_0 iR}{4\pi r^3}(2\pi R) = \frac{\mu_0 iR^2}{2r^3}$$

Putting $r = (R^2 + x^2)^{1/2}$, we get $B = \frac{\mu_0 iR^2}{2(R^2 + x^2)^{3/2}}$

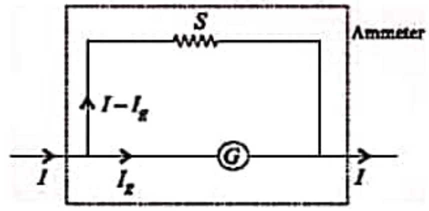
For N turns, $B = \frac{\mu_0 NiR^2}{2(R^2 + x^2)^{3/2}}$

OR

(a) Current sensitivity : It is defined as the deflection of coil per unit current flowing in it, *i.e.*,

$$S = \frac{\theta}{I} = \frac{NAB}{k}$$

(b) (i) A galvanometer can be converted into an ammeter of given range by connecting a suitable low resistance S called shunt in parallel to the given galvanometer, whose value is given by $S = \left(\frac{I_g}{I - I_g}\right)G$ where I_g is the current for full scale deflection of galvanometer, I is the current to be measured by the galvanometer and G is the resistance of galvanometer.



(ii) Effective resistance, $R_p = \frac{GS}{G+S}$

34. Given ${}^{235}_{92}\text{Y} \longrightarrow {}^{231}_{90}\text{X} + {}^{4}_{2}\text{He} + \text{energy}$

Since share of energy of daughter nucleus can be neglected,

$$\text{KE of } \alpha \text{ particle} = \left(\frac{A-4}{A}\right)Q$$

Now Q = (231 × 7.835 + 4 × 7.07) − 235 × 7.8
= 5.165 MeV

$$\therefore \text{ K.E.} = \left(\frac{231}{235}\right) 5.165 \times 1.6 \times 10^6 \times 10^{-19} = \frac{1}{2} m_\alpha v_\alpha^2$$

$$\Rightarrow v_\alpha^2 = 2 \times \left(\frac{231}{235}\right) \times \frac{5.165 \times 1.6 \times 10^6 \times 10^{-19}}{6.68 \times 10^{-27}}$$

$v = 1.55 \times 10^7$ m s^{-1}.

35. (a) *Refer to answer 84, Page no. 117* (MTG CBSE Champion Physics Class 12).

Magnetic field is made radial in moving coil galvanometer so that the plane of the coil always lies in the direction of the magnetic field.

(b) Given $\Delta V = 10 \times 10^3$ V $= 10^4$ V, $B = 2 \times 10^{-3}$ T

Since the charge is accelerated through V,

$$\text{Velocity} = \sqrt{\frac{2q\Delta V}{m}} \quad \text{...(i)}$$

Now when it enters a magnetic field,

$$qvB = \frac{mv^2}{r};\ r = \frac{mv}{qB} = \frac{m}{qB}\sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2m\Delta V}{B^2 q}}$$

For α-particle, $q = 2e$, $m = 6.4 \times 10^{-27}$ kg

$$\therefore r = \sqrt{\frac{2 \times 6.4 \times 10^{-27} \times 10^4}{(2 \times 10^{-3})^2 \times 2 \times 1.6 \times 10^{-19}}} = 10 \text{ m}$$

OR

(a) *Refer to answer 66 (i), Page no. 178* (MTG CBSE Champion Physics Class 12).

(b) (i) $F = \frac{B^2 l^2 v}{R}$ (ii) $P = \frac{B^2 l^2 v^2}{R}$

36. (a) *Refer to answer. 100, Page no. 229,* (MTG CBSE Champion Physics Class 12).

(b) (i) Angular magnification, $m = \frac{-f_0}{f_e}$

(ii) $\beta = m \times \alpha$; $D' = 0.01 \times \tan\beta$

OR

(a) *Refer to answer 14, Page no. 215* (MTG CBSE Champion Physics Class 12).

(b) Using lens maker's formula,

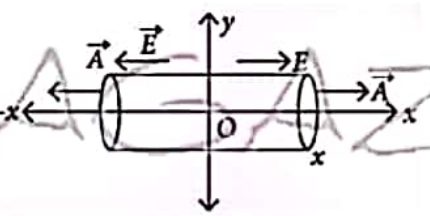
$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{\infty} - \frac{1}{-R}\right] = 0.5 \times \frac{1}{20} = \frac{1}{40} \Rightarrow f = 40 \text{ cm}$$

Now using thin lens formula,

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{40} + \frac{1}{-30} \Rightarrow v = -120 \text{ cm}$$

37. (a) *Refer to answer 53, Page no. 17* (MTG CBSE Champion Physics Class 12).

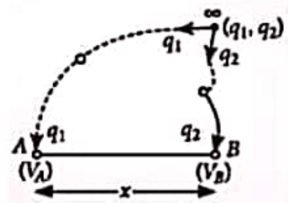
(b) (i) Net flux, $\phi = \int E.A + \int E.A$



(ii) The net charge enclosed, $q = \phi_1 \varepsilon_0$

OR

(a) Potential energy of a system of two charges in an external field



$W_1 = q_1(V_A - 0) = q_1 V_A$

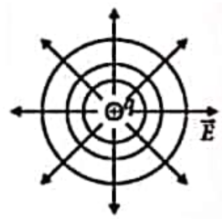
$$V_B = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{x}$$

$$W_2 = q_2 V_B + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{x}$$

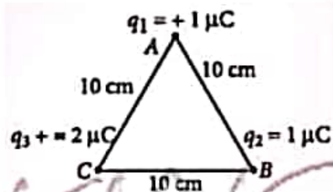
Total work done in assembling the configuration of two charges in an electric field is

$W = W_1 + W_2$

(b) For an isolated charge the equipotential surfaces are concentric spherical shells and the separation between consecutive equipotential surfaces increases in the weaker electric field.



(c) $W_A = 0$.



$$W_B = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{-1 \times 10^{-12}}{10 \times 10^{-2}}$$

$$W_C = \frac{1}{4\pi\varepsilon_0}\frac{1 \times 2 \times 10^{-12}}{10 \times 10^{-2}} + \frac{1}{4\pi\varepsilon_0}\frac{1 \times (-1) \times 10^{-12}}{10 \times 10^{-2}}$$

∴ Total work done, $W = W_A + W_B + W_C$

◆◆

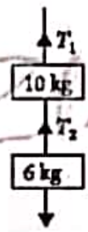
(For complete solutions, refer to MTG CBSE Champion Physics Class 12)

GET SET GO for NEET

Exam on May 3, 2020

with exclusive and brain storming MCQs

1. A body of mass 6 kg is hanging from another of mass 10 kg as shown in figure. This combination is being pulled up by a string with an acceleration of 2 m s^{-2}. The tension T_1 is ($g = 10$ m s^{-2})



(a) 240 N (b) 150 N
(c) 220 N (d) 192 N

2. A spherical soap bubble of radius 1 cm is formed inside another bubble of radius 3 cm. The radius of a single soap bubble which maintains the same pressure difference as inside the smaller and outside the larger soap bubble is
(a) 0.75 cm (b) 0.75 m (c) 7.5 cm (d) 7.5 m

3. If the length of a simple pendulum is comparable to the radius of the Earth, the period of the pendulum is
(a) $T = 2\pi\sqrt{\dfrac{1}{g\left(\dfrac{1}{L}+\dfrac{1}{R}\right)}}$ (b) $T = 2\pi\sqrt{\dfrac{L}{g}}$
(c) $T = 2\pi\sqrt{\dfrac{R}{g}}$ (d) $T = 2\pi\sqrt{\dfrac{\frac{1}{L}+\frac{1}{R}}{g}}$

4. A player throws a ball upwards with an initial speed 30 m s^{-1}. To what height does the ball rise and after how long does the ball return to the player's hands? (Take $g = 10$ m s^{-2} and neglect air resistance).
(a) 45 m, 6 s (b) 45 m, 3 s
(c) 20 m, 6 s (d) 20 m, 3 s

5. The ratio of radii of Earth to another planet is 2/3 and the ratio of their mean densities is 4/5. If an astronaut can jump to a maximum height of 1.5 m on the Earth, with the same effort, the maximum height he can jump on the planet is
(a) 1 m (b) 0.8 m (c) 0.5 m (d) 1.25 m

6. Heat is supplied to a diatomic gas at constant pressure. The ratio of $\Delta Q : \Delta U : \Delta W$ is
(a) 5 : 3 : 2 (b) 7 : 5 : 2
(c) 2 : 3 : 5 (d) 2 : 5 : 7

7. A circular disc of radius R is removed from a bigger circular disc of radius $2R$, such that the circumferences of the discs coincide. The centre of mass of the new disc is αR from the centre of the bigger disc. The value of α is
(a) $\frac{1}{4}$ (b) $\frac{1}{3}$ (c) $\frac{1}{2}$ (d) $\frac{1}{6}$

8. A ball is allowed to fall down with initial speed u from a height of 10 m. It loses 50% kinetic energy after striking the floor and reaches to the same

height after collision. What is the value of u?
(a) 28 m s^{-1} (b) 7 m s^{-1}
(c) 14 m s^{-1} (d) 35 m s^{-1}

9. In an experiment of simple pendulum, the errors in the measurement of length of the pendulum (L) and time period (T) are 3% and 2% respectively. The maximum percentage error in the value of $\frac{L}{T^2}$ is
(a) 5% (b) 7% (c) 8% (d) 1%

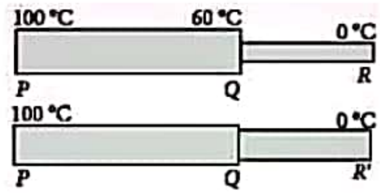
10. A motor cycle starts from rest and accelerates along a straight path at 2 m s^{-2}. At the starting point of the motor cycle there is a stationary electric siren. How far has the motor cycle gone when the driver hears the frequency of the siren at 94% of its value when the motor cycle was at rest?
(Speed of sound = 330 m s^{-1}).
(a) 49 m (b) 98 m (c) 147 m (d) 196 m

11. A light particle moving horizontally with a speed of 12 m s^{-1} strikes a very heavy block moving in the same direction at 10 m s^{-1}. The collision is one dimensional and elastic. After the collision, the particle will

(a) move at 2 m s^{-1} in its original direction
(b) move at 8 m s^{-1} in its original direction
(c) move at 8 m s^{-1} opposite to its original direction
(d) move at 12 m s^{-1} opposite to its original direction.

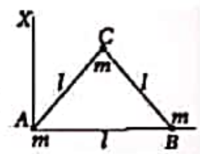
12. Two particles A and B are projected with same speed so that the ratio of their maximum height reached is 3 : 1. If the speed of A is doubled without altering other parameters, the ratio of the horizontal ranges attained by A and B is
(a) 1 : 1 (b) 2 : 1 (c) 4 : 1 (d) 3 : 2

13. Two metallic rods PQ and QR of different materials are joined together at the junction Q as shown in figure. It is observed that if the ends P and R are kept at 100°C and 0°C respectively, the temperature of the junction Q is 60°C. There is no loss of heat to the surroundings. The rod QR is replaced by another rod QR' of the same material and length ($QR = QR'$). If the area of cross-section of QR' is twice that of QR and the ends P and R' are maintained at 100°C and 0°C respectively, the temperature of the junction Q will be nearly



(a) 29 °C (b) 33 °C (c) 60 °C (d) 43 °C

14. Three particles, each of mass m gram, are situated at the vertices of an equilateral triangle ABC of side l cm as shown in figure. The moment of inertia of the system about a line AX perpendicular to AB and in the plane of ABC, in gram cm² will be

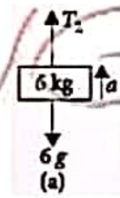


(a) $\frac{5}{4}ml^2$ (b) $\frac{3}{2}ml^2$ (c) $\frac{3}{4}ml^2$ (d) $2ml^2$

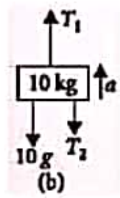
15. An engine has an efficiency of 1/6. When the temperature of sink is reduced by 62 °C, keeping temperature of source constant, its efficiency is doubled. Temperature of the source is
(a) 37 °C (b) 62 °C (c) 99 °C (d) 124 °C

SOLUTIONS

1. (d) : Here, $a = 2 \text{ m s}^{-2}$
The free body diagram of 6 kg block is as shown in figure (a).



The equation of motion of 6 kg block is
$T_2 - 6g = 6a$
$T_2 = 6(g + a) = 6(10 + 2) = 72 \text{ N}$
The free body diagram of 10 kg block is as shown in figure (b).



The equation of motion of 10 kg block is
$T_1 - 10g - T_2 = 10a$
$T_1 = 10(a + g) + T_2$
$= 10(2 + 10) + 72$
$= 120 + 72 = 192 \text{ N}$

2. (a) : Pressure outside the bigger drop = P_1
Pressure inside the bigger drop = P_2
Radius of bigger drop, $r_1 = 3$ cm
Excess pressure $= P_2 - P_1 = \frac{4S}{r_1} = \frac{4S}{3}$
Pressure inside small drop = P_3
Excess pressure $= P_3 - P_2 = \frac{4S}{r_2} = \frac{4S}{1}$
Pressure difference between inner side of small drop and outer side of bigger drop

$= P_3 - P_1 = \frac{4S}{3} + \frac{4S}{1} = \frac{16S}{3}$

This pressure difference should exist in a single drop of radius r.

$\therefore \frac{4S}{r} = \frac{16S}{3}$ or $r = \frac{3}{4}$ cm $= 0.75$ cm

3. (a): The weight of the bob acts towards the centre of the earth, Restoring torque, $\tau = -r \times F = -AB \times mg$

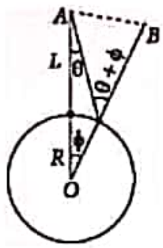
$\Rightarrow \tau = -mgL\sin(\theta + \phi) = -mgL(\theta + \phi)$ ...(i)

From figure, $\angle\theta = R\alpha$

$\therefore \theta + \phi = \theta\left(1 + \frac{\phi}{\theta}\right) = \theta\left(1 + \frac{L}{R}\right)$ ...(ii)

$I\alpha = mL^2\frac{d^2\theta}{dt^2}$ (iii)

Substituting (iii) and (ii) in (i)



$mL^2\frac{d^2\theta}{dt^2} = -mgL\theta\left(1 + \frac{L}{R}\right)$

$\frac{d^2\theta}{dt^2} = -\omega^2\theta = -g\left(\frac{1}{L} + \frac{1}{R}\right)\theta$

$\therefore T = 2\pi\sqrt{\frac{1}{g\left(\frac{1}{L} + \frac{1}{R}\right)}}$

4. (a): At the highest point, velocity is zero.

Using, $v^2 - u^2 = 2as$

Here, $u = 30$ m s^{-1}, $a = -g = -10$ m s^{-2}, $s = H$, $v = 0$ m s^{-1}

$\therefore (0)^2 - (30)^2 = 2 \times (-10) \times H$

$H = 45$ m

Let t be the time taken by the ball to reach the maximum height.

Using $v = u + at \Rightarrow 0 = 30 - 10 \times t; t = 3$ s

Neglecting air resistance,

Time of ascent = Time of descent

Therefore, time taken by the ball to return to the players' hand $= t + t = 2t = 2 \times 3$ s $= 6$ s

5. (b): Here, $\frac{R_e}{R_p} = \frac{2}{3}; \frac{\rho_e}{\rho_p} = \frac{4}{5}; h_e = 1.5$ m; $h_p = ?$

K.E. of person = P.E. at the maximum height to which he can jump.

$\therefore mg_e h_e = mg_p h_p$

or $m\frac{GM_e}{R_e^2}h_e = m\frac{GM_p}{R_p^2}h_p$

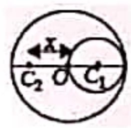
or $mG\frac{\frac{4}{3}\pi R_e^3\rho_e h_e}{R_e^2} = mG\frac{\frac{4}{3}\pi R_p^3\rho_p h_p}{R_p^2}$

or $R_e\rho_e h_e = R_p\rho_p h_p$

or $h_p = \frac{R_e}{R_p} \times \frac{\rho_e}{\rho_p} \times h_e = \frac{2}{3} \times \frac{4}{5} \times 1.5 = 0.8$ m

6. (b)

7. (b): In figure, O is the centre of circular disc of radius $2R$ and mass M. C_1 is centre of disc of radius R, which is removed. If σ is mass per unit area of bigger disc, then $M = \pi(2R)^2\sigma$



Mass of disc removed, $M_1 = \pi R^2\sigma = \frac{1}{4}M$

Mass of remaining disc, $M_2 = M - M_1$

$= M - \frac{1}{4}M = \frac{3}{4}M$

Let centre of mass of remaining disc be at C_2 where $OC_2 = x$

As $M_1 \times OC_1 = M_2 \times OC_2$

$\therefore \frac{M}{4}R = \frac{3M}{4}x; x = \frac{R}{3} = \alpha R \therefore \alpha = \frac{1}{3}$

8. (c): To reach same height of 10 m after collision, velocity after collision $= \sqrt{2gh}$

$= \sqrt{2 \times 10 \times 10} = 10\sqrt{2}$ ms^{-1}

As energy lost in collision is 50%, final velocity is $\frac{v}{\sqrt{2}}$.

$\therefore$ Velocity of ball on striking,

$v = (10\sqrt{2})\sqrt{2} = 20$ ms^{-1}

From $v^2 - u^2 = 2gh$; $(20)^2 - u^2 = 2 \times 10 \times 10$,

$u = \sqrt{200} = 10\sqrt{2} = 14.14$ ms^{-1}

9. (b): As the error in measurement of length, L and time period, T are 3% and 2%.

Maximum percentage error in the value of L/T^2.

$= \left(\frac{\Delta L}{L} + \frac{2\Delta T}{T}\right) \times 100 = 3\% + 2 \times 2\% = 7\%$

10. (b): Here, the source (electric siren) is at rest and the observer is moving away from the source

$\therefore \upsilon' = \frac{\upsilon(v - v_o)}{v}$

where v is the speed of the sound

$\frac{\upsilon'}{\upsilon} = \frac{v - v_o}{v}; \frac{94}{100} = 1 - \frac{v_o}{v}; 0.94 = 1 - \frac{v_o}{v}$

$\frac{v_o}{v} = 1 - 0.94 = 0.06$

$v_o = 0.06v = 0.06 \times 330 = 19.8$ m s^{-1}

$\therefore$ Distance covered, $s = \frac{v^2 - u^2}{2a} = \frac{(19.8)^2 - (0)^2}{2 \times 2}$

$= 98$ m

11. **(b)**: Here, $u_1 = 12\ \text{m s}^{-1}, u_2 = 10\ \text{m s}^{-1}$
Let v_1 be velocity of the light particle after collision

$$v_1 = \frac{(m_1 - m_2)u_1}{m_1 + m_2} + \frac{2m_2u_2}{m_1 + m_2} \quad \text{...(i)}$$

Given : $m_1 << m_2$
m_1 can be ignored compared to m_2
From equation(i), we get
$v_1 = -u_1 + 2u_2$
Substituting the values, we get
$v_1 = -12\ \text{m s}^{-1} + 2\ (10\ \text{m s}^{-1})$
$= 8\ \text{m s}^{-1}$ in its original direction

12. **(c)**: Here, $\frac{H_1}{H_2} = \frac{3}{1}$ or $H_1 = 3H_2$

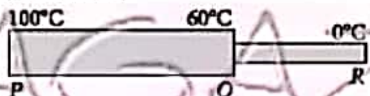
or $\frac{u^2 \sin^2\theta_1}{2g} = \frac{3u^2 \sin^2\theta_2}{2g}$; $\frac{\sin^2\theta_1}{\sin^2\theta_2} = \frac{3}{1}$

It is true if $\theta_1 = 60°$ and $\theta_2 = 30°$
When speed of A is doubled, then horizontal range

$$R_1 = \frac{(2u)^2 \sin(2\times 60°)}{g} = \frac{4u^2 \sin 120°}{g} = \frac{4u^2 \sin 60°}{g}$$

and $R_2 = \frac{u^2 \sin(2\times 30°)}{g} = \frac{u^2 \sin 60°}{g}$ $\therefore \frac{R_1}{R_2} = \frac{4}{1}$

13. **(d)**: In the first case,



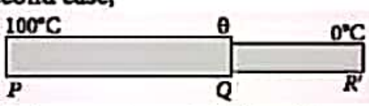
Since the rods are connected in series, therefore rate of heat *i.e.*, heat current is same.

$\therefore H_{PQ} = H_{QR}$

$$\therefore \frac{K_{PQ}A_{PQ}(100-60)}{L_{PQ}} = \frac{K_{QR}A_{QR}(60-0)}{L_{QR}}$$

$$\text{or } \frac{K_{PQ}}{K_{QR}} = \frac{A_{QR}L_{PQ}\ (60-0)}{A_{PQ}L_{QR}\ (100-60)} \quad \text{...(i)}$$

In the second case,



Let θ is the temperature of the junction.
$\because H_{PQ} = H_{QR'}$ in steady state

$$\therefore \frac{K_{PQ}A_{PQ}(100-\theta)}{L_{PQ}} = \frac{K_{QR'}A_{QR'}(\theta-0)}{L_{QR'}}$$

$$\frac{K_{PQ}}{K_{QR'}} = \frac{A_{QR'}L_{PQ}(\theta-0)}{A_{PQ}L_{QR'}(100-\theta)} \quad \text{... (ii)}$$

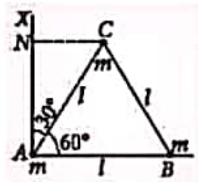
Divide eqn. (i) by (ii), we get

$$\frac{K_{QR'}}{K_{QR}} = \frac{A_{QR}L_{QR'}(60-0)(100-\theta)}{A_{QR'}L_{QR}(100-60)(\theta-0)} \quad \text{... (iii)}$$

Since both rods QR and QR' are made of same material, therefore
$\therefore K_{QR'} = K_{QR}$
$A_{QR'} = 2A_{QR}$ (Given)
$L_{QR'} = L_{QR}$ (Given)
Substituting these values in eqn (iii), we get
$2(100-60)(\theta-0) = (60-0)(100-\theta)$
$80(\theta) = 60\ (100 - \theta)$ or $8\theta = 600 - 6\theta$
$14\theta = 600$

$$\theta = \frac{600}{14} \approx 43°\text{C}$$

14. **(a)**: From figure,



$\sin 30° = \frac{CN}{CA} = \frac{CN}{l}$

$CN = l \sin 30° = \frac{l}{2}$

Moment of inertia of the system about the given axis is
$I = m_A(0)^2 + m_B(l)^2 + m_C(CN)^2$

$$= 0 + ml^2 + m\left(\frac{l}{2}\right)^2 = \frac{5}{4}ml^2$$

15. **(c)**: Here $\eta_1 = \frac{1}{6}, \eta_2 = 2\times\frac{1}{6}$

$\therefore \eta_1 = 1 - \frac{T_2}{T_1}$

$\frac{1}{6} = 1 - \frac{T_2}{T_1}; \frac{T_2}{T_1} = \frac{5}{6}$ or $T_2 = \frac{5T_1}{6}$

Again, $\eta_2 = 1 - \frac{(T_2 - 62)}{T_1}$

$2\times\frac{1}{6} = 1 - \frac{(T_2-62)}{T_1}; \frac{(T_2-62)}{T_1} = 1 - \frac{1}{3} = \frac{2}{3}$

$3T_2 - 186 = 2T_1; 3\times\frac{5}{6}T_1 - 186 = 2T_1$

$0.5T_1 = 186; T_1 = 372\ \text{K} = 372 - 273 = 99°\text{C}$

Monthly Test Drive CLASS XI ANSWER KEY

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

MONTHLY TEST DRIVE

XI

This specially designed column enables students to self analyse their extent of understanding of all chapters (Class XI). 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

Only One Option Correct Type

1. 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) $\frac{R}{2}$

2. 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) $2\sqrt{2gH}$

3. An open pipe is in resonance in its 2^{nd} harmonic with a tuning fork of frequency υ_1. Now it is closed at one end. If the frequency of tuning fork is increased slowly from υ_1 then again a resonance is obtained with a frequency υ_2. If in this case the pipe vibrates in n^{th} harmonic, then

(a) $n = 5, \upsilon_2 = \frac{3}{4}\upsilon_1$ (b) $n = 5, \upsilon_2 = \frac{5}{4}\upsilon_1$

(c) $n = 3, \upsilon_2 = \frac{3}{4}\upsilon_1$ (d) $n = 3, \upsilon_2 = \frac{9}{4}\upsilon_1$

4. In a Carnot engine, the temperature of reservoir is 927 °C and that of sink is 27 °C. If the work done by the engine when it transfers heat from reservoir to sink is 12.6×10^6 J, the quantity of heat absorbed by the engine from the reservoir is

(a) 16.8×10^6 J (b) 4×10^6 J

(c) 7.6×10^6 J (d) 4.2×10^6 J

5. 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) $\frac{2T}{5}$

6. A projectile is thrown with initial velocity $(a\hat{i} + b\hat{j})$ 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) $b = 2a$

7. A machine gun fires 360 bullets per minute, with a velocity of 600 m s^{-1}. If the power of the gun is 5.4 kW, mass of each bullet is

(a) 5 kg (b) 0.5 kg (c) 5 g (d) 0.5 g

8. A disc of mass m and radius R has a concentric hole of radius r. Its moment of inertia about an axis through its centre and perpendicular to its plane is

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

(c) $\frac{1}{2}m(R + r)^2$ (d) $\frac{1}{2}m(R^2 + r^2)$

9. The radii of the two columns of U-tube are r_1 and r_2. When a liquid of density ρ (angle of contact is 0°) is filled in it, the difference of liquid level in two arms is h. The surface tension of liquid is

(a) $\frac{\rho g h r_1 r_2}{2(r_2 - r_1)}$ (b) $\frac{\rho g h (r_2 - r_1)}{2 r_1 r_2}$

(c) $\frac{2(r_2 - r_1)}{\rho g h r_1 r_2}$ (d) $\frac{\rho g h}{2(r_2 - r_1)}$

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. 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%

12. 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

Assertion and 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 :** 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.

14. **Assertion :** It is better to wash the clothes in cold soap solution.
Reason : The surface tension of cold solution is more than the surface tension of hot solution.

15. **Assertion :** The first derivative of a vector of constant magnitude (either zero or a non-zero) is perpendicular to the vector itself.
Reason : Scalar product of two vectors obeys commutative law.

JEE MAIN / ADVANCED

Only One Option Correct Type

16. A wheel of moment of inertia 2.5 kg m^2 has an initial angular velocity of 40 rad s^{-1}. A constant torque of 10 N m acts on the wheel. The time during which the wheel is accelerated to 60 rad s^{-1} is

(a) 4 s (b) 6 s (c) 5 s (d) 2.5 s

17. 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}

18. Three discs A, B and C having radii 2, 4 and 6 cm respectively are coated with carbon black. Wavelengths for maximum intensity for the three discs are 300, 400 and 500 nm respectively. If Q_A, Q_B and Q_C are powers emitted by A, B and C respectively, then

CROSSWORD SOLUTION MARCH 2020

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(a) Q_A will be maximum
(b) Q_B will be maximum
(c) Q_C will be maximum
(d) $Q_A = Q_B = Q_C$

19. Certain amount of an ideal gas is contained in a closed vessel. The vessel is moving with a constant velocity v. The molecular mass of gas is M. The rise in temperature of the gas when the vessel is suddenly stopped is ($\gamma = C_P/C_V$)

(a) $\frac{Mv^2(\gamma-1)}{2R(\gamma+1)}$ (b) $\frac{Mv^2(\gamma-1)}{2R}$

(c) $\frac{Mv^2}{2R(\gamma+1)}$ (d) $\frac{Mv^2}{2R(\gamma-1)}$

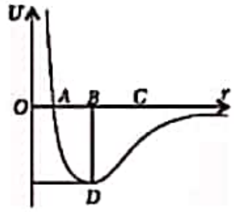
More than One Options Correct Type

20. 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. Which of the following statements is/are correct?
(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.

21. 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. Which of the following statements are correct?
(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

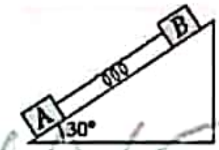
22. A student uses a simple pendulum of exactly 1 m length to determine g, the acceleration due to gravity. He uses a stopwatch with the least count of 1 sec for this and records 40 seconds for 20 oscillations. For this observation, which of the following statements are correct?
(a) Error ΔT in measuring T, the time period, is 0.05 seconds.
(b) Error ΔT in measuring T, the time period, is 1 second.
(c) Percentage error in the determination of g is 5%.
(d) Percentage error in the determination of g is 2.5%.

23. The potential energy curve for interaction between two molecules is shown in figure. Which of the following statements are correct?



(a) The molecules have maximum attraction for $r = OA$.
(b) The molecules have maximum kinetic energy for $r = OB$.
(c) The intermolecular force is zero for $r = OB$.
(d) For the gaseous state, the depth BD of the potential energy curve is much smaller than K_BT.

24. Two blocks A and B of masses 5 kg and 2 kg, respectively, connected by a spring of force constant = 100 N m^{-1} are placed on an inclined plane of inclination 30° as shown in figure. The system is released from rest. Which of the following statements are correct?



(a) There will be no compression or elongation in the spring if all surfaces are smooth.

(b) there will be elongation in the spring if A is rough and B is smooth.

(c) Maximum elongation in the spring is 35 cm if all surfaces are smooth.

(d) There will be elongation in the spring if A is smooth and B is rough.

25. Which of the following statements are correct regarding base and derived quantities?

(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.

Numerical Value Type

26. 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 ________.

27. A man standing on a trolley pushes another identical trolley (both trolleys are at rest on a rough surface), so that they are set in motion and stop after some time. If the ratio of mass of first trolley with man to mass of second trolley is 3, then find the ratio of the stopping distances of the second trolley to that of the first trolley is __________. (Assume coefficient of friction to be the same for both the trolleys)

28. A cylindrical vessel of height 500 mm has an orifice (small hole) at its bottom. The orifice is initially closed and water is filled in it upto height H. Now the top is completely sealed with a cap and the orifice at the bottom is opened. Some water comes out from the orifice and the water level in the vessel becomes steady with height of water column being 200 mm. The fall in height (in mm) of water level due to opening of the orifice is____. [Take atmospheric pressure $= 1.0 \times 10^5$ N m^{-2}, density of water = 1000 kg m^{-3} and g = 10 m s^{-2}. Neglect any effect of surface tension.]

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.

29. 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

30. 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

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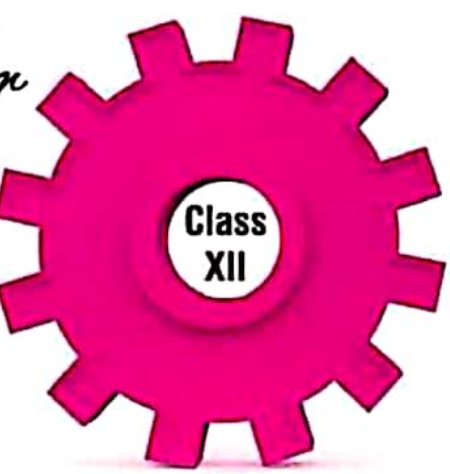

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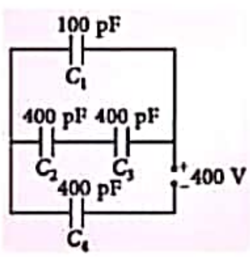
Only One Option Correct Type

1. In the Bohr model of a π-mesic atom, a π-meson of mass m_π and of the same charge as the electron is in a circular orbit of radius r about the nucleus with an orbital angular momentum $h/2\pi$. If the radius of a nucleus of atomic number Z is given by $R = 1.6 \times 10^{-15} Z^{1/3}$m, then the limit on Z for which π-mesic atoms might exist is
(Given $\varepsilon_0 h^2/\pi m_e e^2 = 0.53$ Å and $m_\pi/m_e = 264$)
(a) < 105 (b) > 105
(c) < 37 (d) > 37

2. The equivalent capacitance for the network shown in the figure is



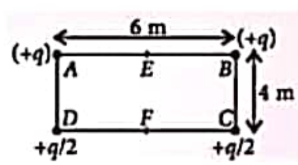
(a) $\frac{1200}{7}$ pF
(b) $\frac{1000}{4}$ pF
(c) $\frac{1800}{7}$ pF
(d) $\frac{1300}{3}$ pF

3. In a common emitter configuration of a transistor, the voltage drop across a 500 Ω resistor in the collector circuit is 0.5 V when the collector supply voltage is 5 V. If the current gain in the common base mode is 0.96, the base current is
(a) $\frac{1}{20}$ μA (b) $\frac{1}{5}$ μA
(c) $\frac{1}{20}$ mA (d) $\frac{1}{24}$ mA

4. In a single slit diffraction experiment, first minimum for λ_1 = 660 nm coincides with first maxima for wavelength λ_2. Then λ_2 is
(a) 220 nm (b) 330 nm
(c) 440 nm (d) 660 nm

5. The current sensitivity of a moving coil galvanometer is increases by 35 %, when its resistance is increased by a factor of 3. The voltage sensitivity of galvanometer changes by a factor
(a) 35% (b) 45%
(c) 55% (d) None of these

6. Find the potential difference between the points E and F in the figure given below. Assume E and F are the midpoints of AB and DC respectively.



(a) $(1.2 \times 10^9 q)$ volt (b) $(1.8 \times 10^9 q)$ volt
(c) $(1.5 \times 10^9 q)$ volt (d) $(3 \times 10^9 q)$ volt.

7. A conducting ring of radius 1 m is placed in a uniform magnetic field B of 0.01 T oscillating with frequency 100 Hz with its plane at right angle to B. What will be induced electric field?

(a) π V m^{-1} (b) 0.5 V m^{-1}
(c) 10 V m^{-1} (d) 62 V m^{-1}

8. An electromagnetic wave in vacuum has the electric and magnetic fields $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by $\vec{X}$ and that of wave propagation by $\vec{k}$. Then

(a) $\vec{X} \| \vec{B}$ and $\vec{k} \| (\vec{B} \times \vec{E})$ (b) $\vec{X} \| \vec{E}$ and $\vec{k} \| (\vec{E} \times \vec{B})$
(c) $\vec{X} \| \vec{B}$ and $\vec{k} \| (\vec{E} \times \vec{B})$ (d) $\vec{X} \| \vec{E}$ and $\vec{k} \| (\vec{B} \times \vec{E})$

9. The magnification produced by an astronomical telescope for normal adjustment is 10 and the length of the telescope is 1.1 m. The magnification, when the image is formed at least distance of distinct vision is

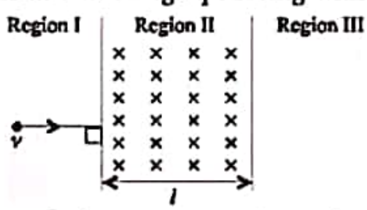
(a) 6 (b) 14 (c) 16 (d) 18

10. The half-life of radium is 1620 yr and its atomic weight is 226 g mol^{-1}. The number of atoms that will decay from its 1 g sample per second will be (Avogadro's number $N_A = 6.023 \times 10^{23}$ atom per mole)

(a) 3.61×10^{10} Bq (b) 3.61×10^{12} Bq
(c) 3.11×10^{15} Bq (d) 31.1×10^{15} Bq

More Than One Options Correct Type

11. A particle of mass m and charge q moving with velocity v enters region II normal to the boundary as shown in the figure.



Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the region II is l. Choose the correct choices.

(a) The particle enters region III only if its velocity $v > \frac{qlB}{m}$

(b) The particle enters region III only if its velocity $v < \frac{qlB}{m}$

(c) Path length of the particle in region II is maximum when velocity $v = \frac{qlB}{m}$

(d) Time spent in region II is same for any velocity v as long as the particle returns to region I.

12. A series RC circuit is connected to AC voltage source. Consider two cases; (A) when C is without a dielectric medium and (B) when C is filled with dielectric of constant 4. The current I_R through the resistor and voltage V_C across the capacitor are compared in the two cases. Which of the following are true?

(a) $I_R^A > I_R^B$ (b) $I_R^A < I_R^B$
(c) $V_C^A > V_C^B$ (d) $V_C^A < V_C^B$

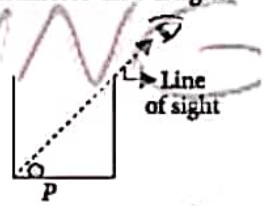
13. The distance between a light source and photoelectric cell is d. If the distance is decreased to $d/2$ then

(a) the emission of electron per second will be four times.
(b) maximum Kinetic energy of photoelectrons will be four times.
(c) stopping potential will remain same.
(d) the emission of electrons per second will be doubled.

Numerical Value Type

14. Two bulbs 40 W and 60 W rated voltage 240 V are connected in series across a potential difference of 420 V. The potential difference (in V) across 60 W bulb is ______.

15. A cylindrical vessel, whose diameter and height both are equal to 30 cm, is placed on a horizontal surface and a small particle P is placed in it at a distance of 5.0 cm from the center. An eye is placed at a position such that the edge of the bottom is just visible. The particle P is in the plane of drawing. The minimum height (in cm) up to which water should be poured in the vessel to make the particle P visible is ______.



(Take, refractive index of water $= \frac{4}{3}$)

SOLUTIONS

1. (c) : Angular momentum, $mvr = \frac{nh}{2\pi}$ ...(i)

Centripetal force, $\frac{m_\pi v^2}{r} = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$ ...(ii)

From eqns (i) and (ii)

$$r = \frac{\varepsilon_0 n^2 h^2}{\pi m_\pi e^2 Z} = \left(\frac{\varepsilon_0 h^2}{\pi m_e e^2}\right)\left(\frac{m_e}{m_\pi}\right)\frac{1}{Z}$$

$$= \frac{0.53 \times 10^{-10}}{264 Z} = \frac{200 \times 10^{-15}}{Z} \quad \left[\because \frac{m_\pi}{m_e} = 264\right]$$

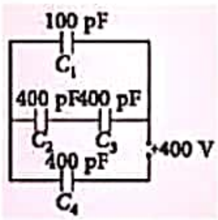
Since r cannot be less than nuclear radius,

$$r > 1.6Z^{\frac{1}{3}} \times 10^{-15}\,\text{m}$$

or $\dfrac{200\times10^{-15}}{Z} > 1.6\times10^{-15} Z^{\frac{1}{3}}$

$$\Rightarrow \quad Z < \left(\frac{200}{1.6}\right)^{\frac{3}{4}} \approx 37$$

2 (a): $C_1 = C_4 = 100$ pF,
$C_2 = C_3 = 400$ pF
Supply voltage, $V = 400$ V
Capacitors C_2 and C_3 are connected in series,



Equivalent capacitance

$$\frac{1}{C'} = \frac{1}{400} + \frac{1}{400} = \frac{2}{400} \text{ or } C' = 200 \text{ pF}$$

Capacitors C_1 and C' are in parallel
Their equivalent capacitance

$$C'' = C' + C_1 = 200 + 100 = 300 \text{ pF}$$

Capacitors C'' and C_4 are connected in series
Equivalent capacitance,

$$\frac{1}{C_{eq}} = \frac{1}{C''} + \frac{1}{C_4} = \frac{1}{300} + \frac{1}{400}$$

$$\frac{1}{C_{eq}} = \frac{7}{1200} \quad \therefore \quad C_{eq} = \frac{1200}{7} \text{ pF}$$

3. (d): Here, $R_C = 500\,\Omega$, $I_C R_C = 0.5$ V,
$V_{CC} = 5$ V, $\alpha = 0.96$

As $I_C R_C = 0.5$ V

$$\therefore \quad I_C = \frac{0.5\text{ V}}{R_C} = \frac{0.5\text{ V}}{500\,\Omega} = 1\times10^{-3}\text{ A} = 1\text{ mA}$$

The current gains α and β are related as

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24$$

The base current is

$$I_B = \frac{I_C}{\beta} = \frac{1\text{ mA}}{24} = \frac{1}{24}\text{ mA}$$

4. (c): Position of minima in diffraction pattern is given by, $d\sin\theta = n\lambda$
For first minima of λ_1, we have

$$d\sin\theta_1 = (1)\lambda_1 \text{ or } \sin\theta_1 = \frac{\lambda_1}{d}$$

Position of maxima in diffraction pattern is given by, $d\sin\theta = \dfrac{(2n+1)}{2}\lambda$

$\therefore$ For wavelength λ_2,

$$d\sin\theta_2 = \frac{3}{2}\lambda_2 \text{ or } \sin\theta_2 = \frac{3\lambda_2}{2d}$$

The two will coincide if, $\theta_1 = \theta_2$

or $\sin\theta_1 = \sin\theta_2 \quad \therefore \quad \dfrac{\lambda_1}{d} = \dfrac{3\lambda_2}{2d}$

or $\lambda_2 = \dfrac{2}{3}\lambda_1 = \dfrac{2}{3}\times 660\text{ nm} = 440\text{ nm}$

5. (c): Given $I_s' = I_s + \dfrac{35}{100}I_s = \dfrac{135}{100}I_s$

Initial voltage sensitivity, $V_s = \dfrac{I_s}{R}$

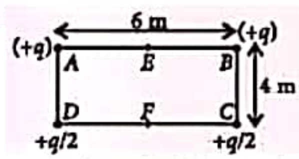
New voltage sensitivity, $V_s' = \dfrac{I_s'}{R'}$

$$= \left(\frac{135}{100}I_s\right)\times\frac{1}{3R} = \frac{9}{20}V_s$$

% decrease in voltage sensitivity

$$\left(\frac{V_s - V_s'}{V_s}\right)\times100\% = \frac{V_s - \frac{9}{20}V_s}{V_s}\times100\% = 55\%$$

6. (a):



$$DE = CE = \sqrt{(AE)^2 + (AD)^2} = \sqrt{(3)^2 + (4)^2} = 5\text{ m}$$

Potential at E,

$$V_E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AE} + \frac{q}{BE} + \frac{q/2}{DE} + \frac{q/2}{CE}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{3} + \frac{q}{3} + \frac{q/2}{5} + \frac{q/2}{5}\right] = \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{3} + \frac{q}{5}\right]$$

$$AF = BF = \sqrt{(AD)^2 + (DF)^2} = \sqrt{(4)^2 + (3)^2} = 5\text{ m}$$

Potential at F,

$$V_F = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AF} + \frac{q}{BF} + \frac{q/2}{DF} + \frac{q/2}{CF}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{5} + \frac{q}{5} + \frac{q/2}{3} + \frac{q/2}{3}\right] = \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{5} + \frac{q}{3}\right]$$

$$\therefore \quad V_E - V_F = \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{3} + \frac{q}{5} - \frac{2q}{5} - \frac{q}{3}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{3} - \frac{1}{5}\right]$$

$$= \frac{2q}{15\times4\pi\varepsilon_0} = \frac{2}{15}\times9\times10^9\times q = 1.2\times10^9 q \text{ volt.}$$

7. (b): Here, $r = 1$ m, $B = 0.01$ T, $t = \dfrac{1}{\upsilon} = \dfrac{1}{100}$ s

Induced e.m.f, $|\varepsilon| = \dfrac{d\phi}{dt}$

$$= \frac{BA}{t} = \frac{B\pi r^2}{t} = \frac{0.01\times\pi(1)^2}{\left(\frac{1}{100}\right)} = \pi\text{ V}$$

Induced electric field, $E = \dfrac{|\varepsilon|}{l} = \dfrac{|\varepsilon|}{2\pi r} = \dfrac{\pi}{2\times\pi\times1}$
$= 0.5\text{ V m}^{-1}$

8. (b)

9. (b): Let f_o and f_e be focal lengths of objective and eye piece respectively.

For normal adjustment,

Magnification of the telescope, $m=\frac{f_o}{f_e}$

and length of the telescope, $L=f_o+f_e$

Here, m = 10 and L = 1.1 m

$\therefore\quad 10=\frac{f_o}{f_e}$ or $f_o=10f_e$ ...(i)

and $1.1=f_o+f_e$ ...(ii)

From eqns. (i) and (ii), we get f_o = 1 m and f_e = 0.1 m

When the image is formed at least distance of distinct vision D (= 25 cm), then

$$m=\frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)=\frac{1\text{ m}}{0.1\text{ m}}\left(1+\frac{0.1\text{ m}}{0.25\text{ m}}\right)=14$$

10. (a) : Rate of change of radioactive nuclei,

$$\left(-\frac{dN}{dt}\right)=\lambda N$$

$$\because\quad \lambda=\frac{0.693}{T_{1/2}}=\frac{0.693}{1620\times365\times24\times60\times60}$$

and $\quad N=\frac{6.023\times10^{23}}{226}$

$$\therefore\quad \left(-\frac{dN}{dt}\right)=\frac{0.693\times6.023\times10^{23}}{1620\times365\times24\times60\times60\times226}$$

$$=3.61\times10^{10}\text{ Bq}$$

11. (a, c, d) : The velocity of the particle is normal to the magnetic field and the magnetic field is uniform, so the particle will follow a circular path. The radius of the circular path is

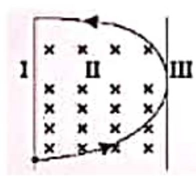
$R=\frac{mv}{qB}$

For the particle to enter region III

$R>l$ or $\frac{mv}{qB}>l$

For path length of particle in region II to be maximum

$l=R\quad$ or $v=\frac{qlB}{m}$



The time spent in region II is

$t=\frac{\pi}{\omega}=\frac{\pi m}{qB}$,

which is same for all the velocities for which the charged particle returns to region I.

12. (b, c) : In case A

Impedance of the circuit is, $Z_A=\sqrt{(R)^2+\left(\frac{1}{\omega C}\right)^2}$

$$I_R^A=\frac{V}{\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}};\ V_C^A=\frac{I_R^A}{\omega C}=\frac{V}{\sqrt{(R\omega C)^2+1}}$$

In case B,

impedance of the circuit is, $Z_B=\sqrt{R^2+\left(\frac{1}{4\omega C}\right)^2}$

$$I_R^B=\frac{V}{\sqrt{R^2+\left(\frac{1}{4\omega C}\right)^2}};\ V_C^B=\frac{V}{\sqrt{(4R\omega C)^2+1}}$$

We conclude that $I_R^A<I_R^B,\ V_C^A>V_C^B$

13. (a, c) : Intensity of light, $I\propto\frac{1}{r^2}$

Also, $I\propto N$ (Number of photons per second)

$\therefore\quad N\propto\frac{1}{r^2}$

Hence, number of emitted electrons will be four times.

According to Einstein's photoelectric equation,

$KE_{max}=eV_s=h\upsilon-\phi$

Here, υ remains constant hence stopping potential (V_s) will remain same.

14. (168) : Resistance of 40 W bulb, $R_1=\frac{(240)^2}{40}\ \Omega$

Resistance of 60 W bulb, $R_2=\frac{(240)^2}{60}\ \Omega$

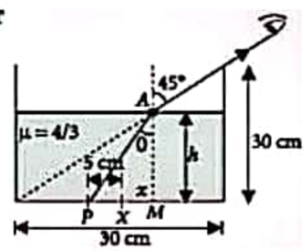
When bulbs are in series, the effective resistance

$R=R_1+R_2=\frac{(240)^2}{24};\ I=\frac{21}{120}$

Potential difference across 60 W bulb

$=\frac{21}{120}\times\frac{(240)^2}{60}=168$ V

15. (26.7) : If we pour water in vessel, refraction will take place at air and water interface. Applying Snell's law at A, we get



$1\times\sin45°=\frac{4}{3}\sin\theta$

$\Rightarrow\quad \sin\theta=\frac{3}{4\sqrt2};\ \tan\theta=\frac{3}{\sqrt{23}}$

$\Rightarrow$ In ΔAPM, $\tan\theta=\frac{PM}{AM}=\frac{5+x}{h}=\frac{5+h-15}{h}$

$\frac{3}{\sqrt{23}}=\frac{h-10}{h}\Rightarrow h=26.7$ cm

Hence, water should be poured upto height 26.7 cm to make the particle P visible. ◆◆

MONTHLY TEST DRIVE

XII

This specially designed column enables students to self analyse their extent of understanding of all chapters (Class XII). 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

Only One Option Correct Type

1. 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 mm 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

2. A rectangular loop of sides 25 cm and 10 cm carrying a current of 15 A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25 A. What is the net force on the loop?
(a) 7.8×10^{-4} N (b) 6.6×10^{-4} N
(c) 8.2×10^{-4} N (d) 5.4×10^{-4} N

3. 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

4. An observer is 4 m from an isotropic point light source whose power is 500 W. The rms value of electric field due to the source at the position of observer is
(a) 12.6 V m^{-1} (b) 15.6 V m^{-1}
(c) 25.6 V m^{-1} (d) 30.6 V m^{-1}

5. The refracting angle of a prism is A and refractive index of the material of prism is $\cot\left(\frac{A}{2}\right)$. The angle of minimum deviation will be
(a) $180° - 3A$ (b) $180° + 3A$
(c) $90° - 3A$ (d) $180° - 2A$

6. 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 Q_2 (b) Q_1 and Q_2
(c) P_1 and Q_1 (d) P_2 and Q_2

7. 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.

8. In a photoemissive cell, with exciting wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be
(a) less than $v\left(\frac{4}{3}\right)^{1/2}$ (b) $v\left(\frac{4}{3}\right)^{1/2}$
(c) $v\left(\frac{3}{4}\right)^{1/2}$ (d) greater than $v\left(\frac{4}{3}\right)^{1/2}$

9. If K_1 and K_2 are maximum kinetic energies of photoelectrons emitted when lights of wavelengths λ_1 and λ_2 respectively incident on a metallic surface and $\lambda_1 = 3\lambda_2$, then
(a) $K_1 > \left(\frac{K_2}{3}\right)$ (b) $K_1 < \left(\frac{K_2}{3}\right)$
(c) $K_1 = 2K_2$ (d) $K_2 = 2K_1$

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

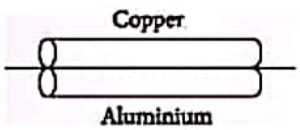
(a) BIl (b) B_0Il (c) $2B_0Il$ (d) $B_0Il/2$

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 copper rod of length 20 cm and cross-sectional area 2 mm^2 is joined with a similar aluminium rod as shown in figure below. Find the resistance of the combination between the ends. Resistivity of copper $= 1.7 \times 10^{-8}\ \Omega$ m and resistivity of aluminium $= 2.6 \times 10^{-8}\ \Omega$ m.

(a) 2.424 m Ω
(b) 1.028 m Ω
(c) 3.012 m Ω
(d) 4.009 m Ω



Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. Assertion : The conduction current and displacement current together has the property of continuity.

Reason : The conduction current is same as displacement current when source is only dc and not ac.

14. Assertion : The fringe obtained at the centre of the screen is known as zeroth order fringe, or the central fringe.

Reason : Path difference between the waves from S_1 and S_2, reaching the central fringe (or zero order fringe) is zero.

15. 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.

mcq's MEMORY CONTEST

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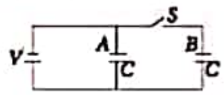
JEE MAIN / ADVANCED

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 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) $\dfrac{\alpha I^2 R}{\lambda}$ (b) $\dfrac{\alpha I^2 R}{2\lambda}$

(c) $\alpha\lambda IR$ (d) $2\alpha\lambda IR$

18. Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ [in terms of the Rydberg constant R for the hydrogen atom] equal to

(a) $\dfrac{9}{5R}$ (b) $\dfrac{36}{5R}$

(c) $\dfrac{18}{5R}$ (d) $\dfrac{4}{5R}$

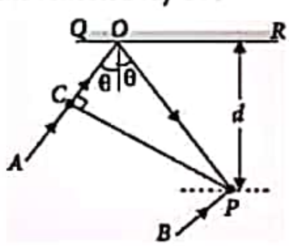
19. In the figure, CP represents a wave front and AO and BP, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and the reflected ray OP.

(a) $\cos\theta = \dfrac{3\lambda}{2d}$

(b) $\cos\theta = \dfrac{\lambda}{4d}$

(c) $\sec\theta - \cos\theta = \dfrac{\lambda}{d}$

(d) $\sec\theta - \cos\theta = \dfrac{4\lambda}{d}$



More than One Options Correct Type

20. The breakdown in a reverse biased p–n junction diode is more likely to occur due to

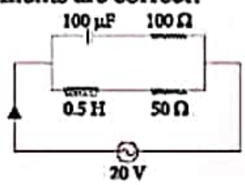
(a) large velocity of the minority charge carriers if the doping concentration is small.

(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.

21. In the given circuit, the AC source has $\omega = 100\ \text{rad s}^{-1}$. Consider the inductor and capacitor to be ideal. Which of the following statements are correct?



(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.

22. A radioactive sample has initial concentration N_0 of nuclei. Which of the following statements are correct?

(a) the number of undecayed nuclei present in the sample decays exponentially with time

(b) the activity (R) of the sample at any instant is directly proportional to the number of undecayed nuclei present in the sample at that time.

(c) the number of decayed nuclei grows exponentially with time.

(d) the number of decayed nuclei grows linearly with time.

23. 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?

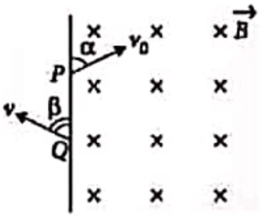
(a) If a lens is used to obtain the image, then it must be a diverging lens and its optical center will be the intersection point of line AB and OI

(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.

24. A particle of charge $-q$ and mass m enters a uniform magnetic field $\vec{B}$ (perpendicular to paper inwards) at P with a velocity v_0 at an angle α and leaves the field at Q with velocity v at an angle β as shown in figure. Which of the following statements are correct?



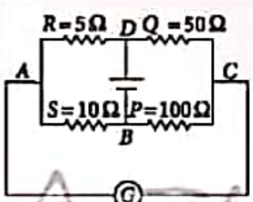
(a) $\alpha = \beta$

(b) $v = 3v_0$

(c) $PQ = \dfrac{2mv_0 \sin\alpha}{Bq}$

(d) particle remains in the field for time $t = \dfrac{2m}{Bq}$.

25. Figure shows a balanced Wheatstone bridge. Which of the following statements are correct?



(a) If P is slightly increased, the current in the galvanometer flows from C to A.

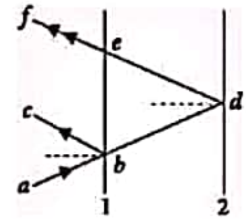
(b) If P is slightly increased, the current in the galvanometer flows from A to C.

(c) If Q is slightly increased, the current in the galvanometer flows from C to A.

(d) If Q is slightly increased, the current in the galvanometer flows from A to C.

Numerical Value Type

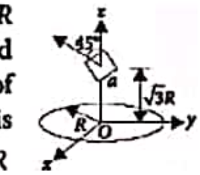
26. A narrow monochromatic beam of light of intensity I is incident on a glass plate as shown in figure. Another identical glass plate is kept close to the first one and parallel to it. Each glass plate reflects 25% of the light incident on it and transmits the remaining.



The ratio $\sqrt{\dfrac{I_{max}}{I_{min}}}$, if the interference pattern formed by two beams obtained after one reflection at each plate is ______.

27. A Bohr hydrogen atom undergoes a transition $n = 5$ to $n = 4$ and emits a photon of frequency υ. Frequency of circular motion of electron in $n = 4$ orbit is υ_4. The ratio υ/υ_4 is found to be $18/5m$. The value of m is ______.

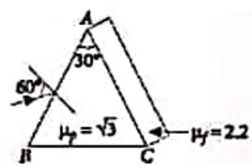
28. A circular wire loop of radius R is placed in the x-y plane centered at the origin O. A square loop of side a ($a << R$) having two turns is placed with its center at $z = \sqrt{3}R$ along the axis of the circular wire loop, as shown in figure. The plane of the square loop makes an angle of 45° with 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 $\mu_f = 2.2$. A monochromatic light of wavelength $\lambda = 550$ nm falls on the face AB at an angle of incidence of 60°.



29. The angle of emergence of light will be

(a) 0° (b) 30° (c) 45° (d) 60°

30. 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

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.

PHYSICS MUSING

SOLUTION SET-80

1. **(b) :** Applying KVL to the circuit, then

$$\frac{q_0}{C_0}+\frac{q}{C}+IR=E \quad \text{... (i)}$$

Differentiating this equation, we get

$$\frac{1}{C_0}\frac{dq_0}{dt}+\frac{1}{C}\frac{dq}{dt}+R\frac{dI}{dt}=0$$

or $\frac{dI}{I}=-\frac{dt}{RC_{eq}}$ (where, $C_{eq}=\frac{C_0C}{C_0+C}$) ...(ii)

Integrating eqn. (ii), we get , $\int_{I_0}^{I(t)}\frac{dI}{I}=-\int_0^t\frac{dt}{RC_{eq}}$

$\therefore \quad I(E)=I_0e^{-t/R}$ ...(iii)

where I_0 is the initial current.

Now $I_0R+\frac{q_0}{C_0}=E \Rightarrow I_0=\frac{\left(E-\frac{q_0}{C_0}\right)}{R}$ ...(iv)

Substituting eqn. (iv) in eqn. (iii), we get

$$I(t)=\left[\frac{E-(q_0/C_0)}{R}\right]e^{-t/RC_{eq}}$$

2. **(a) :** Consider a coaxial cylinder as a Gaussian surface, then

$\varepsilon_0(2\pi rL)E=(2\pi R_0L)\sigma$ or $E=\frac{\sigma R_0}{\varepsilon_0 r}$ ...(i)

According to Newton's second law,

$$m_e\frac{d^2r}{dt^2}=-e\left(\frac{R_0\sigma}{\varepsilon_0 r}\right) \quad \text{...(ii)}$$

Where, m_e is the mass of electron and e is the electronic charge.

From law of conservation of energy,

$$\frac{1}{2}m_ev_0^2-eV_0=-eV, \quad \text{...(iii)}$$

$$E=-\frac{dV}{dr} \quad \therefore \frac{R_0\sigma}{\varepsilon_0 r}=-\frac{dV}{dr}$$

On integrating both sides, we get

$$V=-\frac{\sigma R_0}{\varepsilon_0}\ln r+C \quad \text{...(iv)}$$

Also, $V_0=-\frac{R_0\sigma}{\varepsilon_0}\ln R_0+C$ ...(v)

From equations (iii), (iv) and (v), we get

$$v_0=\sqrt{\frac{2eR_0\sigma\ln(r/R_0)}{\varepsilon_0 m_e}}$$

3. **(c) :** Let h be the height of water level in the vessel at instant t which decreases by dh in time dt.

$\therefore$ Rate of flow of water through the capillary tube

$V=-A\left(\frac{dh}{dt}\right)$ ...(i)

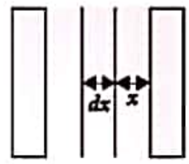
From Poiseuille's formula, $V=\frac{\pi Pr^4}{8\eta l}$ ...(ii)

The hydrostatic pressure at depth h is $P=\rho gh$

From (i) and (ii), we get $dt=-\frac{8\eta lA}{\pi\rho gr^4}\frac{dh}{h}$

$$\therefore \quad t=\int dt=-\frac{8\eta lA}{\pi\rho gr^4}\int_{h_1}^{h_2}\frac{dh}{h}=\frac{8\eta lA}{\pi\rho gr^4}\ln\frac{h_1}{h_2}$$

4. **(a) :** Let the number of electrons at a distance 'x' be n, then the increase in number of electrons per unit length is



$\frac{dn}{dx}=\alpha n$ ... (i)

$\int_{n_0}^{n}\frac{dn}{n}=\alpha\int_0^d dx$ or $\ln\left(\frac{n}{n_0}\right)=\alpha d$

$n=n_0e^{\alpha d}$ ... (ii)

Hence number of electrons reaching other plate per unit time is $n_0e^{\alpha d}$.

$\therefore$ Electronic current at opposite plate

= charge reaching per unit time

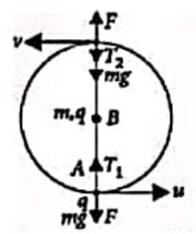
or $I=en=en_0e^{\alpha d}$ ... (iii)

Here, $n_0=(n_iAdx)$ and $n=(n_iAdx)e^{\alpha x}$

So, $I=\int en=\int_0^d en_iAe^{\alpha x}dx \Rightarrow I=en_iA\left(\frac{e^{\alpha d}-1}{\alpha}\right)$

Hence, $J=\frac{I}{A}=\frac{en_i}{\alpha}(e^{\alpha d}-1)$

5. **(5.86) :** From Newton's second law,



$T_2+mg-\frac{q^2}{4\pi\varepsilon_0l^2}=\frac{mv^2}{l}$ ...(i)

At the topmost point, $T_2=0$

$\therefore \quad mg-\frac{q^2}{4\pi\varepsilon_0l^2}=\frac{mv^2}{l}$ ...(ii)

From principle of energy conservation,

Energy at the lowest point = Energy at top most point

$\frac{1}{2}mu^2=\frac{1}{2}mv^2+mg(2l)$ or $v^2=u^2-4gl$ ...(iii)

From eqn. (ii), $v^2=gl-\frac{q^2}{4\pi\varepsilon_0ml}$ ...(iv)

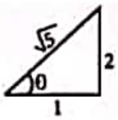
From equations (iii) and (iv), using $m=2\times10^{-3}$ kg we get, $u=5.86$ m s^{-1}

6. **(8.26)** : From equation $y = ax^2$,
$h_A = 1 \times (-2)^2 = 4$ m and $h_B = 1 \times (1)^2 = 1$ m
Let v be the velocity at point B.
From energy conservation between points A and B, we get, $mgh_A = mgh_B + \frac{1}{2}mv^2$

$$v = \sqrt{2g(h_A - h_B)} = \sqrt{2 \times 10(4-1)} = 2\sqrt{15}\ \text{m s}^{-1}$$

Slope of the path at B is $\frac{dy}{dx} = 2ax = \tan\theta$

$\therefore\ \tan\theta = 2 \qquad (\because\ x = 1,\ a = 1)$



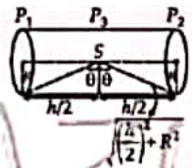
$\therefore\ \sin\theta = \frac{2}{\sqrt{5}}$ and $\cos\theta = \frac{1}{\sqrt{5}}$

Let t be the time of flight of ball from B to C. The vertical displacement of ball is 1 m. So

$$-h = v_y t - \frac{1}{2}gt^2;\ -1 = v\sin\theta t - \frac{1}{2}gt^2 \Rightarrow t = 1.52\ \text{s}$$

$\therefore$ The horizontal distance travelled is 5.26 m
$\therefore$ $D = 2 + 1 + 5.26 = 8.26$ m

7. **(70)** : Total power, $P = P_1 + P_2 + P_3$
As the end caps are placed symmetrically relative to the source, $P_1 = P_2$.
Thus, $P_3 = P - (P_1 + P_2) = P - 2P_1$
From figure, power flow through ring



$$P_1 = \frac{P}{4\pi} \times [2\pi(1 - \cos\theta)] = \frac{P}{2}\left[1 - \frac{h}{\sqrt{h^2 + 4R^2}}\right]$$

$$\therefore\ P_3 = P - 2 \times \frac{P}{2}\left[1 - \frac{h}{\sqrt{h^2 + 4R^2}}\right] = \frac{Ph}{\sqrt{h^2 + 4R^2}}$$

$$= \frac{0.1 \times 2}{\sqrt{(2)^2 + 4(1)^2}} \Rightarrow P_3 = 0.07\ \text{W} = 70\ \text{mW}.$$

8. **(6.3)** : As initially torque about P is zero, angular momentum of the system is conserved.

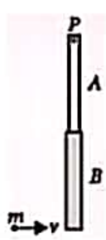
$\therefore\ mv \times 2L = I\omega$ ...(i)

Here $I = I_b + I_A + I_B$

$$I = m(L_A + L_B)^2 + M_B\left[\frac{L_B^2}{12} + \left(\frac{L_B}{2} + L_A\right)^2\right] + M_A\frac{L_A^2}{3}$$

Substituting the given values, we get $I = 0.09$ kg m^2

Thus, $0.05 \times v \times 1.2 = 0.09\omega \Rightarrow \omega = \frac{2}{3}v$



Now due to angular velocity ω the system will rotate and kinetic energy of rotation will be converted into potential energy.

$$\Delta U = mgh + M_Bg\left[L_A + \frac{L_B}{2}\right] + M_Ag\frac{L_A}{2}$$

$\Delta U = 0.081 \times 9.8$ J
By conservation of mechanical energy (after collision), we get

$$\frac{1}{2}I\omega^2 = \Delta U = 0.081 \times 9.8\ \text{J}$$
$\Rightarrow\ v = 6.3$ m s^{-1}

9. **(d)** : Suppose final temperature of gases = T
Heat rejected by gas in lower compartment

$= nC_V\Delta T = 2 \times \frac{3}{2}R(700 - T)$ ... (i)

Heat received by gas in upper compartment,
$= nC_P\Delta T$ (as piston is movable, so pressure is constant)

$= 2 \times \frac{7}{2}R(T - 400)$ ...(ii)

From eqn. (i) and (ii), $T = 490$ K

10. **(d)** : Let equilibrium temperature of the gases in the two compartments = T
Pressure of the gases in each compartment is constant and same.
Heat given by lower compartment = $nC_P\Delta T$

$= 2 \times \frac{5}{2}R(700 - T)$ ... (i)

Heat taken by upper compartment = $nC_P\Delta T$

$= 2 \times \frac{7}{2}R(T - 400)$ ... (ii)

From eqn. (i) and (ii), $T = 525$ K
In isobaric process, work done by gas, $\Delta W = nR\Delta T$
For lower compartment, $\Delta W_1 = -350\ R$
For upper compartment, $\Delta W_2 = 250\ R$
Net work done by gases to attain equilibrium
$= \Delta W_1 + \Delta W_2 = -100\ R$

YOU ASK WE ANSWER

Do you have a question that you just can't get answered? Use the vast expertise of our MTG team to get to the bottom of the question. From the serious to the silly, the controversial to the trivial, the team will tackle the questions, easy and tough. The best questions and their solutions will be printed in this column each month.

1. Suppose a current-carrying wire has a cross-sectional area that gradually becomes smaller along the wire, so that the wire has the shape of a very long cone. How does the drift speed of electrons vary along the wire?

– Sachin, Chennai

Ans. Every portion of the wire is carrying the same amount of current—otherwise, charge would build up or disappear somewhere along the wire. Thus for equation $I = \frac{\Delta Q}{\Delta t} = nqv_dA$ to be satisfied, as the cross-sectional area decreases, the drift speed must increase to maintain the constant current. This increased drift speed is a result of the electric field lines in the wire being distributed over a smaller area, thus increasing the magnitude of the field, and, in turn, increasing the electric force on the electrons.

2. How can the total energy of an atom be negative? For that matter, how can any energy be negative?

– Soumya Das (W.B.)

Ans. The way the total energy of an atom, and in fact other energies, can be negative is through an arbitrary choice of the zero point for potential energies. The electrostatic potential energy between charged particles is arbitrarily chosen to be zero when the particles are separated by an infinite distance. When two particles having opposite signs, such as the electron and proton in a hydrogen atom, are at finite distance apart, the potential energy is less than zero, or negative. If they are sufficiently close, the magnitude of the negative potential energy may exceed the positive kinetic energy, making the total energy negative.

3. You set up two oscillating systems, a simple pendulum and a block hanging from a vertical spring. You carefully adjust the length of the pendulum so that both oscillators have the same period. You now take the two oscillators to the Moon. Will they still have the same period as each other? What happens if you observe the two oscillators in an orbiting space shuttle?

– Santosh (Bihar)

Ans. The block hanging from the spring will have the same period on the Moon that it had on the Earth because the period depends on the mass of the block and the force constant of the spring, neither of which have changed. The period of the pendulum on the Moon will be different from its period on the Earth because the period of the pendulum depends on the value of g. Because g is smaller on the Moon than on the Earth, the pendulum will oscillate with a longer period.
In the orbiting space shuttle, the block-spring system will oscillate with the same period as on the Earth when it is set into motion, because the period does not depend on gravity. The pendulum will not oscillate at all. If you pull it to the side from a direction you define as "vertical" and release it, it stays there. Because the shuttle is in free-fall while in orbit around the Earth, the effective gravity is zero, and there is no restoring force on the pendulum.

4. It is a common observation that as a light bulb ages, it gives off less light than when new. Why?

– Rubby Yadav (Bihar)

Ans. There are two reasons for this, one electrical and one optical, but both are related to the same phenomenon occurring within the bulb. The filament of a light bulb is made of a tungsten wire that, in old light bulb, has been kept at a high temperature for many hours. These high temperatures cause tungsten to be evaporated from the filament, decreasing its radius. From $R = \rho l/A$, we see that a decreased cross-sectional area leads to an increase in resistance of the filament. This increasing resistance with age means that the filament will carry less current for the same applied voltage. With less current in the filament, there is less light output, and the filament glows more dimly.
At the high operating temperature of the filament, tungsten atoms leave the surface of the filament, much as water molecules evaporate from a puddle of water. These atoms are carried away by convection currents in the gas in the bulb and are deposited on the inner surface of the glass. In time, the glass becomes less transparent because of this tungsten coating, which decreases the amount of light that passes through the glass.

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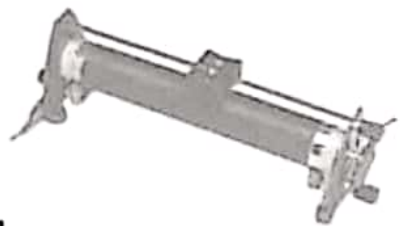
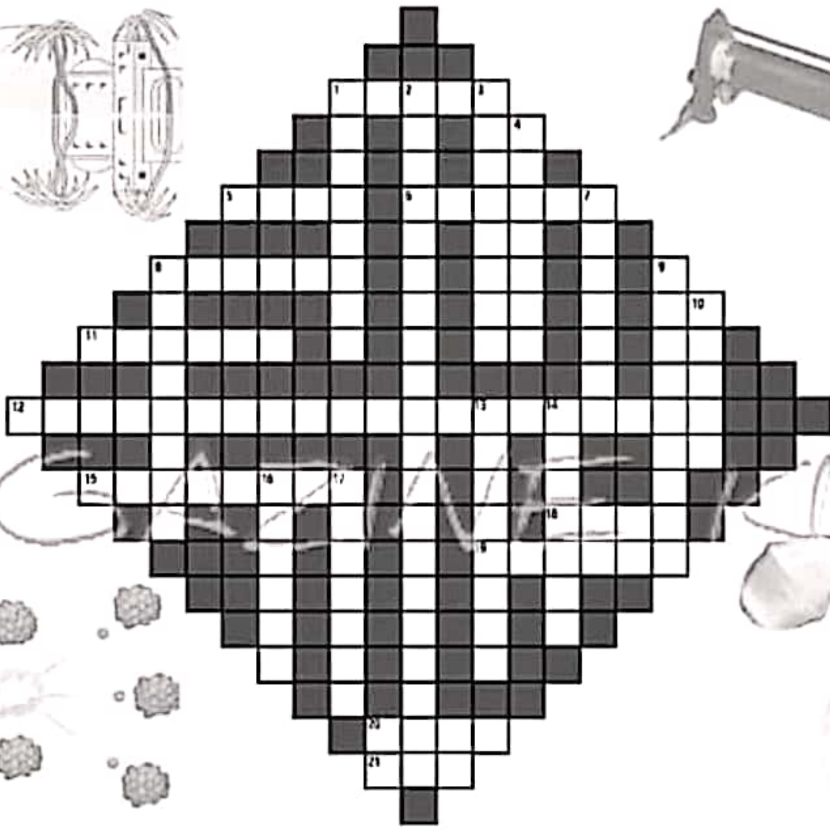
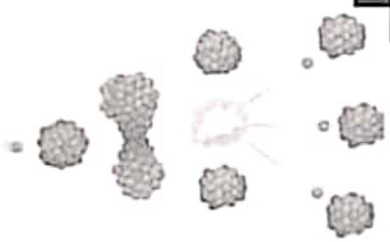
CROSSWORD

Readers can send solutions at editor@mtg.in or post us with their complete address by 10th of every month to get their names published in next issue.







DOWN

1. An electronic device that receives a signal and retransmits it. **(8)**
2. The harmonic motion in which amplitude decreases over time **(6, 8, 6)**
3. Any frequency greater than the fundamental frequency of a sound **(8)**
4. Splitting of heavy nucleus into two or more small fragments **(7)**
7. The force directed along the line joining the object and the origin **(7)**
8. Vectors which are scalar multiples of one another **(8)**
9. Substance in which stress and strain are not proportional **(9)**
10. Unit of electric dipole moment **(5)**
13. Device used to fine spray liquids **(8)**
14. Atoms with same atomic number but different mass number **(7)**
16. Perpendicular force acting on a surface **(6)**
17. The force exerted by a string when it is subjected to pull **(7)**

ACROSS

1. The process of communication across space without using wires **(5)**
5. A disturbance that moves through a medium **(4)**
6. An astronomical unit of distance **(6)**
8. A nuclide that undergoes radioactive decay **(6)**
11. An optical illusion caused by total internal reflection in the air **(6)**
12. Ratio of magnetic flux density and applied external magnetic field strength **(8, 12)**
15. A variable resistor, used to control voltage **(8)**
18. Distance/velocity/ **(4)**
19. Molecules with identical formulas but distinct structures **(6)**
20. Unit of pressure **(4)**
21. A logic gate in which output is obtained only when both inputs are high.**(3)**