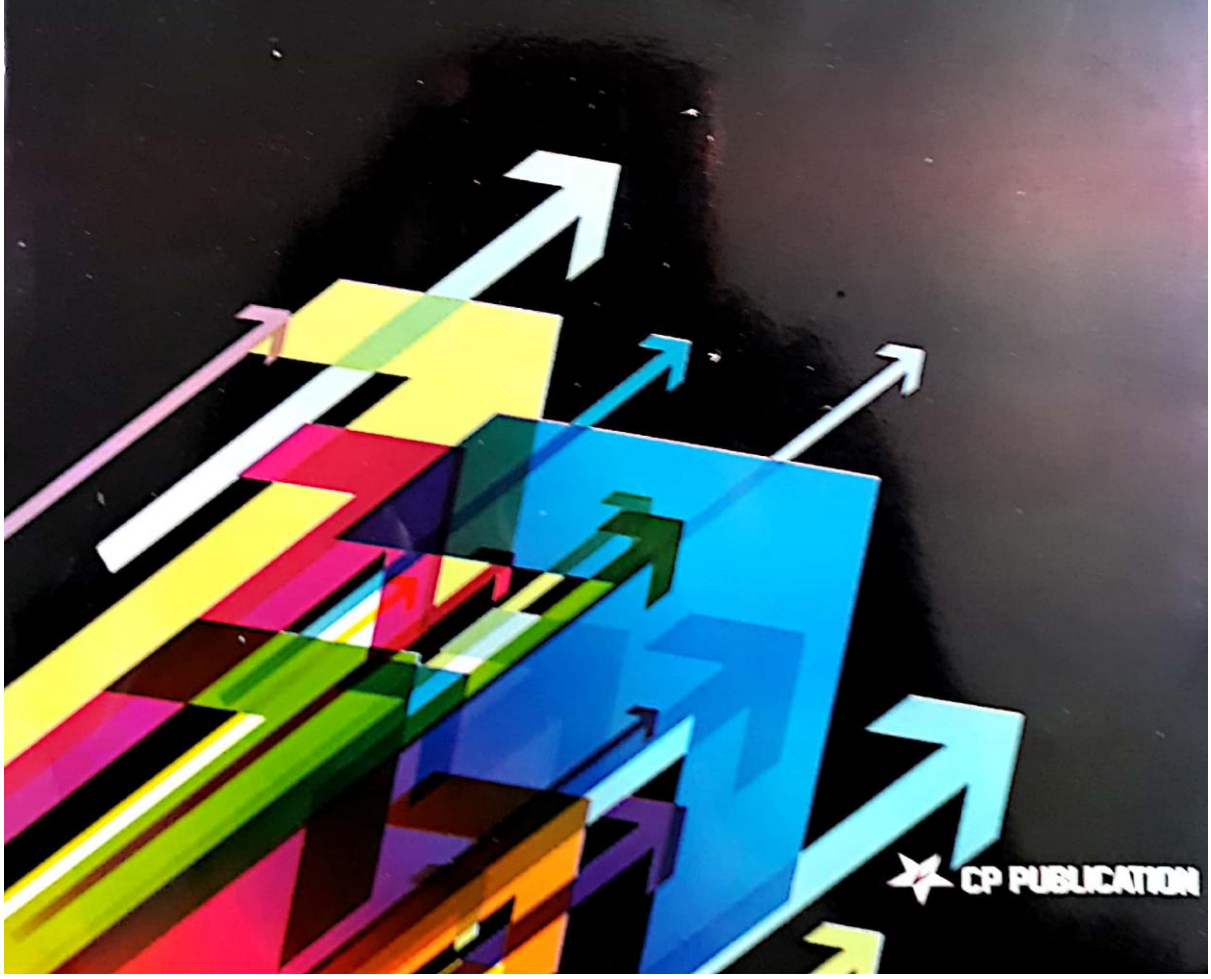
JEE (Advanced)
Physics
Challenging Problems For
Lakshya Batch



CP PUBLICATION

JEE ADVANCED

PHYSICS

Challenging Problems
FOR LAKSHYA BATCH

Preface

The primary objective this book is to help students to develop command over fundamentals and their application through challenging questions. In this book, only those problems have been selected, which in the opinion of Career Point Faculty team, are most important for mastering application of concepts.

This book covers variety of questions asked in the examination ~ be it MCQ (One or More than One correct choice), Numeric Response Type, Matrix match type, paragraph based questions etc. A mix of questions helps stimulated and strengthen question solving skills of the student.

The majority of questions are not easy; some of them are definitely difficult. We believe if you solve these questions at your own, you will achieve higher degree of understanding of concepts. We suggest you to attempt this book only after you complete a chapter.

This book is also used by "*Lakshya Batch*" students of Career Point to give finishing touch to their preparation for JEE-Advanced.

We hope this book would immensely help genuine, hardworking students in sharpening their questions solving skills enabling them to achieve a seat in most prestigious colleges.

We take this opportunity to express our deepest appreciation to CP Publishing team, who helped in editing of the book.

We will greatly appreciate if the users of this book communicate to us any errors, misprints or weaknesses that they may detect. We will incorporate the same in the subsequent editions.

Authors
Career Point

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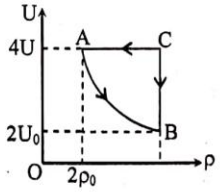
Chapter 16

Thermodynamics

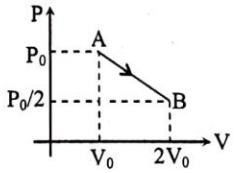
Single Correct Option Type Questions

Q.1 Figure show the variation of internal energy U with the density of one mole of monoatomic gas for a thermodynamic cycle ABCA. AB process is a rectangular hyperbola. The amount of work done in the process $A \rightarrow B$ is -



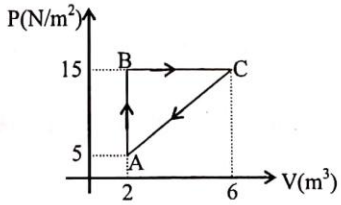
(A) $\frac{2U_0}{3}$ (B) $-\frac{2U_0}{3}$ (C) $\frac{4U_0}{3}$ (D) $-\frac{4U_0}{3}$

Q.2 One mole of a gas expands obeying the relation as shown in P-V diagram. The maximum temperature in this process is equal to -



(A) $\frac{P_0V_0}{R}$ (B) $\frac{3P_0V_0}{R}$ (C) $\frac{9P_0V_0}{8R}$ (D) None of these

Q.3 An ideal gas is taken along the reversible processes as represented by the adjoining diagram.



Select the incorrect statement

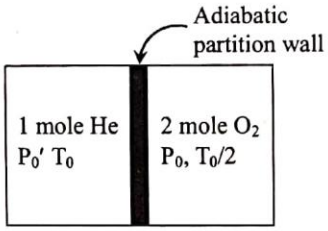
(A) For process $B \rightarrow C$, $\Delta U > 0$

(B) For process $C \rightarrow A$, work done by gas is negative

(C) For isochoric process change in internal energy is zero

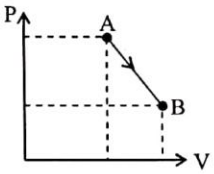
(D) For Isochoric process work done by gas is zero

Q.4 1 mole of He and 2 moles of O_2 are contained in an adiabatic cylinder at pressures and temperatures as shown in figure. If the adiabatic partition wall is removed then the final pressure will be



(A) $\frac{12}{13}P_0$ (B) $\frac{13}{16}P_0$ (C) P_0 (D) None of these

Q.5 One mole of an ideal gas undergoes a process AB where A ($2P_0$, V_0) & B ($1.5\ P_0$, $1.5\ V_0$). The process is shown in the PV diagram. The temperature of the gas (select the **WRONG** statement) :



(A) Increases and then decreases. (B) Only increases.

(C) Has a maximum value of $\frac{9}{4}\frac{P_0V_0}{R}$ (D) Is more at B than at A.

Q.6 For a process, relation between temperature and volume is TV^3 = constant. If a monatomic gas follows this process, then find the molar specific heat for this process [R is a gas constant].

(A) $\frac{7R}{6}$ (B) $\frac{R}{3}$ (C) $\frac{11R}{6}$ (D) zero

Q.7 A carnot refrigeration cycle absorbs heat at 270 K and rejects heat at 300K. If the cycle is absorbing 1260 kJ/min at 270K, then work required per second is :

(A) 2.33 kJ/sec (B) 4.66 kJ/sec (C) 1 kJ/sec (D) 4 kJ/sec

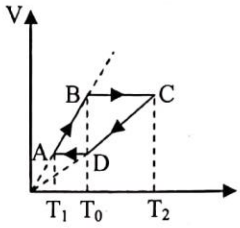
Q.8 Two adiabatic vessels, each containing the same mass m of water but at different temperatures, are connected by a rod of length L, cross-section A, and thermal conductivity K. The ends of the rod are inserted into the vessels, while the rest of the rod is insulated so that there is negligible loss of heat into the atmosphere. The specific heat capacity of water is s, while that of the rod is negligible.

The temperature difference between the two vessels reduces to $\frac{1}{e}$ of its original value after a time, Δt.

The thermal conductivity (K) of the rod may be expressed by

(A) $\frac{msL}{A\Delta t}$ (B) $\frac{emsL}{A\Delta t}$ (C) $\frac{msL}{2eA\Delta t}$ (D) $\frac{msL}{2AK}$.

Q.9 He work done by the one mole gas in the cyclic process shown in graph is W. Then



(A) $T_0 = \frac{T_1 + T_2}{2}$ (B) $T_o = \frac{W}{2R} + \frac{T_1 + T_2}{2}$ (C) $T_o = \frac{W}{2R}$ (D) $T_o = \frac{W}{2R} + \frac{T_1 - T_2}{2}$

Q.10 The relation between internal energy U, pressure P and volume V of a gas in an adiabatic process is :

$$U = a + bPV$$

Where a and b are constants. What is the value of the ratio of the specific heats ?

(A) $\frac{a}{b}$ (B) $\frac{b+1}{b}$ (C) $\frac{a+1}{a}$ (D) $\frac{b}{a}$

Q.11 The internal energy of a system remains constant when it undergo -

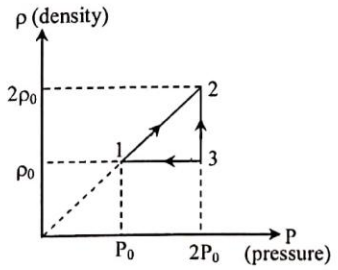
(a) a cyclic process
(b) an isothermal process
(c) an adiabatic process
(d) any process in which the heat given out by the system is equal to the work done on the system

(A) a, b, d (B) a, b, c (C) b, d (D) None

Q.12 Three moles of an inert monatomic gas is mixed with two moles of diatomic gas and mixture is heated by a process $V = \frac{K}{\sqrt{T}}$, where V and T are volume and temperature of mixture and K is constant. The molar heat capacity of this process for the mixture is.

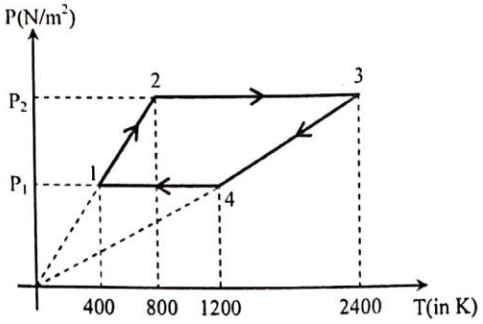
(A) $\frac{7R}{5}$ (B) $\frac{9R}{5}$ (C) $\frac{11R}{5}$ (D) None of these

Q.13 The density (ρ) versus pressure (P) graph of an ideal gas (monoatomic) undergoing a cyclic process is shown in figure. The gas taken has molecular weight M and one mole gas is taken. The heat reject by gas in process 3 to 1 in cycle is.



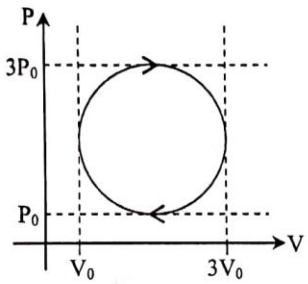
(A) $\frac{3P_0M}{\rho_0}$ (B) $\frac{3P_0M}{2\rho_0}$ (C) $\frac{5P_0M}{2\rho_0}$ (D) $\frac{5P_0M}{3\rho_0}$

Q.14 A thermal engine having three moles of mono-atomic gas as its working fluid undergoes the cycle process as shown in the figure. Find the mechanical work over one cycle approximately (R = 8.314 J/mole/k) -



(A) 40 kJ (B) 30 kJ (C) 20 kJ (D) 10 kJ

Q.15 An ideal gas undergoes a circular cycle as shown in the figure. Find the ratio of maximum temperature of cycle to minimum temperature of cycle -



(A) $\left(\frac{1+\sqrt{2}}{\sqrt{2}-1}\right)^2$ (B) $\left(\frac{2+\sqrt{2}}{2-\sqrt{2}}\right)^2$ (C) $\left(\frac{3+\sqrt{2}}{3-\sqrt{2}}\right)^2$ (D) $\left(\frac{4+\sqrt{2}}{4-\sqrt{2}}\right)^2$

Q.16 A gas is undergoing an adiabatic process. At a certain state, the value of volume and temperature = (V_0, T_0) and the magnitude of the slope of V-T curve is α. The value of C_V is

(A) $\left(1+\frac{\alpha T_0}{V_0}\right)R$ (B) $\frac{\alpha R V_0}{\cdot T_0}$ (C) $\left(1-\frac{\alpha T_0}{V_0}\right)R$ (D) $\frac{\alpha R T_0}{V_0}$

Q.17 An ideal diatomic gas undergoes a process in which the heat absorbed by the gas is twice the increment of its internal energy. Then the polytropic exponent of the process is

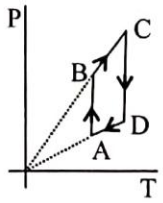
(A) 2 (B) 3/5 (C) 2/5 (D) 5/2

Q.18 A perfect gas of a given mass is heated first in a small vessel and then in a large vessel, such that their volumes remain unchanged. The P-T curves are

(A) parabolic with same curvature (B) parabolic with different curvature

(C) linear with same slopes (D) linear with different slopes

Q.19 Pressure versus temperature graph of an ideal gas is shown in figure



(A) During the process AB work done by the gas in positive
(B) during the process CD work done by the gas is negative
(C) during the process BC intemal energy of the gas is increasing
(D) None

Q.20 Two moles of monoatomic gas is expanded from (P_0, V_0) to $(P_0, 2V_0)$ under isobaric condition. Let ΔQ_1, be the heat given to the gas, ΔW_1 the work done by the gas and ΔU_1 the change in internal energy. Now the monoatomic gas is replaced by a diatomic gas. Other conditions remaining the same. The corresponding values in this case are ΔQ_2, ΔW_2, ΔU_2 respectively, then

(A) $\Delta Q_1 - \Delta Q_2 = \Delta U_1 - \Delta U_2$
(B) $\Delta U_2 + \Delta W_2 > \Delta U_1 + \Delta W_1$
(C) $\Delta U_2 > \Delta U_1$
(D) All of these

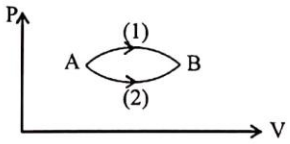
Q.21 The relation between U, p and V for an ideal gas in an adiabatic process is given by relation $U = a + bpV$. Find the value of adiabatic exponent (γ) of this gas.

(A) $\frac{b+1}{b}$ (B) $\frac{b+1}{a}$ (C) $\frac{a+1}{b}$ (D) $\frac{a}{a+b}$

Statement Based Questions

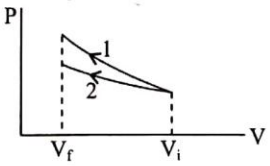
Q.22 **Statement-1 :** A gas is taken from state A to state B through two different paths. Molar specific heat capacity in path (1) is more as compared to (2).

Statement-2 : $C = \frac{\Delta Q}{n\Delta T}$; $\Delta Q = \Delta U + W$ and W is equal to area under p–V diagram.



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.23 **Statement-1 :** Work done in process 1 is greater than work done in process 2.
Statement-2 : Process 1 is isothermal and process 2 is adiabatic.



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.24 **Statement-1 :** For same compression ratio $\left(\frac{P_2}{P_1}\right)$ work done on system in isothermal process is less than the adiabatic process, if initial temperature, pressure and volume are same.
Statement-2 : Slope of the adiabatic process is more than isothermal process in P–V diagram.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

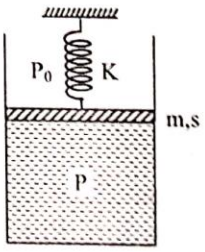
Q.25 **Statement-1 :** Temperature of Real gases often changes when undergoing a free expansion under adiabatic condition whereas that of an ideal gas does not.
Statement-2 : First law of thermodynamics holds for ideal goes only.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

Q.26 For 1 mole of monoatomic gas process is $T = V^2$ and temperature changes from 100 K to 400 K, then choose the correct option(s)
(A) Work done by the gas is 300 R
(B) Work done by the gas is 150 R
(C) Heat supplied to the gas is 600 R
(D) Heat supplied to the gas is 150 R

Q.27 Two cylinders A and B of equal capacity are connected to each other via a stop cock. A contains a gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. If the stop cock is suddenly opened then -
(A) Final pressure of gas in A and B is 0.5 atm
(B) There is no change in internal energy of the system
(C) The intermediate states of the system (before setting to the final equilibrium state) are well defined
(D) Through out the process, temperature remains constant.

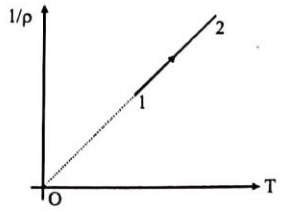
Q.28 In the arrangement shown in figure, vessel is thermally insulated. An ideal gas is filled in the cylinder having pressure P greater than atmospheric pressure P_0. The spring of force constant K is initially unstretched. The piston of mass m and area s is frictionless. In equilibrium, the piston rises up a distance x_0, then -



(A) Final pressure of the gas is $P_0 + \frac{Kx_0}{s} + \frac{mg}{s}$
(B) Work done by the gas is $\frac{1}{2}Kx_0^2 + mgx_0$
(C) Decrease in internal energy of the gas is $\frac{1}{2}Kx_0^2 + mgx_0 + P_0sx_0$
(D) Temperature of the gas increases

Q.29 The molar heat capacity for an ideal gas
(A) is zero for an adiabatic process
(B) is infinite for an isothermal process
(C) depends only on the nature of the gas for a process in which either volume or pressure is constant
(D) is equal to the product of the molecular weight and specific heat capacity for any process

Q.30 The figure shows a $1/\rho$ versus T graph from ideal gas. Choose the correct statements.



(A) The graph represents in isobaric expansion.
(B) Large the slope of straight line higher the pressure.
(C) Internal energy of the gas increases.
(D) Work done during the process is positive.

Q.31 An ideal gas undergoes a process such that $P \propto \frac{1}{T}$. The molar heat capacity of this process is 33.24 J/mol K.

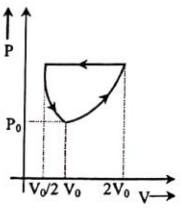
(A) The work done by the gas is $2R\Delta T$.
(B) Degree of freedom of the gas is 4.
(C) Degree of freedom of the gas is 3.
(D) $\gamma\left(\frac{C_P}{C_V}\right)$ for the gas is 1.5.

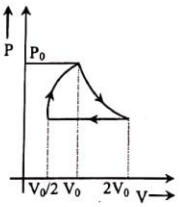
Q.32 A partition divides a container having insulated walls into two compartments I and II. The same gas fills the two compartments whose initial parameters are given. The partition is a conducting wall which can move freely without friction. Which of the following statements is/are correct, with reference to the final equilibrium position ?

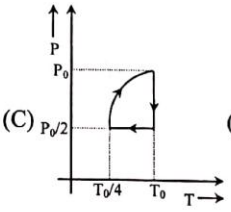
P, V, T I	2P, 2V, T II

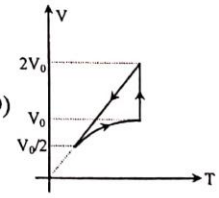
(A) The pressure in the two compartments are equal.
(B) Volume of compartment I is $\frac{3V}{5}$
(C) Volume of compartment II is $\frac{12V}{5}$
(D) Final pressure in compartment I is $\frac{5P}{3}$

Q.33 One mole of an ideal gas at volume V_0, pressure P_0 and temperature T_0 is expanded isothermally to twice its volume and then compressed at constant pressure to $(V_0/2)$ and the gas is brought back to original state by process in which $P \propto V$ (Pressure is directly proportional to volume). The correct representation of process is

(A) 

(B) 

(C) 

(D) 

Q.34 During an experiment, an ideal gas is found to obey a condition P^2/ρ = constant (ρ = density of the gas). The gas is initially at temperature T, pressure P and density ρ. The gas expands such that density changes to $\rho/2$ -

(A) The pressure of the gas changes to $\sqrt{2}P$
(B) The temperature of the gas changes to $\sqrt{2}T$
(C) The graph of the above process on the P – T diagram is parabola
(D) The graph of the above process on the P – T diagram is rectangular hyperbola

Q.35 A closed vessel contains a mixture of two diatomic gases A and B. Molar mass of A is 16 times that of B and mass of gas A, contained in the vessel is 2 times that of B -

(A) Average kinetic energy per molecule of gas A is equal to that of gas B

(B) Root mean square value of translational velocity of gas B is four times that of A

(C) Pressure exerted by gas B is eight times of that exerted by gas A

(D) Number of molecules of gas B in the cylinder is eight times that of gas A

Q.36 An insulated 0.2 m^3 tank contains helium at 1200 kPa and 47°C. A valve is now opened, allowing some helium to escape. The valve is closed when one half of the initial mass has escaped and pressure becomes 375 kPa. Then final temperature of the gas is ($\sqrt[3]{4} = 1.6$)

(A) 100 K (B) 200 K (C) 73°C (D) –73°C

Q.37 An ideal gas undergoes a process such $P \propto \frac{1}{T}$. The molar heat capacity of this process is 33.24 J/mol K.

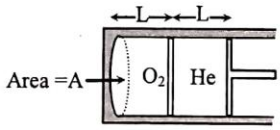
(A) The work done by the gas is $2R\Delta T$.

(B) Degree of freedom of the gas is 4.

(C) Degree of freedom of the gas is 3.

(D) $\gamma\left(\frac{C_P}{C_V}\right)$ for the gas is 1.5.

Q.38 An insulating cylinder contains equal volumes of He and O_2 separated by a massless freely moving adiabatic piston as shown. The gas is compressed by moving the insulating piston so that volume of He becomes half. Select the correct alternative(s).



(A) Pressure in He chamber will be equal to pressure in O_2 chamber

(B) Pressure in He chamber will be less then pressure in O_2 chamber

(C) Volume of He chamber will be equal to volume of O_2 chamber

(D) Volume of O_2 chamber will be $\frac{(LA)}{(2)^{25/21}}$

Q.39 One mole of an ideal gas undergoes a process $P = \frac{P_0}{1+(3V_0/V)^2}$. Here P_0 and V_0 are constants. Volume is changed from $V = V_0$ to $V = 3V_0$ -

(A) temperature of gas when its volume is $3V_0$ is $\frac{3P_0V_0}{2R}$

(B) temperature of gas when its volume is V_0 is $\frac{P_0V_0}{10R}$

(C) change in temperature is $5P_0V_0/8R$

(D) temperature remains constant

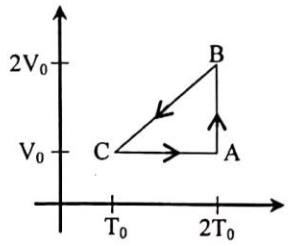
Q.40 The volume versus temperature graph given below, represents a process in which (γ-Adiabatic exponent)

(A) Work done by the gas is $nRT_0\,(1-2\log_e 2)$

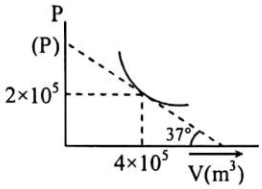
(B) Heat absorbed by the gas in BC is $\dfrac{\gamma nRT_0}{\gamma-1}$

(C) Efficiency of (with an ideal gas) the system is $\dfrac{2\log_e 2-1}{\gamma}$

(D) Heat evolved by the gas is $\dfrac{\gamma nRT_0}{\gamma-1}$



Q.41 P-V graph for an ideal gas undergoing polytropic process PV^N = constant is shown here. Then N is



(A) 1 (B) 2 (C) 1.5 (D) None of these

Q.42 One mole of a monoatomic ideal gas undergoes a thermodynamic process such that $\dfrac{V^3}{T^2}$ = constant. Then,

(A) work done by the gas is 200 R when temperature of the gas is raised by 300 K

(B) the specific heat of the gas in the process is $\dfrac{13}{6}R$

(C) work done by the gas is 300 R when temperature of the gas is raised by 600 K

(D) the specific heat of the gas in the process is $\dfrac{21}{4}R$

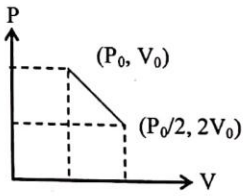
Q.43 One mole an ideal gas expands obeying the relation as shown in the P-V diagram.

(A) The maximum temperature in this process is equal to $9P_0V_0/8R$

(B) The maximum temperature in this process is equal to $9P_0V_0/4R$

(C) Maximum temperature occurs when pressure is $3P_0/4$

(D) Minimum temperature in this process is P_0V_0/R.



Q.44 A gas is enclosed in a cylinder of volume V_0 fitted with piston of cross-sectional area A and mass m. Atmospheric pressure is P_0. Adiabatic exponent of gas is γ. The piston is slightly depressed and released.

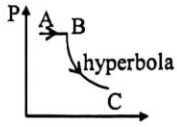
(A) Time period of oscillation of piston if the process is isothermal is $2\pi\sqrt{\dfrac{mV_0}{A^2P_0}}$

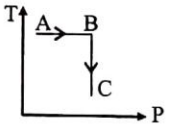
(B) Time period of oscillation of piston if the process is adiabatic is $2\pi\sqrt{\dfrac{\gamma mV_0}{A^2P_0}}$

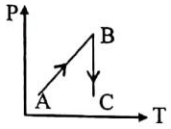
(C) Time period of oscillation of piston if the process is isothermal is $2\pi\sqrt{\dfrac{mV_0}{AP_0}}$

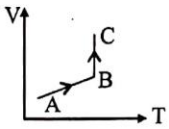
(D) Time period of oscillation of piston if the process is adiabatic is $2\pi\sqrt{\dfrac{mV_0}{\gamma A^2P_0}}$

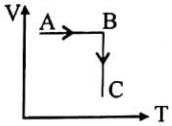
Q.45 A process is shown in the diagram. Which of the following curves may represent the same process?



(A) 

(B) 

(C) 

(D) 

Q.46 An ideal gas expands in such a way that PV^2 = constant throughout the process.

(A) The graph of the process of T-V diagram is a parabola

(B) The graph of the process of T-V diagram is a straight line.

(C) Such an expansion is possible only with heating.

(D) Such an expansion is possible only with cooling.

Q.47 A gas expands such that its initial and final temperature are equal. Also, the process followed by the traces a straight line on the P-V diagram

(A) The temperature of the gas remains constant throughout.

(B) The temperature of the gas first increases and then decreases.

(C) The temperature of the gas first decreases and then increases.

(D) The straight line has a negative slope.

Q.48 A mixture of ideal gases 7 kg of nitrogen and 11 kg of CO_2. Then

(Take for γ nitrogen and CO_2 as 1.4 and 1.3 respectively)

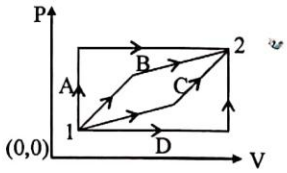
(A) equivalent molecular weight of the mixture is 36.

(B) equivalent molecular weight of the mixture is 18.

(C) γ for the mixture is 5/2

(D) γ for the mixture is 47/35.

Q.49 An ideal gas is taken from state 1 to state 2 through optional path A, B, C & D as shown in P-V diagram. Let Q, W and U represent the heat supplied, work done & internal energy of the gas respectively. Then



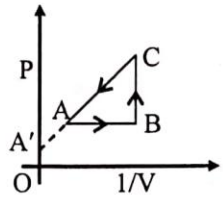
(A) $Q_B - W_B > Q_C - W_C$

(B) $Q_A - Q_D = W_A - W_D$

(C) $W_A < W_B < W_C < W_D$

(D) $Q_A > Q_B > Q_C > Q_D$

Q.50 An enclosed ideal gas is taken through a cycle as shown in the figure. Then



(A) Along AB, temperature decreases while along BC temperature increases
(B) Along AB, temperature increases while along BC the temperature decreases.
(C) Along CA work is done by the gas and the internal energy remains constant.
(D) Along CA work is done on the gas and internal energy of the gas increases.

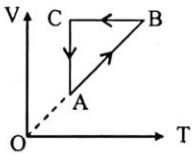
Q.51 Two gases have the same initial pressure, volume and temperature. They expand to the same final volume, one adiabatically and the other isothermally
(A) The final temperature is greater for the isothermal process
(B) The final pressure is greater for the isothermal process
(C) The work done by the gas is greater for the isothermal process
(D) All the above options are incorrect

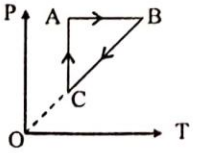
Q.52 The first law of thermodynamics can be written as $\Delta U = \Delta Q + \Delta W$ for an ideal gas. Which of the following statement is correct?
(A) ΔU is always zero when no heat enters or leaves the gas
(B) ΔW is the work done by the gas in this written law.
(C) ΔU is zero when heat is supplied and the temperature stays constant
(D) $\Delta Q = -\Delta W$ when the temperature increases very slowly.

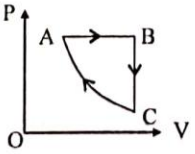
Q.53 2 moles of a monoatomic gas are expanded to double its initial volume, through a process P/V = constant. If its initial temperature is 300 K, then which of the following is not true.
(A) $\Delta T = 900$ K (B) $\Delta Q = 3200$ R (C) $\Delta Q = 3600$ R (D) W = 900 R

Q.54 An ideal gas is subjected to a thermodynamic process in which its pressure increases but volume decreases. Then
(A) the process may be isothermal
(B) work done by the gas is positive
(C) the process may be adiabatic
(D) change in its internal energy is equal to the work done by the gas

Q.55 An ideal gas undergoes a thermodynamics cycle as shown in figure. Which of the following graphs represents the same cycle?



(A)


(B)


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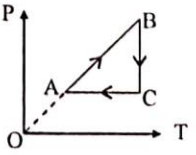

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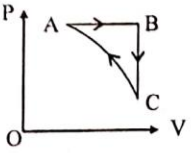
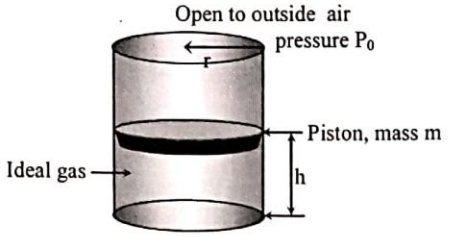


Passage Based Questions

Passage # 1 (Q.56 to 58)



A vertical cylinder of radius r contains a quantity of ideal gas and is fitted with a piston with mass m that is free to move. The piston and the walls of the cylinder are frictionless. Entire cylinder is placed in a constant temperature bath. The outside air pressure is P_0. In equilibrium the piston sits at a height h above the bottom of the cylinder.

Q.56 Absolute pressure of the gas trapped below the piston when it is in equilibrium -

(A) P_0 (B) $P_0 + mg$ (C) $P_0 + \frac{mg}{\pi r^2}$ (D) $P_0 - \frac{mg}{\pi r^2}$

Q.57 After the piston is displaced slightly from equilibrium and released, it oscillates up and down. The angular frequency of these small oscillations is -

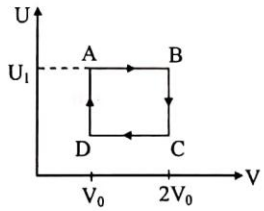
(A) $\sqrt{\frac{g}{h}\left(1-\frac{P_0\pi r^2}{mg}\right)}$ (B) $\frac{g}{h}\left(1+\frac{P_0\pi r^2}{mg}\right)$ (C) $\sqrt{\frac{g}{h}\left(1+\frac{P_0\pi r^2}{mg}\right)}$ (D) $\sqrt{\frac{g}{h}\left(1+\frac{mg}{P_0\pi r^2}\right)}$

Q.58 If the displacement of piston is not small then motion of piston is -

(A) simple harmonic motion (B) non-simple harmonic motion
(C) no motion takes place (D) data is insufficient

Passage # 2 (Q.59 to 61)

One mole of an ideal gas has an internal energy given by $U = U_0 + 2\,PV$, where P is the pressure and V the volume of the gas. U_0 is a constant. This gas undergoes the quasi-static cyclic process ABCD as shown in the U–V diagram.



Q.59 The molar heat capacity of the gas at constant pressure is

(A) 2R (B) 3R (C) $\frac{5}{2}R$ (D) 4R

Q.60 The work done by the ideal gas in the process AB is

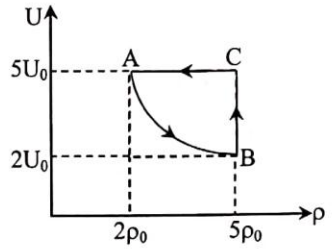
(A) zero (B) $\frac{U_1 - U_0}{2}$ (C) $\frac{U_0 - U_1}{2}$ (D) $\frac{U_1 - U_0}{2}\log_e 2$

Q.61 Assuming that the gas consists of a mixture of two gases, the gas is

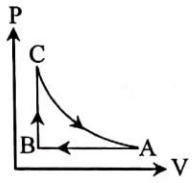
(A) Monatomic. (B) Diatomic.
(C) A mixture of mono and diatomic gases. (D) A mixture of di- and tri-atomic gases

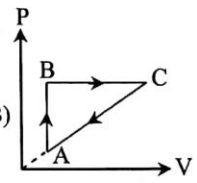
Passage # 3 (Q.62 & 63)

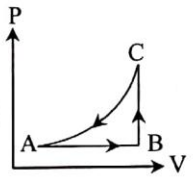
Figure shows the variation of internal energy U with the density ρ of one mole of ideal monatomic gas for a thermodynamics cyclic process ABCA. Here process AB is a part of rectangular hyperbola,



Q.62 The P-V diagram of above

(A) 

(B) 

(C) 

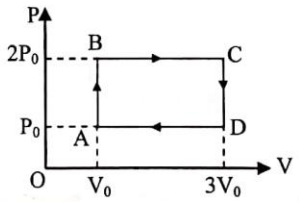
(D) None of these

Q.63 The total amount of heat absorbed by the system for cyclic process is -

(A) $\left(\frac{10}{3}\ell n2.5-2\right)U_0$ (B) $\left(\frac{10}{3}\ell n0.4-2\right)U_0$ (C) $50\ U_0$ (D) None of these

Passage # 4 (Q.64 & 65)

The figure shows P–V diagram of a thermodynamic cycle



Q.64 If T_A, T_B, T_C and T_D are the respective temperature at A, B, C and D. Then, choose the correct statement. $T_A = T_0$.

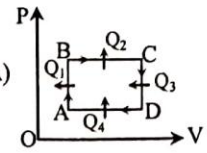
(A) The maximum temperature during the cycle occurs at C

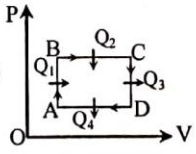
(B) $T_D = 3T_0$

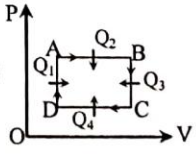
(C) $T_B = 2T_0$

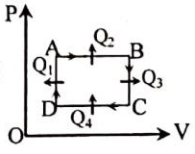
(D) all the above

Q.65 Identify the diagram which correctly represents the heat inflow and outflow of the system

(A) 

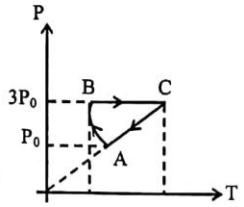
(B) 

(C) 

(D) 

Passage # 5 (Q.66 & 67)

One mole of monoatomic gas is taken through cyclic process. $T_A = 300$ K.
Process AB is defined as PT = constant.



Q.66 Work done by gas in process AB is

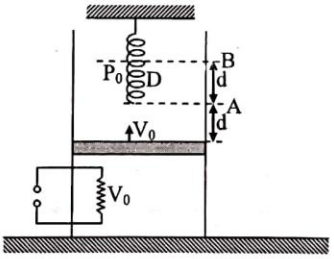
(A) more than work done by gas in process CA (B) – 400 R
(C) 200 R (D) – 300 R

Q.67 Change in internal energy in process CA

(A) –900 R (B) + 900 R (C) is negative (D) is positive

Passage # 6 (Q.68 to 70)

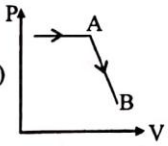
A mass less piston, which can move without friction, closes a sample of Helium in a vertical, thermally insulated cylinder, when is closed at its bottom, and the cross-section of which is A = 2 dm^2. Above the piston there is a fixed stand to which an unstretched spring of spring constant 2000 N/m is attached, whose bottom end is at a distance of 2 dm from the piston when the volume of the gas is $V_0 = 8$ dm^3. The external pressure is $p_0 = 10^5$ Pa, g = 10 m/s^2. The gas confined in the cylinder is heated with an electric heating element. (1 dm = 10^{-1} m)

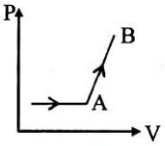


Q.68 How much heat is supplied by the element till it reaches the spring

(A) Zero (B) 600 J (C) 8000 J (D) 1000 J

Q.69 How will process look like on a PV diagram

(A)


(B)


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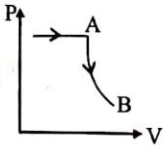

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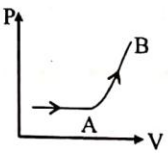
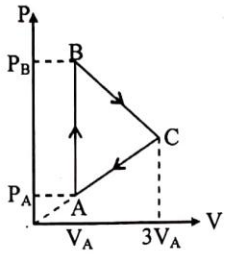


Q.70 What is the ratio of work done by gas in moving the piston from initial position to A, and from there to B

(A) $\frac{10}{11}$ (B) $\frac{11}{10}$ (C) $\frac{5}{3}$ (D) $\frac{3}{5}$

Passage # 7 (Q.71 to 73)

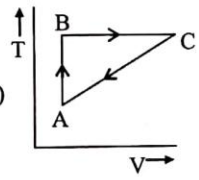
A sample of ideal gas is taken through the cyclic process shown in the figure. The temperature of the gas at state A is $T_A = 200$ K. At states B and C the temperature of the gas is the same.

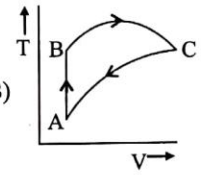


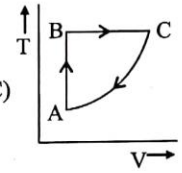
Q.71 Net work done by the gas in the process is

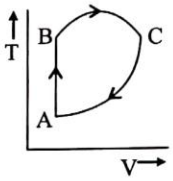
(A) $2P_AV_A$ (B) $4P_AV_A$ (C) $6P_AV_A$ (D) $8P_AV_A$

Q.72 Which of the following graphs best represent the cyclic process in T-V diagram

(A) 

(B) 

(C) 

(D) 

Q.73 What is the greatest temperature of the gas during the cylic process?

(A) 600 K (B) 1200 K

(C) 2400 K (D) None of these

Column Matching Type Questions

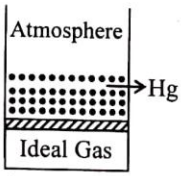
Q.74 Column I contain different process and column II contains molar heat capacity. Match the following:

Column-I	**Column-II**
(A) $T = T_0 e^{\alpha V}$	(P) $C_V + \frac{R}{1+\alpha V}$
(B) $P = P_0 e^{\alpha V}$	(Q) $\frac{\gamma R}{\gamma - 1} + \frac{\alpha R}{P_0 V}$
(C) $P = P_0 + \alpha/V$	(R) $C_V + \frac{R}{\alpha V}$
(D) $T = T_0 + \alpha/V$	(S) $C_V + R(1 + \frac{T_0}{\alpha V})$
	(T) None

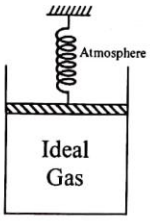
Q.75 Column I shows certain thermodynamic systems and column II represents thermodynamic properties.

Column I

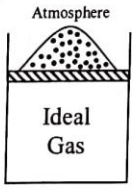
(A) An ideal gas is filled in a cylindrical vessel of which is enclosed by a massless piston. Mercury is filled above the piston as shown. Now gas is slowly supplied heat. Mercury does not spill. The system is kept in open atmosphere.



(B) A cylindrical vessel is enclosed by a light piston. The piston is connected to ceiling by an ideal spring as shown in figure. Spring is initially relaxed and then heat is supplied slowly to the ideal gas in the vessel. The system is kept in open atmosphere



(C) A thermally insulated cylindrical vessel is enclosed by a light thermally insulated piston. Some sand is kept on top of piston as shown in figure. The system is kept in open atmosphere. Now sand grains are removed slowly one by one



(D) A good conducting cylindrical vessel is enclosed by a light thermally insulated piston. Some sand is kept on top of piston as shown in figure. The system is kept in open atmosphere. Now sand grains are added slowly one by one.

Column II

(P) Internal energy of the gas is increasing

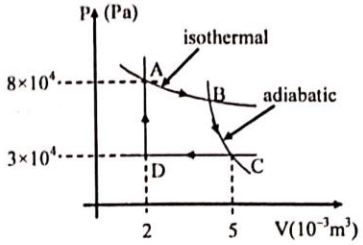
(Q) Pressure of the gas is increasing

(R) Temperature of the gas is decreasing

(S) Work done by gas is positive

(T) Molar heat capacity of the gas is finitely positive

Q.76 Figure shows a cyclic process for one mole of an ideal gas C_p and C_v of the gas is 20.8 J/molK and 12.5 J/molK respectively. Match the column A with B.



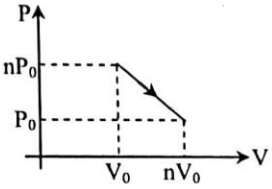
Column-I	Column-II
(A) $T_A = T_B$.	(P) 18 K.
(B) T_C.	(Q) – 15 J.
(C) ΔQ (CD).	(R) – 225 J.
(D) ΔU (BC).	(S) 19.2 K.

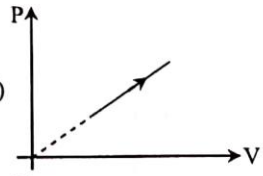
Q.77 Match the following :

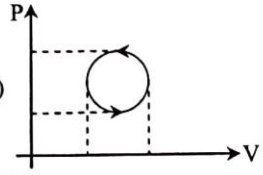
Column I	Column II
(A) Work done by an ideal gas in a closed system	(P) Path dependent
(B) Internal energy of an ideal gas in a closed system	(Q) State function
(C) Molar heat capacity of an ideal gas in a closed system	(R) May be constant (other than zero)
(D) Heat absorbed or rejected by an ideal gas in a closed system	(S) May be zero.

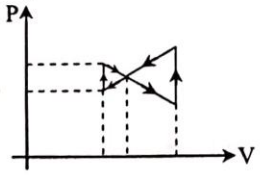
Q.78 Match the following.

List-I

(P)


(Q)


(R)


(S)


List-II

(1) W > 0

(2) $\Delta Q > 0$

(3) $\Delta U = 0$

(4) $\Delta U > 0$

(5) W < 0

Codes :

	P	Q	R	S
(A)	(1, 2)	(1, 4)	3	5
(B)	(2, 3)	4	(3, 5)	5
(C)	(1, 2, 3)	(1, 2, 4)	(3, 5)	(3, 5)
(D)	(1, 2)	(2, 4)	(3, 5)	5

Q.79 When gases are heated, the amount of heat energy depends on the increase in its internal energy and external work done. List-I mentions the heat absorbed by ideal gas while List-II mentions the corresponding changes.

List-I	List-II
(P) Heat absorbed does not do any external work	(1) Isothermal changes
(Q) Heat absorbed is used to do maximum external work	(2) Adiabatic changes
(R) Heat absorbed or evolved is zero during changes in temperature	(3) Isochoric changes
(S) Internal energy of system containing gas remains constant	(4) Isobaric changes

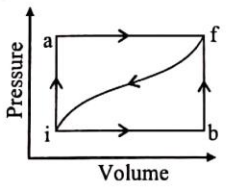
Codes :

	P	Q	R	S
(A)	3	4	2	1
(B)	4	3	1	2
(C)	1	2	3	4
(D)	4	1	2	3

Q.80 Match the processes in column I with the possibilities in column II, where ΔQ and W are heat change and work done respectively.

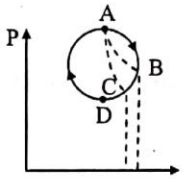
	Column I		Column II
(A)	Isobaric	(P)	$\Delta Q > 0$
(B)	Isothermal	(Q)	$\Delta Q < 0$
(C)	Isochoric	(R)	$W > 0$
(D)	Adiabatic	(S)	$W < 0$

Q.81 When a sample of a gas is taken from state i to state f along path iaf, heat supplied to the gas is 50 cal and work done by the gas is 20 cal. If it is taken by path ibf, then heat supplied is 36 cal.



Column I	Column II
(A) Work done by the gas along path ibf is	(P) 6 cal
(B) If work done upon the gas is 13 cal for the return path fi, then heat rejected by the gas along path fi is	(Q) 18 cal
(C) If internal energy of the gas at state i is 10 cal, then internal energy at state f is	(R) 40 cal
(D) If internal energy at state b is 22 cal and at i is 10 cal then heat supplied to the gas along path ib is	(S) 43 cal

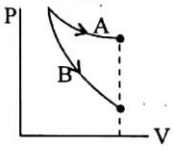
.82 For an ideal gas a process PV diagram is a circle. An adiabatic from A passes through C. An isotherm from A passes through B. We take part of the circular cyclic process. Comment on the sign of the quantity Column-I.



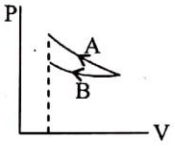
Column I	Column II
(a) Heat given to the gas in going from A to C	(P) Positive
(b) Heat given to the gas in going from B to C	(Q) Negative
(c) Heat given to the gas in going from C to D	(R) Zero
	(S) Can't be said

Q.83 An ideal gas undergoes two processes A and B. One of these is isothermal and the other is adiabatic.

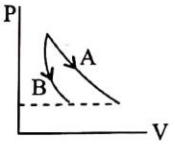
Column I **Column II**

(A) 

(P) Heat supplied during curve A is positive

(B) 

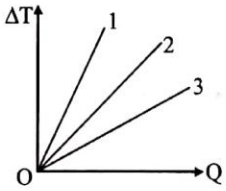
(Q) Work done by gas in both processes positive

(C) 

(R) Internal energy increases in adiabatic process

(S) Temperature of gas in process B is constant

Q.84 The straight lines in the figure depict the variations in temperature ΔT as a function of the amount of heat supplied Q in different process involving the change of state of a monatomic and a diatomic ideal gas. The initial states (P, V, T) of the two gases are the same. Fill in the blanks correct number of the straight line as shown in the figure.

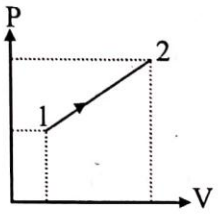


Column I	Column II
(A) Isobaric process of monoatomic gas	(P) 1
(B) Isobaric process of diatomic gas	(Q) 2
(C) Isochoric process of monoatomic gas	(R) 3
(D) Isochoric process of diatomic gas	(S) x-axis (i.e. 'Q' axis)

Numeric Response Type Questions

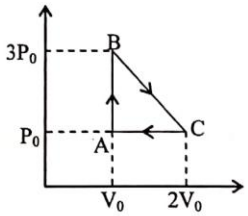
Q.85 The equation of state for a gas is given by $PV = nRT + \alpha V$, where n is the number of moles and α is a positive constant. The initial temperature and pressure of one mole of the gas contained in a cylinder are T_0 and P_0 respectively. The work done by the gas when its temperature doubles isobarically is $\frac{x}{7}\left(\frac{P_0T_0R}{P_0-\alpha}\right)$. Find x.

Q.86 A process $1 \rightarrow 2$ using 1 mole of diatomic gas is shown on the P-V diagram below. $P_2 = 2P_1$, $V_2 = 4V_1$. The molar heat capacity of the gas in this process is (22R/x). Find x

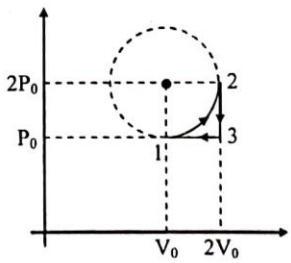


Q.87 One mole of an ideal gas (mono-atomic) at temperature T_0 expands slowly according to law $P = C\sqrt{T}$ (C is constant). If final temperature is $2T_0$. heat supplied to gas is $\frac{14}{x}RT_0$. Find x

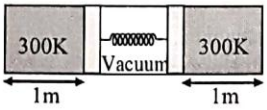
Q.88 One mole of an ideal monoatomic gas is taken round the cyclic process ABCA as shown in figure. If net heat absorbed by gas in the path BC is $\frac{P_0V_0}{n}$, then find the value of n.



Q.89 One mole of ideal monoatomic gas is taken along a cyclic process as shown in the figure. Process $1 \rightarrow 2$ shown is $1/4^{th}$ part of a circle as shown by dotted line process $2 \rightarrow 3$ is isochoric while $3 \rightarrow 1$ is isobaric. If efficiency of the cycle is n% where n is an integer. Find n.

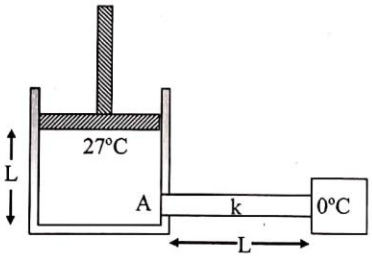


Q.90 Consider the shown diagram where the two chambers separated by piston-spring arrangement contain equal amounts of certain ideal gas. Initially, when the temperatures of the gas in both the chambers are kept at 300 K. The compression in the spring is 1 m. The temperature of the left and the right chambers are now raised to 400 K and 500 K respectively. If the pistons are free to slide, if the final compression in the spring (in cm) is 65 x. Find value of x.

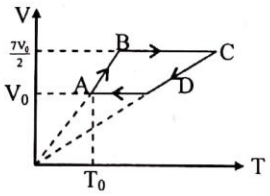


Q.91 A vessel of volume 3V contains a gas at pressure $4P_0$ and another vessel of volume 2V contains the same gas at pressure 1.5 P_0. Both vessels have same temperature. When both vessels are connected by a tube of negligible volume, the equilibrium pressure is IP_0, where I is an integer. Find the value of I.

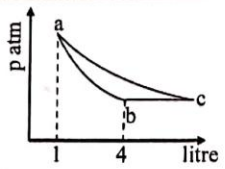
Q.92 0.5 mole of an ideal gas is kept inside an adiabatic cylinder of length 'L' and cross-sectional area 'A' closed by massless adiabatic piston. The cylinder is attached with a conducting rod of length 'L', cross-sectional area $\frac{1}{900}m^2$ and thermal conductivity 415.5 W/m-K, whose other end is maintained at 0°C. The piston is moved such that the temperature of the gas remains constant at 27° C. Find the velocity (in mm/sec) of piston when it is at height L/2 from the bottom of cylinder. Rod is well lagged and has negligible heat capacity. R = 8.31 J/mol-K.



Q.93 A sample of an ideal non linear tri-atomic gas has a pressure P_0 and temperature T_0 taken through the cycle as shown starting from A. Pressure for process C → D is 3 times P_0 Calculate heat absorbed in the cycle and work done.

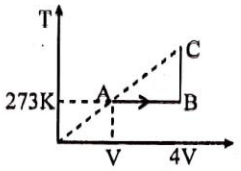


Q.94 Figure shows three processes for an ideal gas. The temperature at 'a' is 600 K, pressure 16 atm and volume 1 litre. The volume at 'b' is 4 litre. Out of the two process ab and ac, one is adiabatic and he other is isothermal. The ratio of specific heats of the gas is 1.5. Answer the following



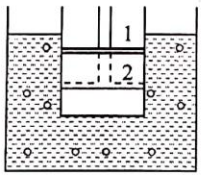
(i) Which of ab and ac processes is adiabatic. Why?
(ii) Compute the pressure of the gas at b and c.
(iii) Compute the temperature at b and c.
(iv) Compute the volume at c.

Q.95 At a temperature of $T_0 = 273°$ K, two moles of an ideal gas undergoes a process as shown. The total amount of heat imparted to the gas equals $Q = 27.7$ kJ.

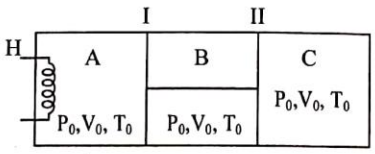


Determine the ratio of molar specific heat capacities.

Q.96 A cylinder containing a gas is closed by a movable piston. The cylinder is submerged in an ice-water mixture. The piston is quickly pushed down from position 1 to position 2. The piston is held at position 2 until the gas is again at 0° C and then slowly raised back to position 1. Represent the whole process on P-V diagram. If m = 100 gm of ice are melted during cycle, how much work is done on the gas. Latent heat of ice = 80 cal/gm.

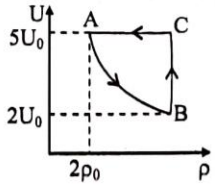


Q.97 The figure shows an insulated cylinder divided into three parts A, B and C. Pistons I and II are connected by a rigid rod and can move without friction inside the cylinder. Piston I is perfectly conducting while piston II is perfectly insulating. The initial state of the gas ($\gamma = 1.5$) present in each compartment A, B and C is as shown. Now, compartment A is slowly given heat through a heater H such that the final volume of C becomes $\frac{4V_0}{9}$. Assume the gas to be ideal and find.



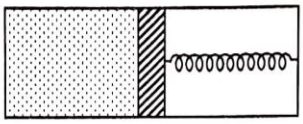
(a) Final pressures in each compartment A, B and C
(b) Final temperatures in each compartment A, B and C
(c) Heat supplied by the heater
(d) Work done by gas in A and B
(e) Heat flowing across piston I.

Q.98 Figure shows the variation of the internal energy U with the density ρ of one mole of ideal monatomic gas for a thermodynamic cycle ABCA. Here process AB is a part of rectangular hyperbola



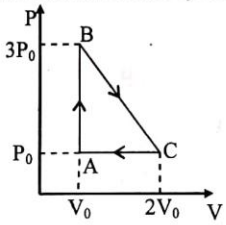
(a) Draw the P-V diagram for the above process.
(b) Find the net amount of heat absorbed by the system for the cyclic process.
(c) Find the work done in the process AB.

Q.99 A thermally insulated vessel is divided into two parts by a heat-insulating piston which can move in the vessel without the friction. The left part of the vessel constains one mole of an ideal monatomic gas, & the right part is vacuum. The piston is connected to the right wall of the vessel through a spring whose length in free state is equal to the length of the vessel as shown in the figure Determine the heat capacity C of the system, neglecting the heat capacities of the vessel, piston and spring.



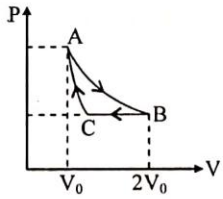
Q.100 A weightless piston divides a thermally insulated cylinder into two parts of volumes V and 3V. 2 moles of an ideal gas at pressure P = 2 atmosphere are confined to the part with volume V = 1 litre. The remainder of the cylinder is evacuated. The piston is now released and the gas expands to fill the entire space of the cylinder. The piston is then pressed back to the initial position. Find the increase of internal energy in the process and final temperature of the gas. The ratio of the specific heat of the gas $\gamma = 1.5$.

Q.101 One mole of an ideal monoatomic gas is taken round the cyclic process ABCA as shown in figure, calculate



(a) the work done by the gas
(b) the heat rejected by the gas in the path CA and the heat absorbed by the gas in the path AB.
(c) the net heat absorbed by the gas in the path BC
(d) the maximum temperature attained by the gas during the cycle.

Q.102 In a cycle ABCA consisting of isothermal expansion AB, isobaric compression BC and adiabatic compression CA, find the efficiency of cycle
(Given : $T_A = T_B = 400$ K, $\gamma = 1.5$)



ANSWER KEY

Single Correct Option type Questions

1. (D)	**2.** (C)	**3.** (C)	**4.** (A)	**5.** (A)	**6.** (A)	**7.** (A)
8. (D)	**9.** (B)	**10.** (B)	**11.** (A)	**12.** (A)	**13.** (B)	**14.** (C)
15. (D)	**16.** (D)	**17.** (B)	**18.** (D)	**19.** (C)	**20.** (D)	**21.** (A)

Statement Based Questions

22. (A)	**23.** (C)	**24.** (A)	**25.** (C)

Multiple Correct Option type Questions

26. (B,C)	**27.** (A,B)	**28.** (A,C)	**29.** (A,B,C,D)	**30.** (A,C,D)	**31.** (A,B,D)	**32.** (A,B,C,D)
33. (C,D)	**34.** (B,D)	**35.** (A,B,C,D)	**36.** (B,D)	**37.** (A,B,D)	**38.** (A,D)	**39.** (A,B)
40. (A,D)	**41.** (C)	**42.** (A,B)	**43.** (A,C,D)	**44.** (A,D)	**45.** (C)	**46.** (D)
47. (B,D)	**48.** (A,D)	**49.** (B,D)	**50.** (A)	**51.** (A,B,C)	**52.** (C)	**53.** (B)
54. (A,C)	**55.** (A,B)					

Passage Based Questions

56. (C)	**57.** (C)	**58.** (B)	**59.** (B)	**60.** (D)	**61.** (C)	**62.** (A)
63. (A)	**64.** (D)	**65.** (B)	**66.** (A,B)	**67.** (A,C)	**68.** (C)	**69.** (B)
70. (A)	**71.** (D)	**72.** (D)	**73.** (C)			

Column Matching Type Questions

74. $A \to R; B \to P; C \to Q; D \to S$

75. $A \to P,S; B \to P,Q; C \to R,S; D \to Q,T$

76. $A \to S; B \to P; C \to R; D \to Q$

77. $A \to P,S; B \to Q,R,S; C \to P,R,S; D \to P,S$

78. (C)

79. (A)

80. $A \to P,Q,R,S$; $B \to P,Q,R,S$; $C \to P,Q$; $D \to R,S$

81. $A \to P; B \to S; C \to R; D \to Q$

82. $a \to P; b \to Q; c \to Q$

83. $A \to P,Q; B \to R,S; C \to P,Q$

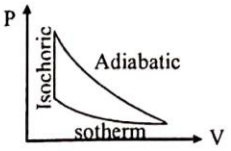
84. $A \to Q; B \to R; C \to P; D \to Q$

Numeric Response Type Questions

85. 7	**86.** 7	**87.** 7	**88.** 2	**89.** 4	**90.** 2	**91.** 3
92. 0	**93.** $31P_0V_0$; $-5P_0V_0$					

94. (ii) $P_b = P_c = 2$ atm, (iii) $T_b = 300$ K, $T_c = 600 = 600$ K, (iv) $V_c = 8$ litre **95.** 1.63

96. 8000 cal.



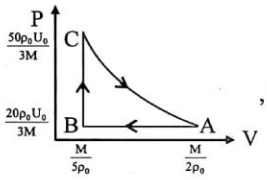
97. (a) Final pressure in A = $\frac{27}{8}P_0$ = Final pressure in C, Final pressure in B = $\frac{21}{4}P_0$

(b) Final temperature in A (and B) = $\frac{21}{4}T_0$, Final temperature in C = $\frac{3}{2}T_0$,

(c) $18\ P_0V_0$,

(d) work done by gas in A = $+\ P_0V_0$, work done by gas in B = 0,

(e) $\frac{17}{2}P_0V_0$

98. (a) 

, (b) $Q = \left(\frac{10}{3}\ell n2.5 - 2\right)U_0$, (c) $-2U_0$

99. C = 2 R

100. 400 J, 2 T_0

101. (a) P_oV_o, (b) 5/2 P_oV_o, $3P_oV_o$, (c) 1/2 P_oV_o, (d) T_{max} = 25/8 P_oV_o/R

102. $1 - \frac{3\left(\frac{1}{2^{1/3}}\right)}{\ell n2}$

Chapter 17

Heat Transfer

Single Correct Option Type Questions

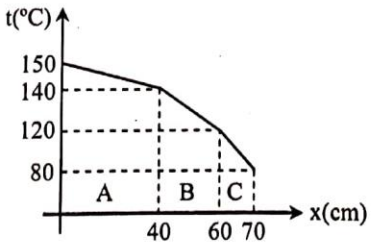
Q.1 A cube, a pyramid (with all four faces identical) and a sphere (all of them hollow) are made from the same material having same surface finish and have equal masses and bound equal volumes. They are heated to the same temperature and then left to cool. After some time

1. sphere will have the highest temperature
2. pyramid will have the highest temperature
3. cube will have the lowest temperature
4. sphere will have the lowest temperature
5. pyramid will have the lowest temperature

The correct option would be

(A) 2 and 3 (B) 3 and 1 (C) 1 and 5 (D) 2 and 4

Q.2 The graph shown gives the temperature along an x-axis that extends directly through a wall consisting of three layers A, B and C. The air temperature on one side of the wall is 150°C and on the other side is 80°C. Thermal conduction through the wall is steady. Out of the three layers A, B and C thermal conductivity is greatest of the layer -



(A) A

(B) B

(C) C

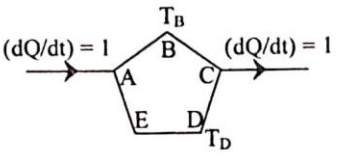
(D) Thermal conductivity of A = Thermal conductivity of B

Q.3 Two solid steel cylinders A and B of same temperature (higher than the surrounding temperature) are of same length and of radii r and $2r$, respectively. Only radiation considered, if the rate of fall of temperature of A is k, then the rate of fall of temperature B would be -

(A) > k (B) < k

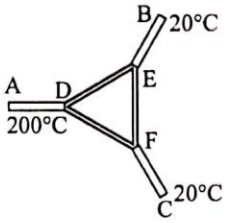
(C) = k (D) Can't be determined

Q.4 ABCDE is a regular pentagon of uniform wire. The rates of heat entering at A and leaving at C are equal. T_B and T_D are temperatures of B and D respectively. Find the temperature T_C -



(A) $\frac{3T_B + 2T_D}{5}$ (B) $3T_D - 2T_B$ (C) $3T_D + 2T_B$ (D) Can have any value

Q.5 Six identical rods are connected as shown in the figure. The temperatures of free ends A, B, C are 200°C, 20°C and 20°C respectively. The temperature of junction D, E and F in °C will be, respectively -

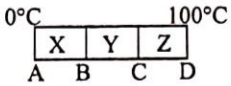


(A) 140, 80, 80 (B) 155, 110, 110 (C) 110, 65, 65 (D) None of these

Q.6 The emissivity and the surface area of filament of electric bulb are 0.7 and 5×10^{-5} m^2 and the operating temperature of the filament is 3000 K. If $\sigma = 5.67 \times 10^{-8}$ $W/m^2 K^4$, then power of the bulb is approximately -

(A) 230 W (B) 160 W (C) 9000 W (D) 4150 W

Q.7 Three pieces of metallic heat conductors X, Y, Z of equal lengths and cross-section areas are connected in series as shown in the figure. Ends A and D are maintained at constant temperature 0°C and 100°C, respectively. If Y is made up of same material as that of Z and point B is at 20°C, what will be the temperature of B, if Y is made up of a same material as that of X ? Consider only conduction and laterally insulated surfaces of conductors



(A) 25°C (B) 50°C (C) 40°C (D) 20°C

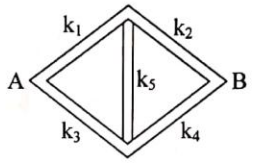
Q.8 A polished metal plate with rough black spot on it is heated to about 1400 K and quickly taken to dark room. Which one of the following statements is true?

(A) Spot will appear brighter than plate
(B) Spot will appear darker than plate
(C) Spot and plate will be equal bright
(D) Spot and plate will not be visible in dark

Q.9 A plane thick wall having uniform surface temperature along planes are 0°K and T_0°K (T_0 = 300K) at x = 0 and x = x_0 respectively. Thermal conductivity K varies linearly with temperature as $K = K_0 (1 + T)$ the temperature of wall at the plane $x = 2x_0$ is approximately : (where T is in kelvin)

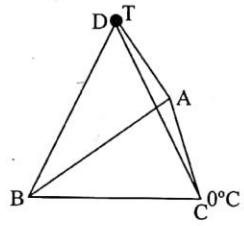
(A) 300 K (B) 400 K (C) 425 K (D) 450 K

Q.10 Five rods of the same dimensions are arranged as shown. They have thermal conductivities k_1, k_2, k_3, k_4 and k_5. When points A and B are maintained at different temperatures, no heat flows through the central rod. It follows that



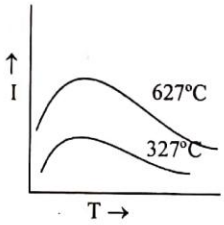
(A) $k_1 = k_4$ and $k_2 = k_3$ (B) $k_1/k_4 = k_2/k_3$ (C) $k_1k_4 = k_2k_3$ (D) $k_1k_2 = k_3k_4$

Q.11 Six similar bars each of thermal resistance R are joined to form a regular tetrahedron as shown in the figure. Point D is maintained at a constant temperature T°C and point C at 0°C. Temperature of junction A is



(A) $\frac{T}{4}$ (B) $\frac{T}{3}$ (C) $\frac{T}{2}$ (D) $\frac{T}{5}$

Q.12 The spectra of a black body at temperatures 327°C and 627°C are shown in the Fig. If A_1 and A_2 be the areas under the two curves respectively, the value of A_2/A_1 is –



(A) $\frac{81}{16}$ (B) $\frac{9}{4}$ (C) $\frac{27}{8}$ (D) $\frac{16}{81}$

Q.13 Photons absorbed in matter are converted into heat. A source emitting n photon/ sec of frequency ν is used to convert 1 kg of ice at 0.°C. Then, the time T taken for the conversion

(i) decrease with increasing n, with ν fixed.

(ii) decreases with n fixed, ν increasing.

(iii) remains constant with n and ν changing such that nν = constant.

(iv) increase when the product nν increase

(A) All the statements are correct (B) only (i) and (ii) are correct

(C) Only (ii) is correct (D) Only (iv) is correct

Q.14 When the centre of earth is at a distance of 1.5×10^{11} m from the centre of sun, the intensity of solar radiation reaching at the earth's surface is 1.26 kW/m^2. There is a spherical cloud of cosmic dust, containing iron particles. The melting point for iron particles in the cloud is 2000 K. Find the distance of iron particles from the centre of sun at which the iron particle starts melting.

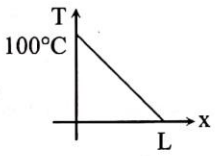
(Assume sun and cloud as a black body, $\sigma = 5.6 \times 10^{-8}$ W/m^2 K^4) -

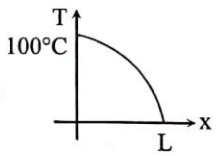
(A) 2.81×10^8 m (B) 2.81×10^{10} m (C) 2.81×10^9 m (D) 1.40×10^{10} m

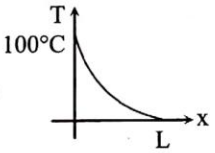
Q.15 A wall of width ℓ and cross sectional area A is having variable coefficient of thermal conductivity given by $k = k_0 + \alpha x$ (where k_0 and α are positive constant) and x is measured from outer surface of wall. If the temperature of surroundings is T_0 °C and the temperature of the room is maintained at T_r °C($T_0 > T_r$). The temperature of the wall at $x = \ell/2$ is (given $\alpha\ell/K_0 = 1$ S.I. unit, $T_0 = 45$°C, and $T_r = 20$°C)

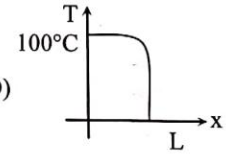
(A) 20°C (B) 25°C (C) 28°C (D) 30.37°C

Q.16 A rod of length L and uniform cross-sectional area have varying thermal conductivity which changes linearly from 2K at end A to K at other end B. The ends A and B of the rod are maintained at constant temperature 100°C and 0°C, respectively. At steady state, the graph of temperature : T = T(x) where x = distance from end A will be

(A)


(B)


(C)


(D)


Q.17 Statement-1 : Water is filled up in a hollow cylindrical container of conducting bases and adiabatic curved surface and kept vertical in an isolated system. If temperature of cylinder is decreased slowly from the bottom, the ice formation will start from the bottom.

Statement-2 : The temperature of liquid which is at the top will be lowest first.

(A) Statement-1 is True, Statement-2 is True ; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True ; Statement-2 is NOT a correct explanation for Statement-1.

(C) Statement-1 is True, Statement-2 is False

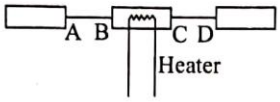
(D) Statement-1 is False, Statement-2 is True

Multiple Correct Option Type Questions

Q.18 A metal cylinder of mass 5 kg is heated electrically by a 20 W heater in a room at 20°C. The cylinder temperature rises uniformly to 30°C in 5 min and finally becomes constant at 45°C. Assume that the rate of heat loss is proportional to the excess temperature over the surroundings. Which of the following is/are correct ?

(A) The rate of loss of heat of cylinder to surrounding at 25°C is 4W
(B) The rate of loss of heat of cylinder to surrounding at 45°C is 20 W
(C) The rate of loss of heat of cylinder to surrounding at 25°C is 8W
(D) The rate of loss of heat of cylinder to surrounding at 45°C is zero.

Q.19 Three liquid baths are thermally connected with the help of two identical rods AB and CD, each having thermal resistance 1°C/W. There is a heater of 100 W in the middle bath; the temperature of the left hand liquid bath is maintained at 100°C and that of right hand side is maintained at 40°C. Assume there is no heat loss to surroundings.

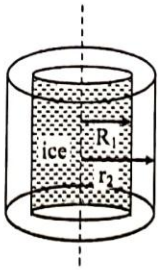


(A) The steady temperature of the middle bath would be 120°C
(B) The heat current in the left hand side rod would be 20 W
(C) The heat current in the right hand side rod would be 65 W
(D) The heat current in the right hand side rod would be towards right

Q.20 A polished metallic piece and a black painted wooden place (of same shape and size) are kept in open in bright sun for a long time. Choose the correct option(s)

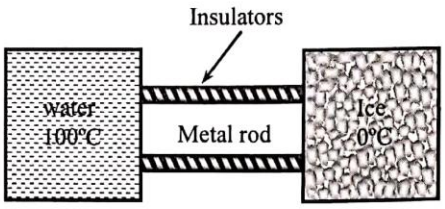
(A) the wooden piece will absorb less heat than the metallic piece
(B) the wooden piece will have a lower temperature than the metallic piece
(C) if touched, the metallic piece will be felt hotter than the wooden piece
(D) when the two pieces are removed from the open to a cold room, the wooden piece will lose heat at a faster rate than the metallic piece

Q.21 A 100 cm long cylindrical flask with inner and outer diameters 2 cm and 4 cm respectively is completely filled with ice as shown in the figure. The constant temperature outside the flask is 40°C. (Thermal conductivity of the flask is 0.693 W/m°C, L_{ice} = 80 cal/gm).



(A) Rate of heat flow from outside to the flask is 80π J/s.
(B) The rate at which ice melts is $\frac{\pi}{4200}$ Kg/s.
(C) The rate at which ice melts is 100π Kg/s.
(D) Rate of heat flow from outside to flask is 40π J/s.

Q.22 An insulated container is filled with ice at 0°C, and another container is filled with water that is continuously boiling at 100°C. In series of experiments, the container connected by various, thick metal rods that pass through the walls of container as shown in the figure.



In the experiment I : a copper rod is used and all ice melts in 20 minutes.

In the experiment II : a steel rod of identical dimensions is used and all ice melts in 80 minutes.

In the experiment III : both the rods are used in series and all ice melts in t_{10} minutes.

In the experiment IV : both rods are used in parallel all ice melts in t_{20} minutes.

(A) The value of t_{10} is 100 minutes
(B) The value of t_{10} is 50 minutes
(C) The value of t_{20} is 16 minutes
(D) The value of t_{20} is 8 minutes

Q.23 One end of a conducting rod is maintained at temperature 50°C and at the other end, ice is melting at 0°C. The rate of melting of ice is doubled if :

(A) the temperature is made 200°C and the area of cross-section of the rod is doubled

(B) the temperature is made 100°C and length of rod is made four time

(C) area of cross-section of rod is halved and length is doubled

(D) the temperature is made 100°C and the area of cross-section of rod and length both are doubled.

Q.24 Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies radiate energy at the same rate. The wavelength λ_B, corresponding to the maximum spectral radiancy in the radiation from B, is shifted from the wavelength corresponding to the maximum spectral radiancy in the radiation from A by 1.00 μm. If the temperature of A is 5802 K,

(A) The temperature of B is 1934 K
(B) $\lambda_B = 1.5$ μm
(C) The temperature of B is 11604 K
(D) The temperature of B is 2901 K

Q.25 Three bodies A, B and C have equal surface area and thermal emissivities in the ratio $e_A : e_B : e_C = 1 : \frac{1}{2} : \frac{1}{4}$.

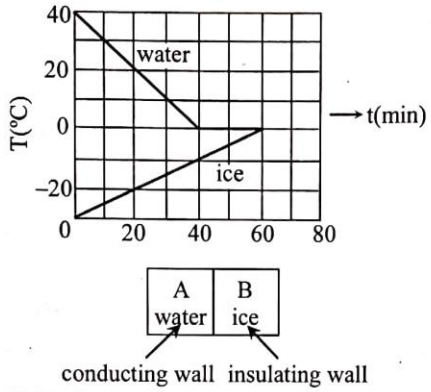
All the three bodies are radiating at same rate. Their wavelength corresponding to maximum intensity are λ_A, λ_B and λ_C respectively and their temperatures are T_A, T_B and T_C on Kelvin scale, then select the **Incorrect** statement

(A) $\sqrt{T_A T_C} = T_B$
(B) $\sqrt{\lambda_A \lambda_C} = \lambda_B$
(C) $\sqrt{e_A T_A}\sqrt{e_C T_C} = e_B T_B$
(D) $\sqrt{e_A \lambda_A T_A e_B \lambda_B T_B} = e_C \lambda_C T_C$

Passage Based Questions

Passage # 1 (Q.26 to 28)

A 0.60 kg sample of water and a sample of ice are placed in two compartments A and B that are separated by a conducting wall in a thermally insulated container. The rate of heat transfer from the water to the ice through the conducting wall is constant P, until thermal equilibrium is reached. The temperatures T of the liquid water and the ice are given in graph as functions of time t. Temperature of the compartments remain homogeneous during the whole heat transfer process.



Given, specific heat of ice = 2100 J/kg-K
specific heat of water = 4200 J/Kg-K
latent heat of fusion of ice = 3.3×10^5 J/kg

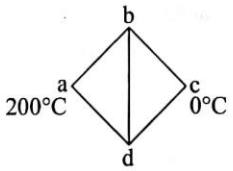
Q.26 The value of rate P is -
(A) 36 W (B) 42 W (C) 21 W (D) 18 W

Q.27 The initial mass of ice in the container is equal to-
(A) 0.36 kg (B) 1.2 kg (C) 3.6 kg (D) 2.4 kg

Q.28 The mass of the ice formed due to conversion from the water till thermal equilibrium is reached, is equal to -
(A) 0.12 kg (B) 0.25 kg (C) 0.15 kg (D) 0.40 kg

Passage # 2 (Q.29 to 31)

Five rods of same material and same length are joined as shown. Cross-section of rods *ab*, *ad* and *bc* are A, 2A and 3A respectively. Ends *a* and *c* are maintained at temperatures 200°C and 0°C respectively.



Q.29 For what cross-section x of rod *dc* there will be no heat flow through rod *bd* ?
(A) 4 A (B) 2 A (C) 6 A (D) 9 A

Q.30 If *x* has the value calculated in above question, then the temperature of junction *b* or *d* is -
(A) 50°C (B) 100°C (C) 90° C (D) 150°C

Q.31 The rate of heat flow through rod *bd* is equal to -
(A) zero (B) $\frac{150}{6R}$ (C) $\frac{50}{6R}$ (D) None of these

Passage # 3 (Q.32 to 34)

End A of a rod AB of length ℓ_0 = 5m and cross-section area S = $1m^2$ is maintained at some constant temperature. The heat conductivity of the rod is varying with the distance x from, the end A as $K = K_0 [1 + ax]$, where $K_0 = \frac{W}{mK}$ and $a = 0.2\ ms^{-1}$. the other end B of this rod is radiating energy at the rate of P = 4560 J/s and the wavelength with maximum energy density emitted from this end is 14500Å. (Assume that except the ends, the rod is thermally insulated. Wein's constant $b = 2.9 \times 10^{-3}$ m-K.)

Q.32 The temperature of end B is -

(A) 200 K (B) 2000 K (C) 1000 K (D) 100 K

Q.33 The variation of temperature as a function of x can be expressed as -

(A) $T = \frac{P}{K_0 aS}\ell n\left(\frac{1+a\ell_0}{1+ax}\right)+T_B$

(B) $T = \frac{P}{K_0 aS}\ell n\left(\frac{2+a\ell_0}{2+ax}\right)+T_B$

(C) $T = \frac{P}{K_0 aS}\ell n\left(\frac{1-a\ell_0}{1-ax}\right)+T_B$

(D) $T = \frac{P}{K_0 aS}\ell n\left(\frac{\ell_0}{x}\right)+T_B$

Q.34 The temperature of the end A is equal to -

(A) $T_A = 2000\left[\ell n\left(\frac{2}{1-0.2x}\right)+1\right]$

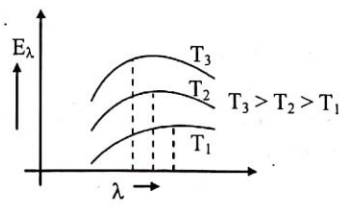
(B) $T_A = 2000\left[\ell n\left(\frac{1}{1+0.2x}\right)+1\right]$

(C) $T_A = 2000\left[\ell n\left(\frac{1}{1-0.2x}\right)+1\right]$

(D) $T_A = 2000\left[\ell n\left(\frac{2}{1+0.2x}\right)+1\right]$

Passage # 4 (Q.35 to 37)

A black body is one which absorbs completely all the radiation falling on its surface whatever be the wavelength. These bodies are also good radiators. They emit radiation of all wavelength possible. While analyzing the spectral distribution of energy in radiation of black body at different temperatures on $E_\lambda - \lambda$ graph, the curves obtained show that at a given temperature with increases in wavelength λ, energy E_λ first increase, reaches a maximum and then decreases.



This means at a particular temperature, radiant energy emitted by a black body is maximum for a particular wavelength. As the temperature increases, peak of curve shift towards shorter wavelength. For this graph the relation between T and λ_m (for which E_λ is maximum) is as under $\lambda_m T$ = constant

After looking on the curve answer the following questions

Q.35 As the temperature of black body rises, maximum energy of emitted radiation shifts towards

(A) Shorter Wavelength (B) Longer Wavelength

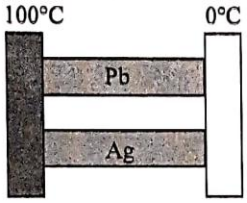
(C) Remain Same (D) Cannot be predicted

Q.36 Sun and moon emit maximum radiation at 5000 Å and 15×10^4 Å respectively. If the temperature of sun is 6000 K, the temperature of moon will be
(A) 100 K (B) 200 K (C) 300 K (D) 400 K

Q.37 On investigation of light from three different stars, A, B and C, it was found that in spectrum of A the intensity of red color is maximum, in B the intensity of blue color is maximum and in 'C' the intensity of yellow color is maximum. From their observation we can conclude that
(A) Temperature of A is maximum, of B is minimum & 'C' is intermediate
(B) Temperature of A is maximum, of C is minimum & 'B' is intermediate
(C) Temperature of B is maximum, of A is minimum & 'C' is intermediate
(D) Temperature of C is maximum, of B is minimum & 'A' is intermediate

Passage # 5 (Q.38 & 39)

Two insulated metal bars each of length 5 cm and rectangular cross section with sides 2 cm and 3 cm are wedged between two walls, one held at 100°C and the other at 0°C. The bars are made of lead and silver. K_{pb} = 350 W/mK, K_{Ag} = 425 W/mK.



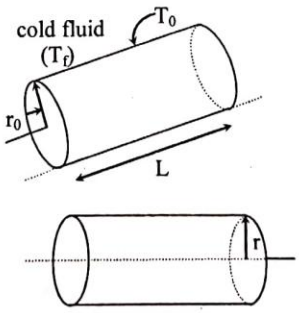
Q.38 Thermal current through lead bar is
(A) 210 W (B) 420 W (C) 510 W (D) 930 W

Q.39 Total thermal current through the two-bar system is
(A) 210 W (B) 420 W (C) 510 W (D) 930 W

Passage # 6 (Q.40 & 41)

Heat generation may occur in a variety of radial geometries. Consider a long, solid cylinder as shown in the figure, which could represent a current-carrying wire or a fuel element in a nuclear reactor. For steady state conditions, the rate at which heat is generated within the cylinder must equal to the rate at which heat is convected from the surface of the cylinder to a moving fluid. This condition allows the surface temperature to be maintained at a fixed value of T_S.

To determine the temperature distribution in the cylinder, we begin with energy conservation principle. Consider a cylindrical section of radius r.



The rate at which energy is generate within the given volume is conducted radially outward.

$\therefore q \pi r^2 \ell = -K2\pi r\ell \frac{dT}{dr}$, where q is the energy generated per unit time per unit volume , K is the thermal conductivity and $\frac{dT}{dr}$, is the temperature gradient at radius r.

If q is constant

$T(r) = -\frac{q}{4k} r^2 + C$

At $r = r_0$, $T(r_0) = T_S$

Therefore, $T(r) = \frac{q}{4k} r_0^2 \left(1 - \frac{r^2}{r_0^2}\right) + T_S$

The rate of heat convected to the surrounding fluid (at temperature T_f) by the surface at temperature T_S is proportional to the temperature difference ($T_S - T_f$) and the surface area in contact with the fluid.

Rate of heat convection = $h(2\pi r_0 L)(T_S - T_f)$

where h is a constant called heat convection coefficient.

By overall energy balance,

$q(\pi r_0^2 L) = h(2\pi r_0 \ell)(T_S - T_f)$

$\Rightarrow T_S = T_f + \frac{q r_0}{2h}$

Q.40 Consider a spherical nuclear fuel material of radius r_0 and rate of heat generation q (watt/m^3). Find the temperature difference between the surface and surrounding fluid in steady state (h is the heat convection coefficient).

(A) $\frac{\dot{q} r_0}{2h}$ (B) $\frac{2}{3}\frac{\dot{q} r_0}{h}$ (C) $\frac{\dot{q} r_0}{3h}$ (D) $\frac{\dot{q} r_0}{h}$

Q.41 In the above passage, the ratio of temperature gradient at $r = r_0/2$ and $r = r_0$ is

(A) 1 (B) $\frac{1}{4}$ (C) $\frac{1}{2}$ (D) $\frac{1}{8}$

Passage # 7 (Q.42 & 43)

Imagine a system, that can keep the room temperature within a narrow range between 20°C to 25°C. The system includes a heat engine operating with variable power P = 3 KT, where K is a constant coefficient, depending upon the thermal insulation of the room, the area of the walls and the thickness of the walls. T is temperature of the room in degree. When the room temperature drops lower than 20°C, the engine turns on, when the temperature increase over 25°C, the engine turns off, room looses energy at a rate of $K(T - T_0)$. T_0 is the outdoor temperature. The heat capacity of the room is C. (Given : T_0 = 10°C, $\ln\left(\frac{3}{2}\right) = 0.4$, $\ln\left(\frac{6}{5}\right) = 0.18$, $\frac{C}{K} = 750$ SI-unit).

Q.42 Suppose at t = 0, the engine turns off, after how much time interval, again, the engine will turn on -

(A) 10 min (B) 5 minute (C) 1.125 minute (D) 2.25 minute

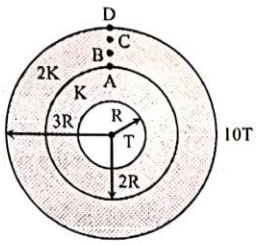
Q.43 Suppose at t = 0, the engine turns on, after how much time interval again, the engine will turn off -

(A) 10 minute (B) 5 minute (C) 1.125 minute (D) 2.25 minute

Passage # 8(Q.44 to 46)

A composite spherical shell is made up of two materials having thermal conductivities K and 2K respectively as shown in the figure. The temperature at the innermost surface is maintained at T whereas the temperature at the outermost surface is maintained at 10T.

A, B, C and D are four points in the outer material such that AB = BC = CD. Now answer the following questions.



Q.44 The effective thermal resistance between the inner surface of the shell and the outer surface of the shell for the radical heat flow is

(A) $\frac{1}{8\pi KR}$ (B) $\frac{1}{7\pi KR}$ (C) $\frac{7}{48\pi KR}$ (D) $\frac{6}{49\pi KR}$

Q.45 The net rate of heat flow from the outermost surface to the innermost surface of the shell will be

(A) $63\pi RKT$ (B) $72\pi RKT$ (C) $\frac{432}{7}\pi RKT$ (D) $\frac{142}{2}\pi RKT$

Q.46 Out of the segments AB, BC and CD the magnitude of the temperature difference will be maximum across

(A) AB (B) BC

(C) CD (D) equal across all the three

Passage # 9 (Q.47 to 49)

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

Q.47 After the tea is added to the thermos, the temperature of the liquid quickly falls from 80°C to 75°C as it reaches thermal equilibrium with the thermos flask. What is the heat capacity of the thermos ?

(A) 9.5 J/K (B) 14 J/K (C) 95 J/K (D) 878 J/K

Q.48 An alternative method for keeping the tea hot would be to place the teapot on a 10 pound block the has been heated in an oven to 300°C. A block of which of the following substances would best be able to keep the tea hot ?

(A) copper (specific heat = 0.39 J/g K) (B) granite (specific heat = 0.79 J/g K)

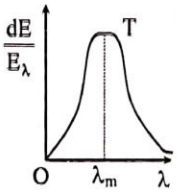
(C) iron (specific heat = 0.45 J/g K) (D) pewter (specific heat = 0.17 J/g K)

Q.49 If after some of the tea has been transfer to the thermos (as described in the passage), the teapot with its contents (at a temperature of 80°C) was placed on the insulated warmer for 5 minutes, what would be the temperature at the end of this 5 minute period ? (Assume that no significant heat transfer occurs with the surroundings)

(A) 80.7°C (B) 82.5°C (C) 83.2°C (D) 95.2°C

Passage # 10 (Q.50 to 52)

The figure shows a radiant energy spectrum graph for a black body at a temperature T.



Q.50 Choose the correct statement(s)

(A) The radiant energy is not equally distributed among all the possible wavelengths

(B) For a particular wavelength the spectral intensity is maximum

(C) The area under the curve is equal to the total rate at which heat is radiated by the body at that temperature

(D) None of these

Q.51 If the temperature of the body is raised to a higher temperature T', then choose the correct statement(s)

(A) The intensity of radiation for every wavelength increases

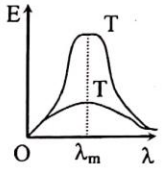
(B) The maximum intensity occurs at a shorter wavelength

(C) The area under the graph increases

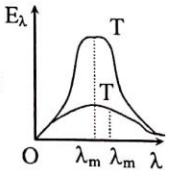
(D) The area under the graph is proportional to the fourth power of temperature

Q.52 Identify the graph which correctly represents the spectral intensity versus wavelength graph at two temperatures T' and T (T < T')

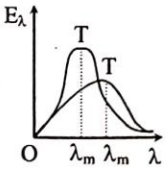
(A)



(B)



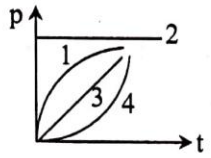
(C)



(D) None of these

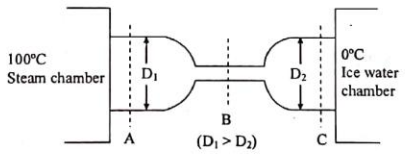
Column Matching Type Questions

Q.53 A ball has surface temperature T initially at time t = 0, that is less than the surrounding constant temperature T_0. On the vertical axis of the graph shown has either thermal energy radiated/absorbed per unit time or total energy radiated/absorbed till time *t* by the ball. Correctly match the curves marked in the graph.



Column -I	Column-II
(A) Thermal energy emitted per unit time	(P) 1
(B) Thermal energy absorbed per unit time	(Q) 2
(C) Total energy emitted till time t	(R) 3
(D) Total energy absorbed till time t	(S) 4
	(T) None

Q.54 A copper rod (initially at room temperature 20°C) of non uniform cross-section is placed between a steam chamber at 100°C and ice water chamber at 0°C



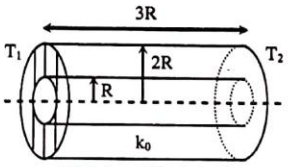
List-I	List-II
(P) At steady state Temperature will be	(1) maximum at section A
(Q) At steady state rate of heat flow $\left(\frac{dQ}{dt}\right)$ will be	(2) maximum at section B
(R) At steady state temperature gradient $\frac{dT}{dx}$ will be	(3) minimum at section C
(S) At steady state rate of change of temperature $\left(\frac{dT}{dt}\right)$ at a certain point	(4) minimum at section B
	(5) same for all section

Codes :

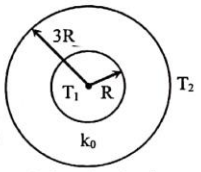
	P	Q	R	S
(A)	(1,3)	5	(2,3)	5
(B)	1	2	3	4
(C)	2	3	5	4
(D)	2	(2,3)	4	1

Q.55 Entries in column I consists of diagrams of thermal conductors. The type of conductor & direction of heat flows are listed below. Entries in column II consists of the magnitude of rate of heat flow belonging to any of the entries in column I. If temperature difference in all the cases is $(T_1 - T_2)$, then match column

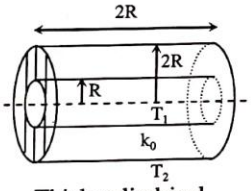
Column I | **Column II**

(A)


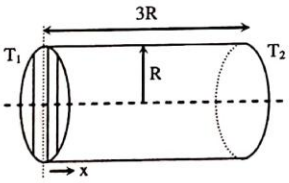
Thick cylindrical shell, flow along axis

(B)


Thick spherical shell, radial flow

(C)


Thick cylindrical shell, radial flow

(D)


Solid cylinder flow along axis, variable k as $k = k_0(1+x/(3R))$

(P) $6\pi k_0 R(T_1 - T_2)$

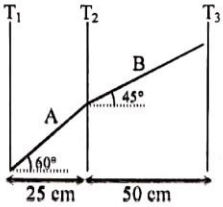
(Q) $\dfrac{\pi k_0 R}{3\ell n2}(T_1 - T_2)$

(R) $\pi k_0 R(T_1 - T_2)$

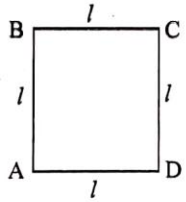
(S) $\dfrac{4\pi k_0 R}{\ell n2}(T_1 - T_2)$

Numeric Response Type Questions

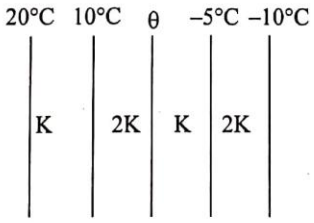
Q.56 Two conductors A and B each of cross section area 5 cm^2 arte connected in series. Variation of temperature (in °C) along the length (in cm) is as shown in the figure. If thermal conductivity of A is 200 J/m-sec-°C and the heat current in the conductors is 0.173 J/s. The thermal conductivity of B is $K \times 50\sqrt{3}$ J/m –sec-°C. Find the value of K.



Q.57 In the square frame of side ℓ of metallic rods, the corners A and C are maintained at T_1 and T_2 respectively. The rate of heat flow from A to C is ω. If A and D are instead maintained T_1 & T_2 respectively, find the total rate of heat flow.



Q.58 The figure shows the face and interface temperature of a composite slab containing of four layers of two materials having identical thickness. Under steady state condition, find the value of temperature θ.



k = thermal conductivity

Q.59 A solid copper cube and sphere, both of same mass & emissivity are heated to same initial temperature and kept under identical conditions. What is the ratio of their initial rate of fall of temperature ?

ANSWER KEY

Single Correct Option type Questions

1. (C)	**2.** (A)	**3.** (B)	**4.** (B)	**5.** (C)	**6.** (B)	**7.** (A)
8. (A)	**9.** (C)	**10.** (C)	**11.** (C)	**12.** (A)	**13.** (A)	**14.** (C)
15. (D)	**16.** (B)	**17.** (D)				

Multiple Correct Option type Questions

18. (A,B)	**19.** (A,B,D)	**20.** (A,D)	**21.** (A,B)	**22.** (A,C)	**23.** (D)	**24.** (A,B)
25. (D)						

Passage Based Questions

26. (B)	**27.** (D)	**28.** (C)	**29.** (C)	**30.** (A)	**31.** (A)	**32.** (B)
33. (A)	**34.** (D)	**35.** (A)	**36.** (B)	**37.** (C)	**38.** (B)	**39.** (D)
40. (C)	**41.** (C)	**42.** (B)	**43.** (C)	**44.** (C)	**45.** (C)	**46.** (A)
47. (C)	**48.** (B)	**49.** (C)	**50.** (A,B)	**51.** (A,B,C,D)	**52.** (B)	

Column Matching Type Questions

53. $A \rightarrow P$; $B \rightarrow Q$; $C \rightarrow S$; $D \rightarrow R$ **54.** (A) **55.** $A \rightarrow R$; $B \rightarrow P$; $C \rightarrow S$; $D \rightarrow Q$

Numeric Response Type Questions

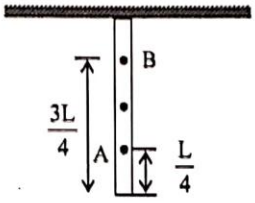
56. 4 **57.** $4/3\omega$ **58.** $5^{\circ}C$ **59.** $\left(\frac{6}{\pi}\right)^{1/3}$

Chapter

18 Transverse Wave

Single Correct Option Type Questions

Q.1 A string of mass m and length l is hanging from ceiling as shown in the figure. Wave in string move upward. v_A and v_B are the speed of wave at A and B respectively. Then v_B is



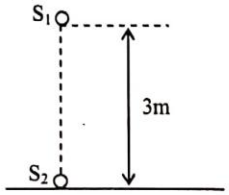
(A) $\sqrt{3}v_A$ (B) v_A (C) $< v_A$ (D) $\sqrt{2}v_A$

Q.2 A rope of length ℓ and mass per unit length μ is suspended vertically. If mass M is suspended from the bottom of the rope. Then time for a transverse wave to travel the rope is

(A) $\ell\sqrt{\frac{\mu}{Mg}}$ (B) $2\sqrt{\frac{\ell}{g}}$

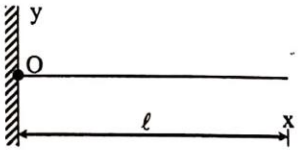
(C) $2\frac{1}{\sqrt{\mu g}}[\sqrt{M+\mu\ell}-\sqrt{M}]$ (D) $\frac{1}{\sqrt{\mu g}}\cdot[\sqrt{M+\mu\ell}-\sqrt{M}]$

Q.3 S_1 and S_2 are two coherent sources of sound having no initial phase difference. No minima will be formed on the line passing through S_2 and perpendicular to the line joining S_1 and S_2, if the frequency of both the source is (v_{sound} = 330 m/s)



(A) 50 Hz (B) 60 Hz (C) 70 Hz (D) 80 Hz.

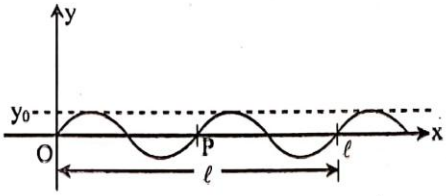
Q.4 Transverse waves are set in a thin rod clamped at one end O. The wave velocity is v. The rod vibrates in the 4th overtone mode with amplitude y_0. The equation of motion of the point at $x = \frac{2\ell}{3}$ is



(A) $y = y_0 \sin\frac{5\pi}{3}\cos\frac{5\pi vt}{2\ell}$ (B) $y = y_0 \sin\frac{7\pi}{3}\cos\frac{7\pi vt}{2\ell}$

(C) $y = y_0 \sin 10\frac{\pi}{3}\cos\frac{9\pi vt}{2\ell}$ (D) $y = 0$

Q.5 The snap shot of a traveling transverse wave along a stretched string at time t = 0 is shown. The velocity of point P is in positive Y direction. The wave velocity is v. The equation of the traveling wave is



(A) $y = y_0 \sin\left(\frac{2\pi x}{\ell} + \frac{2\pi vt}{\ell}\right)$ (B) $y = y_0 \sin\left(\frac{4\pi x}{\ell} - \frac{4\pi vt}{\ell}\right)$

(C) $y = y_0 \sin\left(\frac{5\pi x}{\ell} - \frac{5\pi vt}{\ell}\right)$ (D) $y = y_0 \sin\left(\frac{4\pi x}{\ell} + \frac{4\pi vt}{\ell}\right)$

Q.6 One end of a string of length L is tied to ceiling of lift accelerating upwards with an acceleration 3g. The other end of the string is free. The linear mass density of string varies linearly from 0 to λ from bottom to top. Then correct statement for wave traveling in string

(A) Wave speed is increasing as it travels from bottom to top

(B) Acceleration of wave on string is uniform

(C) Time taken by pulse to reach from bottom to top will be $\sqrt{\frac{2L}{g}}$

(D Time taken by pulse to reach from bottom to top will be $\sqrt{\frac{L}{g}}$.

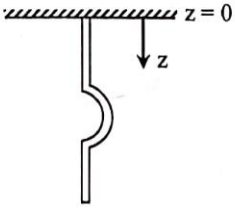
Q.7 A ℓ cm long string fixed at both ends, sustains a standing wave such that all the points on the string having displacement amplitude 1 mm (less than maximum amplitude) are separated by d cm. The string is oscillating in its third overtone then

(A) $\frac{\ell}{d} = 2$ (B) $\frac{\ell}{d} = 3$ (C) $\frac{\ell}{d} = 6$ (D) $\frac{\ell}{d} = 8$

Q.8 Standing waves are set up in a string of length 240 cm clamped horizontally at both ends. The separation between any two consecutive points where displacement amplitude is $3\sqrt{2}$ cm, is 20 cm. The standing waves were set by two traveling waves of equal amplitude of 3 cm. The overtone in which the string is vibrating will be

(A) 2nd (B) 3rd (C) 4th (D) 5th

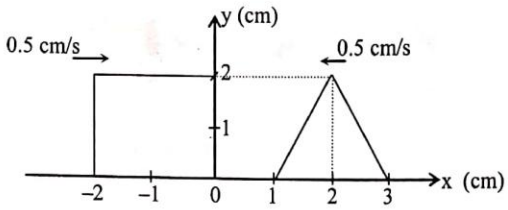
Q.9 A rope hangs from a rigid support. A pulse is set by jiggling the bottom end. We want to design a rope in which velocity v of pulse is independent of z, the distance of the pulse from fixed end of the rope If the rope is very long the desired function for mass per unit length $\mu(z)$ in terms of μ_0 (mass per unit length of the rope at the top (z = 0), g v and z is :



(A) $\mu(z) = \mu_0 e^{-[g/v^2]z}$ (B) $\mu(z) = \mu_0 e^{+[g/v^2]z}$

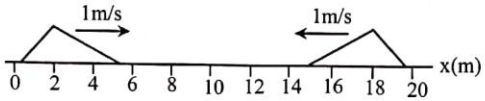
(C) $\mu(z) = \mu_0 \log_e\left(\frac{g}{v^2}\right)z$ (D) $\mu(z) = \mu_0 e + \left(\frac{v^2}{g}\right)z$

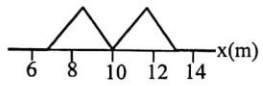
Q.10 Figure shows a rectangular pulse and a triangular pulse approaching each other along x-axis. The pulse speed is 0.5 cm/s. What is the resultant displacement of medium particles due to superposition of waves at x = 0.5 cm and t = 2 sec.

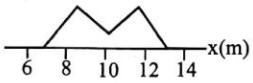


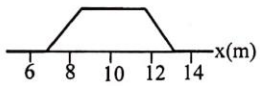
(A) 3.5 cm (B) 2.5 cm (C) 4 cm (D) 3 cm

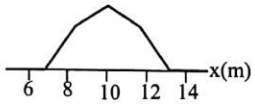
Q.11 Two pulses on a string approach each other at speeds of 1 m/s. What is the shape of the string at t = 6s ?



(A) 

(B) 

(C) 

(D) 

Multiple Correct Option Type Questions

Q.12 Two identical coherent source produce maximum intensity I_0 during interference, then what will be the percentage increase in maximum intensity during interference in three identical same source -

(A) 200% (B) 225% (C) 125% (D) 100%

Q.13 A transverse wave is represented by : $y = \frac{10}{\pi} \sin\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x\right)$. Symbols have usual meaning. y, x, λ in cm and t, T in sec. For what value of the wavelength the wave velocity is twice the maximum particle velocity?

(A) 40 cm (B) 10 cm (C) 60 cm (D) 20 cm

Q.14 The figures represent two snaps of a traveling wave on a string of mass per unit length, $\mu = 0.25$ kg/m. The two snaps are taken at time t = 0 and at $t = \frac{1}{24}$ s. Then

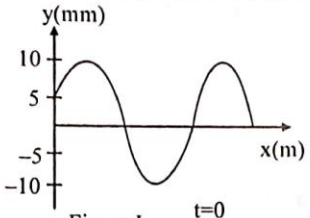


Figure I t=0

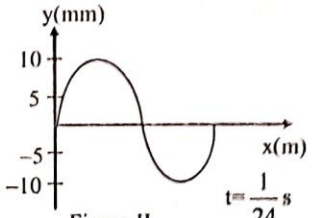
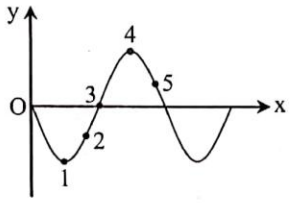


Figure II $t = \frac{1}{24}$ s

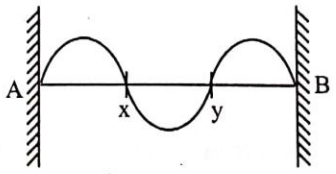
(A) Speed of wave is 4 m/s
(B) The tension in the string is 4 N
(C) The equation of the wave is $y = 10 \sin (\pi x - 4\pi t + \frac{\pi}{6})$
(D) The maximum velocity of the particle = $\frac{\pi}{25}$ m/s

Q.15 A wave is passing along a string in the positive x-direction as shown in figure. Select the correct option form following statements ?



(A) Acceleration is positive at point 1
(B) Velocity is negative at point 3
(C) Velocity and acceleration are in opposite direction at point 2
(D) Speeds at point 1 and 4 are equal

Q.16 A string fixed at both ends is vibrating as shown in figure, then mark correct statements -



(A) All particles in between x and y are vibrating in phase
(B) All particles in between A and x are vibrating in phase with particles between x and y
(C) All particles between A and x are vibrating in phase with particles between y and B
(D) All particles of string are in phase

Q.17 The extension produced in a wire of length L when under tension T is ℓ. One of the notes emitted by the wire when it is used in sonometer is (d = density, Y = Young's modulus, mass per unit length = μ, area = A)

(A) $f = \frac{2}{3L^{3/2}}\sqrt{\frac{Y\ell}{d}}$
(B) $f = \frac{2}{L^{3/2}}\sqrt{\frac{Y\ell}{d}}$
(C) $f = \frac{1}{2L}\sqrt{\frac{AY\ell}{L\mu}}$
(D) $f = \frac{1}{4L}\sqrt{\frac{AY\ell}{\mu L}}$

Q.18 Two points on string are being observed as a travelling wave passes them. The point are at $x_1 = 0$ and $x_2 = 1$, the transverse motions of two points are found to be as follows : $y_1 = A \sin(3\pi t)$ and $y_2 = A \sin\left(3\pi t + \frac{\pi}{8}\right)$

t is in seconds and y in metre. Mark correct options

(A) Frequency of wave is 3Hz
(B) Frequency of wave is 1.5 Hz
(C) Wavelength may be 16m
(D) Wavelength may be $\frac{16}{15}$ m

Q.19 If the tension in a string is changed by 21%, fundamental frequency of the string changes by 15 Hz. Which of the following statements will also be correct?

(A) Original fundamental frequency is about 150 Hz
(B) Velocity of propagation changes by nearly 4.5%
(C) Velocity of propagation changes by nearly 10%
(D) Fundamental wavelength changes by nearly 10%

Q.20 The particle displacement of a travelling sinusoidal longitudinal wave is represented by $\xi = \xi(x,t)$. The midpoints of a compression zone and an adjacent rarefaction zone are represented by the letter 'C' and 'R'. Which of the following is true ?

(A) $|\partial\xi / \partial x|_C = |\partial\xi / \partial x|_R$
(B) $|\partial\xi / \partial t|_C = |\partial\xi / \partial t|_R = 0$
(C) $(\text{pressure})_C - (\text{pressure})_R = 2\beta|\partial\xi / \partial x|_C$ (where β = Bulk modulus of air.)
(D) Particles of air are stationary mid-way between 'C' and 'R'

Q.21 For a sine wave passing through a medium, let y be the displacement of a particle, v be its velocity and a be its acceleration.

(A) y, v and a are always in the same phase.
(B) y and a are always in opposite phase.
(C) Phase difference between y and v is $\frac{\pi}{2}$.
(D) Phase difference between v and a is $\frac{\pi}{2}$

Q.22 Consider standing wave formed due to superposition of two plane waves having the same amplitude, frequency and moving in opposite direction. Mark the correct statements :

(A) the energy of a standing wave transforms completely into potential energy and at some other instant into kinetic energy during a part of complete cycle.
(B) kinetic energy and potential energy attain their maximum and minimum values simultaneously
(C) At node point there is only potential energy
(D) the time averaged energy flux in any cross section of the wave is zero.

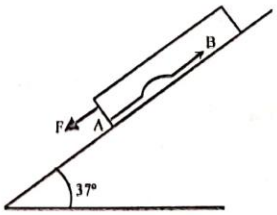
Q.23 The displacement of a string is given by

$$y(x, t) = 0.06 \sin \frac{2\pi x}{3} \cos 120\pi t$$

Where x and y are meter and t is in sec. The length of string is 1.5 m and mass is 3×10^{-2} kg.

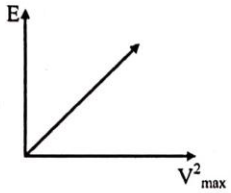
(A) It represents a progressive wave of frequency 60 Hz.
(B) It represents a stationary wave of frequency 60 Hz.
(C) It is the reult of super position of two waves of wave length 3 metre frequency 60 Hz each travelling with speed 180 m/s
(D) Amplitude of the waves is constant.

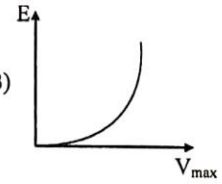
Q.24 A box of mass 14m with smooth base is sliding on an inclined plane of inclination θ under the influence of a force F. A string of mass m length ℓ is attached at A. The box is released from rest and a transverse pulse is produced at other end. 'B'. Mark the correct statement (s) for the pulse.

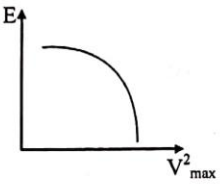


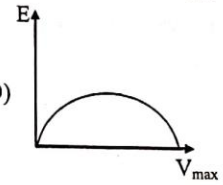
(A) If F = 0 the pulse will remains stationary
(B) If F = 0 the pulse will not reach to end A.
(C) For F = 9 mg the time taken by the pulse in moving from B to A will be $2\sqrt{\frac{5\ell}{3g}}$
(D) If F = 18 mg the time taken by the pulse in moving from B to A will be $2\sqrt{\frac{5\ell}{3g}}$

Q.25 A source of sound emits sound waves in a uniform medium. If energy density is E and maximum speed of particles of the medium is V_{max} then the graph giving correct information for energy density and maximum speed is/are :

(A)


(B)


(C)


(D)


Q.26 A wave is represented by the equation $y = A \sin(10\pi x + 15\pi t + \pi/3)$ where x is in meters and t is in seconds. The expression represents
(A) a wave travelling in the positive x-direction with a velocity 1.5m/s.
(B) a wave travelling in the negative x-direction with a velocity 1.5m/s.
(C) a wave travelling in the negative x-direction having a wavelength 0.2m.
(D) a wave travelling in the positive x-direction having a wavelength 0.2m.

Q.27 A perfectly elastic uniform string is suspended vertically with its upper end fixed to the calling and the lower end is loaded with a weight. If a transverse wave is imparted to the lower end of the string, the pulse will
(A) not travel along the length of the string
(B) travel upwards with increasing speed
(C) travel upwards with decreasing speed
(D) travel upwards with constant acceleration

Q.28 Two waves of same frequency and wavelength but amplitude A_1 and A_2 meet a point at the same time. According to the superposition principle, the resultant amplitude

(A) may be $A_1 + A_2$
(B) may be $A_1 - A_2$
(C) $A_1 + A_2$ or $A_1 - A_2$
(D) $A_1 - A_2 \le A \le A_1 + A_2$

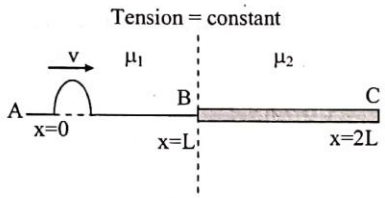
Q.29 Which of the following statements are true for a stationary waves.

(A) Energy particle has a fixed amplitude which is different from the amplitude of material particle.
(B) All the particle cross their mean position at the same time
(C) There is net transfer of energy across any plane.
(D) There are some particles which are always at rest.

Passage Based Questions

Passage # 1 (Q.30 to 32)

Speed of a transverse wave depends on mass and tension. Two strings of equal lengths are joined at B. Mass of string BC is four times mass of string AB. If a wave pulse is generated in string AB, which travels towards boundary at B with speed v. Equation of incident pulse is given as



$y_i = A_i \sin(\omega t - kx)$

Based on above information, answer the following questions.

Q.30 Amplitude of wave reflected back after incident on boundary at point B

(A) $-\frac{A_i}{3}$
(B) $-\frac{2A_i}{3}$
(C) $\frac{A_i}{3}$
(D) $\frac{2A_i}{3}$.

Q.31 Speed of transmitted wave on string BC is

(A) v
(B) $\frac{v}{2}$
(C) 2v
(D) None of these.

Q.32 Equations of reflected and transmitted waves respectively are :

(A) $y_r = -\frac{A_i}{3}\sin(\omega t + kx)$, $y_t = -\frac{2A_i}{3}\sin(\omega t - 2kx)$

(B) $y_r = \frac{A_i}{3}\sin(\omega t + kx)$, $y_t = \frac{2A_i}{3}\sin(\omega t + 2kx)$

(C) $y_r = -\frac{A_i}{3}\sin(\omega t + kx)$, $y_t = \frac{2A_i}{3}\sin(\omega t - 2kx)$

(D) $y_r = -\frac{A_i}{3}\sin(\omega t - kx)$, $y_t = \frac{2A_i}{3}\sin(\omega t + \frac{k}{2}x)$

Passage # 2 (Q.33 & 34)

Four pieces of string each of length L are joined end to end to make a long string of length 4L. The linear mass density of the strings are μ, 4μ, 9μ and 16μ, respectively, One end of the combined string is tied to a fixed support and a transverse wave has been generated at the other end having frequency f (ignore any reflection and absorptions). String has been stretched under a tension F.

Q.33 Find the time taken by wave to reach from source end to fixed end.

(A) $\frac{25}{12} \times \frac{L}{\sqrt{F/\mu}}$ (B) $\frac{10L}{\sqrt{F/\mu}}$ (C) $\frac{4L}{\sqrt{F/\mu}}$ (D) $\frac{L}{\sqrt{F/\mu}}$

Q.34 Find the ratio of wavelength of the waves on four strings, starting from right hand side.

(A) 12 : 6 : 4 : 3 (B) 4 : 3 : 2 : 1 (C) 3 : 4 : 6 : 12 (D) 1 : 2 : 3 : 4

Passage # 3 (Q.35 & 36)

A pulse is started at a time t = 0 along the +x direction on a long, taut string. The shape of the pulse at t = 0 is given by function f(x) with

$$f(x) = \begin{cases} \frac{x}{4}+1 & \text{for } -4 < x \le 0 \\ -x+1 & \text{for } 0 < x < 1 \\ 0 & \text{otherwise} \end{cases}$$

Here f and x are in centimeters. The linear mass density of the string is 50 g/m and it is under a tension of 5N.

Q.35 The shape of the string is drawn at t = 0 and the area of the pulse enclosed by the string and the x-axis is measured. It will be equal to

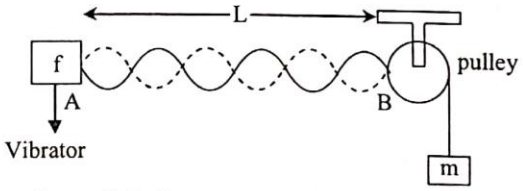
(A) 2 cm^2 (B) 2.5 cm^2 (C) 4 cm^2 (D) 5 cm^2

Q.36 The vertical displacement of the particle of the string at x = 7 cm and t = 0 0.01 sec will be

(A) 0.75 cm (B) 0.5 cm (C) 0.25 cm (D) zero

Passage # 4 (Q.37 & 38)

In the arrangement shown in the figure a mass can be hung from a string with a linear mass density of 2×10^{-3} kg/m that pass over a light pulley. The string is connected to a vibrator of frequency 700 Hz and the length of the string between the vibrator and the pulley is 1 m. ($g = 10\ m/s^2$)



Q.37 If the standing waves are observed, the largest mass to be hung is

(A) 160 kg (B) 125 kg (C) 320 kg (D) 392 kg

Q.38 If the mass suspended is 16 kg, then the number of loops formed in the string is- $\left(\frac{1}{\sqrt{2}} = 0.7\right)$

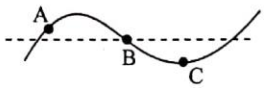
(A) 1 (B) 3 (C) 5 (D) 8

Column Matching Type Questions

Q.39 Match the Columns I and II.

Column-I	Column-II
(A) $y = 4 \sin (5x - 4t) + 3 \cos (4t - 5x + \pi/6)$	(P) Particles at every position are performing SHM
(B) $y = 10 \cos \left(t - \frac{x}{330}\right) \sin (100) \left(t - \frac{x}{330}\right)$	(Q) Equation of traveling wave
(C) $y = 10 \sin (2\pi x - 120t) + 10 \cos (120\, t + 2\pi x)$	(R) Equation of standing wave
(D) $y = 10 \sin (2\pi x - 120\, t) + 8 \cos (118\, t - 59/30\pi x)$	(S) Equation of beats
	(T) None

Q.40 The figure shows a string at a certain moment as a transverse wave passes through it. Three particles A, B and C of the string are also shown. Match the physical quantities in the left column with the description in the column on the right.

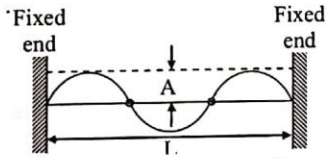


Column I	Column II
(A) Velocity of A	(P) Downwards, if the wave is travelling towards right.
(B) Acceleration of A	(Q) Downwards, if the wave is traveling towards left.
(C) Velocity of B	(R) Downwards, no matter which way the wave is travelling.
(D) Velocity of C	(S)Zero.

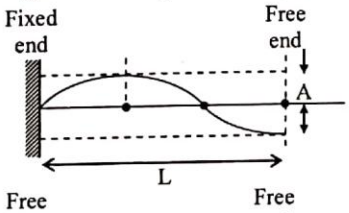
Q.41 The diagrams in Column A show transverse sinusoidal standing/traveling waveforms on stretched strings. In each case, the string is oscillating in a particular mode, and, its shape and other characteristics are shown at time t = 0. The maximum amplitude (in all the cases) is A, the velocity of the waveform on the string is e, the mass per unit length of the string is μ and the frequency of vibration is f (angular frequency = ω).
The kinetic energy of the string (of length L) is represented by the functions in Column B. Match the correct entries in Column B.

Column I

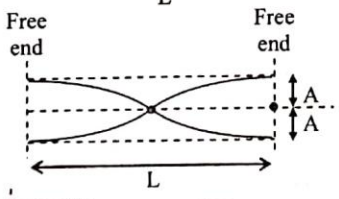
(A)



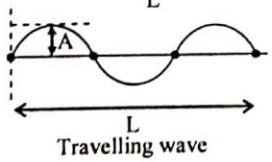
(B)



(C)



(D)



Travelling wave

Column II

(P) $\frac{9\pi^2}{4} \frac{\mu c^2}{L} A^2$

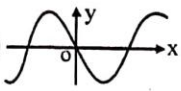
(Q) $\frac{9\pi^2}{4} \frac{\mu c^2}{L} A^2 \sin^2 \omega t$

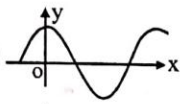
(R) $\frac{9\pi^2}{16} \frac{\mu c^2}{L} A^2 \sin^2 \omega t$

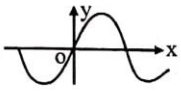
(S) $\frac{\pi^2}{4} \frac{\mu c^2}{L} A^2 \sin^2 \omega t$

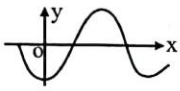
Q.42 For four sine waves, moving on a string along positive X direction, displacement-distance curves (y–x curves) are shown at time t = 0. In the right List, expressions for y as function of distance X and time t for sinusoidal waves are given. All terms in the equations have general meaning. Correctly match y–x curves with corresponding equations.

List-I

(P) 

(Q) 

(R) 

(S) 

List-II

(1) $y = A \cos(\omega t - kx)$

(2) $y = -A \cos(kx - \omega t)$

(3) $y = A \sin(\omega t - kx)$

(4) $y = A \sin(kx - \omega t)$

Codes :

	P	Q	R	S
(A)	1	3	4	2
(B)	3	1	4	2
(C)	4	1	2	3
(D)	3	4	1	2

Q.43 In case of mechaical wave a particle oscillates and during oscillation its kinetic energy and potential energy changes.

List -I	List -II
(P) When particle of travelling wave is passing through mean position	(1) Kinetic energy is maximum
(Q) When particle of travelling wave is at extreme position	(2) Potential energy is maximum
(R) When particle between node and antinode in standing wave is passing through mean position	(3) Kinetic energy is minimum
(S) When particle between node and antinode in standing wave is at extreme position	(4) Potential energy is minimum

Codes :

	P	Q	R	S
(A)	1	(2,4)	4	(2,3)
(B)	(2,3)	(3,4)	(1, 4)	(2,3)
(C)	(1,2)	(2,4)	(2, 3)	3
(D)	(1,4)	(2,3)	(1, 4)	(2,3)

Q.44 Match the following.

Column -I	Column -II
(A) Transverse progressive wave	(P) Amplitude of all particle same
(B) Longitudinal progressive wave	(Q) Phase of all particles may be same for a region
(C) Transverse standing wave	(R) May occur in gases
(D) Longitudinal standing wave	(S) KE and PE of a small element are maximum simultaneously.
	(T) When KE is maximum, PE is minimum for a region

Q.45 Match the following.

	List-I		List-II
(P)	For the propagation of mechanical wave	(1)	have zero displacement simultaneously at some instant.
(Q)	In a stationary wave, all the particles of the medium.	(2)	no material medium is required
(R)	In a transverse progressive wave, all the particles of the medium.	(3)	material medium is required
(S)	For the propagation of e.m. wave	(4)	have the same time period and amplitude of vibration through out the wave

Codes :

	P	Q	R	S
(A)	3	1	4	2
(B)	2	1	3	4
(C)	4	3	2	1
(D)	4	1	2	3

Numeric Response Type Questions

Q.46 A simple harmonic progressive wave is represented by the equation $y = 8 \sin 2\pi (0.1x - 2t)$ where x and y are in cm and t is in sec. At any instant the phase difference between two particles separated by 2.0 cm in the x-direction is '8n', find the value of 'n'.

Q.47 Small amplitude progressive wave in a stretched string have a speed of 100 cm/s and frequency 100 Hz. The phase difference between two points 2.75 cm apart on the string, in radians, is $(1.5 + n)\pi$, then find the value of 'n'.

Q.48 Sinusoidal waves 5.00 cm in amplitude are to be transmitted along a string having a linear mass density equal to 4.00×10^{-2} kg/m. If the source can deliver a maximum power of 90W and the string is under a tension of 100 N, then the highest frequency at which the source can operate it, is '5n' then find the value of 'n' (take $\pi^2 = 10$)

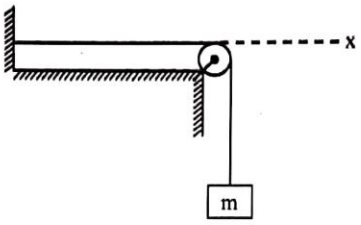
Q.49 At t = 0, a transverse wave pulse travelling in the positive x-direction with a speed of 2 m/s in a wire is described by the function $y = 6/x^2$ given that $x \neq 0$. Find the transverse velocity of a particle at x = 2 m and t = 2 s.

Q.50 Time taken by waves to travel the distance ℓ between the points A and B if the air temperature between them varies linearly from T_1 to T_2, is $\dfrac{n \times \ell}{\alpha[\sqrt{T_2} + \sqrt{T_1}]}$, then find the value of 'n'. Given : the velocity of sound propagation in air is equal to $v = \alpha\sqrt{T}$, where α is a constant.

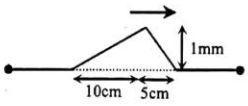
Q.51 A thin plane membrane separates hydrogen at 7°C from hydrogen at 47°C, both being at the same pressure. If a collimated sound beam travelling from then cooler gas makes an angle of incidence of 30° at the membrane, the angle of refraction is $r = \sin^{-1}\sqrt{\frac{2}{n}}$ find the value of 'n'.

Q.52 For an organ pipe, three successive resonance are observed at 425, 595 and 765 Hz. Taking speed of sound to be 340 m/s, find length of pipe in metre.

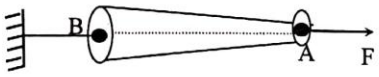
Q.53 A transverse wave is passing through a string shown in figure. Mass density of the string is 1 kg/m^3 and cross section area of string is 0.01 m^2. Equation of wave in string is $y = 2 \sin (20t - 10x)$. Find the hanging mass (in gm). (t is time in sec. and x is position in m)



Q.54 If the kinetic energy of pulse travelling in a taut string is $3K \times 10^{-2}$ mJ then find the value of K. (Given T = 10 N & $\mu = 0.1$ kg/m.



Q.55 In string radius is varying from 5 mm to 15 mm. Uniformly a force of $\frac{22}{175} \times 10^4$ N acting at one end as shown in the figure. Density of material of wire is 10^4 kg/m^3 length of wire is 1 m long. Time taken by a transverse pulse from A to B is $k \times 10^{-2}$ sec the value of k will be



Q.56 A sonometer wire 64 cm long produces 8 beats per second with a tuning fork. If length of sonometer wire is increased by one centimeter it resonates with the tuning fork. The frequency of tuning fork is observed 64x. The value of x is

Q.57 The displacement of string is given by $y(x_1, t) = 0.06\sin\left[\frac{2\pi X}{3}\right]\cos[120\pi t]$

Where X and Y are in m and t in sec. The length of the string is 1.5 m and its mass is 3.0×10^{-2} kg. This is a result of super position of two waves travelling in opposite directions.
The speed of any one of the component waves is 36X ms^{-1}. Then X = ?

ANSWER KEY

Single Correct Option type Questions

1. (A)	**2.** (C)	**3.** (A)	**4.** (D)	**5.** (D)	**6.** (D)	**7.** (D)
8. (D)	**9.** (A)	**10.** (D)	**11.** (C)			

Multiple Correct Option type Questions

12. (C)	**13.** (C)	**14.** (A,B,C,D)	**15.** (A,B,C,D)	**16.** (A,C)	**17.** (B,C)	**18.** (B,C)
19. (A,C)	**20.** (A,C,D)	**21.** (B,C,D)	**22.** (A,C,D)	**23.** (B,C)	**24.** (B,C)	**25.** (A,B)
26. (B,C)	**27.** (B,D)	**28.** (A,B,D)	**29.** (A,B,C,D)			

Passage Based Questions

30. (A)	**31.** (B)	**32.** (C)	**33.** (B)	**34.** (C)	**35.** (B)	**36.** (C)
37. (D)	**38.** (C)					

Column Matching Type Questions

39. $A \to P,Q;\ B \to S;\ C \to P,R;\ D \to S$

40. $A \to P;\ B \to R;\ C \to Q;\ D \to S$

41. $A \to Q;\ B \to R;\ C \to S;\ D \to P$

42. (B)

43. (D)

44. $A \to P,S;\ B \to P, R;\ C \to Q,T\ ;\ D \to Q,R,T$

45. (A)

Numeric Response Type Questions

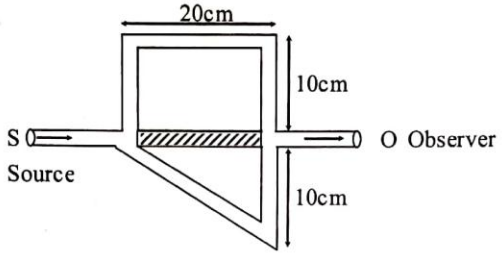
46. 9	**47.** 4	**48.** 6	**49.** 3	**50.** 2	**51.** 7	**52.** 1
53. 4	**54.** 5	**55.** 5	**56.** 8	**57.** 5		

Chapter 19

Sound Wave

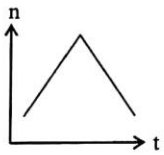
Single Correct Option Type Questions

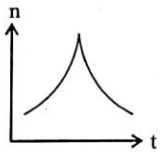
Q.1 Find out frequency at which maximum intensity detected by observer O. If velocity of sound = 340 m/s^{-1} and frequency range of source 2000 Hz to 5000 Hz

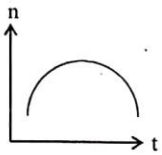


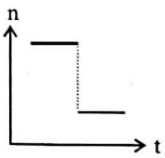
(A) 3350 Hz (B) 4450 Hz (C) 2900 Hz (D) None of these

Q.2 A railway engine whistling at a constant frequency moves with a constant speed. It goes past a stationary observer standing beside the rail track. The frequency (n) of the sound heard by the observer is plotted against time (t). Which of the followings best represents the resulting curve?

(A) 

(B) 

(C) 

(D) 

Q.3 At a point on the screen in YDSE experiment 3rd maxima is observed at t = 0. Now screen is slowly moved with constant speed away from the slits in such a way that the centre of slits and centre of screen lie on same line always and at t = 1 sec the intensity at that point is observed $(3/4)^{th}$ of maximum intensity in between 2nd and 3rd maxima. The speed of screen may be (D = separation between the screen and slits d = separation between the slits, $d << D$, $\lambda = 5000$ Å)

(A) $\frac{7D}{13}$ (B) $\frac{13D}{5}$ (C) $\frac{D}{17}$ (D) None of these

Q.4 A radar wave (speed 3×10^8 m/s) has a frequency 7.9×10^9 Hz, is reflected from an aeroplane, shows a frequency difference of 2.7×10^3 Hz on the higher side (if we assume that Doppler's effect can be applied on light wave similar as sound wave)

(A) velocity of aeroplane is 1.87×10^3 km/m

(B) velocity of aeroplane in the line of sight is 1.87×10^3 km/m

(C) velocity of aeroplane is 1.35×10^3 km/m

(D) velocity of aeroplane in the line of sight is 1.35×10^3 km/m.

Q.5 A closed organ pipe of length 99.4 cm is vibrating in its first overtone and in always resonance with a tunning fork having frequency f = (300 – 2t) Hz. Where t is time in second. The rate by which radius of organ pipe changes when its radius is 1 cm , is (speed of sound in organ pipe = 320 m/s)

(A) $\frac{1}{72}$ m/s (B) $\frac{1}{36}$ m/s (C) $\frac{1}{18}$ m/s (D) $\frac{1}{9}$ m/s

Q.6 Temperature dependence of speed of sound could be expressed as $v = k\sqrt{T}$, where k is some positive constant. In a medium sound is traveling along x-axis. At x = 0 temperature is T_1 and at $x = \ell$, temperature is T_2 and the temperature varies linearly with x. Time taken by sound to travel from x = 0 to $x = \ell$ is

(A) $\frac{2\ell}{k\left(\sqrt{T_1}+\sqrt{T_2}\right)}$ (B) $\frac{\ell}{k\left(\sqrt{T_1}+\sqrt{T_2}\right)}$ (C) $\frac{\ell}{2k\left(\sqrt{T_1}+\sqrt{T_2}\right)}$ (D) $\frac{1}{2k\left(\sqrt{T_1}+\sqrt{T_2}\right)}$

Q.7 A closed organ pipe has length 'ℓ' The air in it is vibrating in 3rd overtone with maximum amplitude 'a'. The amplitude at a distance of $\ell/7$ from closed end of the pipe is equal to -

(A) a (B) a/2 (C) $\frac{a\sqrt{3}}{2}$ (D) zero

Q.8 In a stationary longitudinal wave at pressure antinode
(A) Pressure is maximum.
(B) Pressure remains constant.
(C) Pressure difference is maximum.
(D) density varies maximum to minimum at a regular interval of time.

Q.9 An organ pipe of cross sectional area 100 cm^{-2} resonates with a tuning fork of frequency 1000 Hz in fundamental tone. The minimum volume of water to be drain out so that the pipe again resonate with the same tuning fork is (take velocity of wave = 320 m/s)

(A) 800 cm^3 (B) 1200 cm^3 (C) 1600 cm^3 (D) 2000 cm^3

Q.10 A closed organ pipe of length ℓ is sounded together with another closed organ pipe of length $\ell + x$ ($x << \ell$). Both vibrate in their fundamental modes. If the speed of sound is v, then the beat frequency heard is

(A) $\frac{vx}{2\ell^2}$ (B) $\frac{vx}{4\ell^2}$ (C) $\frac{vx^2}{4\ell}$ (D) None

Q.11 The speed of sound in air
(A) is independent of pressure
(B) increases with temperature
(C) increases with humidity
(D) all the above are true

Q.12 A bat emits ultrasonic sound of frequency 1000 kHz in air. If the sound encounters a water surface, what is ratio of the wavelengths of the reflected sound, to the refracted sound? Speed of sound in air is 340 ms^{-1} and in water 1486 ms^{-1}.

(A) 4.4 (B) 0.23 (C) 3.4 (D) 1

Q.13 Diffraction of sound waves is more evident in daily life than that of light waves because
(A) for sound waves wavelength is comparable to slit width
(B) for light waves wavelength is comparable slit width
(C) velocity of sound is less in comparison to light
(D) wavelength range of sound is broader in comparison to wavelength range of light.

Q.14 If three sources of sound of equal intensities and having frequencies 300 Hz, 301 Hz and 302 Hz are sounded together, the number of beats heard is
(A) 1 (B) 2 (C) 3 (D) None

Q.15 A metal bar clamped at its centre resonates in its fundamental mode to produce longitudinal waves of frequency 4 kHz. Now, the clamp is moved to one end. If f_1 and f_2 are the frequencies of first overtones and second overtone in second case, respectively, then
(A) $3f_2 = 5f_1$ (B) $3f_1 = 5f_2$ (C) $f_2 = 2f_1$ (D) $2f_2 = f_1$

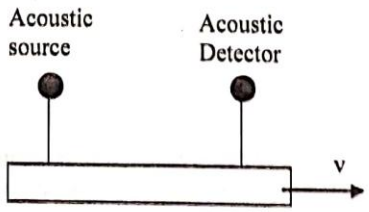
Statement Based Questions

Q.16 **Statement-1 :** A balloon filled with ω_2 gas acts as a converging lens for a sound wave.
Statement-2 : Sound waves travel faster in air than in ω_2.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.17 **Statement-1` :** Velocity of particles, while crossing mean position (in stationary waves) varies from maximum at antinodes to zero at nodes.
Statement-2 : Amplitude of vibration at antinodes is maximum and at nodes, the amplitudes is zero and all particles between two successive nodes cross the mean position together.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.18 **Statement-1 :** Newton's equation for speed of sound in air was found wrong because, he assumed process as isothermal.
Statement-2 : Flow of sound wave in a medium is very fast. Quick process suppress heat exchange, hence this process must be adiabatic in nature.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.19 **Statement-1 :** If a plank is moving with speed v (v is greater than speed of sound). Acoustic source and detector are fixed as shown. Acoustic detector will never detect the sound emitted by acoustic source
and
Statement-2 : The speed of sound is reference frame dependent.



(A) Statement -1 is True, Statement -2 is True; Statement -2 is a correct explanation for Statement -1
(B) Statement -1 is True, Statement -2 is True; Statement -2 is **NOT** a correct explanation for Statement -1
(C) Statement -1 is True, Statement -2 is False.
(D) Statement -1 is False, Statement -2 is True.

Multiple Correct Option Type Questions

Q.20 As a wave propagates,

(A) the wave intensity remains constant for a plane wave.

(B) the wave intensity decrease as the inverse of the distance from the source for a spherical wave.

(C) the wave intensity decreases as the inverse square of the distance from the source for spherical wave.

(D) total intensity of the spherical wave over the spherical surface remains constant at all times, while source is at the centre of spherical surface.

Q.21 A source is moving across a circle given by the equation $x^2 + y^2 = R^2$, with constant speed $v = \frac{330\pi}{6\sqrt{3}}$ m/s, in anti-clockwise sense. A detector is at rest at point (2R, 0) w.r.t. the centre of the circle. If the frequency emitted by the source is f and the speed of sound, C = 330 m/s. Then

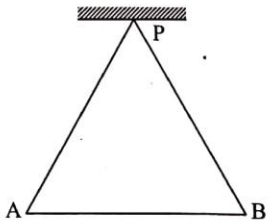
(A) The position of the source when the detector records the maximum frequency $\left(+\frac{\sqrt{3}}{2}R, -\frac{R}{2}\right)$.

(B) The co-ordinate of the source when the detector records minimum frequency is (0, R).

(C) The maximum frequency recorded by the detector is $\frac{6\sqrt{3}}{\pi + 6\sqrt{3}}$ f.

(D) The minimum frequency recorded by the detector is $\frac{6\sqrt{3}}{6\sqrt{3} - \pi}$ f.

Q.22 A very light rod AB is initially hung from a point P by means of two identical copper wires of the same length as the rod as shown in the figure. Particles of masses 1 kg and 4 kg are then attached to the ends A and B of the rod. The ratio of the fundamental frequencies of vibration of the wires AP and BP, i.e., $\frac{f_A}{f_B} =$



(A) 4 (B) $\frac{1}{2}$ (C) 16 (D) 2

Q.23 In a resonance tube experiment, an 80 cm air column is in resonance with a turning fork in first overtone. Which equation can represent correct pressure variation in the air column

(x = 0 is the top point of the tube, neglect end correction, speed of sound = 320 m/sec)

(A) $A \sin \frac{15\pi}{8} x \cos 600\,\pi t$

(B) $A \cos \frac{15\pi}{8} x \sin 600\,\pi t$

(C) $A \cos \frac{15\pi}{8} x \sin 300\,\pi t$

(D) $A \sin \frac{15\pi}{8} x \sin 300\,\pi t$

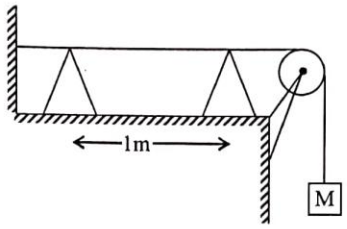
Q.24 When tuning forks A and B are struck, a beat frequency f_{AB} is heard. When A and C are struck a beat frequency of f_{AC} is heard. It was found that $f_{AC} > f_{AB}$. If f_A, f_B and f_C are individual frequencies, then what are the possible relations ?

(A) $f_A > f_B > f_C$ (B) $f_A < f_B < f_C$ (C) $f_B > f_A > f_C$ (D) $f_C > f_A > f_B$

Passage Based Questions

Passage # 1 (Q.25 & 26)

A sonometer apparatus is shown in the figure. The distance between bridges is 1 m. Linear mass density of wire is 2 g/m. Fundamental frequency of wire is 100 Hz. When apparatus is accelerated up with acceleration a, the fundamental frequency becomes twice. [neglect length of hanging wire].



Q.25 When sonometer apparatus is at rest, if block is made to move as a conical pendulum of angle 60° (from vertical) then fundamental frequency of sonometer wire will increase by :

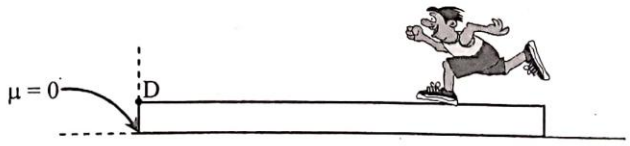
(A) 82.8% (B) 41.4% (C) 20% (D) 1.41%

Q.26 The value of acceleration a is :

(A) 10 m/sec^2 (B) 20 m/sec^2 (C) 30 m/sec^2 (D) zero.

Passage # 2 (Q.27 to 29)

A man of mass 50 kg is running on a plank of mass 150 kg with speed of 8 m/s relative to plank as shown in the figure (both were initially at rest and the velocity of man with respect to ground any how remains constant). Plank is placed on smooth horizontal surface. The man, while running whistles with frequency f_0. A detector (D) placed on plank detects frequency. The man jumps off with same velocity from point D and slides on the smooth horizontal surface [Assume coefficient of friction between man and horizontal surface is zero]. The speed of sound in still medium is 330 m/s. Answer following questions on the basis of above situations.



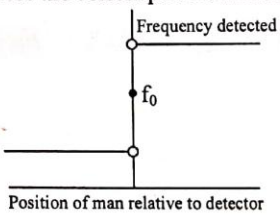
Q.27 The frequency of sound detected by detector D, before man jumps of the plank is.

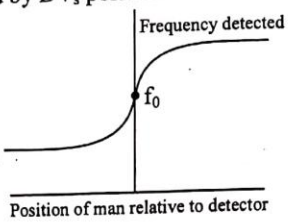
(A) $\frac{332}{324} f_0$ (B) $\frac{330}{322} f_0$ (C) $\frac{328}{336} f_0$ (D) $\frac{330}{338} f_0$

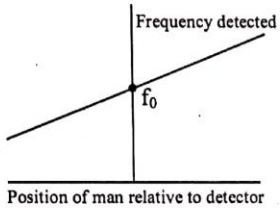
Q.28 The frequency of sound detected by detector D, after man jumps of the plank is.

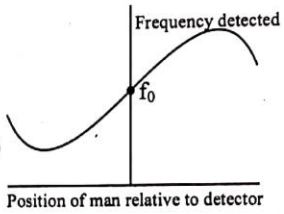
(A) $\frac{332}{324} f_0$ (B) $\frac{330}{322} f_0$ (C) $\frac{328}{336} f_0$ (D) $\frac{330}{338} f_0$

Q.29 Choose the correct plot between the frequency detected by DV_s position of the man relative to detector.

(A)


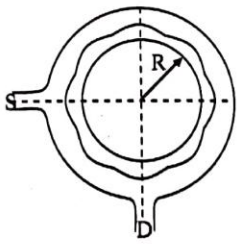
(B)


(C)


(D)


Passage # 3 (Q.30 to 32)

A narrow tube is bent in the form of a circle of radius R, as shown in the figure. Two small holes S and D are made in the tube at the positions right angle to each other. A source placed at S generates a wave of intensity I_0 which is equally divided into two parts: one part travels along the longer path, while the other travels along the shorter path. Both the part waves meet at the point D where a detector is placed.



Q.30 If a maxima is formed at a detector then, the magnitude of wavelength λ of the wave produced is given by

(A) πR (B) $\frac{\pi R}{2}$ (C) $\frac{\pi R}{4}$ (D) All of these

Q.31 If a minima is formed at the detector then, the magnitude of wavelength λ of the wave produced is given by

(A) $2\pi R$ (B) $\frac{3}{2}\pi R$ (C) $\frac{2}{5}\pi R$ (D) None of these

Q.32 The maximum intensity produced at D is given by

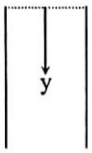
(A) $4I_0$ (B) $2I_0$ (C) I_0 (D) $3I_0$

Passage # 4 (Q.33 & 34)

In an organ (may be closed or open) of 99 cm length standing wave is setup, whose equation is given by longitudinal displacement

$$\zeta = (0.1 \text{ mm}) \cos \frac{2\pi}{0.8} (y + 1\text{cm}) \cos 2\pi (400)t$$

Where y is measured from the top of the tube in meters and t in second.
Here 1 cm is the end correction.



Q.33 The air column is vibrating in
(A) First overtone (B) fifth harmonic (C) Third harmonic (D) Fundamental mode

Q.34 Equation of the standing wave in terms of excess pressure is –
(Bulk modulus of air $B = 5 \times 10^5$ N/m^2)
(A) $P_{ex} = (125\pi N/m^2) \sin \frac{2\pi}{0.8} (y + 1\text{cm}) \cos 2\pi (400\,t)$ (B) $P_{ex} = (125\pi N/m^2) \cos \frac{2\pi}{0.8} (y + 1 \text{ cm}) \sin 2\pi (400\,t)$
(C) $P_{ex} = (225\pi N/m^2) \sin \frac{2\pi}{0.8} (y + 1 \text{ cm}) \cos 2\pi (200\,t)$ (D) $P_{ex} = (225\pi N/m^2) \cos \frac{2\pi}{0.8} (y + 1 \text{ cm}) \sin 2\pi (200\,t)$

Passage # 5 (Q.35 & 36)

A linear simple harmonic oscillator has small sonic sources of frequency 90 Hz, fixed on it. The harmonic oscillator is placed in a room where air flow direction is either in the direction of motion of oscillator or against it. A sonic detector is placed along the axis of the simple harmonic oscillator. Speed of airflow is half of speed of sound in given medium and maximum speed of oscillator is one fourth of the speed of the sound.

Q.35 The maximum possible frequency recorded by the detector
(A) 120 (B) 140 (C) 180 (D) 240

Q.36 The minimum possible frequency recorded by the detector
(A) 60 (B) 30 (C) 40 (D) 50

Passage # 6 (Q.37 to 39)

The air column in a pipe closed at one end is made to vibrate in its third over tone by tuning fork of frequency 220 Hz. The speed of sound in air is 330 m/sec. End correction may be neglected. Let P_0 denote the mean pressure at any point in the pipe and ΔP_0 the maximum amplitude of pressure vibration.

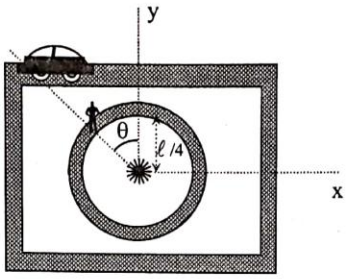
Q.37 Find the length of the air column
(A) 3.2 m (B) 2.625 m (C) 4.23 m (D) 1.16 m

Q.38 What is the amplitude of pressure variation at the middle of the column
(A) $\frac{\Delta P_0}{\sqrt{2}}$ (B) $\frac{\sqrt{3}\Delta P_0}{2}$ (C) ΔP_0 (D) $\frac{\Delta P_0}{2}$

Q.39 What is the maximum pressure at the open end of the pipe ?
(A) P_0 (B) $P_0 + \Delta P_0$ (C) $P_0 + \frac{P_0}{2}$ (D) None of these

Passage # 7 (Q.40 & 41)

A square ground of side $\ell = \frac{10}{\sqrt{2}}$ has a circular running track of radius $\ell/4$. The centre of square ground coincides with the centre of circular track. A man is running on the circular track, the angular velocities of line joining man to centre of the circle is 22 rad/s , while a car is running on adjacent road as shown. The car moves in such a way that the car, man and centre lie on a straight line always. A source of sound is kept at the centre of circular track. The frequency of sound produced by source is 300 Hz. The velocities of sound in air is 330 m/s. Now answer the following question. (width of the track is ignorable)

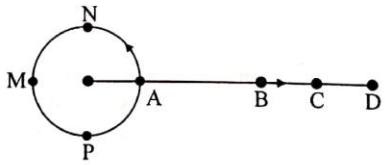


Q.40 If at any time t line joining man to centre of the track makes angle θ with y - axis. Find the value of θ at which an observer in the car observes minimum frequency.
(A) 30° (B) 45° (C) 60° (D) 37°

Q.41 The minimum frequency observed by the observer in the car will be
(A) 250Hz (B) 200 Hz (C) 275 Hz (D) 150 Hz

Column Matching Type Questions

Q.42 A source of sound in moving along a circular orbit of radius 3 m with angular velocity of 10 rad s^{-1}. A sound detector located for away is executing linear SHM with amplitude 6 m on line BCD as shown. The frequency of detector for oscillation is $\left(\frac{5}{\pi}\right)$ per second. The source is at A when detector at B at t = 0. Source emits a continuous sound wave of frequency 340 Hz. (Velocity of sound = 330 ms^{-1}). Match the column A with B.



Column-I	Column-II
(A) The frequency of sound recorded by detector at t = 3T/4.	(P) 255 Hz
(B) The frequency of sound recorded by detector at t = T/4.	(Q) 1 : 1
(C) The ratio of the time period of source and detector (circular motion and SHM).	(R) 442 Hz
(D) Maximum velocity of detector/maximum velocity of source. (T is time period of oscillation).	(S) 2 : 1

Q.43 A wave is transmitted from denser to rarer medium than match following :

List-I	List-II
(P) Frequency of wave	(1) will increase for sound wave
(Q) speed of wave	(2) will decrease for sound wave
(R) Wavelength of wave	(3) Remains unchanged for sound wave or light wave
(S) Amplitude of wave	(4) Will increase for light wave
	(5) Will decrease for light wave

Codes :

	P	Q	R	S
(A)	2	(2,4)	3	(2, 5)
(B)	3	5	(2,3)	3
(C)	3	(2,4)	(2,3)	(2, 5)
(D)	2	5	(2,3)	2

Q.44 In closed organ pipe at one end -

List-I	List-II
(P) Third overtone frequency is x times fundamental frequency then x is	(1) 3
(Q) Number of nodes in second overtone	(2) 4
(R) Number of antinodes in second overtone	(3) 5
(S) n^{th} harmonic does not exists, where n is	(4) 7
	(5) 6

Codes :

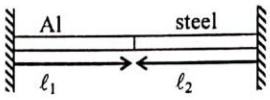
	P	Q	R	S
(A)	5	1	1	5
(B)	4	1	1	(2,5)
(C)	4	2	3	2
(D)	3	2	4	(2,5)

Q.45 Consider a situation (i) that two sound waves, $y_1 = (0.2\text{ m}) \sin 504\pi\left(t - \frac{x}{300}\right)$ and $y_2 = (0.6\text{ m}) \sin 496\pi\left(t - \frac{x}{300}\right)$ are super imposed. Consider another situation (ii) that two sound waves $y_1 = (0.4\text{ m}) \sin 504\pi\left(t - \frac{x}{300}\right)$ and $y_2 = (0.4\text{ m}) \sin 504\pi\left(t + \frac{x}{300}\right)$ are superimposed. Match the following

	Column – I		Column – II
(A)	In situation (i)	(P)	Stationary waves are formed
(B)	In situation (ii)	(Q)	There will be phenomenon of beats
(C)	When two waves of same frequency and amplitude and travelling in opposite direction superimpose.	(R)	Amplitude of the resultant wave will vary periodically with position
(D)	If the intensity of sound alternately increases and decreases periodically a result of superposition of waves of highly different frequencies.	(S)	Amplitude of the resultant wave will vary periodically with line
		(T)	Amplitude of the resultant wave will be constant

Numeric Response Type Questions

Q.46 There is a composite wire of aluminium and steel having uniform cross-section (A) throught. The composite wire is in stretched condition with tension T.



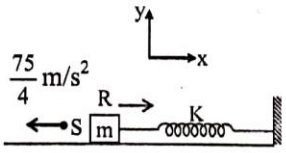
$\ell_1 = \frac{2}{\sqrt{3}}$ m, $\ell_2 = 1$m.

density of Al = 2.6 gm/cm^3

density of steel = 7.8 gm/cm^3

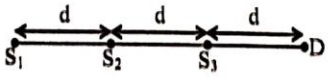
the external source is of lowest possible frequency to strike resonance in the composite wire with junction as a node. How many loops on the string are formed?

Q.47 A sound source S emitting a sound of frequency 500 Hz and receiver R of mass 'm' are at the same point. R is performing SHM with the help of a spring of force constant k. At a time t = 0, R is at mean position and moving toward right as shown in figure. At the same time, source starts moving away from the R with an acceleration $\frac{75}{4}$ m/s^2. Given that $\frac{m}{k} = \frac{100}{\pi^2}$ and amplitude of oscillation of R = $\frac{150}{\pi}$m, speed of sound = 300 m/s. If the frequency (in Hz) registered by detector at t = 10 second is (50x)Hz, find x.



Q.48 A string 25 cm long fixed at both ends and having a mass of 2.5g is under tension of 25N. A pipe closed from one end is 40 cm long. When the string is set vibrating in its first overtone and the air in the pipe in its fundamental mode, beat are heard. It is observed that increasing the tension in the string decrease the beat frequency. If the speed of sound in air is 328 m/s, find the beat frequency.

Q.49 Three coherent sources generating waves in the same phase are placed as shown. The wave length of the wave is 40×10^{-7}m. The minimum distanced (in μm), such that intensity at point D is 9 times the intensity of each source will be _____.



Q.50 A source of sound with natural frequency n = 1.8 kHz moves uniformly along a straight line separated from a stationary observer by a distance ℓ = 250 m. The velocity of the source is equal to η = 0.80 fraction of the velocity of sound. Find the frequency in kHz of sound received by the observer at the moment when the source gets closest to him;

Q.51 A pop-gun consists of a cylindrical barrel 3 cm^2 in cross-section closed at one end by a cork and having a well fitting piston at the other. If the piston is pushed slowly in, the cord is finally ejected, giving a pop, the frequency of which is found to be 512 Hz. Assuming that the initial distance between the cork and the piston was 25 cm and there is no leakage of air, If the force required to eject the cork is $0.75 \times x$ kg – wt. Find the value of x. Atmospheric pressure = 1 kg wt / cm^2, v = 340 m/s.

Q.52 Two sound waves of frequencies 100 Hz and 102 Hz and having same amplitude 'A' are interfering. A stationary detector which can detect waves of amplitude greater than or equal to A. In a time interval of 12 seconds, find the total duration (in sec.) which detector is active.

ANSWER KEY

Single Correct Option type Questions

1. (B)	**2.** (D)	**3.** (C)	**4.** (B)	**5.** (A)	**6.** (A)	**7.** (A)
8. (D)	**9.** (C)	**10.** (B)	**11.** (D)	**12.** (B)	**13.** (A)	**14.** (A)
15. (A)						

Statement Based Questions

16. (B)	**17.** (A)	**18.** (A)	**19.** (B)

Multiple Correct Option type Questions

20. (A,C,D)	**21.** (A,B,C,D)	**22.** (D)	**23.** (A)	**24.** (A,B,C,D)

Passage Based Questions

25. (B)	**26.** (C)	**27.** (A)	**28.** (C)	**29.** (A)	**30.** (D)	**31.** (C)
32. (B)	**33.** (B)	**34.** (A)	**35.** (C)	**36.** (A)	**37.** (B)	**38.** (A)
39. (A)	**40.** (B)	**41.** (B)				

Column Matching Type Questions

42. $A \rightarrow R$; $B \rightarrow P$; $C \rightarrow Q$; $D \rightarrow S$ **43.** (C) **44.** (B)

45. $A \rightarrow Q,S$; $B \rightarrow P,R$; $C \rightarrow P,R$; $D \rightarrow Q, S$

Numeric Response Type Questions

46. 5	**47.** 7	**48.** 5	**49.** 4	**50.** 5	**51.** 2	**52.** 8

Chapter 20

Electrostatics & Gauss's Law

Single Correct Option Type Questions

Q.1 A sphere of radius R carries charge such that its volume charge density is proportional to the square of the distance from the centre. What is the ratio of the magnitude of the electric field at a distance 2R from the centre to the magnitude of the electric field at a distance of R / 2 from the centre (i.e. $E_{r=2R} / E_{r=R/2}$) ?

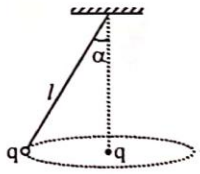
(A) 1 (B) 2 (C) 4 (D) 8

Q.2 A uniform surface charge of density $2\epsilon_0$ in SI unit is distributed over x, y plane. We consider spherical Gaussian surface of radius 5m, and centre at (a, b, c) then which of the following is incorrect -

(A) If (a, b, c) = (2, 0, 0) ; $\phi = 50\pi$ Nm^2/C (B) If (a, b, c) = (0, 4, 0) ; $\phi = 30\pi$ Nm^2/C

(C) If (a, b, c) = (0, 2, 6) ; $\phi = 0$ Nm^2/C (D) If (a, b, c) = (4, 3, 0) ; $\phi = 50\pi$ Nm^2/C

Q.3 A charge 'q' is revolving around another charge 'q' as shown in a conical pendulum. The motion is in a horizontal plane. then which of the following is correct -



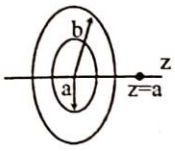
(A) Tension in the string is greater than the weight of the ball

(B) The tension in the string is greater than the electrostatic repulsive force

(C) If the charge is removed, the speed of ball has to be increased to maintain the angle.

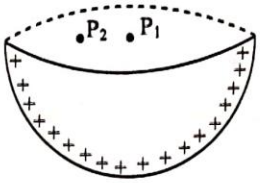
(D) All of the above

Q.4 Two concentric rings one of radius 'a' and the other of radius $b = 2a$ have charges 'q_a' and 'q_b' respectively as shown in figure. A charged particle placed on the axis at $z = a$ is in equilibrium, if the ratio $\frac{q_a}{q_b}$ is equal to -



(A) $-\left(\frac{2}{5}\right)^{3/2}$ (B) $\left(\frac{2}{5}\right)^{3/2}$ (C) $\left(\frac{2}{5}\right)^{2/3}$ (D) $-\left(\frac{2}{5}\right)^{2/3}$

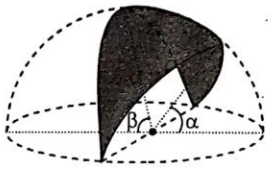
Q.5 Consider a uniformly charged hemispherical shell shown below. Indicate the directions (not magnitude) of the electric field at the central point P_1 and an off-centre point P_2 on the drumhead of the shell.



(A) ↑ ; ↖ (B) ↑ ; ↗

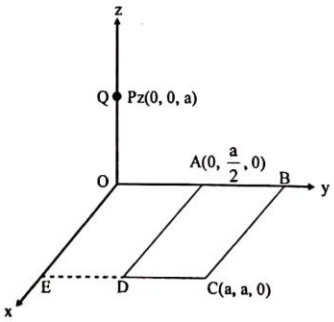
(C) ↑ ; ↑ (D) ↑ ; ←

Q.6 The electric field intensity at the centre of a uniformly charged hemispherical shell is E_0. Now two portions of the hemisphere are cut from either side and remaining portion is shown in figure. If $\alpha = \beta = \frac{\pi}{3}$, then electric field intensity at centre due to remaining portion is.



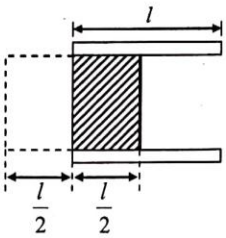
(A) $\frac{E_0}{3}$ (B) $\frac{E_0}{6}$ (C) $\frac{E_0}{2}$ (D) information insufficient

Q.7 A charge Q is placed at P (0, 0, a). The coordinates of A and C of a square are $\left(0, \frac{a}{2}, 0\right)$ and (a, a, 0) respectively. The flux through ABCD is



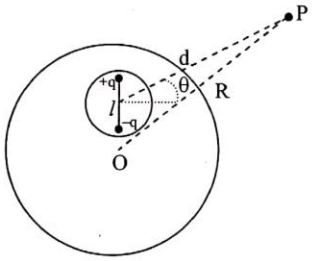
(A) $\frac{Q}{16\varepsilon_0}$ (B) $\frac{Q}{24\varepsilon_0}$ (C) $\frac{Q}{48\varepsilon_0}$ (D) None of these

Q.8 A capacitor of capacitance C is charged by a battery of emf V and then disconnected. The work done by an external agent to insert a dielectric of dielectric strength k of half the length of the capacitor is



(A) $\frac{1}{2}CV^2\left(\frac{k-1}{k+1}\right)$ (B) $\frac{1}{2}CV^2\left(\frac{1-k}{k+1}\right)$ (C) $\frac{1}{4}CV^2(k-1)$ (D) $\frac{1}{4}CV^2(1-k)$

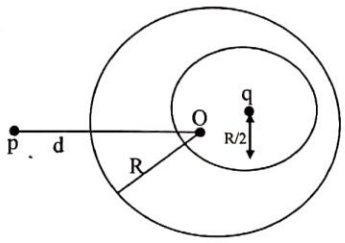
Q.9 A cavity is taken out from a uniform conducting sphere. Inside the cavity a dipole is placed as shown in the figure. Potential at point P is



(A) $\frac{ql\cos\theta}{4\pi\varepsilon_0 d}$ (B) Zero

(C) Insufficient information (D) None of these

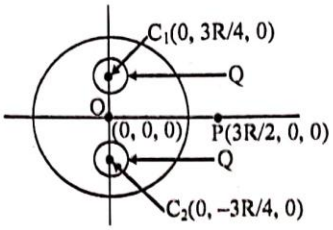
Q.10 From a conducting sphere of radius R a cavity of radius R/2 is cut out as shown in the figure. At the centre of cavity a point charge q is placed then the electric field and potential at point P as shown in the figure is



(A) $V = \frac{q}{2\pi\varepsilon_0 d}$, $E = \frac{q}{2\pi\varepsilon_0 d^2}$ (B) $V = \frac{q}{4\pi\varepsilon_0 d}$, $E = \frac{q}{2\pi\varepsilon_0 d^2}$

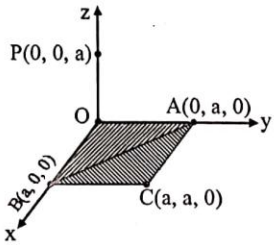
(C) $V = \frac{q}{4\pi\varepsilon_0 d}$, $E = \frac{q}{4\pi\varepsilon_0 d^2}$ (D) $V = \frac{q}{2\pi\varepsilon_0 d}$, $E = \frac{q}{4\pi\varepsilon_0 d^2}$

Q.11 An uncharged solid metallic sphere with two cavities is placed with centre of sphere at origin. Cavities have centres $C_1\left(0,\frac{3R}{4},0\right)$ and $C_2\left(0,\frac{-3R}{4},0\right)$ with same point charge Q placed at centres of cavities. Intensity of the field at point $P\left(\frac{3R}{2},0,0\right)$ is



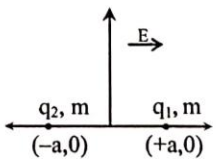
(A) $\frac{1}{4\pi\varepsilon_0}\frac{2Q}{9R^2}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{8Q}{9R^2}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{32Q}{45\sqrt{3}R^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{16Q}{9\sqrt{5}R^2}$

Q.12 A point charge q is placed at P(0, 0, a). The electric flux through CAB due to the electric field of q is Φ. Then



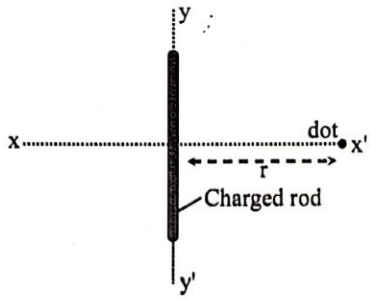
(A) $\Phi = \frac{q}{48\varepsilon_0}$ (B) $\Phi < \frac{q}{48\varepsilon_0}$ (C) $\frac{q}{48\varepsilon_0} < \Phi < \frac{q}{24\varepsilon_0}$ (D) $\Phi > \frac{q}{24\varepsilon_0}$

Q.13 Two positively charged particles of charges q_1 and q_2 have mass m each. A uniform electric field E exists in positive x direction as shown in figure. Two charged particles are released from rest at t = 0 sec. from points (±a, 0) as shown in figure. If position of q_1 at t = 2 sec. is given by coordinate (±2a, 0) then the x-coordinate of q_2 at t = 2 sec is :



(A) $\frac{q_1+q_2}{m}E - 2a$ (B) $\frac{q_1+q_2}{m}E - a$ (C) $2\left(\frac{q_1+q_2}{m}\right)E - 2a$ (D) $2\left(\frac{q_1+q_2}{m}\right)E - a$

Q.14 A uniformly charged rod is kept on y-axis with centre at origin, as shown. Which of the following actions will increase the electric field strength at the position of the dot?



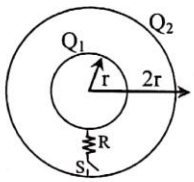
(A) make the rod longer without changing the charge

(B) make the rod shorter without changing the charge

(C) make the rod shorter without changing the linear charge density

(D) rotate the rod about yy'

Q.15 Two concentric, conducting spherical shells are shown in the figure. Inner and outer shells are given charge Q_1 and Q_2 respectively. If both the shells are connected through a switch S as shown in the figure, at time $t = 0$, find the current passing through the switch S at time t.



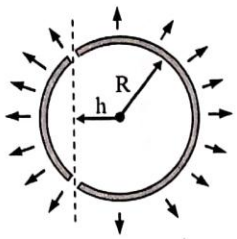
(A) $\frac{Q_1 t}{8\pi\varepsilon_0 rR}$ (B) $\frac{Q_1}{\varepsilon rR} e^{\frac{-t}{\varepsilon_0 rR}}$ (C) $\frac{Q_1}{8\pi\varepsilon_0 rR} e^{\frac{-t}{8\pi\varepsilon_0 rR}}$ (D) $\frac{Q_1}{t} e^{\frac{-t}{8\pi\varepsilon_0 rR}}$

Q.16 At $t = 0$ a proton of mass m accelerated from rest by a potential difference V gets into a uniform electric field of a parallel plate capacitor parallel to plates of length ℓ at mid point of its separation between plates. The field strength in it varies with time as $E = at$, where a is a positive constant. Find the angle of deviation of the proton as it comes out of the capacitor. (Assume that it does not collide with any of the plates).

(A) $\theta = \tan^{-1}\left(\frac{a\ell^2}{V}\sqrt{\frac{m}{8eV}}\right)$ (B) $\theta = \tan^{-1}\left(\frac{a\ell^2}{2V}\sqrt{\frac{m}{eV}}\right)$

(C) $\theta = \tan^{-1}\left(\frac{a\ell^2}{4V}\sqrt{\frac{m}{2eV}}\right)$ (D) $\theta = \tan^{-1}\left(\frac{a\ell^2}{V}\sqrt{\frac{m}{2eV}}\right)$

Q.17 Consider a metal sphere, of radius R that is cut in two parts, along a plane whose minimum distance from the sphere's centre is h. Sphere is uniformly charge by a total electric charge Q. The force necessary to hold the two parts of the sphere together is



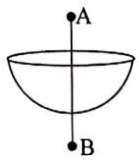
(A) $F = \frac{Q^2}{4\pi\varepsilon_0 R^4}(R^2 - h^2)$ (B) $F = \frac{Q^2}{4\pi\varepsilon_0 R^2}$

(C) $F = \frac{Q^2}{32\pi\varepsilon_0 R^3}(R - h)$ (D) $F = \frac{Q^2}{32\pi\varepsilon_0 R^4}(R^2 - h^2)$

Q.18 An infinitely long metal cylinder of radius R and surface charge density σ is placed symmetrically with an imaginary surface of the shape of a prism. The length of prism is L and its 3 sides are all equal to 3R. The flux through the prism is

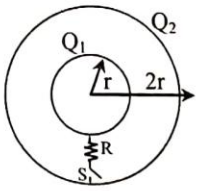
(A) $\frac{\pi}{3}\frac{\pi R\sigma}{\varepsilon_0}$ (B) $\frac{\pi}{2}\frac{\pi R\sigma}{\varepsilon_0}$ (C) $\frac{\pi RL\sigma}{\varepsilon_0}$ (D) $\frac{2\pi RL\sigma}{\varepsilon_0}$

Q.19 The diagram shows a uniformly charged hemisphere of radius R. It has volume charge density ρ. If the electric field at a point 2R distance above its centre is E then what is the electric field at the point which is 2R below its centre.



(A) $\rho R/6\varepsilon_0 + E$ (B) $\rho R/12\varepsilon_0 - E$ (C) $-\rho R/6\varepsilon_0 + E$ (D) $\rho R/24\varepsilon_0 + E$

Q.20 Two concentric, conducting spherical shells are shown in the figure. Inner and outer shells are given charge Q_1 and Q_2 respectively. If both the shells are connected through a switch S as shown in the figure, at time t = 0, find the current passing through the switch S at time t.



(A) $\frac{Q_1 t}{8\pi\varepsilon_0 rR}$ (B) $\frac{Q_1}{\varepsilon rR}e^{\frac{-t}{\varepsilon_0 rR}}$ (C) $\frac{Q_1}{8\pi\varepsilon_0 rR}e^{\frac{-t}{8\pi\varepsilon_0 rR}}$ (D) $\frac{Q_1}{t}e^{\frac{-t}{8\pi\varepsilon_0 rR}}$

Q.21 The intensity of an electric field depends only on the co-ordinates x, y and z as follows :

$$\vec{E} = a\frac{(x\hat{i}+y\hat{j}+z\hat{k})}{(x^2+y^2+z^2)^{3/2}} \text{ unit.}$$

The electrostatic energy stored between two imaginary concentric spherical shells of radii R and 2R with centre at origin is

(A) $\frac{4\pi\varepsilon_0 a^2}{R}$ (B) $\frac{2\pi\varepsilon_0 a^2}{R}$ (C) $\frac{\pi\varepsilon_0 a^2}{R}$ (D) $\frac{\pi\varepsilon_0 a^2}{2R}$

Q.22 A pendulum consists of a ball suspended by a silk thread of length ℓ. The mass of ball is m and it has negative charge (–Q). The radius of a ball can be neglected. The time period of a small oscillation of ball is T_0. Now a positive point charge is kept at three different positions in three different arrangements as shown in the figure. The time-period of small oscillation of pendulum corresponding to figure-I, figure-II and figure-III has values T_1, T_2 and T_3 respectively (AB = ℓ)

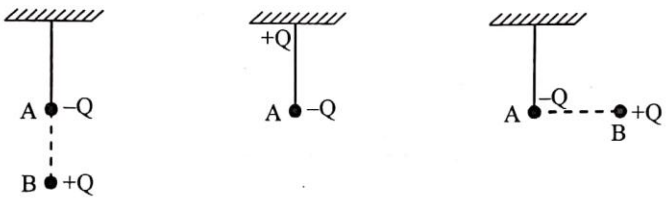


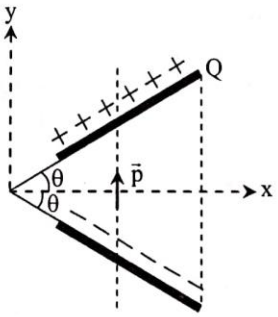
Figure-I **Figure-II** **Figure-III**

Choose the correct statement -

(A) $T_0 < T_1 = T_2 < T_3$ (B) $T_2 = T_0 < T_3 < T_1$

(C) $T_1 < T_2 = T_0 < T_3$ (D) $T_3 < T_2 = T_0 < T_1$

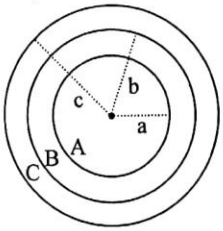
Q.23 Two large conducting identical plates are kept at small inclination θ with x-axis as shown in the figure. The upper plate has charge Q and lower plate has charge –Q. A electric dipole of dipole moment $\vec{p}$, pointing in the y-direction, is placed midway between two conducting plates. The direction of net force on the dipole will be -



(A) $(2\cos\theta\hat{i}+\sin\theta\hat{j})$ (B) $(2\sin\theta\hat{i}+\cos\theta\hat{j})$

(C) $\hat{i}$ (D) $\hat{j}$

Q.24 Three concentric charged metallic spherical shells A, B and C have radii a, b and c ; charge densities σ, $-\sigma$ and σ ; and potentials V_A, V_B and V_C respectively. Then which of the following relations is correct ?



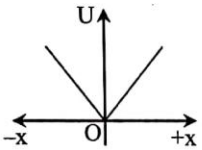
(A) $V_A = \dfrac{(a+b+c)\sigma}{\varepsilon_0}$

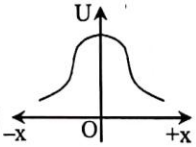
(B) $V_B = \dfrac{[(a^2/b)-b+c]\sigma}{\varepsilon_0}$

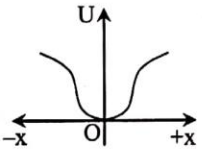
(C) $V_C = \dfrac{[(a^2+b^2)/c+c]\sigma}{\varepsilon_0}$

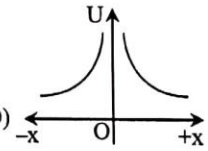
(D) $V_A = V_B = V_C = \dfrac{(a-b+c)\sigma}{\varepsilon_0}$

Q.25 Four identical charges are placed at the four vertical of a square lying in YZ plane. A fifth charge is moved along X axis. The variation of potential energy (U) along X-axis is correctly represented by

(A) 

(B) 

(C) 

(D) 

Q.26 Three point charges +q, –2q and +q are placed at points $\left(0, \frac{a}{\sqrt{2}}, \frac{a}{\sqrt{2}}\right)$; (0, 0, 0) and $\left(0, \frac{a}{\sqrt{2}}, -\frac{a}{\sqrt{2}}\right)$ respectively. Find the net electric dipole moment vector of this charge assembly.

(A) $\sqrt{2}qa(-\hat{j})$ (B) $\sqrt{2}qa(-\hat{k})$ (C) $\sqrt{2}qa(+\hat{j})$ (D) $2qa(+\hat{j})$

Q.27 Choose the INCORRECT STATEMENT.

(A) Gauss' Law can be derived from Coulomb's law.

(B) Gauss' law states that the net number of field lines crossing any closed surface in an outward direction is proportional to the net charge enclosed within the surface.

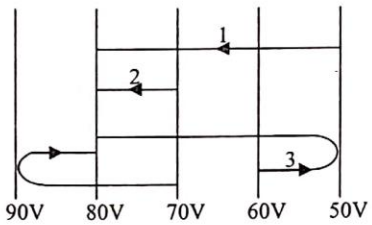
(C) Coulomb's law can be derived from Gauss' law and symmetry.

(D) According to Gauss' law, if a closed surface encloses no charge, then the electrostatic field must vanish everywhere on the surface.

Q.28 Positive charge Q is uniformly distributed throughout the volume of an insulating sphere of radius R, centered at origin. A point charge Q is placed at x = 2R on the x-axis. The magnitude of electrostatic field at x = R/2 on the x-axis is

(A) $\dfrac{Q}{4\pi\varepsilon_0 R^2}$ (B) $\dfrac{Q}{8\pi\varepsilon_0 R^2}$ (C) $\dfrac{Q}{72\pi\varepsilon_0 R^2}$ (D) $\dfrac{17Q}{72\pi\varepsilon_0 R^2}$

Q.29 An electron goes from one equi-potential surface to another along one of the four paths shown in the diagram. Rank the paths according to the work done by the electrostatic field from the least to the greatest

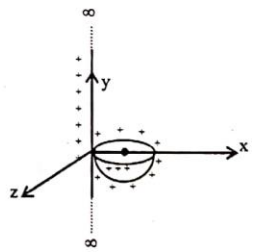


(A) 1, 2, 3, 4 (B) 4, 3, 2, 1 (C) 1, 3, 4 and 2 equal (D) 4 and 2 equal, 3, 1

Q.30 In a uniform electric field the potential of origin is V and $V/2$ at each of the points $(a, 0, 0)$, $(0, b, 0)$, $(0, 0, c)$. The potential at (a, b, c) will be

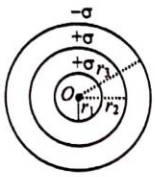
(A) $\frac{V}{2}$ (B) $\frac{-3V}{2}$ (C) $-\frac{V}{2}$ (D) $-V$

Q.31 An infinitely long non-conducting wire carrying uniform linear charge density λ C/m lying along y-axis has a circular bent in xz plane and a semicircular bent in xy plane of radius R as shown in figure. Electric field at the centre of circular bends is -



(A) $2\sqrt{2}\,\frac{k\lambda}{R}$ (B) $\sqrt{5}\,\frac{k\lambda}{R}$ (C) $\sqrt{2}\,\frac{k\lambda}{R}$ (D) $\frac{2k\lambda}{R}$

Q.32 If the electric potential on the surface of inner most sphere is zero, then the relation between r_1, r_2 and r_3 is (here, σ is surface charge density)

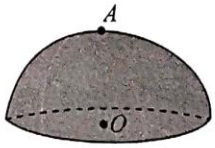


(A) $r_3 = r_1 + r_2$ (B) $r_2 = \sqrt{r_1 r_3}$ (C) $r_2 = r_1 + r_3$ (D) $r_3 = r_1 + r_2$

Q.33 The electric field potential in a certain region of space depends only on the x-coordinate as $V = -2x^3 + 3$. Find the distribution of the space charge $\rho(x)$.

(A) $6\,\epsilon_0 x$ (B) $12\,\epsilon_0 x$ (C) $6\,\epsilon_0$ (D) $-12\,\epsilon_0$

Q.34 A hemispherical bowl of radius R carries a uniform surface charge density σ. Find the potential at the topmost point A, taking potential at infinity to be zero.



(A) $\frac{\sigma R}{\sqrt{2}\varepsilon_0}$ (B) $\frac{\sigma R}{2\varepsilon_0}$ (C) $\frac{\sqrt{2}\sigma R}{\varepsilon_0}$ (D) None of these

Q.35 If electric field between plates of a parallel plate capacitor is 2 N/C and charge on two plates are 10C and 3C, then force on one of the plates is

(A) 20 N (B) 13 N (C) $\frac{60}{7}$ N (D) $\frac{7}{2}$ N

Multiple Correct Option Type Questions

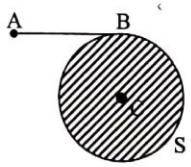
Q.36 A proton moving along positive x-axis enters a uniform electric field $\vec{E} = -400\ \hat{i}$ N/C at time t = 0. It is observed that at t = 12 μ sec, the proton is at rest [Take mass of proton = 1.6×10^{-27} kg ; charge of proton = 1.6×10^{-19} C]. Choose the correct option(s)

(A) Initial speed of the proton is 4.8×10^5 m/sec
(B) Initial speed of the proton is 3.2×10^5 m/sec
(C) Distance travelled by the proton from time t = 0 to time t = 12 μ sec is 2.88 m
(D) Distance travelled by the proton from time t = 0 to time t = 12 μ sec is 2.12 m

Q.37 A small dipole $\vec{p}$ is placed inside an irregular cavity of a spherical conductor having a charge Q on it. Choose the **INCORRECT** option(s)

(A) Net force on dipole is zero
(B) The charge on outer surface of conductor is non uniform
(C) The electric field at a distance r from the dipole in its line outside conductor due to charge on outer surface of conduction is $\frac{2KP}{r^3}$.
(D) Net force on sphere is zero

Q.38 S is a solid neutral conducting sphere. A point charge $q = 1 \times 10^{-6}$ C is placed at point A. C is the centre of sphere and AB is a tangent, BC = 3 m and AB = 4m.



(A) The electric potential at C due to induced charges on the sphere is 0 V.
(B) The electric potential at C due to induced charges on the sphere is – 1.2 kV.
(C) The electric potential at B due to induced charges on the sphere is – 0.45 kV.
(D) The electric potential at B due to induced charges on the sphere is 0.45 kV.

Q.39 Three nonconducting infinite planar sheets are parallel to the y-z plane, Each sheet has a uniform surface charge density. The first sheet, with a negative surface charge density $-\sigma$, passes through the x-axis at x=1 m. The second sheet has an unknown surface charge density and passes through the x-axis at x = 2m. The third sheet has a negative surface charge density -3σ and passes through the x-axis at x = 4m. The net electric field due to the sheets is zero at x = 1.5 m.

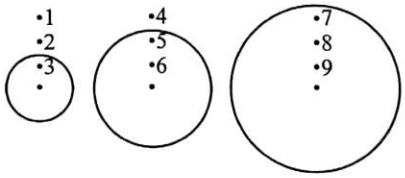
(A) The surface charge density on the second sheet is $+2\sigma$

(B) The electric field at x = –2 m is $\frac{\sigma}{\epsilon_0}\hat{i}$

(C) The electric field at x = 3 m is $\frac{\sigma}{\epsilon_0}\hat{i}$

(D) The electric field at x = 6 m is $\frac{-\sigma}{\epsilon_0}\hat{i}$

Q.40 Figure shows three spherical shells in separate situations, with each shell having the same uniform positive net charge. Points 1, 4 and 7 are at the same radial distances from the centre of their respective shells; so are points 2, 5 and 8; and so are points 3, 6 and 9. With the electric potential taken equal to zero at an infinite distance, choose correct statement(s).



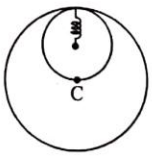
(A) point 3 has highest potential

(B) point 1, 4 and 7 are at same potential

(C) point 9 has lowest potential

(D) point 5 and 8 are at same potential

Q.41 A non-conducting sphere having a spherical cavity centred at distance a from centre of sphere. Charge on the sphere is distributed uniformly with volume density ρ. A particle of mass m having charge – q is suspended vertically from light non-conducting spring of force constant k. Evaluate the correct statements.(No gravity and initially when –q is suspended spring was of natural length)



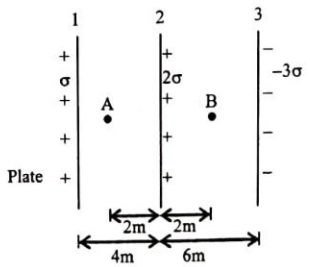
(A) Maximum elongation of the spring is $\frac{2\rho aq}{3\varepsilon_0 k}$

(B) Maximum elongation of the spring is $\frac{\rho aq}{3\varepsilon_0 k}$

(C) Time period of oscillation is $2\pi\sqrt{\frac{m}{k}}$

(D) Time period of oscillation is $2\pi\sqrt{\frac{\rho m}{\varepsilon_0 k}}$

Q.42 The figure shows three infinite thin non-conducting charged plates perpendicular to the plane of the paper with charge per unit area $+\sigma$, $+2\sigma$ and -3σ. As we move from plate 1 to plate 2 magnitude of potential change occured is V_{12}, that from plate 2 to 3 is V_{23} and that from plate 1 to 3 is V_{13}. Then-



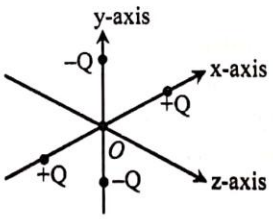
(A) Ratio of net electric field at point A to that at point B is 1/3
(B) $9V_{12} = 2\,V_{23}$
(C) $2V_{13} = 7\,V_{12}$
(D) $3V_{13} = 5V_{23}$

Q.43 Two charge Q_1 & Q_2 placed at (0, 0, 0) and (a, 0, 0) are such that x component of field is zero at $\left(\frac{a}{2}, a, 0\right)$.

Then -

(A) y component of field is zero at $\left(\frac{a}{2}, 0, a\right)$
(B) $\frac{Q_1}{Q_2} = \frac{2}{1}$
(C) $\frac{Q_1}{Q_2} = 1$
(D) y component of field is zero at $\left(\frac{a}{2}, a, 0\right)$

Q.44 Figure shows an arrangement in which four charges are placed at equal distances from the origin. For a positive test charge placed at O, which of the following statements are true ? (all the three axis x, y, z are mutually perpendicular axis)



(A) It is in equilibrium
(B) The equilibrium is neutral along z-axis
(C) The equilibrium is stable along y-axis
(D) The equilibrium is stable along x-axis

Q.45 Electric field intensity at is point (x,y) is given by $\vec{I} = (12\,xy^3 - 4x)\,\hat{i} + 18\,x^2y^2\,\hat{j}$ where all parameters are in S.I. units. Then choose the correct statement (s) out of the following.
(A) it represents a conservative electric field
(B) it represents a non-conservative electric field
(C) electric potential at point (1m, 1m) is – 4V if electric potential at origin is zero
(D) electric potential at point (1m, 1m) is 4V if electric potential at origin is zero

Q.46 A fixed point charge Q is at origin. At t = 0, a charge q with mass m is at x = a with leftward velocity V_0 which satisfies $\frac{kQq}{a} = 3mV_0^2$. The particle turns around and starts to move rightward at the position x = b where b < a.

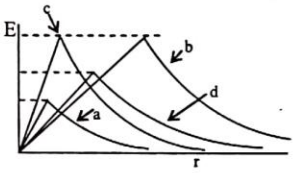
(A) the ratio $\frac{b}{a}$ is $\frac{6}{7}$

(B) the ratio $\frac{b}{a}$ is $\frac{3}{7}$

(C) the velocity of the particle at a large distance from the origin is $\sqrt{7}V_0$

(D) the velocity of the particle at a large distance from the origin is zero.

Q.47 Four sphere each of different radius named 'a', 'b', 'c', 'd' are given, each are solid insulating uniformly charged and carrying equal total charge. Variation of electric field with distance r from the centre is given. Then



(A) Radius of sphere a > Radius of sphere b

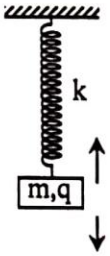
(B) Radius of sphere a < Radius of sphere b

(C)Volume charged density of c > volume charged density of b

(D) Volume charged density of c < volume charged density of b

Q.48 The following figure shows a block of mass m suspended from a fixed point by means of a vertical spring. The block is oscillating simple harmonically and carries a charge q. There also exists a uniform electric field in the region. Consider four different cases.

The electric field is zero, in case-l, $\frac{mg}{q}$ downward in case-2, $\frac{mg}{q}$ upward in case-3 and $\frac{2mg}{q}$ downward in case-4. The speed at mean position is same in all cases. Select the correct alternative (s).



(A) Time periods of oscillation are equal in case -1 and case-3

(B) Amplitudes of displacement are same in case-2 and case-3

(C) The maximum elongation (increment in length from natural length) is maximum in case-4.

(D) Time periods of oscillation are equal in case-2 and case-4

Q.49 Negative charge is revolving around a fixed positive charged in a circular orbit. If the classical idea of an accelerating charge radiating energy is valid, then the negative charge will :

(A) spiral towards the positive charge, with increasing kinetic energy

(B) spiral towards the positive charge with potential energy decreasing at a faster rate than increase in its kinetic energy.

(C) spiral away from the positive charged and finally escape from the binding of the positive charge

(D) revolve around the positive charge with increasing frequency of revolution.

Q.50 Two conducting spheres of radii r and 2r and placed at very large separation. Each sphere possess charge Q. These spheres are connected with a conducting wire of resistance R. Then, which of the following is true ?

(A) Initial current is $\frac{Q}{8\pi\varepsilon_0 rR}$

(B) Initial current is $\frac{Q}{4\pi\varepsilon_0 rR}$

(C) Current reduces to half the initial current after time $8\pi\varepsilon_0 rR \ln 2$

(D) Current reduces to half the initial current after time $\frac{8\pi\varepsilon_0 rR \ln 2}{3}$

Q.51 A point charge q is kept at origin. The space around origin can be considered as non-conducting sphere of radius, tends to infinity and having continuous charge distribution, whose volume charge density is

$$\rho = \frac{-q}{4\pi a} \cdot \frac{e^{-\frac{r}{a}}}{r^2}$$

Where 'a' is a positive constant and 'r' is distance of a point from origin. The potential at infinity can be considered to be zero. The dielectric constant of space is 1. (Neglect the effect of polarization)

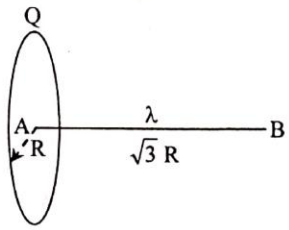
(A) The total charge of system is zero

(B) The total charge of system is q/2

(C) The magnitude of electrostatic field at a distance of r from origin is $\frac{qe^{-r/a}}{4\pi\varepsilon_0 r^2}$

(D) The magnitude of electrostatic field at a distance of r from origin is $\frac{qe^{-r/a}}{8\pi\varepsilon_0 r^2}$

Q.52 A non conducting rod AB of length $\sqrt{3}$ R has uniformly distributed charge of linear charge density λ. A nonconductor ring has uniformly distributed charge Q. Point A is the centre of ring and line AB is the axis of ring, perpendicular to plane of ring. Choose the correct statement(s) -



(A) The net electrostatic force on the ring due to charge on the rod is $\frac{Q\lambda}{8\pi\varepsilon_0 R}$

(B) The net electrostatic force on the ring due to charge on the rod is $\frac{Q\lambda}{4\pi\varepsilon_0 R}$

(C) The electrostatic flux through ring is $\frac{\lambda R}{\varepsilon_0}(\sqrt{3}-1)$

(D) The electrostatic flux through ring is $\frac{\lambda R}{2\varepsilon_0}(\sqrt{3}-1)$

Q.53 10C of charge is given to a conducting spherical shell and another – 3C point charge is placed inside the shell. For this arrangement mark out the correct statement(s).

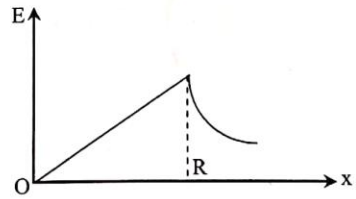
(A) The charge on the inner surface of the shell will be +3C and it can be distributed uniformly or non uniformly

(B) The charge on the inner surface of the shell will be +3C and its distribution would be uniform

(C) The net charge on outer surface of the shell will be +7C and its distribution can be uniform or non uniform

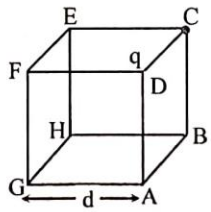
(D) The net charge on outer surface of the shell will be +7C and its distribution would be uniform

Q.54 A sphere has a positive charge. Figure shows variation of electric field (E) with distance x from its centre. From this figure, we conclude that -



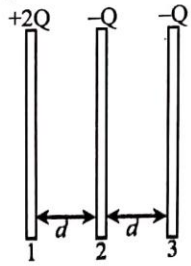
(A) Sphere is made of a non conducting materials
(B) Diameter of sphere is equal to R/2
(C) Electric potential due to sphere is maximum at its centre
(D) Density of charge is uniform throughout the volume of sphere

Q.55 A point charge q is placed at corner D of a cube of side d. Flux of electric field passing through face.



(A) ABCD is zero (B) CDFE is zero (C) DFGA is zero (D) ABHG is $\frac{q}{24\varepsilon_0}$

Q.56 Three identical square plates of surface area A of each side is arranged as shown in the figure. Plates 1,2 and 3 are given charges + 2Q, –Q and –Q respectively. Find out the correct options



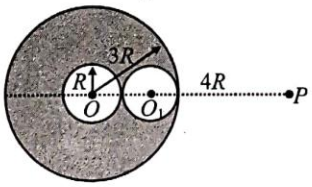
(A) Charges on the two faces of the middle plate are $-\frac{Q}{2}$ and $-\frac{Q}{2}$

(B) Charge on the two faces of the middle plate are –2Q and +Q

(C) Energy of the system is $\left(\frac{5}{2}\frac{Q^2d}{\varepsilon_0 A}\right)$

(D) Energy of the system is $\left(\frac{3}{2}\frac{Q^2d}{\varepsilon_0 A}\right)$

Q.57 A thick shell inner radius R and outer radius $3R$ has uniform charge density ρ. It has a spherical cavity of radius R as shown in figure. Choose the correct options



(A) Electric field at O will be zero

(B) Electric field at O_1 will be $\frac{7}{12}\frac{\rho R}{\varepsilon_0}$

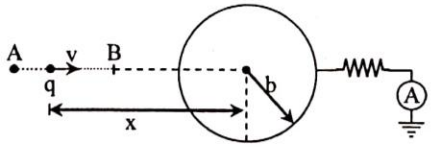
(C) Electric field at P will be $\frac{11}{24}\frac{\rho R}{\varepsilon_0}$

(D) Potential at O will be $\frac{23}{6}\frac{\rho R^2}{\varepsilon_0}$

Passage Based Questions

Passage # 1 (Q.58 to 60)

A charge q is moving towards the centre of an earthed conducting sphere of radius 'b' with uniform velocity 'v'. Distance of two points A and B from centre of the sphere are 3a and 2a, conducting sphere is earthed with an ideal ammeter and a resistance R in series as shown in figure.



Let at any instant point charge q is at a distance x from centre. Then choose the correct answer.

Q.58 Net charge on the surface of conductor at this instant -

(A) $+q$ (B) $-q$ (C) $-\frac{qx}{b}$ (D) $-\frac{qb}{x}$

Q.59 Reading of ammeter at this instant -

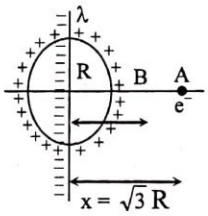
(A) $\frac{dv}{b^2}x$ (B) $\frac{dv}{b}$ (C) $\frac{qbv}{x^2}$ (D) zero

Q.60 Heat energy produced in resistor till charge particle moves from A to B -

(A) $\frac{19q^2b^2vR}{648a^3}$ (B) $\frac{2q^2b^2vR^2}{5a^3}$ (C) zero (D) $\frac{5}{72}\frac{q^2b^2vR}{a^3}$

Passage # 2 (Q.61 & 62)

There is a uniformly charged ring having radius R. An infinite line charge (Charge per unit length – λ) is placed along a diameter of the ring (in gravity free space). Total charge on the ring $Q = 4\sqrt{2}\,\lambda\,R$. An electron of mass m is released from rest on the axis of the ring at a distance $x = \sqrt{3}\,R$ from the centre.



Q.61 Magnitude of initial acceleration of the electron -

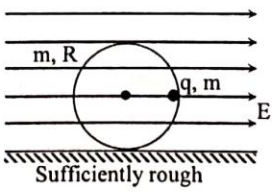
(A) $\frac{e\lambda}{\pi\varepsilon_0 mR}\left(\frac{3-2\sqrt{2}}{4\sqrt{6}}\right)$ (B) $\frac{e\lambda}{\pi\varepsilon_0 mR}\left(\frac{3+2\sqrt{2}}{4\sqrt{6}}\right)$ (C) $\frac{e\lambda}{\pi\varepsilon_0 mR}\left(\frac{3+2\sqrt{2}}{4\sqrt{3}}\right)$ (D) None

Q.62 The distance from centre of ring on the axis where the net force on the electron is zero -

(A) 2R (B) $\sqrt{2}\,R$ (C) R (D) none of these

Passage # 3 (Q.63 & 64)

A charge particle of charge q and mass m is clamped rigidly at the circumference of a ring with mass m and radius R. Initially ring is in vertical plane resting on a sufficiently rough horizontal surface with charge q at the same horizontal level as that of the centre of the ring. There exist uniform horizontal electric field as shown. At t = 0 the system is let free. Given that (qE = mg).



Q.63 The magnitude of the friction force at t = 0.

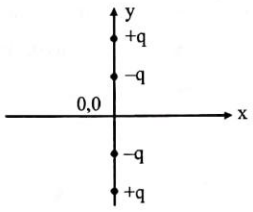
(A) mg (B) $\sqrt{2}$ mg (C) Zero (D) $\frac{mg}{2}$

Q.64 Work done by the electric field when the ring has rotated through 90° (Take $\pi = \frac{22}{7}$)-

(A) $\frac{2}{7}$ mgR (B) $\frac{4}{7}$ mgR (C) – mgR (D) mg$\sqrt{2}$ R

Passage # 4 (Q.65 & 66)

Two rods of length ℓ and 2ℓ are placed in xy plane such that their mid points are at origin and they are free to rotate in xy plane about z-axis. Two +q charges are fixed at two ends of bigger rod and two –q charges are fixed at two ends of smaller rod.



Q.65 Work done in rotating the rod of length ℓ by 180° is

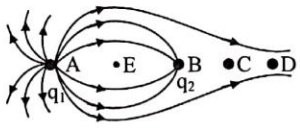
(A) $\frac{5kq^2}{\ell}$ (B) $\frac{3kq^2}{\ell}$ (C) $\frac{kq^2}{\ell}$ (D) None of these

Q.66 Electric field at point (a, 0, 0) is E. Now if a >>>ℓ then-

(A) $E \propto \frac{1}{a^3}$ (B) $E \propto \frac{1}{a^2}$ (C) $E \propto \frac{1}{a^4}$ (D) $E \propto \frac{1}{a^5}$

Passage # 5 (Q.67 & 68)

The electric line of force is defined as the curve in electric filed on which the tangent drawn at a point gives the direction of field intensity. The electric flux is defined as the surface integral of electric field measured normal to that surface area. The figure gives the pattern of electric lines of force of two point charges q_1 and q_2. Answer the following questions with your knowledge of electric lines of force :



Q.67 If r is distance between point charges and x is distance of neutral point from q_1 at A, then $\frac{x}{r}$ is

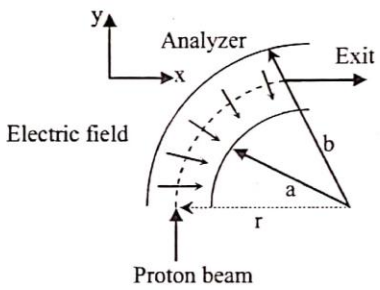
(A) $\frac{1}{\sqrt{3}}$ (B) $\frac{\sqrt{3}}{1}$ (C) $\frac{\sqrt{3}+1}{\sqrt{3}}$ (D) $\frac{\sqrt{3}}{\sqrt{3}-1}$

Q.68 Electric field in magnitude is :

(A) maximum near A, minimum at D
(B) maximum near A, minimum at B
(C) maximum near A, minimum at C
(D) maximum near A, minimum at E

Passage # 6 (Q.69 & 70)

Figure shows a schematic view of an electrostatic analyzer. It can sort out charged particles by speed and charge to mass ratio. Spacecraft use such analyzers to characterize charged particles in interplanetary space. Two curved metal plates establish an electric field given by $E = E_0\left(\frac{b}{r}\right)$ where E_0 and b are positive constants with unit of electric field and length. The field points towards the centre of curvature and r is distance from centre. There is no influence of gravity. Proton (charge +e mass 'm') enters along y-axis and exits x-axis while moving along a circular path.



Q.69 Speed with which proton is to be projected is 'v' and centripetal acceleration of electron is 'a_c' is given by respectively. Mark the correct statement

(A) $v = \sqrt{\frac{eE_0b}{m}}$; $a_c = \frac{2e}{m}E_0\left(\frac{b}{r}\right)$
(B) $v = \sqrt{\frac{2eE_0b}{m}}$; $a_c = \frac{e}{2m}E_0\left(\frac{b}{r}\right)$
(C) $v = \sqrt{\frac{eE_0b}{2m}}$; $a_c = \frac{2e}{m}E_0\left(\frac{b}{r}\right)$
(D) $v = \sqrt{\frac{eE_0b}{m}}$; $a_c = \frac{e}{m}E_0\left(\frac{b}{r}\right)$

Q.70 Mark the incorrect option :

(A) Work done by electric field on proton is zero

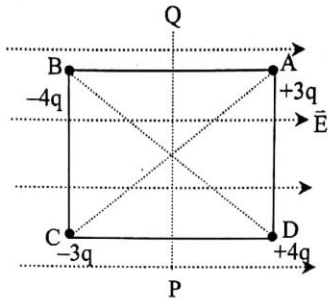
(B) If $v = \sqrt{\frac{2eE_0b}{m}}$ proton may strike outer surface of analyzer

(C) If $v = \sqrt{\frac{2eE_0b}{m}}$ proton may strike inner surface of analyzer

(D) If an electron is released with zero initial velocity from inner surface of analyzer it will strike outer surface with velocity $v = \sqrt{\frac{2eE_0b}{m_e}\ell n\left(\frac{b}{a}\right)}$, where m_e is mass of electron

Passage # 7 (Q.71 & 72)

Four point charges + 3q, –4q , –3q and + 4q are kept of the vertices A , B , C and D of a massless insulating square frame of length $\sqrt{2}$ unit. Mass of each point charge is m. The whole system is in equilibrium in a uniform electric field E . PQ is line which passes through the centre of mass, lie in the plane of charges and perpendicular to E. AC and BD are diagonals of the square. (gravity is absent)



Q.71 From equilibrium position the system is slightly displaced by θ about line BD and released . The system starts oscillating simple harmonically. The time period of oscillation will be

(A) $2\pi\sqrt{\frac{5m}{18qE}}$ (B) $2\pi\sqrt{\frac{5m}{9qE}}$ (C) $2\pi\sqrt{\frac{m\sqrt{2}}{3qE}}$ (D) $2\pi\sqrt{\frac{10m}{9qE}}$

Q.72 From equilibrium position the system is slightly displaced by θ about line PQ and released. The system starts oscillating simple harmonically. The time period of oscillation will be

(A) $2\pi\sqrt{\frac{m}{5qE}}$ (B) $2\pi\sqrt{\frac{m}{7qE}}$ (C) $2\pi\sqrt{\frac{m\sqrt{2}}{7qE}}$ (D) None of these

Passage # 8 (Q.73 & 74)

A charge Q is distributed uniformly over the volume of a dielectric sphere (dielectric constant, k = 2) of radius R. There is no charge anywhere else.

Q.73 The electric field just inside the surface of the sphere is -

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{2R^2}$ (C) $\frac{1}{4\pi\varepsilon_0}\frac{2Q}{R^2}$ (D) Zero

Q.74 The electric potential at the centre of the sphere is -

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{2R}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{4R}$ (C) $\frac{1}{4\pi\varepsilon_0}\left(\frac{3Q}{4R}+\frac{Q}{2R}\right)$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{2R}$

Passage # 9 (Q.75 to 77)

A particle P, of charge q and mass m, is placed at a point in gravity free space and it is free to move. Another particle Q, of same charge and mass, is projected from a distance r from P with an initial speed v_0 towards P. Initially the distance between P and Q decreases and then increases.

Q.75 What are the speeds of particles P and Q, when their separation is minimum ?

(A) $\frac{v_0}{2}, \frac{v_0}{2}$ (B) $0, v$ (C) $\frac{v_0}{3}, \frac{2v_0}{3}$ (D) 0, 0

Q.76 The potential energy of the system of particles P and Q, at closest separation is -

(A) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r}+\frac{1}{2}mv_0^2$ (B) $\frac{-1}{4\pi\varepsilon_0}\frac{q^2}{r}+\frac{1}{2}mv_0^2$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r}+\frac{mv_0^2}{4}$ (D) $\frac{-1}{4\pi\varepsilon_0}\frac{q^2}{r}+\frac{mv_0^2}{4}$

Q.77 If U is the potential energy of the system of P and Q at any instant, then -

(A) U first increases, becomes maximum and then decreases

(B) U first decreases, becomes minimum and then increases

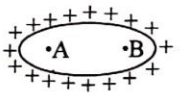
(C) U increases continuously

(D) U decreases continuously

Column Matching Type Questions

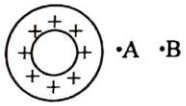
Q.78 Column-I gives some system of charged conductor and column-II gives possible value of electric field and potential then match the columns.

Column-I **Column-II**

(A) 

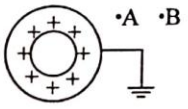
Solid conductor

(P) $E_A = E_B$

(B) 

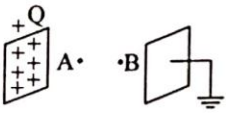
Two conducting shells inner shell is charged

(Q) $E_A > E_B$

(C) 

Outer shell is earthed

(R) $V_A = V_B$

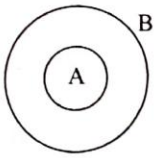
(D) 

Large plates placed near each other is equal to zero

(S) $V_A > V_B$

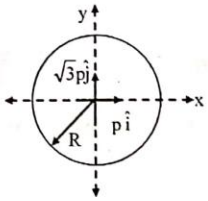
(T) E_A or E_B

Q.79 Two concentric metal shells of radii $r_A = 1$ cm and $r_B = 2$ cm are given charges and action performed as shown.



Column-I	Column-II
(A) $q_A = 2\ \mu C$, $q_B = 4\mu C$ A grounded	(P) Final $\left\lvert\frac{q_A}{q_B}\right\rvert = 1$
(B) $q_A = 4\ \mu C$, $q_B = -4\mu C$ B grounded	(Q) Final $\left\lvert\frac{q_A}{q_B}\right\rvert = 0$
(C) $q_A = -2\ \mu C$, $q_B = 4\mu C$ A and B connected	(R) Final $\left\lvert\frac{q_A}{q_B}\right\rvert < 1$, non zero
(D) $q_A = -1\ \mu C$, $q_B = 2\mu C$ A grounded	(S) q_A and q_B do not change during the process
	(T) Electric field between A and B is zero

Q.80 Column 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 Fig. Column II gives coordinates of certain positions on the circle. Match the statements in Column I with the statements in Column II.

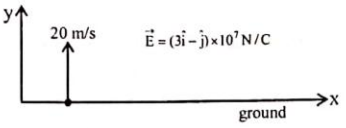


List -I	List-II
(P) The coordinate (s) of point on circle where potential is maximum	(1) $\left(\frac{R}{2}, \frac{\sqrt{3}R}{2}\right)$
(Q) The coordinate(s) of point on circle where potential is zero	(2) $\left(-\frac{R}{2}, -\frac{\sqrt{3}R}{2}\right)$
(R) The coordinate(s) of point on circle where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

Codes :

	P	Q	R	S
(A)	1	3,4	1,2	3,4
(B)	1	2	1,3	3,4
(C)	2	1	1,3	3,4
(D)	4	3	1,3	3,4

Q.81 A charged particle (charge 1μC, mass 1 kg) is fired from a point on ground in vertically upward direction with velocity 20 m/s in a region where an electric field $\vec{E} = (3\hat{i} - \hat{j}) \times 10^7$ N/C also exists as shown. Match different characteristics of its motion given in column-I with their magnitudes in S.I. units in column-II. (Take
$g = 10\ m/s^2$)

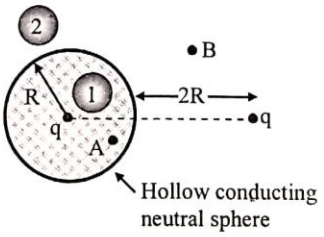


List-I	List-II
(P) Velocity of particle at its highest point	(1) 10
(Q) Minimum distance from point of projection where it lands on ground	(2) 30
(R) Maximum height reached by particle above ground	(3) 45
(S) Angle in degrees which its velocity vector makes with horizontal at $t = \frac{2}{5}$ sec.	(4) 60

Codes :

	P	Q	R	S
(A)	2	4	3	1
(B)	4	2	3	3
(C)	2	4	1	3
(D)	1	2	3	4

Q.82 For the diagram shows, some situations are given in List I and probable effects of these are given in List II. The inner surface of the conductor is marked as (1) and outer surface (2). Match the entries of List I with the entries of List II.



List –I	List -II
(P) Only inside charge q is displaced	(1) Charge distribution on (1) become non-uniform
(Q) Only outside charge q is displaced	(2) Charge distribution on (2) get change
(R) Both charges are displaced	(3) Electric field at A changes.
(S) on earthing of sphere	(4) Electric field at B changes.

Codes :

	P	Q	R	S
(A)	1, 3	2,4	2,3	2
(B)	1,2, 3	4	3,4	2
(C)	1, 2, 3, 4	2	3,4	2,4
(D)	1,3	2,4	1, 2,3,4	2,4

Q.83 Match the facts given in Column-I with the system given in column-II

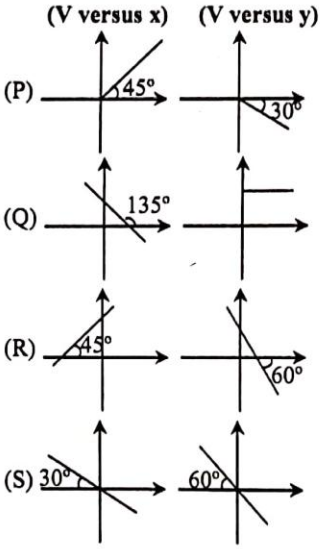
	Column-I		Column-II
(P)	Electric field strength is zero in the volume	(1)	A non conducting solid sphere charged uniformly
(Q)	Electric field strength is non-zero in the volume but zero at the centre	(2)	A conducting spherical shell charged uniformly
(R)	Electric field strength is maximum on the surface	(3)	A non conducting hollow sphere charged uniformly
(S)	Electric field strength outside the system varies inversely as the square of the distance from the centre	(4)	A conducting solid sphere charged uniformly

Codes :

	P	Q	R	S
(A)	2,3	1	2,3,4	1,2,3,4
(B)	2,3,4	1	1,2,3,4	1,2,3,4
(C)	2,3,4	1,2	1,2,3,4	1,2,3
(D)	2,4	1	1,2,3,4	2,3,4

Q.84 List I shows graphs of electric potential V versus x and y in a certain region for four situations. List II shows the range of angle which the electric field vector makes with positive x-direction.

List-I **List-II**



(1) $0 \le \theta < 45°$

(2) $45° \le \theta < 90°$

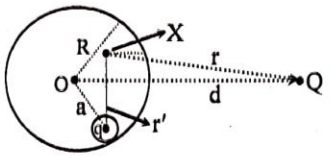
(3) $90° \le \theta < 135°$

(4) $135° \le \theta \le 180°$

Codes :

	P	Q	R	S
(A)	3	2	1	4
(B)	4	3	1	2
(C)	4	1	3	2
(D)	2	1	3	4

Q.85 A charge q is placed inside a spherical cavity at its centre, made in an uncharged conducting sphere of radius R as shown. A point charge Q is placed at a separation d from the centre of solid sphere as shown in the figure.



Column -I	Column-II
(A) Electrostatic potential at point X inside the conductor	(P) $\frac{kQ}{d}+\frac{kq}{R}-\frac{kq}{r'}-\frac{kQ}{r}$
(B) Electrostatic potential at point O.	(Q) $\frac{kQ}{r^2}$
(C) The magnitude of the electrostatic field at point X inside the conductor due to the charges induced at the outermost surface only	(R) $\frac{kQ}{r}$
(D) Electrostatic potential due to all the induced charges at point X inside the conductor	(S) $\frac{kQ}{d}+\frac{kq}{R}$
	(T) $\frac{kQ}{2d}+\frac{kq}{2R}$

Q.86 Three concentric spherical metallic shells A, B, and C of radii a, b, and c ($a < b < c$) have charge densities of $\sigma, -\sigma$ and σ respectively. Match List-I with List –II. (assume reference at infinity)

List –I	List -II
(P) The potential at A	(1) $\frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{c}-\frac{b^2}{c}+c\right)$
(Q) The potential at B	(2) $\frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{b}-b+c\right)$
(R) The potential at C	(3) $\frac{\sigma}{\varepsilon_0}$
(S) The electric field at surface of A	(4) $\frac{\sigma}{\varepsilon_0}(a-b+c)$

Codes :

	P	Q	R	S
(A)	2	3	1	4
(B)	1	4	2	3
(C)	4	2	1	3
(D)	2	3	1	1

Q.87 Consider three concentric conducting spherical shells of radius R, 2R and 3R respectively. Now charge q and 2q are given to innermost shell and outermost shell respectively while intermediate shell is earthed. Then

List-I	List-II
(P) Total charge on intermediate shell	(1) $\frac{-7q}{3}$
(Q) Total charged on outermost shell	(2) $\frac{kq}{2R}$
(R) Charge on outer surface of intermediate shell	(3) 2q
(S) Electric potential at centre (assume. Reference at infinity)	(4) $-\frac{4q}{3}$

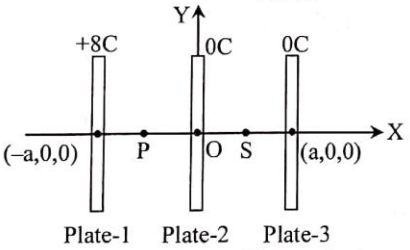
Codes :

	P	Q	R	S
(A)	4	3	1	2
(B)	3	2	1	4
(C)	2	3	1	4
(D)	1	3	4	2

Q.88 List-I shows four electrostatic systems with charge and List-II represents nature of some physical quantity related to system. ($V_P - V_S$) is the potential difference between points P(– a/2, 0, 0) and S(a/2, 0, 0). Match the List-I with List-II.

List-I | **List-II**

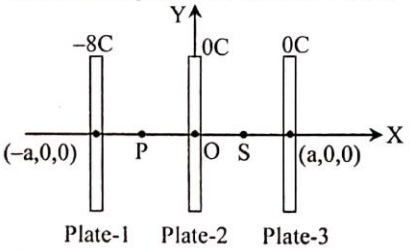
(P)



Three identical square thin metal plates each of cross-section area A are kept parallel to y-z plates as shown in the above figure. The plate 1, plate 2 and plate 3 are given charges 8C, 0C and 0C respectively whose ($a << \sqrt{A}$) centres lie on points A (–a, 0, 0), O (0, 0, 0) and B(a, 0, 0) respectively.

(1) $V_P - V_S > 0$

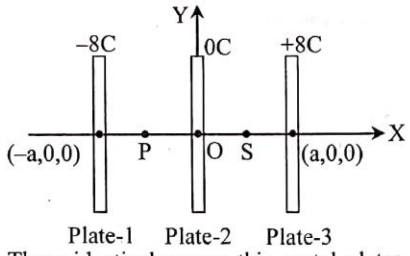
(Q)



Three identical square thin metal plates each of cross-section area A are kept parallel to y-z plates as shown in the above figure. The plate 1, plate 2 and plate 3 are given charges –8C, 0C and 0C respectively whose ($a << \sqrt{A}$) centres lie on points A (–a, 0, 0), O (0, 0, 0) and B(a, 0, 0) respectively.

(2) $V_P - V_S < 0$

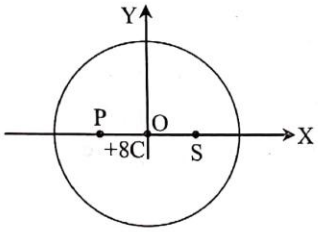
(R)



Three identical square thin metal plates each of cross-section area A are kept parallel to y-z plates as shown in the above figure. The plate 1, plate 2 and plate 3 are given charges –8C, 0C and +8C respectively whose ($a << \sqrt{A}$) centres lie on points A (–a, 0, 0), O(0, 0, 0) and B(a, 0, 0) respectively.

(3) $V_P - V_S = 0$

(S)



A neutral conducting shell has radius a and centre at origin. A point charge 8C is kept at origin.

(4) Nothing can be said for $(V_P - V_S)$

Codes :

	P	Q	R	S
(A)	1	2	2	3
(B)	2	2	4	3
(C)	3	1	2	4
(D)	2	1	4	3

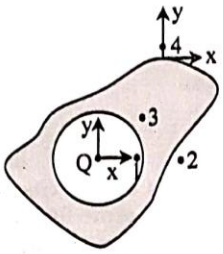
Q.89 List-I specifies a point P at distance r from the center/axis of a symmetrical distribution of charge List-II gives the variation of electric intensity at P as a function of r(> 0) Match the entries of List-I with possible entries of List-II

	List-I		**List-II**
(P)	P lies outside a long cylinder having uniform volume charge density	(1)	$E \propto \frac{1}{r^2}$
(Q)	P lies inside a spherical charged conductor	(2)	$E \propto \frac{1}{r}$
(R)	P lies inside a spherical body having uniform volume charge density	(3)	$E \propto r$
(S)	P lies outside of nonconducting solid sphere of radius R and its volume charge density varies as $\rho = \frac{\rho_0 x^2}{R^2}$, where x is distance from centre of the sphere	(4)	$E \propto r^0$

Codes :

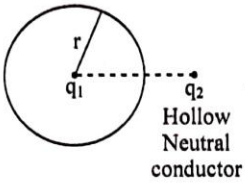
	P	**Q**	**R**	**S**
(A)	2	4	3	1
(B)	4	1	3	2
(C)	2	3	2	4
(D)	4	1	2	3

Q.90 Figure shown an uncharged conducting body having a spherical cavity. Change Q is placed at the centre of the cavity.



Column-I (Point)	Column-II (Components of electric field)
(A) 1 (inside cavity near surface)	(P) $E_x = 0$
(B) 2 (near but outside conductor surface)	(Q) $E_y = 0$
(C) 3 (inside bulk of conductor)	(R) $E_x \neq 0$
(D) 4 (near but outside conductor surface)	(S) $E_y \neq 0$

Q.91 For the situation shown in the figure below, match the entries of column-I with entries of column-II.



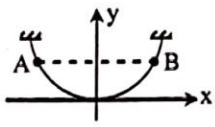
Column-I	Column-II
(A) In the situation shown	(P) Distribution of charge on inner surface of conductor is uniform
(B) If outside charge is not present	(Q) Distribution of charge on inner surface of conductor is non-uniform
(C) If we displace the outside charge while the inside charge remains at centre	(R) Distribution of charge on outer surface of conductor is uniform
(D) If the inside charge is displaced by small amount from centre then	(S) Distribution of charge on outer surface of conductor is non-uniform

Numeric Response Type Questions

Q.92 A disc is charged non uniformly with charge per unit area depending on distance x from the centre as $\sigma = cx$. The radius of disc is 3m and the electric field at a distance of 4m from centre on it's axis is $\frac{1}{5\epsilon_0}$ in SI units. Find the value of 'c' in integer (in SI units)

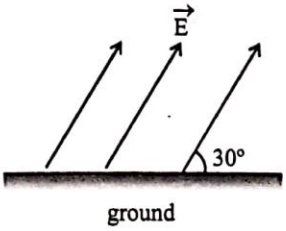
Q.93 A non-conducting spherical ball of radius R contains a spherically symmetric charge with volume charge density $\rho = kr^n$, where r is the distance from the center of the ball and n is a constant. What should be n such that the electric field inside the ball is directly proportional to square of distance from the centre.

Q.94 A smooth parabolic wire track defined by relation $y = \frac{x^2}{2a}$ is fixed in x-y plane in a gravity free space as shown in figure. An electric field $\vec{E} = \alpha y\hat{i} + \alpha x\hat{j}$ (where α is a constant) exist in the region. A small ring of mass 'm', charge 'q', which just fits in wire track, is released from rest at position $A\left(-a, \frac{a}{2}\right)$. Find speed of the ring when it reaches at point $B\left(a, \frac{a}{2}\right)$ if $q\alpha = \frac{2m}{a^2}$



Q.95 Consider a triangular surface whose vertices are three points having co-ordinates A(2a, 0, 0), B(0, a, 0), C(0, 0, a). If there is a uniform electric field $E_0\hat{i} + 2E_0\hat{j} + 3E_0\hat{k}$ then electric flux linked to triangular surface ABC is. $(3.5 + n)\,\varepsilon_0 a^2$ then find the value of 'n'.

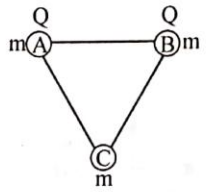
Q.96 In a region an electric field E = 15 N/C making an angle of 30° with the horizontal plane is present. A ball having charge 2C, mass 3 kg and coefficient of restitution with ground $\frac{1}{2}$ is projected at an angle of 30° with the horizontal from the ground in the direction of electric field with speed 20 m/s. Find the time (in sec) after projection when ball hits the ground second time.



Q.97 A long thick cylinder of radius R (uniformly charged with density ρ coulomb/m^3) has a spherical cavity of diameter R touching its axis. If electric field at centre of cavity is $\frac{\rho R}{n\varepsilon_0}$, find n.

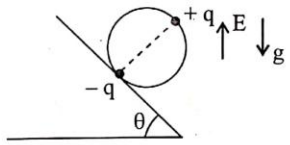
Q.98 A particle is uncharged and is thrown vertically upward from ground level with a speed of $5\sqrt{5}$ m/s. As a result, it attains a maximum height h. The particle is then given a positive charge +q and reaches the same maximum height h when thrown vertically upward with a speed of 13 m/s. Finally, the particle is given a negative charge –q. Ignoring air resistance, determine the speed (in m/s) with which the negatively charged particle must be thrown vertically upward, so that it attains exactly the same maximum height h.

Q.99 Three balls of equal mass m are connected by light insulating inextensible threads of length ℓ each and kept on a level smooth non-conducting ground. The balls A and B are given charge Q each. The strings are all taut. The string connecting A and B suddenly snaps. What is the maximum speed (in m/s) of C during the resulting motion? Q = 1 μC, ℓ = 1.5 m, mass m = 1 gm.



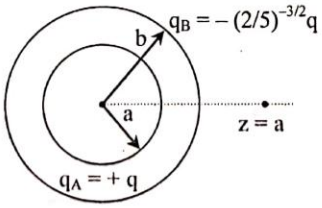
Q.100 The electric field strength depends only on the x, y and z coordinates according to the law $E = \frac{a(x\hat{i} + y\hat{j} + z\hat{k})}{(x^2 + y^2 + z^2)^{3/2}}$, where a = 280 Nm^2/C is a constant. Find the potential difference between (3m, 2m, 6m) and (0, 3m, 4m).

Q.101 A wheel having mass m has charges + q and –q at diametrically opposite points. It remains in equilibrium on rough inclined plane in presence of uniform vertical electric field $E = \frac{mg}{\alpha q}$. Find the value of α (+q & –q are massless)

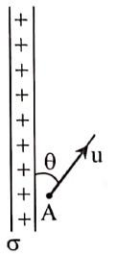


Q.102 Three point charges q, $q/3$ and $16q$ have to be arranged on positive x-axis within 20cm, so that system's potential energy is minimum. Find the distance (in cm) of charge $q/3$ from charge q.

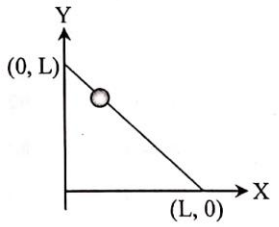
Q.103 Two concentric rings, one of radius 'a' and the other of radius 'b' have the charges + q and $-(2./5)^{-3/2}$ q respectively as shown in the figure. Find the ratio b/a if a charge particle placed on the axis at z = a is in equilibrium.



Q.104 A particle of mass m and negative charge q is thrown in a gravity free space with speed u from the point A on the large non conducting charged sheet with surface charge density σ, as shown in figure. Find the maximum distance from A on sheet where the particle can strike.



Q.105 Electric field given by the vector $\vec{E} = x\hat{i} + y\hat{j}$ is present in the XY plane. A small ring carrying charge +Q, which can freely slide on a smooth non conducting rod, is projected along the rod from the point (0, L) such that it can reach the other end of the rod. What minimum velocity should be given to the ring ? (Assume zero gravity)



Q.106 The electric field in a region is given by $\vec{E} = \frac{E_0 x}{\ell}\vec{i}$. Find the charge contained inside a cubical volume bounded by the surfaces x = 0, x = a, y = 0, y = a, z = 0 & z = a. Take $E_0 = 5 \times 10^3$ N/C, ℓ = 2cm and a = 1cm.

ANSWER KEY

Single Correct Option type Questions

1. (B)	**2.** (B)	**3.** (D)	**4.** (A)	**5.** (C)	**6.** (C)	**7.** (D)
8. (B)	**9.** (B)	**10.** (B)	**11.** (B)	**12.** (C)	**13.** (B)	**14.** (B)
15. (C)	**16.** (C)	**17.** (D)	**18.** (C)	**19.** (B)	**20.** (C)	**21.** (C)
22. (C)	**23.** (C)	**24.** (B)	**25.** (B)	**26.** (C)	**27.** (D)	**28.** (C)
29. (D)	**30.** (C)	**31.** (A)	**32.** (D)	**33.** (B)	**34.** (A)	**35.** (C)

Multiple Correct Option type Questions

36. (A,C)	**37.** (A,B,C,D)	**38.** (A,C)	**39.** (A,B,D)	**40.** (A,C)	**41.** (A,C)	**42.** (A,B)
43. (A,C)	**44.** (A,B,D)	**45.** (A,C)	**46.** (A,C)	**47.** (B,C)	**48.** (A,B,C,D)	**49.** (A,B,D)
50. (A,D)	**51.** (A,C)	**52.** (A,D)	**53.** (A,D)	**54.** (A,C,D)	**55.** (A,B,C,D)	**56.** (B,C)
57. (B,C,D)						

Passage Based Questions

58. (D)	**59.** (C)	**60.** (A)	**61.** (A)	**62.** (C)	**63.** (C)	**64.** (B)
65. (D)	**66.** (C)	**67.** (D)	**68.** (C)	**69.** (D)	**70.** (C)	**71.** (B)
72. (A)	**73.** (B)	**74.** (C)	**75.** (A)	**76.** (C)	**77.** (A)	

Column Matching Type Questions

78. A → P,R,T; B → Q,S; C → P,R; D → P,S **79.** A → R; B → P; C → Q,T; D → R **80.** (A)

81. (C) **82.** (D) **83.** (B) **84.** (C) **85.** A → S ; B → S ; C → Q ; D → P

86. (C) **87.** (D) **88.** (A) **89.** (A) **90.** A → Q,R ; B → R,S ; C → P,Q ; D → P,S

91. A → P,S ; B → P,R ; C → P,S ; D → Q,S

Numeric Response Type Questions

92. 1	**93.** 1	**94.** 2	**95.** 2	**96.** 6	**97.** 4	**98.** 9
99. 2	**100.** 16	**101.** 9	**102.** 4	**103.** 2	**104.** $\frac{2\epsilon_0 u^2 m}{q\sigma}$	

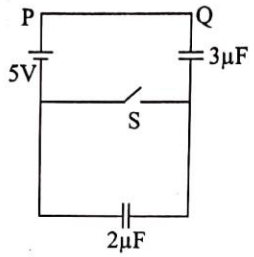
105. $(QL^2/2m)^{1/2}$ **106.** 2.2×10^{-12}C

Chapter 21

Capacitance

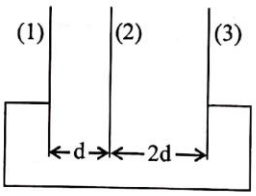
Single Correct Option Type Questions

Q.1 The charge flown from P to Q when the switch S is closed is -



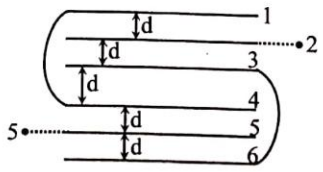
(A) 3 μC (B) 6 μC (C) 9 μC (D) 15 μC

Q.2 Three identical plates of area A are arranged as shown. A charge +Q is given to plate (2). Then -



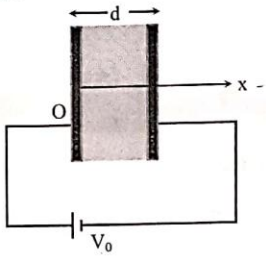
(A) Charge +2Q/3 appears on plate 1
(B) Charge – 2Q/3 appears on plate 1
(C) Charge – Q/3 appears on plate 3
(D) Charge on two faces of plate 2 are 2Q/3 and Q/3

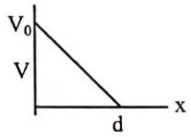
Q.3 There are six plates of equal area A and separation between the plates is d(d << A) are arranged as shown in the figure. Find the equivalent capacitance between points 2 and 5. Plate No. 1 and 4 are connected and plate No. 3 and 6 are connected.

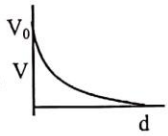


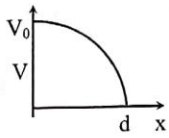
(A) $C = \frac{A\varepsilon_0}{d}$ (B) $C = \frac{A\varepsilon_0}{2d}$ (C) $C = \frac{3A\varepsilon_0}{2d}$ (D) $C = \frac{3A\varepsilon_0}{4d}$

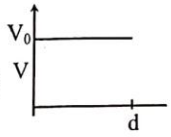
Q.4 The gap between plates of a parallel plate capacitor is field with an isotropic dielectric whose dielectric constant varies linearly in a direction perpendicular to the plates. Potential difference between plates is V. Correct variation of potential with x is .



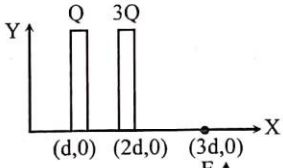
(A) 

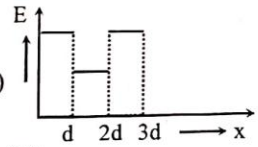
(B) 

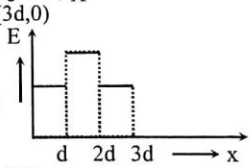
(C) 

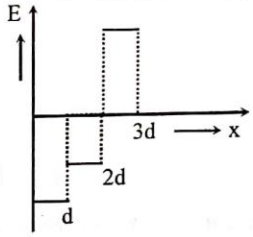
(D) 

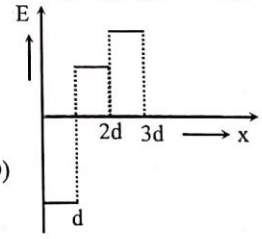
Q.5 Two very large thin conducting plates having same cross-sectional area are placed as shown in figure. They are carrying charges Q and 3Q respectively. The variation of electric field as a function at x(for x = 0 to x = 3d) will be best represented by –



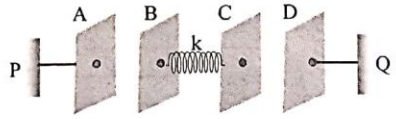
(A) 

(B) 

(C) 

(D) 

Q.6 Four identical conducting plates are placed parallel to each other at equal separation as shown below :



Plates A and B are fixed while B and D are connected with the help of a conducting spring of spring constant k. Initially, the spring is in relaxed position and B and C are at rest, now the spring is compressed slightly by displacing B and C and then plates B and C are released across PQ (Mass of each plate is m) separation between the plates is -

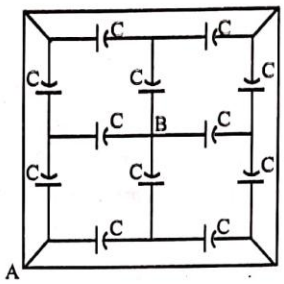
(A) remains constant

(B) increases continuously

(C) decreases continuously

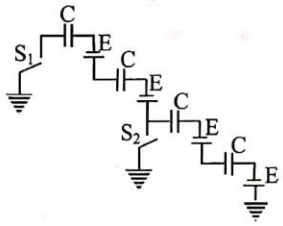
(D) is varying sinusoidally with frequency $\frac{1}{2\pi}\sqrt{\frac{2k}{m}}$

Q.7 Equivalent capacitance between A and B.



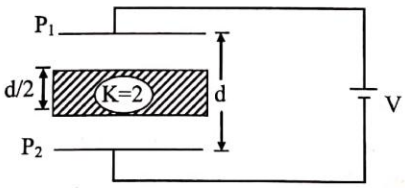
(A) $\frac{4C}{3}$ (B) $\frac{8C}{3}$ (C) 12C (D) $\frac{5C}{12}$

Q.8 In the given circuit , all the capacitors are intially uncharged . After closing the switch S_1 for a long time suddenly S_2 is also closed and kept closed for a long time . Total produced after closing S_2 will be :



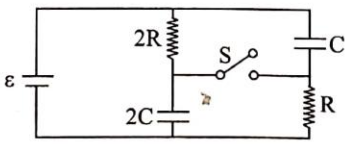
(A) $4C\varepsilon^2$ (B) $\frac{1}{2}C\varepsilon^2$ (C) $2C\varepsilon^2$ (D) 0

Q.9 In the figure shown a parallel plate capacitor has a dielectric of width d/2 and dielectric constant K =2. The other dimensions of the dielectric are same as that of the plates. The plates P_1 and P_2 of the capacitor have area 'A' each . The energy of the capacitor is :



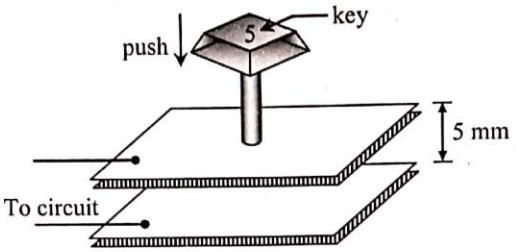
(A) $\frac{\epsilon_0 AV^2}{3d}$ (B) $\frac{2\epsilon_0 AV^2}{d}$ (C) $\frac{3}{2}\frac{\epsilon_0 AV^2}{d}$ (D) $\frac{2\epsilon_0 AV^2}{3d}$

Q.10 Initially switch S was closed for long time. Switch is opened at t = 0. Find the current (in amperes) through battery at time $RC\ell n2$. Take $\varepsilon = 12$ V, R = 4 ohm, C = 1.0 μF.



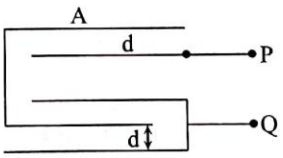
(A) 1.21A (B) 1.34 A (C) 1.43 A (D) 0.98 A

Q.11 In many computers key board, the switches under the keys consist of small parallel plate capacitor as shown in the figure. The key is attached to upper plate, which is movable. When we push the key down, the separation between the plates alter, hence capacitance changes. The capacitor is connected to an external circuit that maintains a constant potential V across the plates. The change in capacitance triggers a transfer of charge between the capacitor and computer circuit. Suppose that the initial plate separation is 5 mm and initial capacitance is 6×10^{-13} F. The final plate separation (with key full depressed) is 0.2 mm. The constant potential difference is 8 volt. What amount of electric charge will be transferred between capacitor and the computer circuit ?



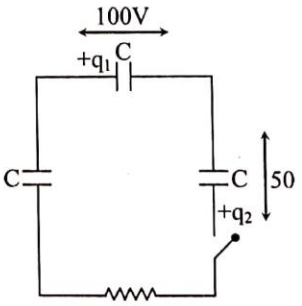
(A) 1.152×10^{-10} C (B) 1.152×10^{-8} C (C) 0.576×10^{-10} C (D) 0.576×10^{-8} C

Q.12 The equivalent capacitance between P and Q in the figure is (area of each plate is A and separation between two consecutive plates is d)



(A) $\frac{A\varepsilon_0}{2d}$ (B) $\frac{3A\varepsilon_0}{2d}$ (C) $\frac{2A\varepsilon_0}{d}$ (D) $\frac{5}{3}\frac{A\varepsilon_0}{d}$

Q.13 Two capacitor each of capacitance C = 1 μF each charged to potential 100 V and 50 V respectively and connected across a uncharged capacitor 'C' = 1μF as shown in the figure if switch 'S' is closed then charge in the uncharged capacitor at equilibrium will be



(A) $\frac{50}{3}\mu C$ (B) 50 μC (C) 25 μC (D) $\frac{100}{3}\mu C$

Q.14 Four charged capacitors (No capacitor has zero charge) are connected in three different configurations as shown in the figure. Q_1, Q_2 and Q_3 represent the magnitude of the charge on each of the plate of capacitor of capacitance 4μF in Figure-I, Figure-II and Figure-III respectively.

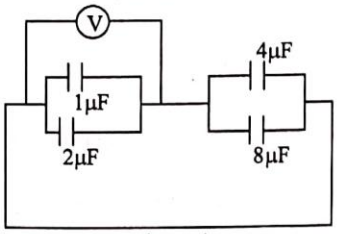


Figure-1

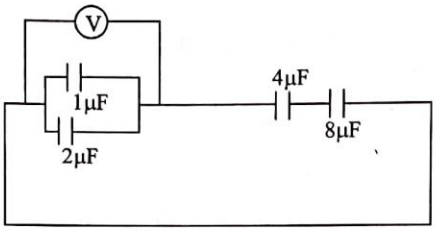


Figure-2

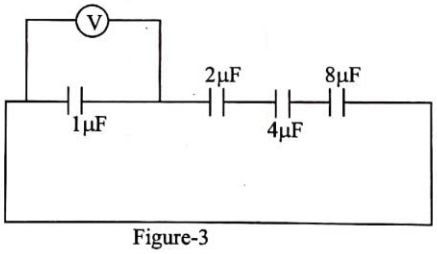
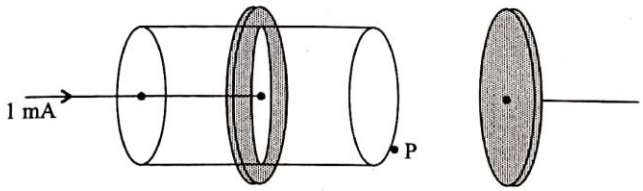


Figure-3

Choose the correct option.

(A) $Q_1 > Q_2 > Q_3$ (B) $Q_1 < Q_2 < Q_3$ (C) $Q_1 < Q_3 < Q_2$ (D) $Q_1 > Q_3 > Q_2$

Q.15 The disc-shaped capacitor plates (as shown in the figure), have radius 10 cm. There is no dielectric between the plates. At a certain instant, the current in the capacitor lead is 1 mA. Consider the Amperian surface shown in the figure, a closed-end cylinder with radius 6 cm. Now choose the **INCORRECT** statement.



(A) The conduction current, threading the Amperian surface at the instant is 0.64 mA.

(B) The displacement current, threading the Amperian surface at that intant is 0.36 mA

(C) The magnitude of magnetic field at point P on the Amperian surface is 0.2×10^{-9} T

(D) The rate of change of electric field is 3.6×10^{8} N/Cs

Multiple Correct Option Type Questions

Q.16 A parallel plate capacitor of capacitance 10 μF is connected to a cell of emf 10 Volt and is fully charged. Now a dielectric slab (k = 3) of thickness equal to the gap between the plates, is very slowly inserted to completely filled in the gap, keeping the cell connected. During the filling process -

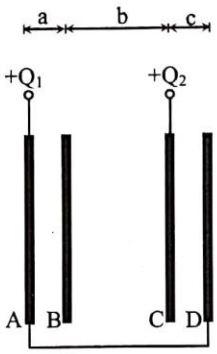
(A) the increase in charge on the capacitor is 200 μC

(B) the heat produced is zero

(C) energy supplied by the cell = increase in stored potential energy + work done on the person who is filling the dielectric slab

(D) energy supplied by the cell = increase in stored potential energy + work done on the person who is filling the dielectric slab + heat produced

Q.17 Figure shows an arrangement of four identical rectangular plates A, B, C and D each of area S. Ignore the separation between the plates in comparison to the plate dimensions. Choose the correct option(s)



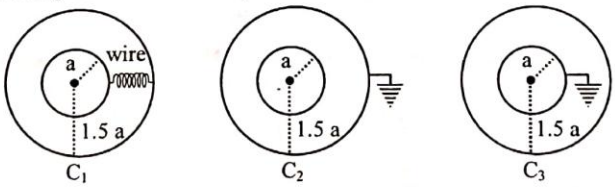
(A) Potential difference between plates A & B is independent of Q_1

(B) Potential difference between plates C & D is independent of Q_1

(C) Potential difference between plates A & B is independent of Q_2

(D) Potential difference between plates C & D is independent of Q_2

Q.18 Capacitance of following combinations of spheres are C_1, C_2 and C_3.



(A) $C_2 > C_1$ (B) $C_1 > C_3$ (C) $C_1 > C_2$ (D) $C_3 > C_2$

Q.19 A parallel plate capacitor is charged and then disconnected from the source of constant emf. The plates are then drawn apart farther. Again, it is connected to the same source. Then -

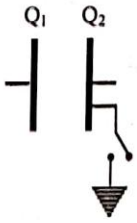
(A) the potential difference across the plates increases, while the plates are being drawn apart

(B) the potential difference across the plates decreases, while the plates are being the drawn apart

(C) the charge from the capacitor flows into the source, when the capacitor is reconnected

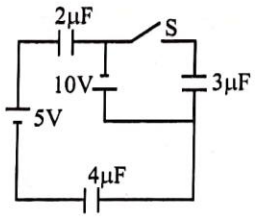
(D) more charge is drawn to the capacitor from the source, when the capacitor is reconnected

Q.20 To two plates of a parallel plate capacitors, charges Q_1 and Q_2 are given. The capacity of the capacitor is C. When the switch is closed, mark out the correct statement(s). (Assume both Q_1, Q_2 to be +ve)



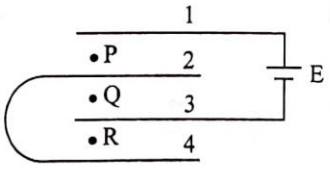
(A) The charge flown through the switch is zero
(B) The charge flown through the switch is $Q_1 + Q_2$
(C) Potential difference across the capacitor plates is Q_1/C
(D) The charge on the capacitor is Q_1

Q.21 In the given circuit (Initially S was opened)-



(A) total energy stored by capacitors is 150 μJ
(B) total energy stored by capacitors is 150/9 μJ
(C) total amount of heat generated is 150 μJ after switch (S) is closed
(D) after the switch is closed, charge stored by 3 μF is 30 μC

Q.22 Four identical plates of area 'A' and separation 'd' are connected as shown in diagram. Each plates of capacitor are in horizontal plane and P, Q and R are three points between plates -



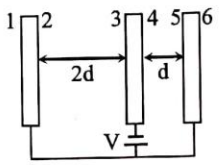
(A) If e^- is in equilibrium between plates 2 and 3, then emf of battery is $\left(\frac{3mgd}{e}\right)$

(B) Ratio of electric field at point P, Q and R is 2 : 1 : 1 respectively

(C) If plate 3 is shifted upward by d/2, ratio of potential difference between plate 1 and 2 and between 2 and 3 will be 8 : 3

(D) Ratio of electric field between plate 2 & 3 and 3 & 4 will be 4 : 1 after the shift

Q.23 In the figure shown, area of each plate is A. Match the following



(A) Charge on plate 5 is $\frac{\varepsilon_0 A}{d}V$

(B) Potential difference between plates 2 and 3 is V

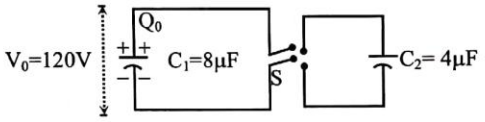
(C) Potential difference between plates 2 and 5 is zero

(D) Charge on the plate 3 is zero

Passage Based Questions

Passage # 1 (Q.24 to 27)

A capacitor of capacitance C_1 = 8μF is charged by connecting it to a source of potential difference V_0 = 120V (not shown in the figure). The switch S is initially open. Once C_1 is charged the source of potential difference is disconnected.



Q.24 The charge Q on C_1, If switch S is left open is -

(A) 960μC (B) 360μC (C) 720μC (D) 520μC

Q.25 The energy stored in C_1, If switch S is left open, is -

(A) 36 mJ (B) 96 mJ (C) 57.6 mJ (D) 24 mJ

Q.26 The capacitor of capacitance C_2 = 4μF is initially uncharged. After we close switch S, the potential difference across C_2 is -

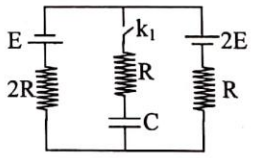
(A) 80V (B) 48V (C) 36V (D) 72V

Q.27 The total energy of the system after we close switch S is -

(A) 72.6 mJ (B) 48 mJ (C) 38.4 mJ (D) 12 mJ

Passage # 2 (Q.28 & 29)

Consider the following circuit, the capacitor is uncharged . Now key k_1 is closed. Take this moment at t = 0



Q.28 After long time energy stored in capacitor will be.

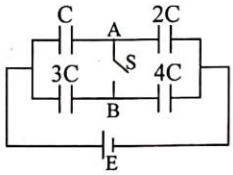
(A) $\frac{CE^2}{2}$ (B) $\frac{CE^2}{4}$ (C) $2CE^2$ (D) less than CE^2

Q.29 At any time, charge on capacitor is $\alpha(1 - e^{-t/\beta})$, then α, β, are respectively

(A) α = CE (B) α = 2CE (C) $\beta = \frac{5}{3}CR$ (D) $\beta = \frac{2}{3}CR$

Passage # 3 (Q.30 & 31)

Four capacitors of capacitance C, 2C, 3C & 4C respectively are connected as shown in figure. Battery is ideal and all the connected wires have no resistance, capacitance or inductance. Initially the switch S is open. If at t = 0 switch S is closed



Q.30 The charge flown through connector AB after switch is closed is

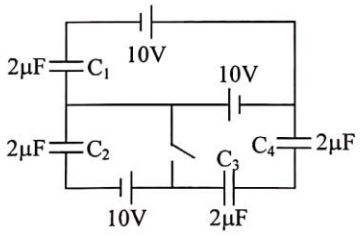
(A) CE (B) $\frac{CE}{2}$ (C) $\frac{CE}{5}$ (D) $\frac{CE}{3}$

Q.31 Heat generated in the switch after closing switch is

(A) $\frac{CE^2}{105}$ (B) $\frac{2CE^2}{105}$ (C) $\frac{CE^2}{5}$ (D) $\frac{CE^2}{35}$

Column Matching Type Questions

Q.32 Before connecting the circuit shown in figure, all capacitors were uncharged. The circuit is in steady state. Now switch is closed. During the time the steady state is reached again, match the following.



Column-I	Column-II
(A) Charge on C_1	(P) Increases
(B) Charge on C_2	(Q) Decreases
(C) Charge on C_3	(Q) remain same
(D) Charge on C_4	(Q) Always remain zero

Q.33 Match the column :

Column-I	Column-II
(A) Plates of an isolated, charged, parallel plate, air core capacitor are slowly pulled apart.	(P) Electric energy stored inside capacitor increases in the process.
(B) A dielectric is slowly inserted inside an isolated and charged parallel plate air cored capacitor to completely fill the space between plates.	(Q) Force between the two plates of the capacitor remains unchanged.
(C) Plates of a parallel plate capacitor connected across a battery are slowly pulled apart.	(R) Electric field in the region between plates remains unchanged.
(D) A dielectric slab is slowly inserted inside a parallel plate capacitor connected across a battery to completely fill the space between plates.	(S) Total electric energy stored inside capacitor decreases in the process.
	(T) Electric field in the region decreases.

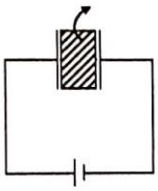
Q.34 Match the following -

	List-I		List-II
(P)	Self-energy of a uniformly charged spherical shell	(1)	$\frac{1}{8\pi\varepsilon_0}\frac{Q^2}{R}$
(Q)	Energy stored per unit volume of a charged air filled capacitor	(2)	$\frac{1}{4\pi\varepsilon_0}\frac{2Q^2}{R^2}$
(R)	Force between two circular plates of a charged parallel plate capacitor, radius of the plates being R and separation R/32	(3)	$\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$
(S)	Work done by electric field in moving a point charge Q from the surface of a uniformly charged sphere of radius R and moving it to infinity, total charge on the sphere = Q	(4)	$\frac{1}{2}\varepsilon_0 E^2$

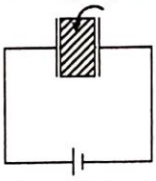
Codes :

	P	Q	R	S
(A)	3	1	4	2
(B)	2	1	3	4
(C)	1	4	2	3
(D)	4	1	2	3

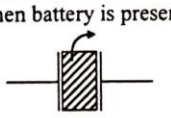
Q.35 **Column-I** **Column-II**

(A) 

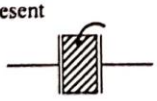
Removal of dielectric when battery is present

(B) 

Insertion of dielectric when battery is present

(C) 

Removal of dielectric when battery is not present

(D) 

Insertion of dielectric when battery is not present

(P) Potential difference between plates increases

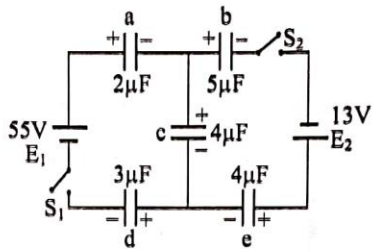
(Q) Capacitance increases

(R) Stored energy increases

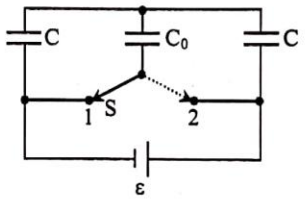
(S) Charge present on plates decreases

Numeric Response Type Questions

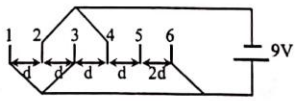
Q.36 Five capacitor, two batteries and two switches connected as shown in the figure. Initially S_1 and S_2 are open and all the capacitors are uncharged. After S_1 and S_2 are closed and steady state is attained, find the p.d. between the terminals of the 5 μF capacitor.



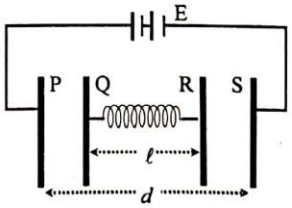
Q.37 The amount of heat generated in the circuit shown in figure after the switch S is shifted from position 1 to position 2, is $\frac{1}{n}C\varepsilon^2$. Then find value of 'n' given that $C_0 = C$.



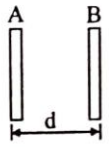
Q.38 In the given circuit six identical plates of area A each are placed as shown below. Five plates are placed at equal separation 'd' while sixth plate is kept at separation 2d. Then find potential difference (in volt) between 5th plate and sixth plates which are at separation 2d.



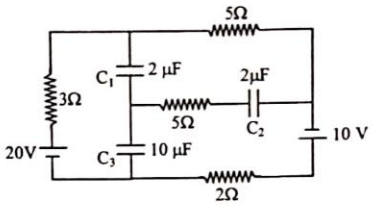
Q.39 Two parallel plate capacitors with area A are connected through a conducting spring of natural length ℓ in series as shown. Plates P and S have fixed positions at separation d. Now the plates are connected by a battery of emf E as shown. If the extension in the spring in equilibrium is equal to the separation between the plates, find the spring constant k.



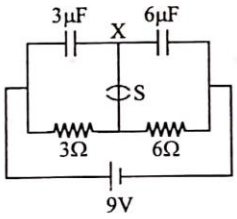
Q.40 Each plate of a parallel capacitor has area $S = 5 \times 10^{-3}\ m^2$ and are $d = 8.85$ mm apart. Plate A has a positive charge $q_1 = 10^{-10}$ C and plate B has charge $q_2 = +2 \times 10^{-10}$ C. Energy supplied by a battery of emf $E = 10$ volt when its positive terminal is connected with plate A and negative terminal with plate B is ..... 10^{-9} Joule.



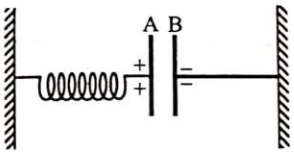
Q.41 In the circuit shown in figure If charge on capacitor C_2 in steady state in μC is $(2 \times n)$. Then find value of n.



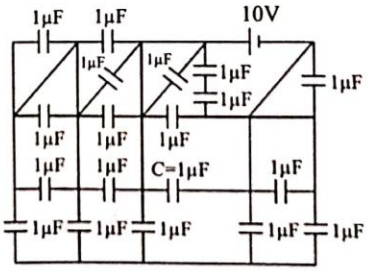
Q.42 A circuit is connected as shown in the figure with the switch S open. When the switch is closed, if total amount of charge that flows from Y to X is Q (in μC), then $\frac{Q}{3} =$



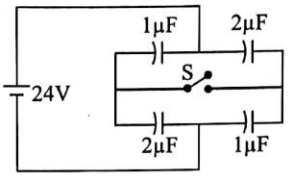
Q.43 Plate A of a parallel plate air filled capacitor is connected to a spring having force constant k and plate B is fixed. They rest on a frictionless table top as shown in the figure. If a charge +q is placed on plate A and a charge −q on plate B, by how much does the spring expand in equilibrium ($q^2 = 6kA\varepsilon_0$)



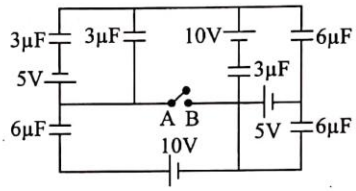
Q.44 Find the charge on the capacitor C = 1 μF in the circuit shown in the figure.



Q.45 The connections shown in figure are established with the switch S open. How much charge will flow through the switch if it is closed?



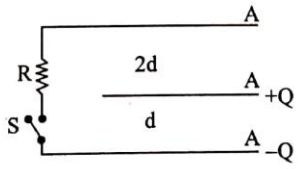
Q.46 Find the charge flown through the switch from A to B when it is closed.



Q.47 The gap between the plates of a plane capacitor is filled with an isotropic insulator whose di-electric constant varies in the direction perpendicular to the plates according to the law $K = K_1\left[1+\sin\frac{\pi}{d}X\right]$, where d is the separation, between the plates & K_1 is a constant. The area of the plates is S. Determine the capacitance of the capacitor.

Q.48 Three identical large metal plates of area A are small at distances d and 2d from each other. Top metal plate is uncharged, while other metal plates have charges +Q and –Q. Top and bottom metal plates are connected by switch S through a resistor of unknown resistance. What energy (in mJ) is dissipated in the resistor when switch is closed?

(Given : $\frac{\epsilon_0 A}{d} = 6\mu F$, $Q = 60\mu C$)



ANSWER KEY

Single Correct Option type Questions

1. (A) **2.** (D) **3.** (A) **4.** (B) **5.** (C) **6.** (D) **7.** (B)
8. (D) **9.** (D) **10.** (B) **11.** (A) **12.** (D) **13.** (A) **14.** (A)
15. (C)

Multiple Correct Option type Questions

16. (A,B,C,D) **17.** (A,B) **18.** (A,D) **19.** (A,C) **20.** (B,C,D) **21.** (A,C,D) **22.** (A,B,C)
23. (A,B,C)

Passage Based Questions

24. (A) **25.** (C) **26.** (A) **27.** (C) **28.** (A,D) **29.** (A,C) **30.** (C)
31. (A)

Column Matching Type Questions

32. $A \to R$; $B \to P$; $C \to Q$; $D \to Q$ **33.** $A \to P,Q,R$; $B \to Q,S,T$; $C \to S,T$; $D \to P,R$

34. (C) **35.** $A \to S$; $B \to Q,R$; $C \to P,R$; $D \to Q$

Numeric Response Type Questions

36. 8 **37.** 3 **38.** 6 **39.** $k = \frac{27}{8}\frac{A\varepsilon_0 E^2}{(d-\ell)^2}$ **40.** 1 **41.** 5

42. 9 **43.** 3 **44.** 10 μC **45.** 12 μC **46.** 69 μC **47.** $C = \frac{\epsilon_0 S\pi K_1}{2d}$

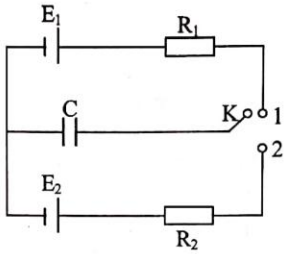
48. 0.10 J

Chapter

22 Current Electricity

Single Correct Option Type Questions

Q.1 The key K (figure) is connected in turn to each of the contacts over short identical time intervals so that the change in the charge on the capacitor over each connection is small. What will be the final charge q_f on the capacitor ?



(A) $\frac{C(E_2R_1 - E_1R_2)}{R_1 + R_2}$ (B) $\frac{C(E_2R_1 + E_1R_2)}{R_1 + R_2}$ (C) $\frac{2C(E_2R_1 + E_1R_2)}{R_1 + R_2}$ (D) $\frac{C(E_2R_1 + E_1R_2)}{2(R_1 + R_2)}$

Q.2 After the switch shown in figure (A) is closed, there is current 'i' through resistance R. Figure (B) indicates current variation curves 'a', 'b', 'c' and 'd' for four sets of values of R and capacitance C

(1) R_0 and C_0 (2) $2R_0$ and C_0 (3) R_0 and $2C_0$ (4) $2R_0$ and $2C_0$

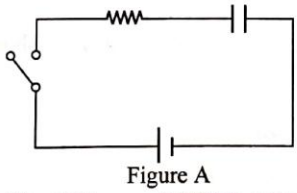


Figure A

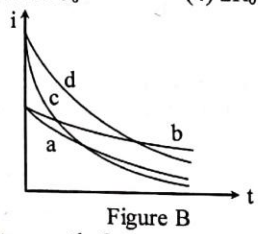


Figure B

Which set goes with which curve ? Which option shows it correctly ?

(A) a-(1), b-(3), c-(2), d-(4) (B) a-(2), b-(4), c-(1), d-(3)

(C) a-(4), b-(2), c-(1), d-(3) (D) None of these

Q.3 The capacitor shown in figure 1 is charged by connecting switch S to contact 'a' for a long time. If switch S is thrown to contact 'b' at time t = 0, which of the curves in figure 2 represents the magnitude of the current through the resistor R as a function of time ?

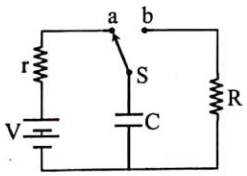


Figure-1

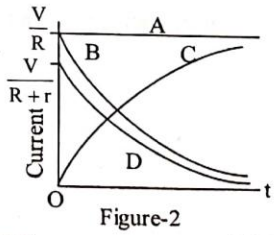
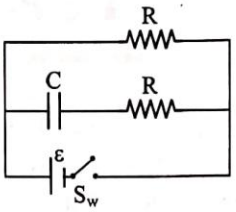


Figure-2

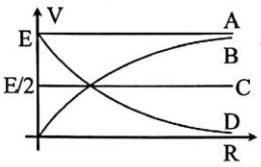
(A) A (B) B (C) C (D) D

Q.4 If at t = 0 the switch S_w is closed, then the charge on capacitor in the given circuit (initially uncharged) when the current through battery becomes 50% of its maximum value is (assume battery is ideal)



(A) $\frac{C\varepsilon}{3}$ (B) $\frac{C\varepsilon}{2}$ (C) $\frac{C\varepsilon}{4}$ (D) $C\varepsilon$

Q.5 A cell of emf E having an internal resistance 'r' is connected to an external resistance R. The potential difference 'V' across the resistance R varies with R as shown by the curve

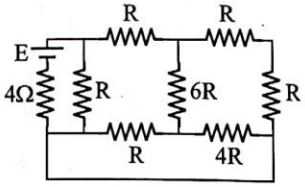


(A) A (B) B (C) C (D) D

Q.6 Resistance of a wire at temperature t °C is $R = R_0 (1 + at + bt^2)$. Here, R_0 is the resistance at 0°C. The temperature coefficient of resistance at temperature 't' is -

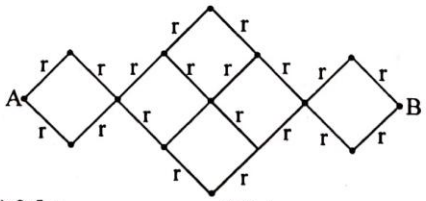
(A) $\frac{a+2bt}{1+at+bt^2}$ (B) $(a + 2bt)$ (C) $\frac{1+at+bt^2}{a+2bt}$ (D) constant

Q.7 A battery of internal resistance 4Ω is connected to the network of resistance as shown. In order to give the maximum power to the network, the value of R should be -



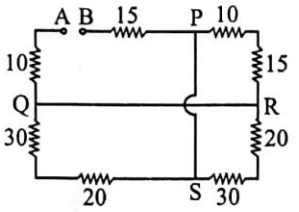
(A) $\frac{4}{9}\Omega$ (B) $\frac{8}{9}\Omega$ (C) $\frac{39}{7}\Omega$ (D) $\frac{11}{7}\Omega$

Q.8 The resistance of each straight section is r. Find the equivalent resistance between A and B.



(A) 3 r (B) 3.5 r (C) 4 r (D) 4.5 r

Q.9 The equivalent resistance of the circuit across point A and B is equal to :



(A) 22.5 Ω (B) 25 Ω]

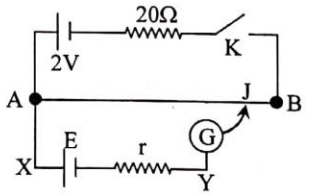
(C) 37.5 Ω (D) 75 Ω

Q.10 A cell of emf E = 1.5 V and internal resistance r = 0.5 Ω is connected to a non ohmic resistor in which the current varies with the voltage as $I = V^2$. Calculate the current drawn from the cell and its terminal voltage.

(A) 1 volt, 1 A (B) 2 volt, 1 A

(C) 2 volt, 2 A (D) 1 volt, 2 A

Q.11 In the potentiometer circuit shown, the length of potentiometer wire AB is 400 cm long and resistance per unit length is 0.2 Ω/cm. If a battery of emf E and internal resistance 'r' is connected across XY as shown, then for



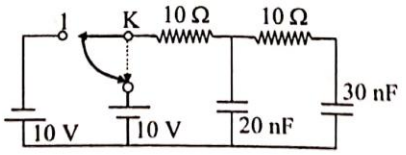
(A) E = 1.5 V, r = 16 Ω, the balance point would exist on the potentiometer wire

(B) E = 1V, R = 25Ω the balance point would exist on the potentiometer wire

(C) We cannot compare emf's of two cells which are more than 1.6 V using this potentiometer

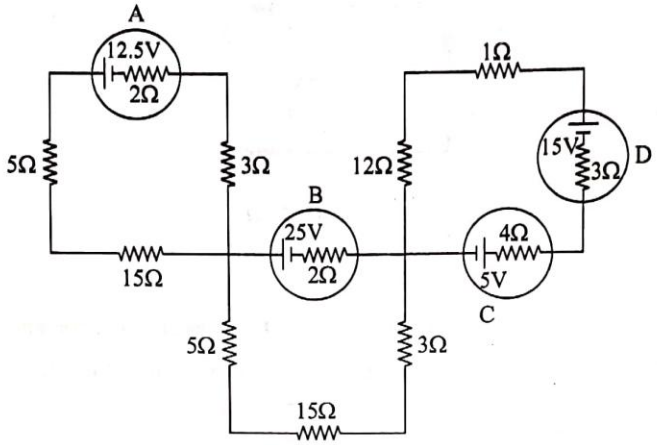
(D) All of the above

Q.12 In the given circuit, when the switch is shifted from position 1 to position 2, find the total heat dissipated in the resistors after switch is shifted.



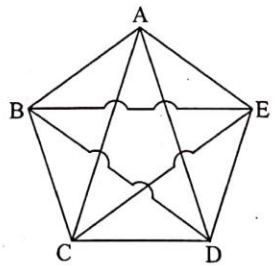
(A) 10 μJ (B) 20 μJ (C) 5 μJ (D) Zero

Q.13 A circuit contains four cells (Cell–A, Cell–B, Cell–C and Cell–D). If P_A, P_B, P_C and P_D are the heat loss per unit time in the Cell–A, Cell–B, Cell–C and Cell–D, respectively then choose correct statement -



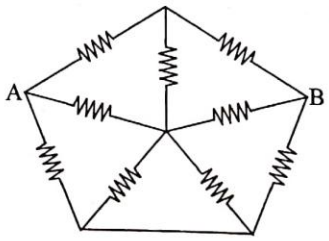
(A) $P_A < P_B < P_C < P_D$
(B) $P_A < P_C < P_D < P_B$
(C) $P_A < P_D < P_B < P_C$
(D) $P_A < P_B < P_D < P_C$

Q.14 A pentagon wire mesh is formed with the help of ten resistance wires, each of resistance R as shown in figure. Find the equivalent resistance across ED



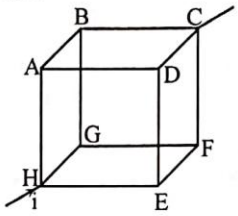
(A) $\frac{R}{5}$
(B) $\frac{2R}{5}$
(C) $\frac{3R}{5}$
(D) $\frac{4R}{5}$

Q.15 If resistance of each resistor is R, then effective resistance between points A and B of the shown network is



(A) $\frac{8R}{11}$
(B) $\frac{6R}{11}$
(C) $\frac{6R}{5}$
(D) $\frac{2R}{3}$

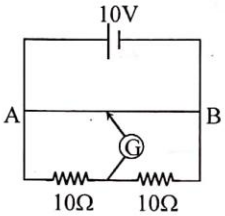
Q.16 In the box shown current i enters at H and leaves at C. If $i_{AB} = \frac{i}{6}, i_{DC} = \frac{2i}{3}$, $i_{HA} = \frac{i}{2}, i_{GF} = \frac{i}{6}, i_{HE} = \frac{i}{6}$, choose the branch in which current is zero



(A) BG (B) FC (C) ED (D) none

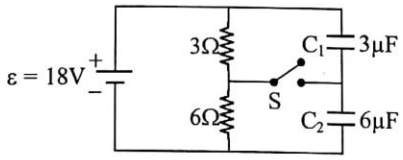
Multiple Correct Option Type Questions

Q.17 The wire AB of a meter bridge changes linearly from radius r to 2r from left end to right end. Length of wire is 1m. Where should the free end of the galvanometer be connected on AB so that the deflection in the galvanometer is zero ?



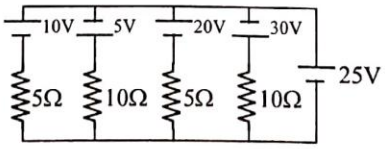
(A) $\frac{2}{3}$ m from end B (B) $\frac{1}{3}$ m from end A (C) $\frac{1}{4}$ m from end A (D) $\frac{3}{4}$ m from end B

Q.18 In the circuit shown, which of the following statements is correct ?



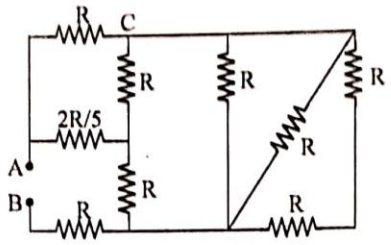
(A) When S is open, charge on C_1 is 36 μC
(B) When S is open, charge on C_2 is 36 μC
(C) When S is closed, the charges on C_1 and C_2 do not change
(D) When S is closed, charges on both C_1 and C_2 change

Q.19 In the figure shown : (All batteries are ideal)



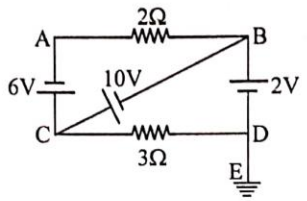
(A) current through 25V cell is 20A
(B) current through 25V cell is 12.5A
(C) power supplied by 20V cell is 20W
(D) power supplied by 20V cell is – 20W

Q.20 Choose the correct option(s)



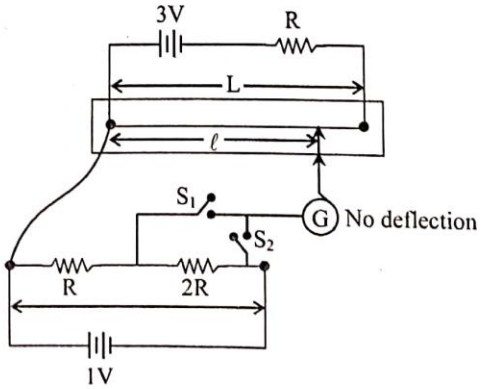
(A) $R_{AB} = \frac{28}{17}R$ (B) $R_{AC} = \frac{118}{179}R$ (C) $R_{AC} = R$ (D) None of these

Q.21 In the circuit shown in figure -



(A) current passing through 2Ω resistance is 2A
(B) current passing through 3Ω resistance is 4A
(C) current in wire DE is zero
(D) potential of point A is 10V

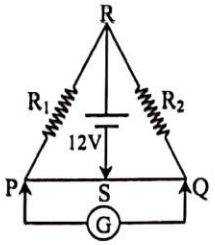
Q.22 Figure shows a potentiometer circuit. The length of potentiometer wire is L and its resistance is 2R. Neglect the internal resistance of the cells. Select the correct alternative.



(A) When only S_1 is closed, $\frac{\ell}{L} = \frac{1}{6}$ (B) When only S_2 is closed, $\frac{\ell}{L} = \frac{1}{2}$

(C) When both S_1 and S_2 are closed, $\frac{\ell}{L} = \frac{1}{6}$ (D) When both S_1 and S_2 are closed, $\frac{\ell}{L} = \frac{1}{2}$

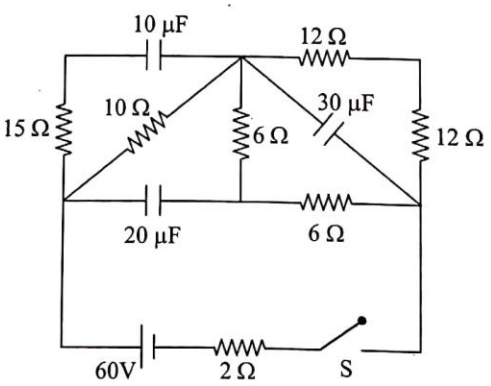
Q.23 In the circuit shown $R_1 = R_2 = 10\ \Omega$ and resistance per unit length of wire PQ = 1Ω/cm and length PQ = 10 cm. S is midpoint of wire PQ. If R_2 is made 20Ω then to get zero deflection in galvanometer.



(A) The jockey at P can be moved towards right 2 cm
(B) The jockey at Q can be moved towards left 2 cm
(C) The jockey at S can be moved towards left a distance 5/3 cm.
(D) The jockey at all positions fixed and R_1 should be made 20Ω.

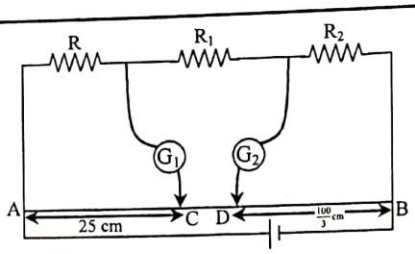
Q.24 If three bulbs of 40W, 60W and 100W all rated at same voltage are connected in series across a 310 V supply and there is no failure (i.e., fusing out). Just above 310 V one of them fails, then (Assume that failure take place at just above rated voltage)
(A) 40 watt bulbs will glow brighter than 100 watt bulb
(B) potential difference across 100 watt will be maximum
(C) rated voltage of each bulb is 150 V
(D) rated voltage of each bulb is 155 V

Q.25 Switch S is closed at t = 0, I_{10} is the current supplied by battery just after closing the switch S. Q_1, Q_2 and Q_3 are the charges on the capacitors of 10 μF, 20 μF and 30 μF in steady state respectively. I_{20} is the current supplied by battery in the circuit at steady state. Choose the correct statements(s) -



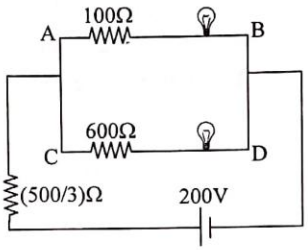
(A) $I_{10} > I_{20}$ (B) $I_{10} < I_{20}$ (C) $Q_1 < Q_2 < Q_3$ (D) $Q_1 < Q_3 < Q_2$

Q.26 The diagram show is a modified meter bridge, which is used for measuring two unknown resistances R_1 and R_2 at the same time. When only the first galvanometer is used, balance point is found at point C. Now the first galvanometer is removed and the second galvanometer is used, which gives balance point D. Using the details given in the diagram, find out the value of R_1 and R_2.



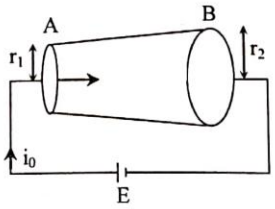
(A) $R_1 = 5\ R/3$ (B) $R_2 = 4\ R/3$ (C) $R_1 = 4\ R/3$ (D) $R_2 = 5\ R/3$

Q.27 Two bulbs 25W, 100V (upper bulb in figure) and 100W, 200V (lower bulb in figure) are connected in the circuit as shown in figure. Choose the correct answer(s)



(A) Heat lost per second in the circuit will be 80J
(B) Ratio of heat produced per second in bulbs will be 1:1
(C) Ratio of heat produced in branch AB to branch CD will be 1:2
(D) Current drawn from the cell is 0.4 A

Q.28 A battery of emf E is connected across a conductor as shown as one observe from A to B then



(A) Current remains same
(B) Drift velocity of electron decreases
(C) Electric field decreases
(D) Potential drop across the length decreases

Q.29 To convert galvanometer into a voltmeter, a large resistance is connected in series with the galvanometer. Due to the use of this large resistance is -

(A) Accuracy increase
(B) Least count increases
(C) Least count decreases
(D) Range increase

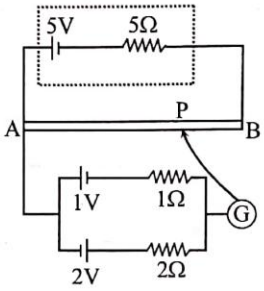
Q.30 A simple circuit contains an ideal battery and a resistance R. If a second resistor is placed in parallel with the first,

(A) the potential across R will decrease
(B) the current through R will decreased
(C) the current delivered by the battery will increases
(D) the power dissipated by R will increased

Q.31 A battery is of emf E is being charged from a charger such that positive terminal of the battery is connected to terminal A of charger and negative terminal of the battery is connected to terminal B of charger. The internal resistance of the battery is r.

(A) Potential difference across points A and B must be more than E
(B) A must be at higher potential than B
(C) In battery, current flows from positive terminal to the negative terminal
(D) No current flows through battery

Q.32 A battery of emf $\varepsilon_0 = 5V$ and internal resistance 5Ω is connected across a long uniform wire AB of length 1 m and resistance per unit length $5\ \Omega m^{-1}$. Two cells of $\varepsilon_1 = 1V$ and $\varepsilon_2 = 2V$ are connected as shown in the figure.



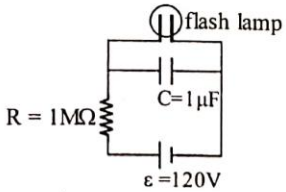
(A) The null point is at A
(B) If the Jockey is touched to point B the current in the galvanometer will be going towards B
(C) When Jockey is connected to point A no current is flowing through 1V battery
(D) The null point is at distance of 8/15 m from A

Passage Based Questions

Passage # 1 (Q.33 to 35)

A highway emergency flasher uses a 120 volt battery, a 1 MΩ resistor, a 1 μF capacitor, a neon flash lamp in the circuit shown in the figure. The flash lamp has a resistance more than $10^{10}\ \Omega$ when the voltage across it is less than 110V. Above 110V, the neon gas ionizes, the lamp's resistance drops to 10Ω and the capacitor discharges completely. Until the capacitor voltage reaches the breakdown voltage $V_b = 110V$, the large resistance of the flash lamp ensures that it draws a negligible current. The capacitor charges as if the lamp were absent.

At V_b, however, the lamp resistance quickly becomes negligible and the capacitor discharges through the lamp as if the battery and the series resistor were absent. The time between the flashes is the time for the capacitor to charge to V_b. The flash duration is roughly the time for the capacitor to discharge through the lamp, or about 3 time constant of the capacitor-lamp circuit. The flash energy is the stored energy in the capacitor at 110 volt.



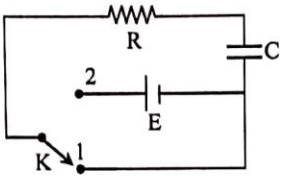
Q.33 Time constant (τ_c) of the capacitor-lamp circuit is -
(A) 20 μs (B) 15 μs (C) 30 μs (D) 10 μs

Q.34 Flash duration is -
(A) 10 μs (B) 20 μs (C) 30 μs (D) 5 μs

Q.35 The energy in the flash is -
(A) 6.1 mJ (B) 6.1 J (C) 3 mJ (D) 12.2 mJ

Passage # 2 (Q.36 & 37)

In the shown circuit involving a resistor of resistance RΩ, capacitor of capacitance C farad and an ideal cell of emf E volts, the capacitor is initially uncharged and the key is in position 1. At t = 0 second the key is pushed to position 2 for t_0 = RC seconds and the key is pushed back to position 1 for t_0 = RC seconds. This process is repeated again and again. Assume the time taken to push key from position 1 to 2 and vice versa to be negligible.

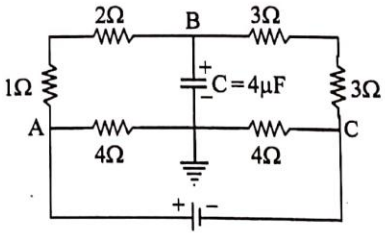


Q.36 The charge on capacitor at t = 2 RC second is -
(A) CE (B) $CE\left(1-\frac{1}{e}\right)$ (C) $CE\left(\frac{1}{e}-\frac{1}{e^2}\right)$ (D) $CE\left(1-\frac{1}{e}+\frac{1}{e^2}\right)$

Q.37 The current through the resistance at t = 1.5 RC seconds is -
(A) $\frac{E}{e^2R}\left(1-\frac{1}{e}\right)$ (B) $\frac{E}{eR}\left(1-\frac{1}{e}\right)$ (C) $\frac{E}{R}\left(1-\frac{1}{e}\right)$ (D) $\frac{E}{\sqrt{e}R}\left(1-\frac{1}{e}\right)$

Passage # 3 (Q.38 to 40)

Analyse the given circuit in the steady state condition. Charge on the capacitor is q_0 = 16 μC.



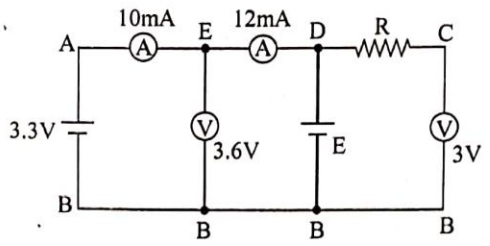
Q.38 Find the current in 2Ω resistance -
(A) $\frac{24}{9}$ A (B) $\frac{20}{9}$ A (C) $\frac{22}{9}$ A (D) None of these

Q.39 Find the emf of the battery -
(A) 20V (B) 24V (C) 22V (D) 8V

Q.40 If now the battery is removed and the points A and C are shorted. Find the time (in micro-second) during which charge on the capacitor becomes 8 μC.
(A) 12 (ln 2) (B) 9 (ln 2) (C) 16 (ln 2) (D) None of these

Passage # 4 (Q.41 & 42)

A circuit contains two identical ammeters (not ideal) and two identical voltmeters (not ideal) as shown in the figure. The readings of ammeters and voltmeters are shown in the figure. There is an unknown resistor of resistance RΩ and unknown ideal battery of emf E volt in the circuit.



Q.41 The current supplied by unknown ideal battery of emf E volt is -

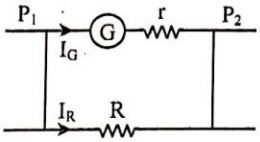
(A) $\frac{41}{3}$ mA (B) $\frac{35}{3}$ mA (C) $\frac{39}{3}$ mA (D) $\frac{5}{3}$ mA

Q.42 The value of R is -

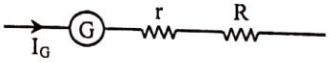
(A) 2.304 kΩ (B) 1.152 kΩ (C) 0.576 kΩ (D) 0.288 kΩ

Passage # 5 (Q.43 & 44)

Measurements and interpretations of voltage and electric current signals are common in modern medicine. Occasionally. a situation arises in which a voltmeter or an ammeter is needed but it is not available. A galvanometer is an instrument that can be used to construct an ammeter. It can also be used to construct a voltmeter. In both cases, a resistor R must be connected to galvanometer to effect the change



(i)



(ii)

To turn the galvanometer into an ammeter, the resister R is connected in parallel, as shown in the figure (i), The resistor R is connected in series with the galvanometer in order to turn it into a voltmeter, as shown in the figure (ii). The current required to produce a full scale deflection in a galvanometer is 10 mA. The internal resistance of galvanometer is 100 Ω. Let V, be the voltage across r and V_r the voltage across R.

Q.43 Which of the following formulas correctly applies to the ammeter concept ?

(A) $V_r > V_R$ (B) $V_r < V_R$ (C) $V_r = V_R$ (D) more information needed

Q.44 What resistance must be connected in parallel to the galvanometer to turn it into an ammeter capable of reading electric current up to 10.01 A ?

(A) 0.1Ω (B) 1Ω (C) 10 Ω (D) none of these

Passage # 6 (Q.45 & 46)

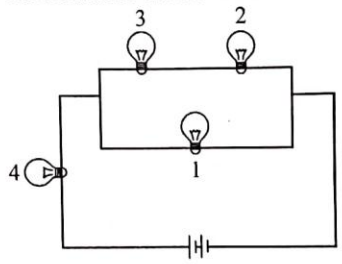
Ends of two wires A and B, having resistivity $\rho_A = 3 \times 10^{-5}\ \Omega m$ and $\rho_B = 9 \times 10^{-5}\ \Omega m$ of same cross section area are joined together to form a single wire. The resistance of the joined wire does not change with temperature. Temperature coefficient of resistivity of wires A and B are $\alpha = 4 \times 10^{-5}/^{o}C$ and $\alpha = -4 \times 10^{-6}/^{o}C$. Assume that mechanical dimensions do not change with temperature.

Q.45 Ratio of length of the wire is
(A) 3 : 10 (B) 10 : 3 (C) 1 : 3 (D) 3 : 1

Q.46 If the ratio of length of the wire is 10 : 3 having resistivity $\rho_A : \rho_B$ not as given about then ρ_A, ρ_B for making the net resistance independent of temperature will be
(A) 10 : 3 (B) 100 : 3 (C) 3 : 100 (D) 3 : 10

Passage # 7 (Q.47 to 49)

All bulbs consume same power. The resistance of bulb 1 is 36Ω.



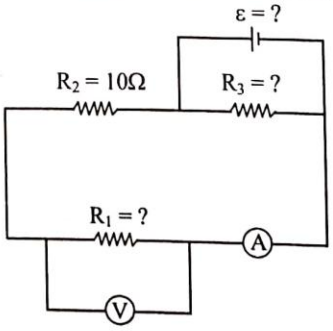
Q.47 What is the resistance of bulb 3 :
(A) 4Ω (B) 9Ω (C) 12Ω (D) 18Ω

Q.48 What is the resistance of bulb 4 :
(A) 4Ω (B) 9Ω (C) 12Ω (D) 18Ω

Q.49 What is the voltage output of the battery if the power of each bulb is 4W :
(A) 12V (B) 16V (C) 24V (D) None of these

Passage # 8 (Q.50 to 52)

The power dissipated in resistor R_3 shown in the figure is 15W. The reading on the ammeter is 500 mA and the reading on the voltmeter is 10V. Ammeter, voltmeter and battery are ideal.



Q.50 Find the resistance R_1 :
(A) 10Ω (B) 15Ω (C) 20Ω (D) 25Ω

Q.51 Find the resistance R_3 :

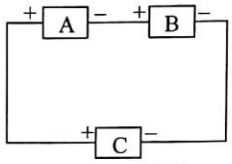
(A) 10Ω (B) 15Ω (C) 20Ω (D) 25Ω

Q.52 What is the emf ε of the supply battery ?

(A) 10V (B) 15V (C) 20V (D) 25Ω

Column Matching Type Questions

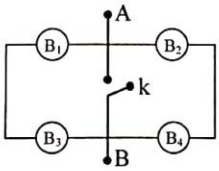
Q.53 In the given circuit A, B, C represent circuit elements. It may be battery or resistor. And +, – sign indicates high potential and low potential respectively.



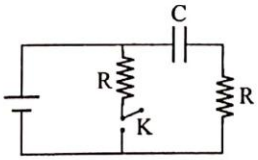
Column-I	Column-II
(A) If 'A' is resistor	(P) Current clockwise
(B) If 'A' is battery	(Q) 'B' may be a battery
(C) If 'B' is resistor	(R) 'C' must be a battery
(D) If 'C' is resistor	(S) Current anticlockwise
	(T) 'B' must be battery

Q.54 Column-I gives some incomplete statements with a parameter x. Column-II gives some statements which can complete the statements given in column-I. Match statements in column-I to all the statements in column-II which can possibly complete the statements in column-I

	Column-I		Column-II
(A)	Two identical fuses rated (in Ampere) at x, when combined together may act as a fuse of rating _____.	(P)	0.5x
(B)	Two identical non-ideal cells of emf x each, when combined together may act as a cell of e.m.f._____.	(Q)	x
(C)	Four identical bulbs (each of power x) are arranged as shown in the diagram. Equivalent power of the combination between points A and B may be _____(Given that key k may be closed or open)	(R)	2x



(D)	Time constant of the circuit shown (key k may be open or closed). x = RC	(S)	4x

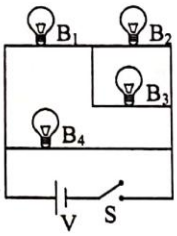


(T) 8x

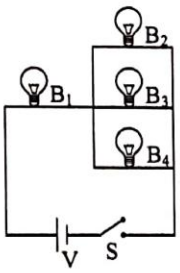
Q.55 Four identical bulbs are connected in the circuit as given in List-I. The name of brightest bulb is given in List-II. Match List-I with List-II and select the correct answer using the code given below the list.

List-I

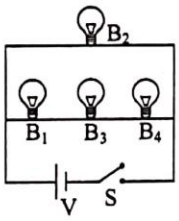
(P)



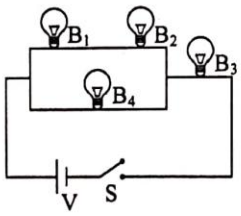
(Q)



(R)



(S)



List-II

(1) Glow of Bulb-1 will be brightest (in the given circuit)

(2) Glow of Bulb-2 will be brightest (in the given circuit)

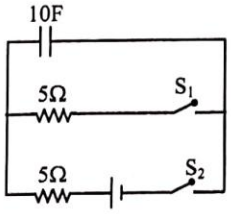
(3) Glow of Bulb-3 will be brightest (in the given circuit)

(4) Glow of Bulb-4 will be brightest (in the given circuit)

Codes :

	P	Q	R	S
(A)	4	2	1	3
(B)	2	4	1	3
(C)	1	2	3	4
(D)	4	1	2	3

Q.56 In the circuit shown the capacitor has an initial charge q = 100 C and a capacitor C = 10F. The emfs of the batteries are shown in the figure and the batteries have negligible internal resistance. The switches are closed at t = 0 Match the following. The quantities on the right columns are given in SI units

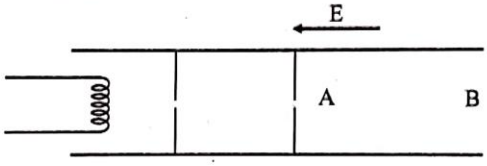


	List-I		List-II
(P)	Time constant of the circuit	(1)	0
(Q)	Current through S_1 at t = 0	(2)	25
(R)	Current through S_2 when $t \to 0$	(3)	2
(S)	Final Charge on the capacitor	(4)	50

Codes :

	P	Q	R	S
(A)	3	1	4	2
(B)	2	1	3	4
(C)	4	3	2	1
(D)	2	1	4	3

Q.57 Electrons are emitted by a hot filament and are accelerated by an electric field as shown in figure. The two stops at the left ensure that the electron beam has a uniform cross-section. Match the entries of column-I with column-II as electron move from A to B :



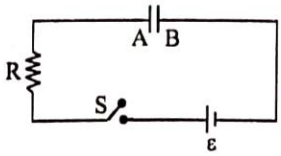
Column-I	Column-II
(A) Speed of an electron	(P) Increases
(B) Number of free electrons per unit volume	(Q) Decreases
(C) Current density	(R) Remains same
(D) Electric potential	(S) Any of the above is possible

Numeric Response Type Questions

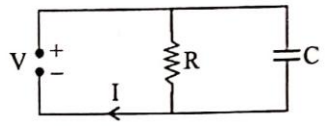
Q.58 The length of a potentiometer wire is 12 m a cell of emf 5V is balanced at a length of 4m from the positive end of wire. If the length of the wire is increased by 6m. Then at what distance (in m) from positive end will the same cell give a balance point.

Q.59 The figure shows a RC circuit with a parallel plate capacitor. Before switching on the circuit, plate A of the capacitor has a charge $-Q_0$ while plate B has no net charge. Now, at t = 0, the circuit is switched on. How much time (in second) will elapse before the net charge on plate A becomes zero.

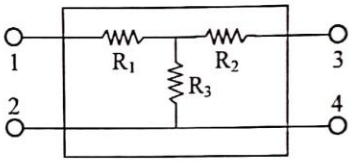
(Given capacitance C = 1 μF, Q_0 = 1 mC, ε = 1000 V and $R = \frac{2\times10^6}{\ln 3}\Omega$)



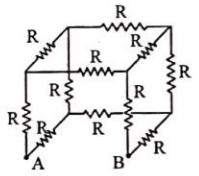
Q.60 In the circuit shown, a time varying voltage V = (2000t) Volt is applied where t is in second. At time t = 5 ms, determine the current I (R = 4Ω and capacitance C = 300 μF). If this current is $\left(\frac{30+x}{10}\right)$ amp. Find x.



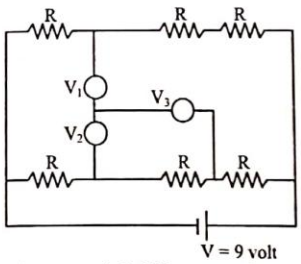
Q.61 A concealed circuit (a black box) consisting of resistors has four terminals. If a voltage is applied between clamps 1 and 2 when clamps 3 and 4 are open, the power liberated is P_1 = 4W and when clamps 3 and 4 are closed, the power librated is P_2 = 8W. If the same source is connected to the clamps 3 and 4, the power liberated in the circuit when clamps 1 and 2 are open is P_3 = 2W. Determine the power P_4 consumed in the circuit when the clamps 1 and 2 are connected and the same voltage is applied between the clamps 3 and 4.



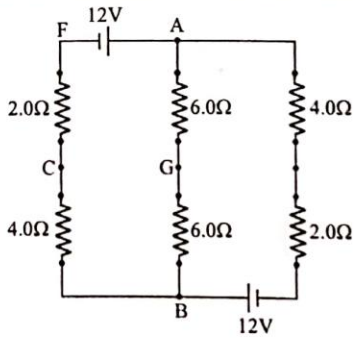
Q.62 Equivalent resistance between A & B is $\frac{n}{5}$ R, then find n.



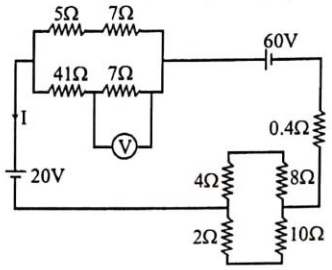
Q.63 In the circuit shown below, all the three voltmeters are identical and have very high resistance. Each resistor has the same resistance. The voltage of the ideal battery shown is 9V. Find the reading of voltmeter V_3 (in volts).



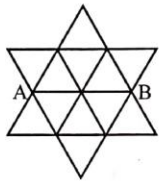
Q.64 In the network shown in the figure, the potential difference (in Volt) across points A and B is



Q.65 Find the current I & voltage V in the circuit shown.



Q.66 Find the equivalent resistance of the circuit between points A and B shown in figure is : (each branch is of resistance = 1Ω)



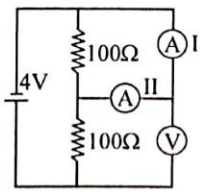
Q.67 A rod of length L and cross-section area A lies along the x-axis between x = 0 and x = L. The material obeys Ohm's law and its resistivity varies along the rod according to $\rho(x) = \rho_0 e^{-x/L}$. The end of the rod at x = 0 is at a potential V_0 and it is zero at x = L.

(i) Find the total resistance of the rod and the current in the wire.

(ii) Find the electric potential in the rod as a function of x.

Q.68 An accumulator of emf 2 volt and negligible internal resistance is connected across a uniform wire of length 10m and resistance 30Ω. The appropriate terminals of a cell of emf 1.5 volt and internal resistances 1Ω is connected to one end of the wire, and the other terminal of the cell is connected through a sensitive galvanometer to a slider on the wire. What length of the wire will be required to produce zero deflection of the galvanometer? How will the balancing change (a) when a coil of resistance 5Ω is placed in series with the accumulator (b) the cell of 1.5 volt is shunted with 5Ω resistor ?

Q.69 In the figure ammeter (I) reads a current of 10 mA, while the voltmeter reads a potential difference of 3V. What does ammeter (II) (in mA) read? The ammeters are identical, the internal resistance of the battery is negligible. (Consider all ammeters and voltmeters as non ideal)



ANSWER KEY

Single Correct Option type Questions

1. (D)	**2.** (B)	**3.** (B)	**4.** (D)	**5.** (B)	**6.** (A)	**7.** (C)
8. (B)	**9.** (C)	**10.** (A)	**11.** (D)	**12.** (A)	**13.** (D)	**14.** (B)
15. (D)	**16.** (B)					

Multiple Correct Option type Questions

17. (A,B)	**18.** (A,B,D)	**19.** (B,D)	**20.** (A,B)	**21.** (A,B,C)	**22.** (A,B,D)	**23.** (A,C,D)
24. (A,C)	**25.** (A,D)	**26.** (A,B)	**27.** (A,D)	**28.** (A,B,C,D)	**29.** (A,B,D)	**30.** (C)
31. (A,B,C)	**32.** (A,B)					

Passage Based Questions

33. (D)	**34.** (C)	**35.** (A)	**36.** (C)	**37.** (D)	**38.** (A)	**39.** (B)
40. (C)	**41.** (A)	**42.** (C)	**43.** (C)	**44.** (A)	**45.** (A)	**46.** (C)
47. (B)	**48.** (A)	**49.** (B)	**50.** (C)	**51.** (B)	**52.** (B)	

Column Matching Type Questions

53. $A \to P,Q,R;\ B \to Q;\ C \to P,R;\ D \to S,T$ **54.** $A \to Q,R;\ B \to Q,R;\ C \to Q;\ D \to Q$

55. (D) **56.** (B) **57.** $A \to P\ ;\ B \to Q\ ;\ C \to R\ ;\ D \to P$

Numeric Response Type Questions

58. 6	**59.** 2	**60.** 1	**61.** 4	**62.** 7	**63.** 2	**64.** 0

65. I = 2.5 A, V = 3.5 Volts **66.** $\frac{22}{35}\Omega$ **67.** $R = \frac{\rho_0 L}{A}\left(1-\frac{1}{e}\right)$; $I = \frac{V_0 A}{\rho_0 L}\left(\frac{e}{e-1}\right)$; $V = \frac{V_0(e^{-x/L} - e^{-1})}{1-e^{-1}}$

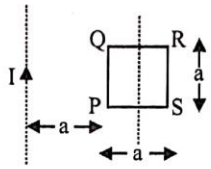
68. 7.5 m, 8.75 m, 6.25 m **69.** 0006.67

Chapter 23

Electro Magnetic Induction

Single Correct Option Type Questions

Q.1 In the figure shown a square loop PQRS of side 'a' and resistance 'r' is placed in near an infinitely long wire carrying a constant current I. The sides PQ and RS are parallel to the wire. The wire and the loop are in the same plane. The loop is rotated by 180° about an axis parallel to the long wire and passing through the mid points of the side QR and PS. The total amount of charge which passes through any point of the loop during rotation is :



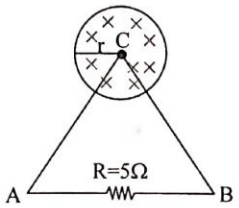
(A) $\frac{\mu_0 Ia}{2\pi r}\ell n2$ (B) $\frac{\mu_0 Ia}{\pi r}\ell n2$

(C) $\frac{\mu_0 Ia^2}{2\pi r}$ (D) cannot be found because time of rotation not give

Q.2 A bulb is rated at 100V, 100W, it can be treated as resistor. Find out the inductance of an inductor (called choke coil) that should be connected in series with the bulb to operate the bulb at its rated power with the help of an ac source of 200 V and 50 Hz.

(A) $\frac{\pi}{\sqrt{3}}$H (B) 100 H (C) $\frac{\sqrt{2}}{\pi}$H (D) $\frac{\sqrt{3}}{\pi}$H

Q.3 A uniform magnetic field of intensity $B = B_0 \sin(\omega t)$ directed into the plane of the paper exists in the cylindrical region of radius r. A loop of resistance $R = 5\Omega$ is folded in the form of an equilateral triangle of side length 2r is placed as shown in the figure. The maximum potential drop in the wire AB is

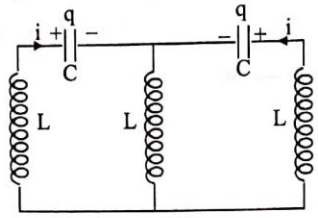


(A) $\frac{\pi r^2 B_0\omega}{6}$ volt (B) $\frac{\pi r^2 B_0\omega}{3}$ volt (C) $\frac{\pi r^2 B_0\omega}{2}$ volt (D) $\pi r^2 B_0\omega$ volt

Q.4 A resistance R draws P power when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes Z, the power drawn will be

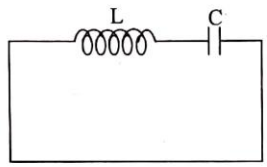
(A) $P\left(\frac{R}{Z}\right)^2$ (B) $P\left(\frac{R}{Z}\right)$ (C) $P\sqrt{\frac{R}{Z}}$ (D) P

Q.5 The natural frequency of the circuit shown in the figure is (Assume that equal currents i, i exist in the two branches, and the charges on the capacitors are equal)



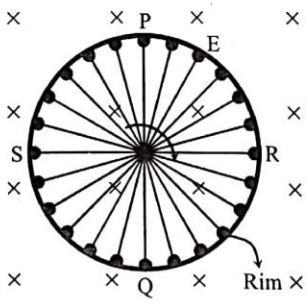
(A) $\frac{1}{2\pi}\frac{1}{\sqrt{LC}}$ (B) $\frac{1}{2\pi}\frac{1}{\sqrt{3LC}}$ (C) $\frac{1}{\pi}\frac{1}{\sqrt{LC}}$ (D) none of the above

Q.6 In an LC circuit the capacitor has maximum charge q_0. The value of $\left(\frac{dI}{dt}\right)_{max}$ is



(A) $\frac{q_0}{LC}$ (B) $\frac{q_0}{\sqrt{LC}}$ (C) $\frac{q_0}{LC} - 1$ (D) $\frac{q_0}{LC} + 1$

Q.7 A wheel of diameter d is rotating about its axis passing through O with angular speed ω. A transverse magnetic field exists in the region. Choose the correct alternative(s).



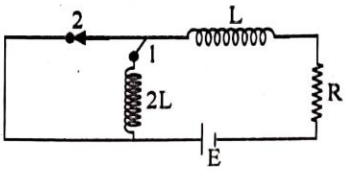
(A) Centre of wheel O is at higher potential compared to any point E on the rim

(B) Potential difference between end Q of one of the spokes and R (end of another spoke) is non-zero

(C) Potential difference between O and R is $\frac{B\omega d^2}{2}$

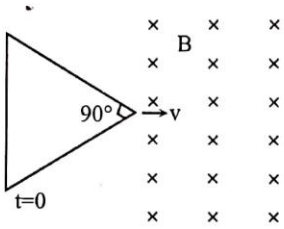
(D) Potential difference between O and E is $\frac{B\omega d^2}{8}$

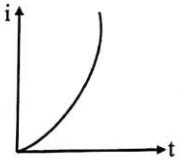
Q.8 In the circuit shown switch is connected to 1 for a very long time . At a particular instant t = 0, switch is shifted to 2, the current in the circuit after a time gap of $\frac{L}{R}$ is

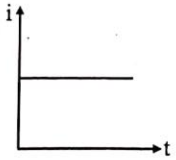


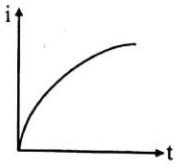
(A) $\frac{E}{2Re}$ (B) $\frac{3E}{R}$ (C) $\frac{3E}{Re}$ (D) $\frac{E}{R}$

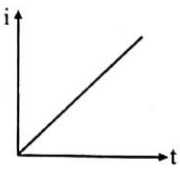
Q.9 The figure shows an isosceles triangle wire frame with apex angle equal to $\pi/2$. The frame starts entering into the region of uniform magnetic field B with constant velocity v at t = 0. The longest side of the frame is perpendicular to the direction of velocity. If i is the instantaneous current through the frame then choose the alternative showing the correct variation of i with time.



(A) 

(B) 

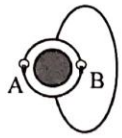
(C) 

(D) 

Q.10 A metallic rod of length L and mass M is moving under the action of two unequal forces F_1 and F_2 (directed opposite to each other) acting at its ends along its length. Ignore gravity and any external magnetic force specific charge of electrons is (e/m), then the potential difference between the end of the rod in steady state must be

(A) $(F_1 - F_2)mL/eM$ (B) $2(F_1 - F_2)mL/eM$ (C) $[mL/eM]\ ln\ [F_1/F_2]$ (D) None

Q.11 A very long solenoid perpendicular to the page generates a downward magnetic field whose magnitude increases with the time. A conducting wire loop around the solenoid contains two identical bulbs A and B which are glowing. Two points diametrically opposite on the wire loop are shorted with another wire lying to the right of bulb B in the plane of the page as shown in figure. After the shorting wire is inserted,



(A) Bulb A goes out and bulb B dims
(B) Bulb A goes out and bulb B gets brighter
(C) Bulb B goes out and bulb A dims
(D) Bulb B goes out and bulb A gets brighter

Statement Based Questions

Q.12 **Statement-1 :** If a coil is rotated in uniform magnetic field about an axis perpendicular to the field, emf induced in coil is maximum for orientation of coil in which magnetic flux through the coil is zero.

Statement-2 : Work done to rotate the coil will convert into electrical energy.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

Q.13 **Statement-1 :** Time dependent magnetic field generates electric field.

Statement-2 : Direction of electric field generated from time variable magnetic field does not obey Lenz's law.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

Q.14 **Statement-1 :** When an inductor L, carries an increasing current i ($i > 0$), the power delivered to the inductor is positive.

Statement-2 : This is because $\frac{d}{dt}\left(\frac{1}{2}Li^2\right) > 0$.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

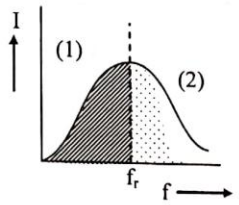
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

Q.15 **Statement-1 :** For series RLC network, power factor of circuit in region (1) leading and in region (2) lagging.

Statement-2 : Overall nature of circuit in region (1) is inductive while in region (2) is capacitive.



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

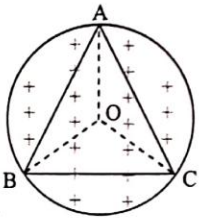
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

Q.16 In the figure shown there exists a uniform time varying magnetic field B = [(4 T/s) t + 0.3 T] in a cylindrical region of radius 4 m. An equilateral triangular conducting loop is placed in the magnetic field with its centroide on the axis of the field and its plane perpendicular to the field.

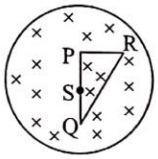


(A) e.m.f. induced in any one rod is 16 V
(B) e.m.f. induced in the complete ΔABC is $48\sqrt{3}$ V
(C) e.m.f. induced in the complete ΔABC is 48 V
(D) e.m.f. induced in any one rod is $16\sqrt{3}$ V

Q.17 An L–C circuit has capacitance $C_1 = C$ and inductance $L_1 = L$. A second circuit has $C_2 = C/2$ and $L_2 = 2L$ and third circuit has $C_3 = 2C$ and $L_3 = L/2$. All the three capacitors are charged to the same potential V and then made to oscillate. Then

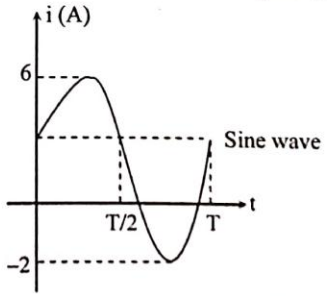
(A) Angular frequency of oscillation is same for all the three circuits.
(B) Maximum current is greatest in first circuit.
(C) Maximum current is greatest in second circuit.
(D) Maximum current is greatest in third circuit.

Q.18 Consider a region of cylindrical magnetic field, changing with time at the rate x. A triangular conducting loop PQR is placed in the field such that mid point of side PQ coincides with axis of the magnetic field region. PQ = 2ℓ, PR = 2ℓ. Emf induced in the sides PQ, QR, PR of the loop are-



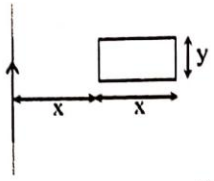
(A) $x\ell^2, 0, x\ell^2$
(B) $0, \frac{x\ell^2}{2}, \frac{3x\ell^2}{2}$
(C) $0, x\ell^2, x\ell^2$
(D) $0, \frac{3}{2}x\ell^2, \frac{x\ell^2}{2}$

Q.19 The current 'i' through a wire varies with time t as shown in the figure. The effective (rms) value of the current is –



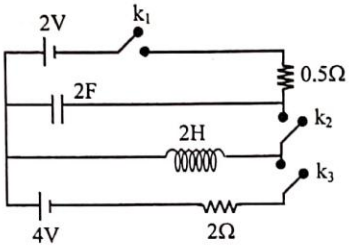
(A) 6A
(B) $2\sqrt{3}$A
(C) $2+2\sqrt{2}$A
(D) 3A

Q.20 Consider a system of coplanar infinite straight wire and a rectangular loop of resistance ℓn a shown in the figure. If current in the wire changes from i to 2i, charge flowing through the rectangular loop is –



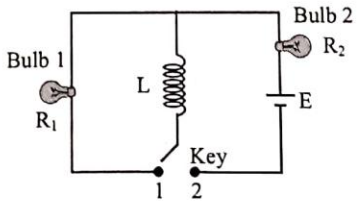
(A) $\frac{\mu_0 yi\ell n2}{4\pi}$ (B) $\frac{\mu_0 yi\ell n4}{4\pi}$ (C) $\frac{\mu_0 yi\ell n8}{4\pi}$ (D) $\frac{\mu_0 yi\ell n10}{4\pi}$

Q.21 For the circuit shown here keys k_1 and k_3 are closed for 1 second. Key k_2 is closed at the instant k_1 and k_3 are opened. Maximum charge on the capacitor after key k_2 is closed is –



(A) $4\left(1-\frac{1}{e}\right)C$ (B) $4\sqrt{2}\left(1-\frac{1}{e}\right)C$ (C) $8\left(1-\frac{1}{e}\right)C$ (D) Zero

Q.22 Key is in position 2 for time t. There after, it is in position 1. Resistances of the bulb and inductance of inductor are marked in the figure choose the correct alternative.



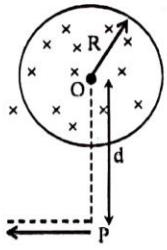
(A) Bulb 2 dies as soon as key is switched into position 1

(B) Time in which brightness of bulb 1 becomes half its maximum brightness does not depend on t

(C) If $t = \infty$, total heat produced in bulb 1 is $\frac{LE^2}{2R_2^2}$

(D) Ratio of maximum power consumption of bulbs depends on time

Q.23 In a cylindrical region of radius R, there exists a time varying magnetic field B such that $\frac{dB}{dt} = K$ (> 0). A charged particle having charge q is placed at the point P at a distances d (> R) from its centre O. Now, the particles is moved in the direction perpendicular to OP (see figure) by an external agent upto infinity so that there is no gain in kinetic energy of the charged particle. Choose the correct statement /s.



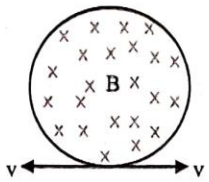
(A) Work done by external agent is $\frac{q\pi R^2}{4}k$ if $d = 2R$

(B) Work done by external agent is $\frac{q\pi R^2}{8}k$ if $d = 4R$

(C) Work done by external agent is $\frac{q\pi R^2}{4}k$ if $d = 4R$

(D) Work done by external agent is $\frac{q\pi R^2}{4}k$ if $d = 6R$

Q.24 A circular conducting loop of radius r_0 and having resistance per unit length λ as shown in the figure is placed in a magnetic field B which is constant in space and time. The ends of the loop are crossed and pulled in opposite directions with velocity v such that the loop always remains circular and the radius of the loop goes on decreasing, then



(A) Radius of the loop changes with r as $r = r_0 - vt/\pi$

(B) EMF induced in the loop as a function of time is $\varepsilon = 2Bv[r_0 - vt/\pi]$

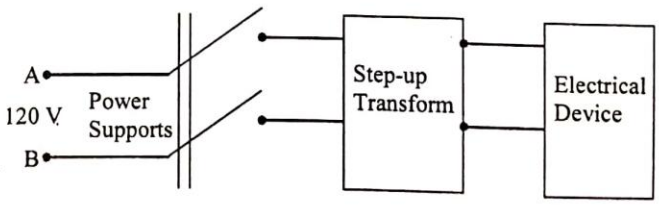
(C) Current induced in the loop is $I = \frac{Bv}{2\pi\lambda}$

(D) Current induced in the loop is $I = \frac{Bv}{\pi\lambda}$

Q.25 A capacitor in an LC oscillator has a maximum potential difference of 15V and a maximum energy of 360 μJ. At a certain instant $t = t_0$ the energy in the inductor is 320 μJ, at that instant, the potential difference across the capacitor is V volt ?

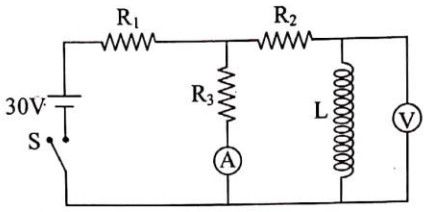
(A) The value of capacitance is 1.6 μF
(B) The value of capacitance is 3.2 μF
(C) The value of V is 5 Volt
(D) The value of V is 10 Volt

Q.26 An electrical device is designed to operate from 240 volt line to obtain the 960 watt of power that it needs. The available power supply is 120 V line, therefore a step-up transformer is used, whose primary winding and secondary winding have N_1 turns and N_2 turns respectively, so that the electrical device works at its optimum power -



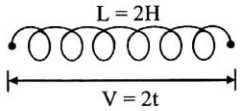
(A) The resistance of electrical device is 60 ohm
(B) The resistance of electrical device is 30 ohm
(C) The current in primary winding is 4 amp.
(D) The current in primary winding is 8 amp.

Q.27 The switch S is closed at t = 0. Just after closing the switch, reading of ideal Voltmeter and reading of ideal Ammeter are V_1 volt and I_1 amp respectively. The final reading of devices are V_2 volt and I_2 amp. (Given : $R_1 = 5\Omega$, $R_2 = R_3 = 10\Omega$, L = 10 mH).



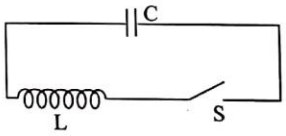
(A) The value of I_1 is 1 amp
(B) The value of I_1 is 2 amp
(C) The value of $\frac{V_1 + V_2}{I_1 + 2I_2}$ is 2 ohm
(D) The value of $\frac{V_1 + V_2}{I_1 + 2I_2}$ is 4 ohm

Q.28 A variable voltage $V = 2t$ is applied across an inductor of inductance $L = 2H$ as shown in figure. Then,



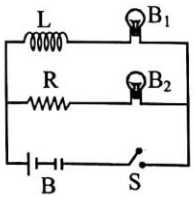
(A) current versus time graph is a parabola
(B) energy stored in magnetic field at t = 2s is 4J
(C) potential energy at time t = 1s in magnetic field is increasing at a rate of 1 J/s
(D) energy stored in magnetic field is zero all the time.

Q.29 In the given circuit, initially the charge on capacitor is Q_0. At t = 0, the switch S is closed. Which of the following statement is/are correct?



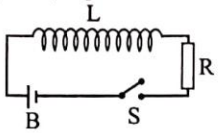
(A) Maximum current through the inductor is $\frac{Q_0}{\sqrt{LC}}$
(B) Charge on the capacitor is zero at $t = \frac{\pi}{2}\sqrt{LC}$
(C) Current through the inductor is zero at $t = \frac{\pi}{2}\sqrt{LC}$
(D) Energy stored in magnetic field is zero all the time.

Q.30 An inductor L, a resistance R and two identical bulbs B_1 and B_2 are connected to a battery through a switch S as shown in the figure. The resistance of coil having inductance L is also R. Which of the following statement gives the correct description of the happenings when the switch S is closed?



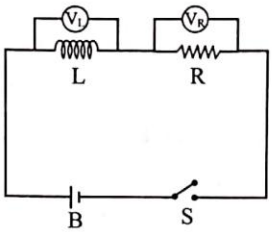
(A) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright
(B) B_1 light up earlier and finally both the bulbs acquire equal brightness
(C) B_2 lights up earlier and finally B_1 shines brighter than B_2
(D) B_1 and B_2 light up together with equal brightness all the time

Q.31 In figure, the switch S is closed so that a current flows in the iron-core inductor which has inductance L and the resistance R. When the switch is opened, a spark is obtained in it at the contacts. The spark is due to



(A) a slow flux change in L
(B) a sudden increase in the emf of the battery B
(C) a rapid flux change in L
(D) a rapid flux change in R

Q.32 An inductance L, resistance R, battery B and switch S are connected in series. Voltmeters V_L and V_R are connected across L and R respectively. When switch is closed :

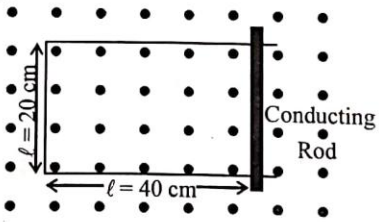


(A) The initial reading in V_L will be greater than in V_R
(B) The initial reading in V_L will be lesser than V_R
(C) The initial readings in V_L and V_R will be the same
(D) The reading in V_L will be decreasing as time increases

Passage Based Questions

Passage # 1 (Q.33 to 35)

Figure shows a conducting rod of negligible resistance that can slide on smooth U-shaped rail made of wire of resistance 1Ω/m. Position of the conducting rod at t = 0 is shown. A time 't' dependent magnetic field B = 2t Tesla is switched on at t = 0.



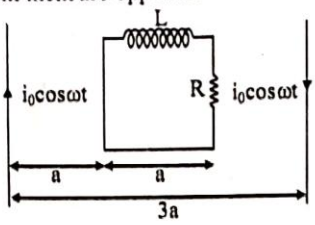
Q.33 The current in the loop at t = 0 due to induced emf is -
(A) 0.16 A, clockwise (B) 0.08 A, clockwise (C) 0.08 A, anticlockwise (D) zero

Q.34 At t = 0, when the magnetic field is switched on, the conducting rod is moved to the left at constant speed 5 cm/s by some external means. The rod moves perpendicular to the rails. At t = 2s, induced emf has magnitude.
(A) 0.12 V (B) 0.08 V (C) 0.04 V (D) 0.02 V

Q.35 Following situation of the previous question, the magnitude of the force required to move the conducting rod at constant speed 5 cm/s at the same instant t = 2s, equal to -
(A) 0.16 N (B) 0.12 N (C) 0.08 N (D) 0.06 N

Passage # 2 (Q.36 to 38)

In figure, a square loop consisting of an inductor of inductance L and resistor of resistance R is placed between two long parallel wires. The two long straight wires have time varying current of magnitude $I = I_0 \cos \omega t$ but the direction of current in them are opposite.



Q.36 Total magnetic flux in this loop is

(A) $\frac{\mu_0 Ia}{\pi} \ln 2$ (B) $\frac{2\mu_0 Ia}{\pi} \ln 2$ (C) $\frac{4\mu_0 Ia}{\pi} \ln 2$ (D) $\frac{\mu_0 Ia}{2\pi} \ln 2$

Q.37 Magnitude of emf in this circuit only due to flux change associated with two long straight current carrying wires will be

(A) $\frac{\mu_0 a \ln 2 I_0 \omega}{\pi} \sin \omega t$ (B) $\frac{2\mu_0 a \ln 2 I_0 \omega}{\pi} \sin \omega t$ (C) $\frac{\mu_0 a \ln 2 I_0 \omega}{2\pi} \cos \omega t$ (D) $\frac{\mu_0 a \ln 2 I_0 \omega}{\pi} \cos \omega t$

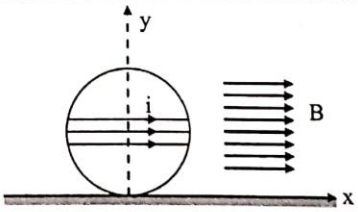
Q.38 The instantaneous current in the circuit will be

(A) $\frac{2\mu_0 a \ln 2 I_0 \omega}{\pi\sqrt{R^2 + \omega^2 L^2}} \sin(\omega t - \phi)$ (B) $\frac{2\mu_0 a \ln 2 I_0 \omega}{\pi\sqrt{R^2 + \omega^2 L^2}} \sin(\omega t + \phi)$

(C) $\frac{\mu_0 a \ln 2 I_0 \omega}{\pi\sqrt{R^2 + \omega^2 L^2}} \sin \omega t$ (D) $\frac{\mu_0 a \ln 2 I_0 \omega}{\pi\sqrt{R^2 + \omega^2 L^2}} \sin(\omega t - \phi)$

Passage # 3 (Q.39 to 41)

A person wants to roll a solid non-conducting spherical ball of mass m and radius r on a surface whose coefficient of static friction is μ. He placed the ball on the surface wrapped with n turns of closely packed conducting coils of negligible mass at the diameter. By some arrangement he is able to pass a current i through the coils either in the clockwise direction or in the anti-clockwise direction.



A constant horizontal magnetic field $\vec{B}$ is present throughout the space as shown in the figure. (Assume μ is large enough to help rolling motion)

Q.39 If current i is passed through the coils the maximum torque in the coil is

(A) $-\pi nir^2 B\hat{k}$ (B) $\pi nir^2 B\hat{j}$ (C) $-\pi nir^2 B\hat{j}$ (D) $\pi nir^2 B\hat{k}$

Q.40 Angular acceleration of the ball after it has rotated through an angle θ ($\theta < 180°$), is

(A) $\frac{5}{7}\frac{\pi niB}{m}\cos\theta$ (B) $\frac{2}{5}\frac{\pi niB}{m}\cos\theta$ (C) $\frac{7}{5}\frac{\pi niB}{m}\cos\theta$ (D) $\frac{5}{2}\frac{\pi niB}{m}\cos\theta$

Q.41 The minimum value of μ for which the rolling motion is possible, is

(A) $\left(\frac{14\pi}{5g}\right)\left(\frac{niB}{m}\right)r$ (B) $\left(\frac{5\pi}{7g}\right)\left(\frac{niB}{m}\right)r$ (C) 0 (D) $\left(\frac{7\pi}{5g}\right)\left(\frac{niB}{m}\right)r$

Passage # 4 (Q.42 to 44)

A fan operates at 200 volt (DC) consuming 1000 W when running at full speed . It's internal wiring has resistance 1Ω . When the fan runs at full speed, it speed becomes constant . This is because the torque due to magnetic field inside the fan is balanced by the torque due to air resistance on the blades of the fan and torque due to friction between the fixed part and the shaft of the fan. The electrical power going into the fan is spent (i) in the internal resistance as heat call it P_1 (ii) in doing work against internal friction and air resistance producing heat , sound etc., call it P_2 . When the coil of fan rotates, an emf is also induced in the coil. This oppose the external emf applied to send the current in to the fan This emf is called back – emf , call it 'e'

Answer the following questions when the fan is running at full speed .

Q.42 The current flowing into the fan and the value of back emf 'e' is :

(A)200 A, 5 volt (B) 5 A, 200 volt (C)5 A, 195 volt (D) 1 A , 0 volt

Q.43 The value of power 'P_1' is

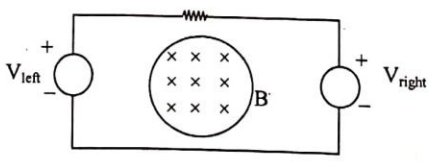
(A) 1000 W (B) 975 W (C) 25 W (D) 200 W

Q.44 The value of power 'P_2' is

(A) 10000 W (B) 975 W (C) 25 W (D) 200 W

Passage # 5 (Q.45 & 46)

Two voltmeters V_{right} & V_{left} each with an internal resistance of $10^4\Omega$ are in series with a resistor R of $5 \times 10^3\ \Omega$. They are connected through wires of negligible resistances. The positive side of voltmeters is up as shown in figure. A changing magnetic field is present in the shaded area. At a particular moment in time V_{left} reads + 0.1volt.



Q.45 At that moment when reading of V_{left} is + 0.1 Volt, the reading of V_{right} is -

(A) – 0. 1 Volt (B) – 0.2 Volt (C) – 0.3 Volt (D) – 0.4 Volt

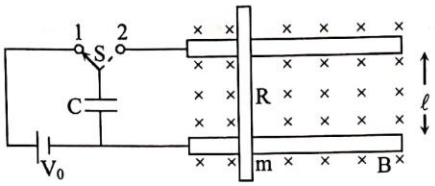
Q.46 At that moment, select the correct options -

(A) current is 10^{-5} Amp clockwise (B) current is 10^{-4} Amp anticlockwise

(C) induced emf is 0.25 Volt (D) magnetic field is increasing

Passage # 6 (Q.47 & 48)

One end of long horizontal fixed track of separation length ℓ and negligible resistance is connected to a capacitor of capacitance C charged to voltage V_0. The inductance of the assembly is negligible. The system is placed in homogenous, vertical magnetic field of induction B as shown in the figure. A frictionless conducting rod of mass m and negligible resistance is placed perpendicularly on the track. Now the switch S is turned from 1 to 2.



Q.47 What is the maximum velocity of the rod ?

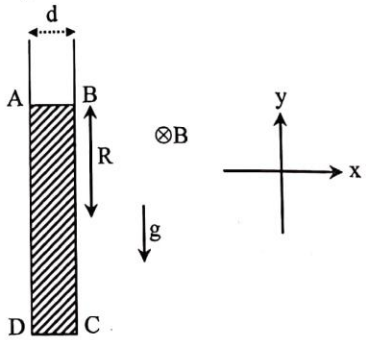
(A) $\dfrac{B\ell CV_0}{m+B^2\ell^2C}$ (B) $\dfrac{2B\ell CV_0}{m+B^2\ell^2C}$ (C) $\dfrac{B\ell CV_0}{2(m+B^2\ell^2C)}$ (D) None of these

Q.48 Find the minimum charge on the capacitor

(A) $\dfrac{B^2\ell^2C^2V_0}{2m+B^2\ell^2C}$ (B) $\dfrac{B^2\ell^2C^2V_0}{m+B^2\ell^2C}$ (C) $\dfrac{2B^2\ell^2C^2V_0}{m+B^2\ell^2C}$ (D) None of these

Passage # 7 (Q.49 & 50)

A circular metal plate starts falling from rest, straight vertically in region of uniform magnetic field of intensity B as shown in the figure. The magnetic field is parallel to the surface of earth and to the plane of the plate. The acceleration of free fall is g. The plate has mass m and its thickness d, is much smaller than its radius R. (neglect the edge effects)



Q.49 The current in plate at any time t is -

(A) $\dfrac{\pi\varepsilon_0R^2Bmg}{m+\pi\varepsilon_0R^2B^2d}$ (B) $\dfrac{\pi\varepsilon_0R^2Bmg}{2m+\pi\varepsilon_0R^2B^2d}$ (C) $\dfrac{2\pi\varepsilon_0R^2Bmg}{m+\pi\varepsilon_0R^2B^2d}$ (D) $\dfrac{\pi\varepsilon_0R^2Bmg}{m+2\pi\varepsilon_0R^2B^2d}$

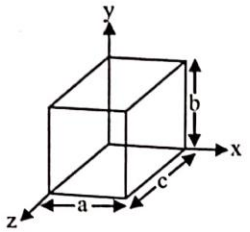
Q.50 The charge on the plate is -

(A) $\dfrac{\pi\varepsilon_0R^2Bmgt}{m+\pi\varepsilon_0R^2B^2d}$ (B) $\dfrac{2\pi\varepsilon_0R^2Bmgt}{m+\pi\varepsilon_0R^2B^2d}$ (C) $\dfrac{\pi\varepsilon_0R^2Bmgt}{m+2\pi\varepsilon_0R^2B^2d}$ (D) $\dfrac{\pi\varepsilon_0R^2Bmgt}{2m+\pi\varepsilon_0R^2B^2d}$

Column Matching Type Questions

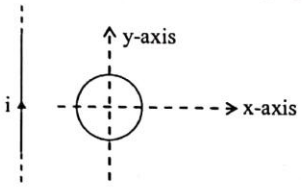
Q.51 Match the column :

The figure shows a metallic solid block, placed in a way so that faces are parallel to the coordinate axes. Edge lengths along axis x, y and z are a, b and c respectively. The block is in a region of uniform magnetic field of magnitude 30 mT. One of the Edge length of the block is 25 cm. The block is moved at 4m/s parallel to each axis and in turn, the resulting potential difference V that appears across the block is measured. When the motion is parallel to the y axis, V = 24 mV; with the motion parallel to the z axis, V = 36 mV; with the motion parallel to the x axis, V = 0. Using the given information, correctly match the dimensions of the block with values given.



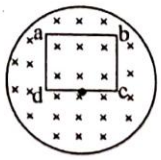
Column -I	Column-II
(A) a	(P) 20 cm
(B) b	(Q) 24 cm
(C) c	(R) 25 cm
(D) $\frac{bc}{a}$	(S) 30 cm
	(T) 10 cm

Q.52 A conducting circular rigid loop near a long straight current carrying wire as shown. Match the following table :



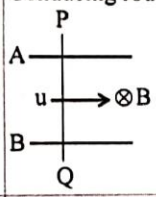
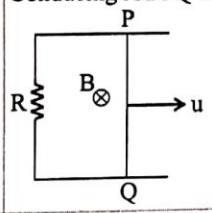
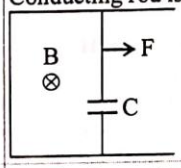
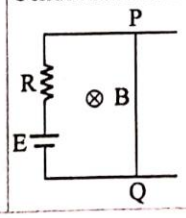
Column I	Column II
(A) If current is increased	(P) Induced current in the loop is clockwise
(B) If current is decreased	(Q) Induced current in the loop is anticlockwise
(C) If wire is moved away from the wire maintaining constant current	(R) Wire will attract the loop and there will be a torque about y-axis
(D) If wire is moved towards the wire maintaining constant current	(S) Wire will repel the loop and there will be no torque about y-axis

Q.53 Consider a uniform transverse magnetic field confined to a cylindrical region (with axis passing through O) as shown in the figure. Also shown is an imaginary rectangular loop *abcd*, with mid point of its side *cd* at O. Magnetic field in the region is increasing at a constant rate. Match the entries in column I to the all possible entries in column II.



	Column-I		Column-II
(A)	Potential difference between points *a* and *c*, $V_a - V_c$	(P)	zero
(B)	work done in carrying charge q from point *c* to *a*	(Q)	positive
(C)	Component of electrostatic field at point a along side *ad*, assuming direction from *a* towards *d* to be positive	(R)	negative
(D)	Component of induced electric field at point *c* along *cb*. assuming direction from *c* towards *b* to be positive	(S)	Not defined
		(T)	May have non-zero value

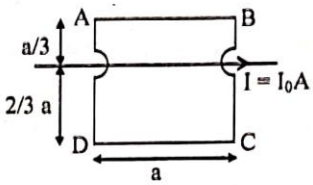
Q.54 The whole motion is in smooth horizontal plane. The parallel bars are infinitely large and vertical uniform magnetic field exist.

	Column-I		Column-II
(A)	Conducing rod PQ is projeted with velocity u 	(P)	Uniform motion
(B)	Conducing rod PQ is projected with velocity with velocity u 	(Q)	Uniformly accelerated motion
(C)	Conducting rod is pulled with constant force F 	(R)	Non uniformly accelerated motion
(D)	Conduction rod PQ is released from rest 	(S)	Velocity of rod after long time is non zero constant
		(T)	Motion is SHM

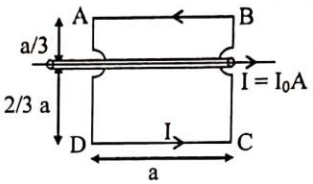
Q.55 Match the following.

List-I

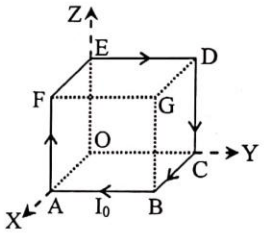
(P) For the square wire loop arrangement ABCD of side a and resistance R, the current in the long straight wire is given by I_0. The induced current in the loop is $\frac{\lambda\mu_0 I_0 a}{4\pi R}\ell n2$. The value of λ is .....



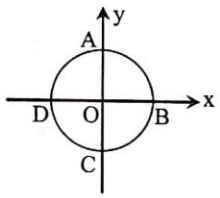
(Q) For the square wire arrangement of side a and resistance R, the current in the long straight wire is given by $I_0 t$ where I_0 is constant and t is time. The induced current in the loop is $\frac{\xi\mu_0 I_0 a}{4\pi R}\ell n2$. The value of ξ is .....



(R) OABCDEFG is a cube of side a. The wire frame of AFEDCBA is carrying current I_0. The magnitude of magnetic moment is $\sqrt{k}\,a^2 I_0$. The value of k is .....



(S) A circular non-conducting loop ABCD, is having uniformly distributed charge Q and radius 'a' with centre at point O, is rotating clockwise with a constant angular velocity ω about an axis passing through O and perpendicular to the plane of paper. The magnetic field at the centre is $\frac{n\mu_0 Q\omega}{4\pi a}$. The value of n is .....



List-II

(1) 0

(2) 1

(3) 2

(4) 3

Codes :

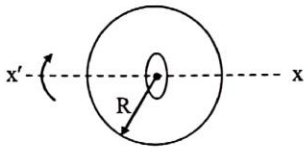
	P	Q	R	S
(A)	1	3	4	2
(B)	2	4	3	1
(C)	1	2	3	4
(D)	4	1	2	3

Numeric Response Type Questions

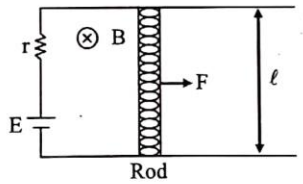
Q.56 An inductor of inductance 2.0 mH is connected across a charged capacitor of capacitance 5.0 mF, and the resulting LC circuit is set oscillating at its natural frequency. Let Q denote the instantaneous charge on the capacitor, and I the current in the circuit. It is found that the maximum value of Q is 200 mC. When Q = 100 mC, the value of |dI/dt| is found to be 10^x A/s. Find the value of x.

Q.57 An ac source of angular frequency ω is connected across a resistance R and a capacitor C in series. The current registered is i. If now the current in the circuit is found to be halved. Then ratio of reactance to resistance at the original frequency is $\sqrt{\frac{n}{5}}$. Find value of n.

Q.58 A non-conducting ring of radius R having uniformly distributed charge Q starts rotating about x–x′ axis passing through diameter with an angular acceleration α as shown in the figure. Another small conducting ring having radius a (a << R) is kept fixed at the centre of bigger ring is such a way that axis xx′ is passing through its centre and perpendicular to its plane. If the resistance of small ring is r = 1Ω, find the induced current in it in ampere. (Given $q = \frac{16 \times 10^2}{\mu_0}$ C, R = 1 m, a = 0.1 m, $\alpha = 8$ rad/s^2)

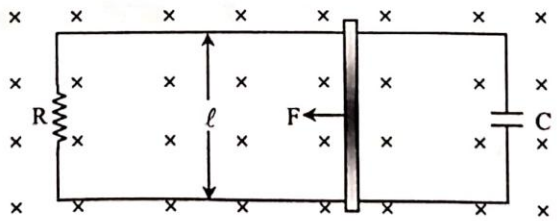


Q.59 Two parallel conducting rails are connected to a source of emf E and internal resistance r. Another conducting rod of length ℓ having negligible resistance lies at rest and can slide without friction over the rails. A uniform magnetic field B is applied perpendicular to the plane of the rails. At t = 0, the rod is pulled along the rails by applying a force F. The velocity of the rod is observed to be $v = v_0 \cos(\omega t)$ then the power (in watt) spent by the force over 1 cycle is $\frac{B^2 \ell^2 V_0^2}{nr}$. Find n. (Given B = 2 Tesla, r = 2 × 10^{-4} Ω, v_0 = 2 ms^{-1}, ℓ = 2 cm)

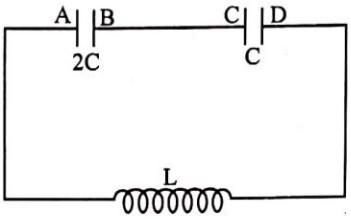


Q.60 A circuit draws a power of 550 watt from a source of 220 volt, 50 Hz. The power factor of the circuit is 0.8 and the current lags in phase behind the potential difference. To make the power factor of the circuit as 1.0, the capacitance will have to be connected with it is 15n μF. Find n.

Q.61 Two parallel long smooth conducting rails separated by a distance ℓ are connected by a movable conducting connector of mass m. Terminals of the rails are connected by the resistor R and the capacitor C as shown in figure. A uniform magnetic field B perpendicular to the plane of the rail is switched on. The connector is dragged by a constant force F. Find the speed of the connector as a function of time if the force F is applied at t = 0. Also find the terminal velocity of the connector.

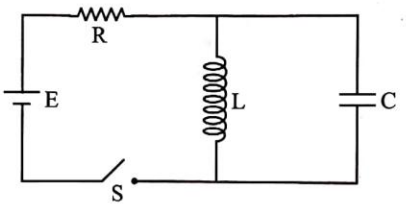


Q.62 Two capacitor of capacitances 2C and C are connected in series with an inductor of inductances L. Initially capacitors have charge such that $V_B - V_A = 4V_0$ and $V_C - V_D = V_0$. Initial current in the circuit is zero. Find

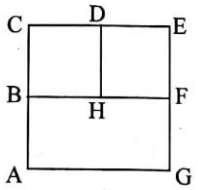


(a) maximum current that will flow in the circuit
(b) potential difference across each capacitor at the instant
(c) equations of current flowing towards left in the inductor

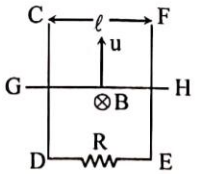
Q.63 In the circuit shown in the figure. E = 50.0 V, R = 250 Ω and C = 0.500 μF. The switch S is closed for a long time, and no voltage is measured across the capacitor. After the switch is opened, the voltage across the capacitor reaches a maximum value of 150 V. What is the inductance L ?



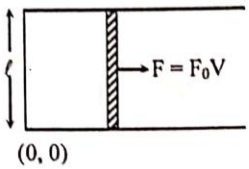
Q.64 In the figure shown ABCDEFGH is a square conducting frame of side 2m and resistance 1Ω/m. A uniform magnetic field B is applied perpendicular to the plane and pointing inwards. It increases with time at a constant rate of 10 T/s. Find the rate at which heat is produced in the circuit. AB = BC = CD = BH.



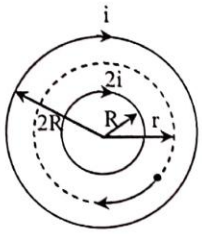
Q.65 In the figure CDEF is a fixed conducting smooth frame in vertical plane. A conducting uniform rod GH of mass 'm' can move vertically and smoothly without losing contact with the frame. GH always remains horizontal. It is given velocity 'u' upwards and released. Taking the acceleration due to gravity as 'g' and assuming that no resistance is present other than 'R'. Find out time taken by rod to reach the highest point.



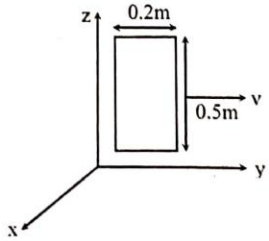
Q.66 Two infinitely long parallel wires, having resistance per unit length λ are connected as shown in the figure. A slide wire of negligible resistance and having mass 'm' and length 'ℓ' can slide between the parallel wires, without any frictional resistance. If the system of wires is introduced to a magnetic field of intensity 'B' (directed into the plane of paper) and the slide wire is pulled with a force which varies with the velocity of the slide wire as $F = F_0V$, then find the velocity of the slide wire as a function of the distance x travelled. (The slide wire is initially at origin and has a velocity v_0).



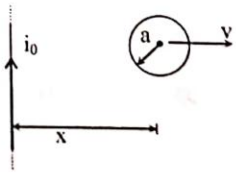
Q.67 A long solenoid contains another coaxial solenoid (whose radius R is half of its own). Their coils have the same number of turns per unit length and initially both carry no current. At the same instant currents start increasing linearly with time in both solenoids. At any moment the current flowing in the inner coil is twice as large as that in the outer one and their directions are the same. As a result of the increasing currents a charged particle, initially at rest between the solenoids, starts moving along a circular trajectory (see figure). What is the radius r of the circle ?



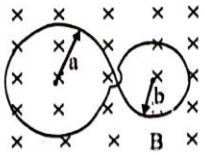
Q.68 A rectangular loop is moved through a region in which the magnetic field is given by $B_y = B_z = 0$, $B_x = (6 - y)$ T. Find the emf in the loop as function of time, if at t = 0, the loop starts moving from the position shown in the figure.
(a) at constant velocity v = 6.5 m/s
(b) at constant acceleration of $2 m/s^2$ from state of rest



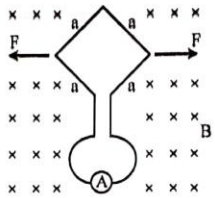
Q.69 A small conducting loop of radius a and resistance r is pulled with velocity v perpendicular to a long straight conductor carrying a current i_0. If a constant power P is dissipated in the loop, find the variation of velocity of the loop as a function of x. Given that x >> a..



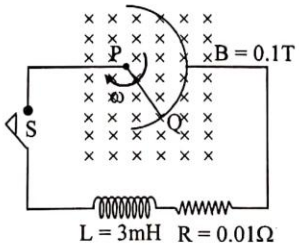
Q.70 A plane loop is shaped in the form as shown in figure with radii a = 20 cm and b = 10 cm and is placed in a uniform time varying magnetic field $B = B_0 \sin \omega t$, where $B_0 = 10$ mT and $\omega = 100$ rad/s. Find the amplitude of the current induced in the loop if its resistance per unit length is equal to $50 \times 10^{-3}\ \Omega$/m. The inductance of the loop is negligible.



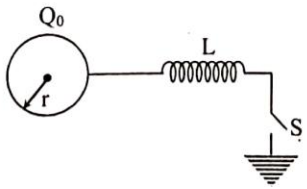
Q.71 The plane of a square loop of wire with edge length $a = 0.2 \times 10^3$ m is perpendicular to the Earth's magnetic field at a point where B = 15.0 μT, as shown in figure. The total resistance of the loop and the wires connecting it to a sensitive ammeter is 0.500Ω. If the loop is suddenly collapsed by horizontal forces as shown. Total charge passing through the ammeter is..... × 0.6 C



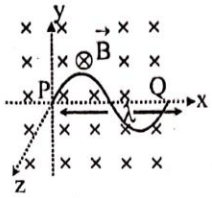
Q.72 The circuit shows a resistance R = 0.01 Ω and inductance L = 3mH connected to a conducting rod PQ of length ℓ = 2m which can slide on a perfectly conducting circular arc of radius ℓ with its centre at P. Assume that friction & gravity are absent and a constant uniform magnetic field B = 0.1 T exists as shown in the figure. At t = 0 , the circuit is switched on and simultaneously an external torque is applied on the rod so that it rotates about P with a constant angular velocity ω = 2 rad/sec. Find the magnitude of this torque (in N-m) at t = (0.3 ln 2) second.



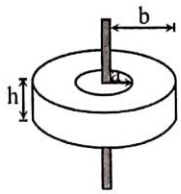
Q.73 A conducting sphere of radius r, having charge Q_0 is connected to earth through an ideal inductor of inductance L and a switch S. The switch S is closed at t = 0. If current through switch S at $t = \dfrac{\pi\sqrt{4\pi\varepsilon_0 rL}}{4}$ is $\dfrac{Q_0}{\sqrt{2n\pi\varepsilon_0 rL}}$ Then find value of n.



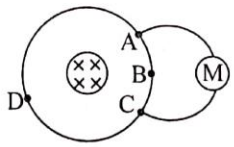
Q.74 A wire forming one cycle of sine curve is moved in x-y plane with velocity $\vec{V} = V_x\hat{i} + V_y\hat{j}$. There exist a magnetic field $\vec{B} = -B_0\hat{k}$. Find the motional emf develop across the ends PQ of wire.



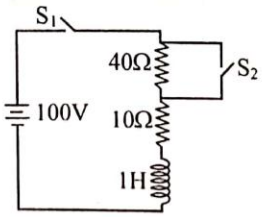
Q.75 A long straight wire is arranged along the symmetry axis of a toroidal coil of rectangular cross-section, whose dimensions are given in the figure. The number of turns on the coil is N, and relative permeability of the surrounding medium is unity. Find the amplitude of the emf induced in this coil, if the current $i = i_m \cos \omega t$ flows along the straight wire.



Q.76 A variable magnetic field creates a constant emf E in a conductor ABCDA. The resistances of portion ABC, CDA and AMC are R_1, R_2 and R_3 respectively. What current will be shown by meter M? The magnetic field is concentrated near the axis of the circular conductor



Q.77 In the circuit shown in the figure the switched S_1 and S_2 are closed at time t = 0. After time t = (0.1) *ln* 2 sec, switch S_2 is opened. Find the current in the circuit at time t = (0.2) *ln* 2 sec.



ANSWER KEY

Single Correct Option type Questions

1. (B) 2. (D) 3. (A) 4. (A) 5. (B) 6. (A) 7. (D)
8. (D) 9. (D) 10. (A) 11. (D)

Statement Based Questions

12. (C) 13. (C) 14. (A) 15. (C)

Multiple Correct Option type Questions

16. (B,D) 17. (A,D) 18. (C) 19. (B) 20. (B) 21. (B) 22. (A,B,C)
23. (A,C,D) 24. (A,B,D) 25. (B,C) 26. (C,D) 27. (B,D) 28. (A,B,C) 29. (A,B)
30. (A) 31. (C) 32. (A,D)

Passage Based Questions

33. (A) 34. (B) 35. (C) 36. (A) 37. (A) 38. (D) 39. (A)
40. (A) 41. (B) 42. (B) 43. (C) 44. (B) 45. (A) 46. (C,D)
47. (A) 48. (B) 49. (A) 50. (B)

Column Matching Type Questions

51. $A \to R; B \to S; C \to P; D \to Q$

52. $A \to R,S; B \to P,R; C \to P,S; D \to Q,S$

53. $A \to P; B \to P,Q,R,T; C \to P; D \to Q,T$

54. $A \to P,S;\ B \to R;\ C \to Q;\ D \to R,S$

55. (A)

Numeric Response Type Questions

56. 4 57. 3 58. 8 59. 2 60. 5

61. $v = \frac{FR}{B^2\ell^2}(1-e^{-\alpha t}),\ \alpha = \frac{B^2\ell^2}{mR + RB^2\ell^2C},\ v_T = \frac{FR}{B^2\ell^2}$

62. (a) $q_0\omega$; (b) $3V_0$; $3V_0$; (c) $i = q_0 \sin \omega t$ here $q_0 = 2CV_0$ and $\omega = \sqrt{\frac{3}{2LC}}$

63. 0.28 H 64. 200 W 65. $t = \frac{mR}{B^2\ell^2}\ln\frac{mg + \frac{B^2\ell^2 v}{R}}{mg}$ 66. $v = v_0 + \frac{F_0 x}{m} - \frac{B^2\ell^2}{2\lambda m}\ln\left(\frac{2x+\ell}{\ell}\right)$

67. $r = \sqrt{2}R$ 68. (a) 0.65 volt ; (b) 0.2t volt 69. $\frac{2x^2}{\mu_0 i a^2}\sqrt{pr}$ 70. 1 71. 2 72. 4

73. 4 74. $\lambda V_y B_0$ 75. $\frac{\mu_0 h\omega i_m N}{2\pi} ln\ \frac{b}{a}$ 76. $\frac{E\,R_1}{R_1R_2 + R_2R_3 + R_3R_1}$ 77. 67/32A.

Chapter

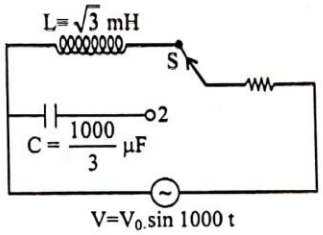
24 Alternating Current

Single Correct Option Type Questions

Q.1 An inductance L, a capacitance C and a resistance R may be connected to an AC source of angular frequency ω, in three different combinations of RC, RL and LC in series. Assume that $\omega L = \frac{1}{\omega C}$. The power drawn by the three combinations are P_1, P_2, P_3 respectively, then,

(A) $P_1 > P_2 > P_3$ (B) $P_1 = P_2 < P_3$ (C) $P_1 = P_2 > P_3$ (D) $P_1 = P_2 = P_3$

Q.2 In the given AC circuit, when switch S is at position 1, the source emf leads current by $\pi/6$ Now, if the switch is at position 2, then



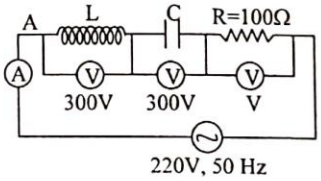
(A) current leads source emf by $\frac{\pi}{4}$ (B) current leads source emf by $\frac{\pi}{3}$

(C) source emf leads current by $\frac{\pi}{4}$ (D) source emf leads current by $\frac{\pi}{3}$.

Q.3 A coil of inductance 0.12 H and resistance 5Ω is connected to an AC–source of 13 V, $\frac{50}{\pi}$ Hz. The power factor of this circuit is

(A) $\frac{12}{5}$ (B) $\frac{12}{13}$ (C) 5 (D) $\frac{5}{13}$.

Q.4 In the circuit shown below, what will be the reading of the voltmeter and ammeter?

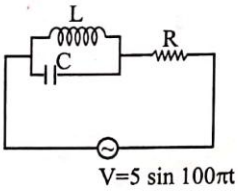


(A) 800 V, 2A (B) 300 V, 2A (C) 220 V, 2.2A (D) 100 V, 2A

Q.5 An electric lamp designed for operation on 110V AC is connected to a 220 V AC supply, through a choke coil of inductance 2H, for proper operation. The angular frequency of the AC is $100\sqrt{10}$ rad/s. If a capacitor is to be used in place of the choke coil, its capacitance must be

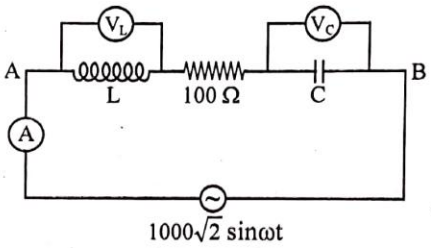
(A) 1 μF (B) 2 μF (C) 5 μF (D) 10 μF

Q.6 In the given circuit inductance $L = \frac{50}{\pi^2} \times 10^{-2}$ Henry, capacitance C = 200 μF and R = 100 Ω are attached as shown. An alternating voltage V = 5 sin 100 πt is applied across the circuit. Find current in the resistance R and voltage across inductor as a function of time t.



(A) 0 A, V = 5 sin 100πt
(B) I = 0.05 sin 100πt, V = 5 sin 100πt
(C) I = 0.05 sin 100πt, V = 0 volt
(D) None of these

Q.7 In the circuit shown, the reading of ammeter is 10 A and that of V_C = 200 V. The reading of V_L is

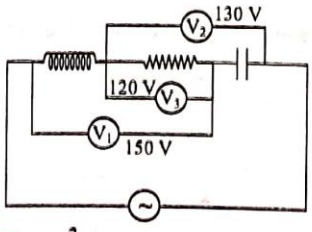


(A) 200 V
(B) $200\sqrt{2}$ V
(C) $(-1200 + 1000\sqrt{2})$ V
(D) Zero

Q.8 An AC source of frequency f is fed across a resistor R and a capacitor C in series. The current flowing in the circuit is I. If now the frequency of source is changed to $\frac{f}{3}$, without any change in magnitude of voltage, the current in the circuit in the circuit is found to halved. The ratio of reactance to resistance at the original frequency f will be

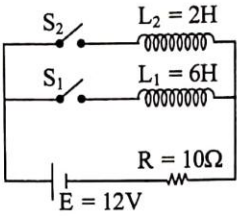
(A) $\frac{3}{\sqrt{5}}$
(B) $\frac{\sqrt{3}}{5}$
(C) $\sqrt{\frac{5}{3}}$
(D) $\sqrt{\frac{3}{5}}$

Q.9 In the circuit reading of voltmeters (rms value) V_1, V_2, V_3 are 150 V, 130 V and 120V respectively. Find the applied ac rms voltage and power factor of the circuit.



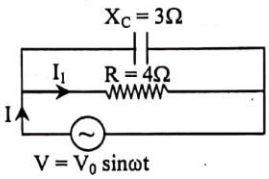
(A) $40\sqrt{10}$ V, $\frac{3}{\sqrt{10}}$
(B) $30\sqrt{7}$ V, $\frac{3}{\sqrt{8}}$
(C) $50\sqrt{10}$ V, $\frac{7}{\sqrt{10}}$
(D) $30\sqrt{10}$ V, $\frac{3}{\sqrt{7}}$

Q.10 In the circuit arrangement shown in figure, initially both the switches S_1 and S_2 are open. At t = 0. the switch S_1 is closed and at $t = t_0$, the switch S_2 is also closed when the current in L_1 has become $i_1 = 0.756A$. At $t = t_0$, the magnitude of current i_2 and rate of change of current $\frac{di_2}{dt}$ are given by ; (i_2 is the current in L_2)



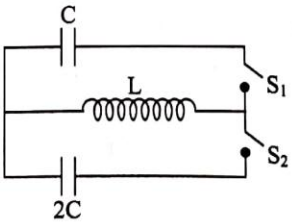
(A) zero, $3As^{-1}$ (B) 0.567A, 2.22 As^{-1} (C) 0.567 A, 3 As^{-1} (D) zero, 2.22 As^{-1}

Q.11 A capacitor and resistor are connected with an A.C. source as shown in figure. Reactance of capacitor is $X_c = 3\Omega$ and resistance of resistor is 4Ω. Phase difference between current I and I_1 is $\left[\tan^{-1}\left(\frac{3}{4}\right) = 37°\right]$



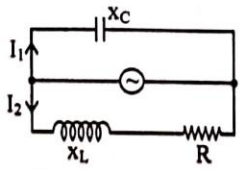
(A) 90° (B) zero (C) 53° (D) 37°

Q.12 A capacitor of capacitance C is charged to potential V_0 and is connected in circuit as shown in the figure. Switch S_1 is closed at t = 0. After time $t = \frac{\pi\sqrt{LC}}{6}$, switch S_1 is opened while switch S_2 is closed. If initially both the switches were open and capacitor of capacitance 2C was uncharged, the maximum charge stored on 2C would be



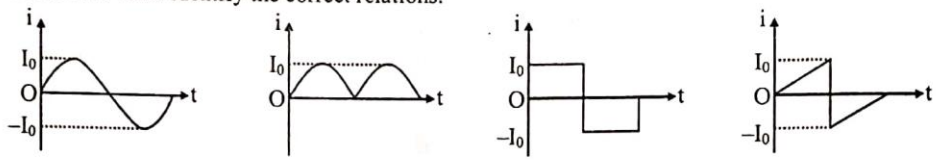
(A) $\frac{CV_0}{\sqrt{2}}$ (B) $\frac{CV_0}{2}$ (C) $\frac{CV_0}{4}$ (D) None of the above

Q.13 In the shown AC circuit phase difference between currents I_1 and I_2 is



(A) $\frac{\pi}{2} - \tan^{-1}\frac{X_L}{R}$ (B) $\tan^{-1}\frac{X_L - X_C}{R}$ (C) $\frac{\pi}{2} + \tan^{-1}\frac{X_L}{R}$ (D) $\tan^{-1}\frac{X_L - X_C}{R} + \frac{\pi}{2}$

Q.14 If I_1, I_2, I_3 and I_4 are the respective r.m.s. values of the time varying currents as shown in the four cases I, II, III and IV. Then identify the correct relations.



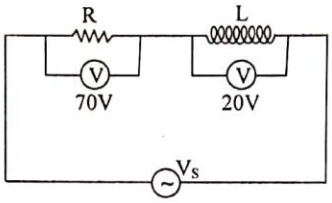
(A) $I_1 = I_2 = I_3 = I_4$ (B) $I_3 > I_1 = I_2 > I_4$ (C) $I_3 > I_4 > I_2 = I_1$ (D) $I_3 > I_2 > I_1 > I_4$

Statement Based Questions

Q.15 In the given figure.

Statement-1 : The source voltage is 72.8 V.

Statement-2 : $V_S^2 = V_R^2 + V_L^2$



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.16 **Statement-1 :** Average power output in AC circuit may be zero.

Statement-2 : $P_{av} = V_m I_m \cos\phi$. If $\cos\phi = 0$, $P_{av} = 0$.

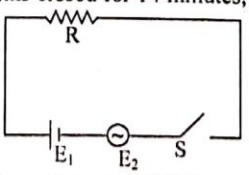
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

Q.17 A current of 4A flows in a coil when connected to 12V dc source. If the same coil is connected to a 12V, 50 rad/s source, a current of 2.4 A flows in the circuit. Then

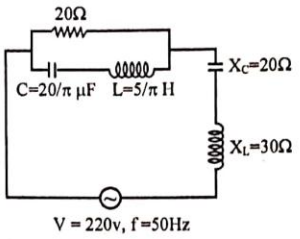
(A) $R = 4\Omega$ (B) $R = 3\Omega$ (C) $L = 4H$ (D) $L = 0.08$ H.

Q.18 In the circuit shown in the figure $R = 50\Omega$, $E_1 = 25\sqrt{3}$ volt and $E_2 = 25\sqrt{6}\ \sin(\omega t)$ volt where $\omega = 100\ \pi s^{-1}$. The switch is closed at t = 0 and remains closed for 14 minutes, then it is opened



(A) The amount of heat produced in the resistor is 63000 J.
(B) The amount of heat produced in the resistor is 7000 J.
(C) If total amount of heat produced is used to heat 3 kg of water at 20°C, the final temperature will be 25°C.
(D) The value of direct current that will produce same amount of heat in same time through same resistor will be $\sqrt{1.5}$ A.

Q.19 The circuit shown below is :



(A) purely resistive (B) purely inductive (C) purely capacitive (D) zero power factor

Q.20 A series RLC circuit is driven by a generator at frequency 1000 Hz. The inductance is 90.0 mH. Capacitance is 0.500 μF; and the phase constant has a magnitude of 60.0° (Take $\pi^2 = 10$)

(A) Here current leads the voltage in phase

(B) Here voltage leads the current in phase

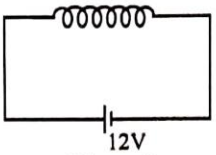
(C) Resistance of circuit is $\frac{80\pi}{\sqrt{3}}\Omega$

(D) At resonance $\omega = \frac{\sqrt{2}}{3} \times 10^4$ rad/sec.

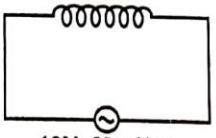
Passage Based Questions

Passage # 1 (Q.21 to 23)

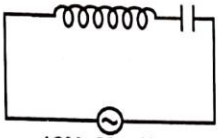
A steady current 4A flows in an inductor coil when connected to a 12V dc source as shown in figure 1. If the same coil is connected to an AC source of 12 V, 50 rad/s, a current of 2.4 A flows in the circuit as shown in figure 2. Now after these observations, a capacitor of capacitance $\frac{1}{50}$F is connected in series with the coil and with the same AC source as shown in figure 3.



(Figure 1)



(Figure 2)



(Figure 3)

Q.21 The inductance of the coil is nearly equal to

(A) 0.01 H (B) 0.02 H (C) 0.04 H (D) 0.08 H

Q.22 The resistance of the coil is :

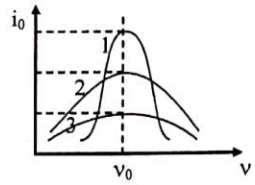
(A) 1 Ω (B) 2 Ω (C) 3 Ω (D) 4 Ω

Q.23 The average power supplied to the circuit after connecting capacitance in series is approximately equal to :

(A) 24 W (B) 72 W (C) 144 W (D) None of these

Passage # 2 (Q.24 to 26)

The figure represents variation of peak current i_0 with applied frequency ν of the AC source of three different LCR circuits having different resistances. The value of inductance L and capacitance C are same for all the three circuits.



Q.24 If R_1, R_2 and R_3 be the resistance of circuit 1, 2 and 3 respectively, then

(A) $R_1 > R_2 > R_3$ (B) $R_1 < R_2 < R_3$ (C) $R_1 > R_2 = R_3$ (D) $R_1 = R_2 = R_3$

Q.25 If $R_1 = 1\ \Omega$, $R_2 = 5\ \Omega$, $R_3 = 10\ \Omega$ and $L = \frac{900}{\pi}$ mH, $C = \frac{40}{\pi}\ \mu$F, then the value of ν_0 is

(A) 250 Hz (B) 125 Hz (C) $\frac{250}{6}$ Hz (D) $\frac{250}{3}$ Hz

Q.26 In the previous question, the frequency with which energy oscillates between Electric Field Energy and Magnetic Field Energy, is

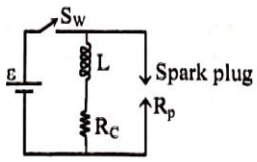
(A) $\frac{1}{4\pi\sqrt{LC}}$ (B) $\frac{1}{\pi\sqrt{LC}}$

(C) $\frac{1}{2\pi\sqrt{LC}}$ (D) the energy in the electric field does not oscillate

Passage # 3 (Q.27 & 28)

The spark plug in an automobile engine is an R-L circuit as shown in figure. The circuit that provides the spark uses an inductor as the energy source. Initially switch is closed and allows current to build through the inductor. When the switch is open the current decreases rapidly through inductor and a large emf is induced by inductor.

Given $\varepsilon = 12$ V, $L = 10$ mH, $R_c = 10\ \Omega$, $R_p = 7k\Omega$



Q.27 If switch must be closed for up to three time constants. Find this time

(A) 3 ms (B) 1.5 ms (C) 6 ms (D) 1/3 ms

Q.28 The spark occurs in the spark plug because

(A) Spark plug short circuits the inductor

(B) Spark plug short circuits the battery

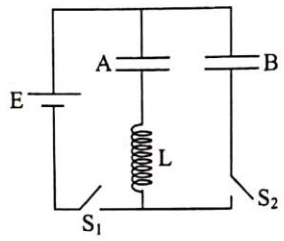
(C) Due to large induced emf generated by inductor air in the gap in spark plug gets ionized

(D) Spark produced is due to conversion of magnetic field energy of inductor to visible electromagnetic radiations.

Passage # 4 (Q.29 & 30)

Two uncharged identical capacitors A and B, each of capacitance C, and an inductor of inductance L are arranged as shown in the adjacent figure.

At t = 0, the switch S_1 is closed while switch S_2 remains open. At time $t = t_0 = \sqrt{LC}\frac{\pi}{2}$, switch S_2 is closed while switch S_1 is opened.



Q.29 The current flowing through the inductor at $t = t_0$ is

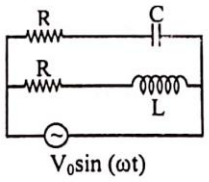
(A) $2CE\frac{1}{\sqrt{LC}}$ (B) 0 (C) $\frac{CE}{2} \times \frac{1}{\sqrt{LC}}$ (D) $CE \times \frac{1}{\sqrt{LC}}$

Q.30 After switch S_2 is closed and S_1 is opened, the maximum value of current through the inductor is

(A) $\left(\sqrt{\frac{C}{L}}\right)E$ (B) $\left(\sqrt{\frac{C}{2L}}\right)E$ (C) $\left(\sqrt{\frac{3}{2}\frac{C}{L}}\right)E$ (D) $\left(\sqrt{\frac{5}{4}\frac{C}{L}}\right)E$

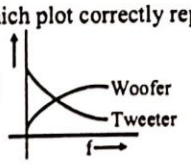
Passage # 5 (Q.31 to 33)

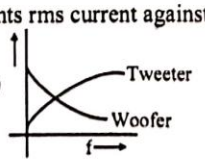
A loudspeaker system uses alternating current to amplify sound of certain frequencies consists of 2 speakers.

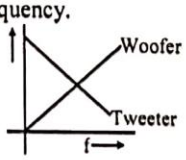


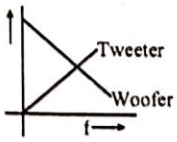
Tweeter-which has smaller diameter produces high frequency sounds. Woofer-which has larger diameter produces low frequency sound. For purpose of circuit analysis, we can take both speakers to be of equal resistance R. The equivalent circuit is shown in the figure. The 2 speakers are connected to the amplifier via capacitance and inductance respectively. The capacitor in tweeter branch blocks the low frequency sound but passes the high frequency. The inductor in woofer branch does the opposite.

Q.31 Which plot correctly represents rms current against frequency.

(A) 

(B) 

(C) 

(D) 

Q.32 What is the frequency which is sounded equally loudly by both speakers

(A) $\frac{1}{2\pi}\sqrt{\frac{R^2}{L^2} - \frac{1}{LC}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{4R^2}{L^2} - \frac{1}{LC}}$ (C) $\frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$ (D) $\frac{1}{2\pi\sqrt{LC}}$

Q.33 For a combination of L, R & C the current in woofer & tweeter are always found to have a phase difference of $\pi/2$. What is the relation between L, R & C.

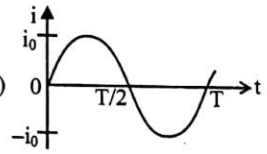
(A) $L = 2R^2C$ (B) $L = \sqrt{2}R^2C$ (C) $L = R^2C$ (D) $L = \frac{R^2C}{\sqrt{2}}$

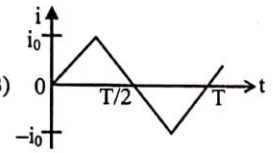
Column Matching Type Questions

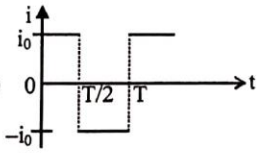
Q.34 Match the column :

In column I, variation of current I with t is given in figures. In column II root mean square current i_{rms}, and average current. Match the column I with corresponding quantities given in Column II

Column -I

(A)


(B)


(C)


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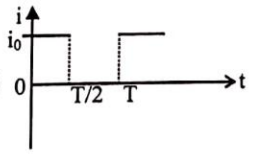


Column-II

(P) $i_{rms} = \frac{i_0}{\sqrt{3}}$

(Q) Average current for positive half cycle is i_0

(R) Average current for position half cycle is $\frac{i_0}{2}$

(S) Full cycle average current is zero

(T) Frequency of current is 1/T

Q.35 Match the Following :

Column-I	Column-II
(A) LCR circuits	(P) Resonant curve will be flattened
(B) Inductor	(Q) Sharpness indicates sensitivity
(C) More of friction or dampness	(R) Have resonant frequency $\omega = \frac{1}{\sqrt{LC}}$ with $A \to A_{max}$
(D) Radio Tuner's characteristic curve	(S) Mass

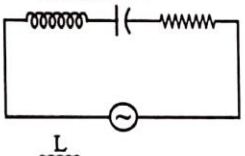
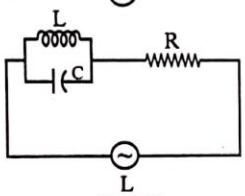
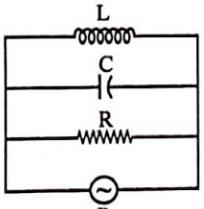
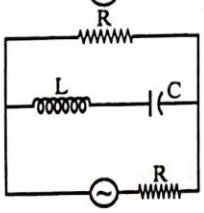
Q.36 Match the Following :

Column-I	Column-II
(A) For square wave having peak value v_0	(P) $v_0 > v_{rms} > v_{av}$
(B) For sinusoidal wave having peak value v_0	(Q) In a pure inductance.
(C) Current leads the voltage by $\pi/2$	(R) $v_{av} = v_{rms} = v_0$
(D) Wattless current	(S) In a pure capacitance

Q.37 Match the following :

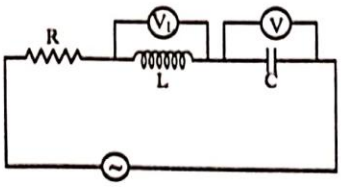
Column-I	Column-II
(A) In L–R series circuit if switch is closed at t = 0 (u sin of DC source)	(P) Current at t = 0 is non–zero
(B) In L–C series combination switch is closed at t = 0 (if initially the capacitor is fully charged)	(Q) Nothing can be said about the current
(C) If voltage $V=V_0 \sin \omega t$ is applied to pure inductor at t = 0	(R) Current in the circuit is zero at t = 0
(D) If voltage $V = V_0 \sin \omega t$ is applied at t = 0 to L–C–R series circuit	(S) Magnetic field energy in inductor is zero at t = 0

Q.38 Let X_L, X_C be the inductive reactance and capacitive reactance and R be the resistance in each of the circuits given in Column-I. Let V_L, V_C and V_R be the r.m.s. voltage drop in each case and i be the r.m.s. current from mains. The supply voltage is 10 V. $X_L = 10\ \Omega$ and $R = 10\ \Omega$.

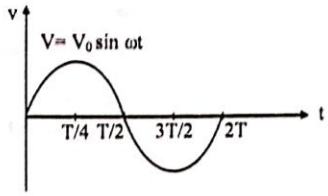
	Column – I		Column – II
(A)		(P)	i = 1 A
(B)		(Q)	i = 0
(C)		(R)	$V_L = 10$ V
(D)		(S)	$V_C = 10$ V

Numeric Response Type Questions

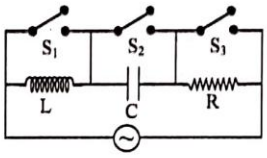
Q.39 In the circuit shown, Resistance R = 100 Ω, inductance $L = \frac{2}{\pi}$ H and capacitance $C = \frac{8}{\pi}$ μF are connected in series with an AC source of 200V and unknown frequency if the reading of each hot wire voltmeters are $\frac{2}{n} \times 10^3$ Volt then find value of n.



Q.40 In an L-R series circuit, a sinusoidal voltage $V = V_0 \sin \omega t$ is applied. It is given that $L = 35$ mH, $R = 11\Omega$, $V_{rms} = 220$ V, $\omega/2\pi = 50$ Hz and $\pi = 22/7$. The amplitude of current in the steady state is 5n A. Find n.

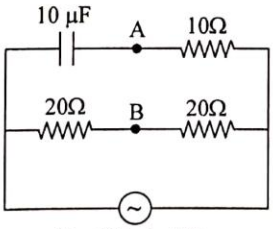


Q.41 Consider the circuit shown in figure. With switch S_1 closed and the other two switches open, the circuit has time constant 0.05 sec. With the switch S_2 closed and the other two switches open, the circuit has time constant 2 sec. With switch S_3 closed and the other two switches open, the circuit oscillates with a period T. Find T (in sec). (Take $\pi^2 = 10$)



Q.42 In a series LCR circuit with a source $E_0 = 50$ V, $R = 300\ \Omega$, frequency $\nu = \frac{50}{\pi}$ Hz. The average electric field energy stored in the capacitor and average magnetic field energy stored in the coil are 25 mJ and 5 mJ respectively. RMS current in the circuit is 0.10 A. If the sum of rms potential differences across the three elements in volts is $(10 \times n)$. Then find value of n .

Q.43 In the given circuit the maximum potential difference between the points A and B is V_1 volt. If the $10\ \Omega$ resistance is replaced by $40\ \Omega$ resistance, the maximum potential difference between points A and B is V_2 volt. Find V_2/V_1.



V = 100 sin 300 t

ANSWER KEY

Single Correct Option type Questions

1. (C) **2.** (C) **3.** (D) **4.** (C) **5.** (C) **6.** (A) **7.** (C)

8. (D) **9.** (A) **10.** (D) **11.** (C) **12.** (A) **13.** (C) **14.** (B)

Statement Based Questions

15. (C) **16.** (A)

Multiple Correct Option type Questions

17. (B,D) **18.** (A,C,D) **19.** (B,D) **20.** (B,C,D)

Passage Based Questions

21. (D) **22.** (C) **23.** (A) **24.** (B) **25.** (D) **26.** (B) **27.** (A)

28. (C) **29.** (D) **30.** (C) **31.** (B) **32.** (D) **33.** (C)

Column Matching Type Questions

34. $A \rightarrow S,T$; $B \rightarrow P,R,S,T$; $C \rightarrow Q,S,T$; $D \rightarrow Q,T$

35. $A \rightarrow Q,R$; $B \rightarrow S$; $C \rightarrow P$; $(D) \rightarrow Q$

36. $A \rightarrow R$; $B \rightarrow P$; $C \rightarrow S$; $D \rightarrow Q,S$

37. $A \rightarrow R$; $B \rightarrow P$; $C \rightarrow S$; $D \rightarrow Q$

38. $A \rightarrow P,R,S$; $B \rightarrow Q,R,S$; $C \rightarrow P,R,S$; $D \rightarrow P,R,S$

Numeric Response Type Questions

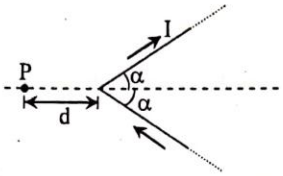
39. 2 **40.** 4 **41.** 2 **42.** 9 **43.** 1

Chapter 25

Magnetic Effect of Current

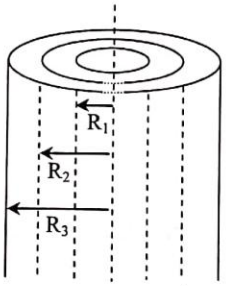
Single Correct Option Type Questions

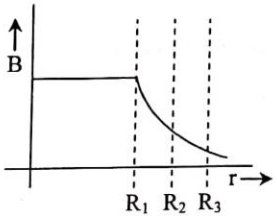
Q.1 If the magnetic field at 'P' can be written as K tan $\left(\frac{\alpha}{2}\right)$, then K is -



(A) $\frac{\mu_0 I}{4\pi d}$ (B) $\frac{\mu_0 I}{2\pi d}$ (C) $\frac{\mu_0 I}{\pi d}$ (D) $\frac{2\mu_0 I}{\pi d}$

Q.2 A coaxial cable is made up of two conductors. The inner conductor is solid and is of radius R_1 and the outer conductor is hollow of inner radius R_2 and outer radius R_3. The space between the conductors is filled with air. The inner and outer conductors are carrying currents of equal magnitudes and in opposite directions. Then the variation of magnetic field with distance from the axis is best plotted as -



(A)


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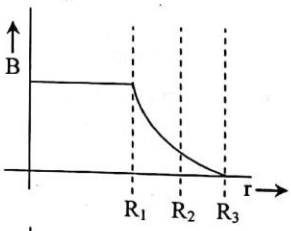

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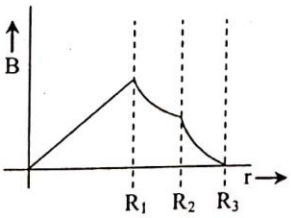
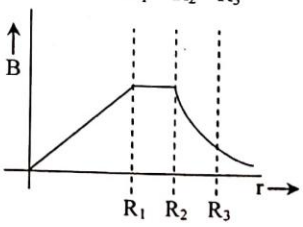
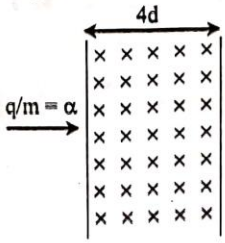


(D)


Q.3 If a charged particle of charge to mass ratio $\frac{q}{m} = \alpha$ is entering in a magnetic field of strength B at a speed ' $v' = (2\alpha d)$ (B), then which of the following is correct -



(A) angle subtended by charged particle at the centre of circular path is 2π
(B) the charge will move on a circular path and will come out from magnetic field at a distance 4d from the point of insertion
(C) the time for which particle will be in the magnetic field is $\frac{2\pi}{\alpha B}$
(D) the charged particle will subtend an angle of 90° at the centre of circular path

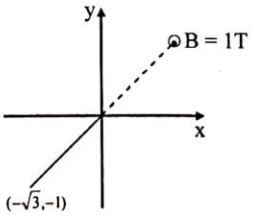
Q.4 A particle of positive charge q and mass m enters with velocity $v\hat{j}$ at the origin in a magnetic field $B(-\hat{k})$ which is present in the whole space. The charge makes a perfectly inelastic collision with identical particle at rest but free to move at its maximum y-coordinate. After collision the combined charge will move on trajectory - (where r = mv/qB)

(A) $y = \frac{mv}{qB}(-\hat{i})$
(B) $(x + r)^2 + (y - r/2)^2 = r^2/4$
(C) $(x - r)^2 + (y - r)^2 = r^2$
(D) $(x - r)^2 + (y + r/2)^2 = r^2/4$

Q.5 There exists a uniform magnetic and electric field of magnitude 1T and 1 V/m respectively along positive y-axis. A charged particle of mass 1 kg and of charge 1 C is having velocity 1 m/sec along x-axis and is at origin at t = 0. Then the coordinates of particle at time π seconds will be -

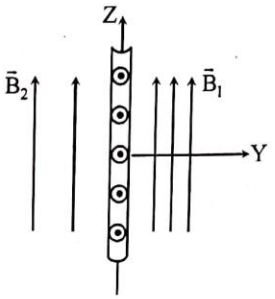
(A) (0, 1, 2)
(B) $(0, -\pi^2/2, -2)$
(C) $(2, \pi^2/2, 2)$
(D) $(0, \pi^2/2, 2)$

Q.6 A uniform magnetic field of magnitude 1T exists in region $y \geq 0$, is along $\hat{k}$ direction as shown. A particle of charge 1C is projected from point $(-\sqrt{3}, -1)$ towards origin with speed 1 m/sec. If mass of particle is 1 kg. then coordinates of centre of circle in which particle moves are -



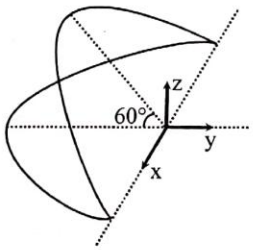
(A) $(1, \sqrt{3})$
(B) $(1, -\sqrt{3})$
(C) $\left(\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$
(D) $\left(\frac{\sqrt{3}}{2}, -\frac{1}{2}\right)$

Q.7 Figure shows a thin metal sheet in the plane y = 0, for which the current of constant density flows in the positive x-direction. It is in a constant homogenous magnetic field of value = (0, 0, B_0). As a result of superposition of magnetic fields in region y > 0, the induction field $B_1 = (0, 0, B)$ and in y < 0 is $B_2 = (0, 0, B_2)$ where $B_1 > B_2$. Specify the correct statement :



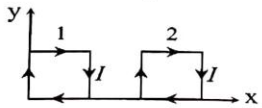
(A) $B_0 = \frac{(B_1 - B_2)}{2}$ (B) $B_0 = \frac{(B_1 + B_2)}{2}$ (C) $B_0 = B_1 + B_2$ (D) $B_0 = B_1 - B_2$

Q.8 A circular loop of wire of radius a is bend about its diameter such that the angle between the plane of two halves, become 60°. The resistance per unit length of the wire is r_0. The magnetic field is varying as $B = B_0t$ along the (+) Z axis. Find the total charge flown through the loop in first t seconds.



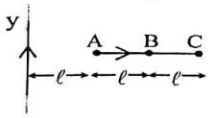
(A) $\frac{Bat}{2r_0}$ (B) $\frac{Bat}{4r_0}$ (C) $\frac{Bat}{r_0}$ (D) $\frac{2Bat}{r_0}$

Q.9 Magnetic field in a region is given by $\vec{B} = B_0x\hat{k}$. Two loops each of side a is placed in this magnetic region in the x-y plane with one of its sides on x-axis. If F_1 is the force on loop 1 and F_2 be the force on loop 2, then



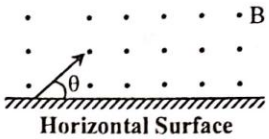
(A) $F_1 = F_2 = 0$ (B) $F_1 > F_2$ (C) $F_2 > F_1$ (D) $F_1 = F_2 \neq 0$

Q.10 A current carrying rod AB is placed perpendicular to an infinitely long current carrying wire as shown in figure. The point at which the conductor should be hinged so that it will not rotate (AB = BC)



(A) A
(B) somewhere between B and C
(C) C
(D) somewhere between A and B

Q.11 A particle of mass *m* and charge – q is projected at angle $\theta = \frac{1}{20}$ radius with a horizontal smooth surface. Magnetic field in the region is uniform and transverse, of strength B. Time after which vertical velocity of the particle ceases to exist, if the coefficient of restitution for each collision the particle makes with the horizontal surface is 0.5, is (neglect gravity)



(A) $\frac{m}{5qB}$ (B) $\frac{m}{qB}$ (C) $\frac{m}{20qB}$ (D) Infinite

Q.12 A particle of specific charge (charge/mass) α start moving from origin under action of an electric field $\bar{E} = E_0\hat{i}$ and magnetic field $\bar{B} = B_0\hat{k}$. Its velocity at $(x_0, y_0, 0)$ is $4\hat{i} + 3\hat{j}$. The value of x_0 is

(A) $\frac{13\alpha E_0}{2B_0}$ (B) $\frac{16\alpha B_0}{E_0}$ (C) $\frac{25}{2\alpha E_0}$ (D) $\frac{5\alpha}{2B_0}$

Q.13 A conducting loop is placed in a magnetic field of strength B perpendicular to its plane. Radius of the loop is r, current in the loop is i and linear mass density of the wire of loop is m. Speed of any transverse wave in the loop will be

(A) $\sqrt{\frac{Bir}{m}}$ (B) $\sqrt{\frac{Bir}{2m}}$ (C) $\sqrt{\frac{2Bir}{m}}$ (D) $2\sqrt{\frac{Bir}{m}}$

Q.14 A particle of charge q and mass m starts moving from origin under action of a magnetic field $\bar{B} = B_0\hat{j}$ and electric field $\bar{E} = E_0\hat{j}$ with a velocity $\bar{v} = v_0\hat{i}$. Work done by the lorentz force till particle crosses y – z plane normally for the first time, does not depend on

(A) m (B) q (C) B (D) E

Q.15 A uniform magnetic field of 1.5 T exists in a cylindrical region of radius 10.0 cm, it's direction being parallel to the axis along east to west. A current carrying wire in north south direction passes through this region. The wire intersects the axis and experience a force of 1.2 N downward. If the wire is turned from North South to north east-south west direction, then magnitude and direction of force is :

(A) 1.2 N, upward (B) $1.2\sqrt{2}$ downward (C) 1.2 N, downward (D) $\frac{1.2}{\sqrt{2}}$ N, downward

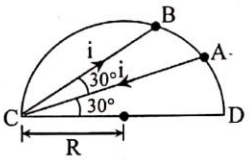
Q.16 A uniform magnetic field exists in region which forms an equilateral triangle of side a. The magnetic field is perpendicular to the plane of the triangle. A charge q enters into this magnetic field perpendicularly with speed v along perpendicular bisector of one side and comes out along perpendicular bisector of other side. The magnetic induction in the triangle is -

(A) $\frac{mv}{qa}$ (B) $\frac{2mv}{qa}$ (C) $\frac{mv}{2qa}$ (D) $\frac{mv}{4qa}$

Q.17 Two electrons each speed v move along same direction in an horizontal plane. At certain instant of time, if two electrons at a distance d apart, are repelled by an electrostatic force $\vec{F}_E$. then the magnetic force between them is of magnitude

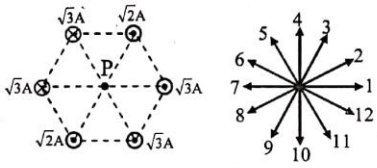
(A) $\frac{v}{c}F_E$, repulsive (B) $\frac{v^2}{c^2}F_E$, attractive (C) $\frac{v^2}{c^2}F_E$, repulsive (D) $\frac{v}{c}F_E$, attractive

Q.18 A Current carrying wire is placed in the grooves of an insulating semicircular disc of radius 'R' as shown. The current enters at point A and leaves point B. Determine the magnetic field at point D.



(A) $\frac{\mu_0 i}{8\pi R\sqrt{3}}$ (B) $\frac{\mu_0 i}{4\pi R\sqrt{3}}$ (C) $\frac{\sqrt{3}\mu_0 i}{4\pi R}$ (D) None of these

Q.19 Consider a set of six infinite long straight parallel wires arranged perpendicular to the plane of paper in a hexagon as shown. The length of the each side of the hexagon is 3cm. What is the magnitude and direction of the magnetic field at point P ? (Twelve direction at consecutive equal angles have been shown, give your answer in forms of their respective numbers)

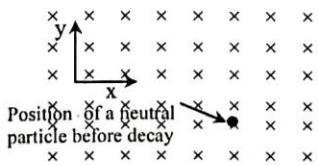


(A) 70 μT along 12 (B) 40 μT along 6 (C) 40 μT along 9 (D) 60 μT along 9

Q.20 A neutral particle is initially at rest in a uniform magnetic field B as shown in the diagram. The particle then spontaneously decays into two fragments. One with a positive charge + q and mass 3m and the other with a negative charge – q and mass m. Neglecting the interaction between the two charged particles and assuming that the speeds are much less than speed of light, the time after the decay at which the two fragments first meet is

[Data : $q = 1\mu C$, $B = 2\pi\ \mu T$, $m = 10^{-15}$ kg

Both the charge have initial velocities in x-y plane]



(A) 250 μS (B) 500 μS (C) 750 μS (D) 1000 μS

Q.21 An electron moving with a velocity $\vec{V}_1 = 2\hat{i}$ m/s at a point in a magnetic field experience a force $\vec{F}_1 = -2\hat{j}$N. If the electron is moving with a velocity $\vec{V}_2 = 2\hat{j}$ m/s at the same point, it experiences a force $\vec{F}_2 = +2\hat{i}$ N. The force the electron would experience if it were moving with a velocity $\vec{V}_3 = 2\hat{k}$ m/s at the same point is

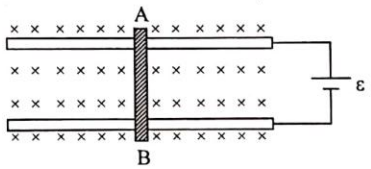
(A) zero (B) $2\hat{k}$N

(C) $-2\hat{k}$N (D) information is insufficient

Q.22 A long solenoid with 10 turns/cm and a radius of 7 cm carries a current of $\frac{20}{\pi}$ mA. A charge of 10 μC move along central axis of solenoid. What is magnetic force on charge ?

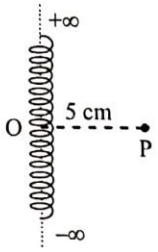
(A) 8π N (B) 11.3 N (C) 11.3×10^{-3} N (D) None of these

Q.23 Consider the shown arrangement where two long conducting smooth rails are connected by an emf source of emf ε volts. There exists a uniform magnetic field B directed normal to the plane of rails. A conducting rod AB of resistance R is then gently placed on the rails at t = 0. Ignore the resistance of rails and the internal resistance of the emf source. Obtain velocity of the rod as function of time.



(A) $v = \frac{\varepsilon}{B\ell}$ (B) $v = \frac{\varepsilon}{B\ell}\left(1 - e^{\frac{\ell^2 B^2 t}{mR}}\right)$ (C) $v = \frac{\varepsilon}{2B\ell}$ (D) $v = \frac{\varepsilon}{B\ell}\left(1 + e^{\frac{\ell^2 B^2 t}{mR}}\right)$

Q.24 The density of turns of a very long solenoid of diameter 1 cm is 2000 m^{-1}. The strength of the magnetic field produced by the coil at a distance of 5 cm from the axis of the solenoid is 4×10^{-4} T. Determine the strength of the magnetic field inside the solenoid -

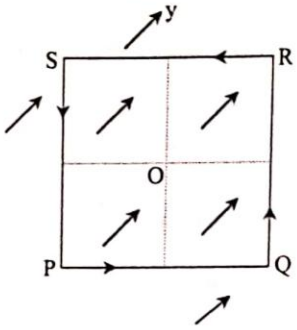


(A) 0.125 T (B) 0.251 T (C) 0.502 T (D) 0.351 T

Q.25 Two long parallel straight conductors carry currents i_1 and i_2 ($i_1 > i_2$). When the current are in the same direction, the magnetic field at a point midway between the wires is 20 μT. If the direction of i_2 is reversed, the field becomes 50 μT, the ratio of the currents i_1 / i_2 is

(A) 5/2 (B) 7/3 (C) 4/3 (D) 5/.

Q.26 A uniform constant magnetic field $\vec{B}$ is directed at an angle of 45° to the axis in the xy – plane. PQRS is a rigid, square wire frame carrying a steady current I_0, with its centre at the origin O. At time t = 0, the frame is at rest in the position as shown in figure, with its sides parallel to the x and y axes. Each side of the frame is of mass M and length L. The torque τ about O acting on the frame due to the magnetic field will be ?

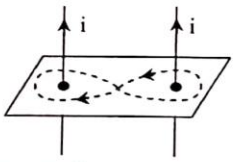


(A) $\frac{BI_0L^2}{\sqrt{2}}[+\hat{j}-\hat{i}]$ (B) $\frac{BI_0L^2}{\sqrt{2}}[-\hat{j}+\hat{i}]$ (C) $BI_0L^2[+\hat{j}-\hat{i}]$ (D) $BI_0L^2[-\hat{j}+\hat{i}]$

Statement Based Questions

Q.27 **Statement-1 :** Figure shows two identical currents i and a close path encircling them. For the close path $\oint \vec{B}\cdot d\vec{\ell} = 2i$.

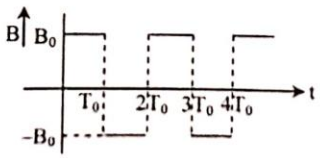
Statement-2 : For the close path $\oint \vec{B}\cdot d\vec{\ell} = 0$



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

Q.28 In a region magnetic field along x axis changes with time according to the given graph.



If time period, pitch and radius of helix path are T_0, P_0 and R respectively then which of the following is correct, if the particle is projected from origin at an angle θ_0 with the positive x-axis in x-y plane -

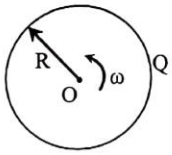
(A) At $t = \frac{T_0}{2}$, coordinates of charge are $\left(\frac{P_0}{2}, 0, -2R_0\right)$

(B) At $t = \frac{3T_0}{2}$, coordinates of charge are $\left(\frac{3P_0}{2}, 0, 2R_0\right)$

(C) Two extremes normal to x-axis are at a distance $2R_0$ from each other

(D) Two extremes normal to x-axis are at a distance $4R_0$ from each other

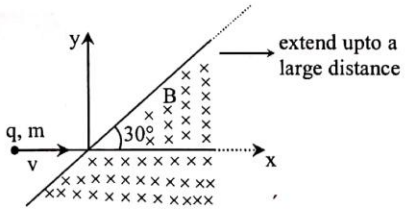
Q.29 A nonconducting disc having uniform positive charge Q, is rotating about its axis with uniform angular velocity ω. The magnetic field at the centre of the disc is -



(A) directed outward (B) having magnitude $\frac{\mu_0 Q\omega}{4\pi R}$

(C) directed inwards (D) having magnitude $\frac{\mu_0 Q\omega}{2\pi R}$

Q.30 A charge particle of charge q, mass m is moving with initial velocity 'v' as shown in figure in a uniform magnetic field $-B\hat{k}$. Select the correct alternative/alternatives -



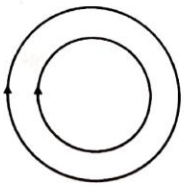
(A) Velocity of particle when it comes out from magnetic field is $\vec{v} = v\cos 30°\,\hat{i} - v\sin 30°\,\hat{j}$

(B) Time for which the particle was in magnetic field is $\frac{\pi m}{3qB}$

(C) Distance travelled in magnetic field is $\frac{\pi mV}{3qB}$

(D) The particle will never come out of magnetic field

Q.31 Two concentric, coplanar, circular loop of wire, different diameter carry current in the same sense as shown in the figure. Which of the following statement(s) is (are) correct?



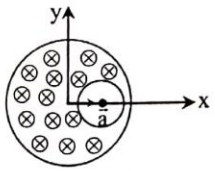
(A) the magnetic force exerted by the outer loop on a short portion of the inner loop is radially outward

(B) the magnetic force exerted by the outer loop on a short portion of the inner loop is radially inward

(C) the net magnetic force exerted by the outer loop on a whole inner loop is non zero and is radially outward

(D) the net magnetic force exerted by the outer loop on a whole inner loop is zero

Q.32 Figure shows cross section view of infinite cylindrical wire with a cavity, current density is uniform $j = -j_0\hat{k}$ as shown in figure.



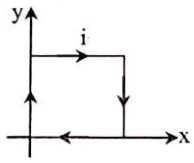
(A) magnetic field inside cavity is uniform

(B) magnetic field inside cavity is along $\vec{a}$

(C) magnetic field inside cavity is perpendicular to $\vec{a}$

(D) If an electron is projected with velocity $v_0\,\hat{j}$ inside the cavity it will move undeviated

Q.33 Figure shows square current carrying coil of edge length L. The magnetic field on the coil is given by $\vec{B} = \frac{B_0 y}{L}\hat{i} + \frac{B_0 x}{L}\hat{j}$ where B_0 is a positive constant.



(A) If coil is free to rotate about x axis torque on the coil is given by $\frac{1}{2}iAB_0\hat{i}$.

(B) If coil is free to rotate about y-axis torque on coil is given by $-\frac{1}{2}iAB_0\hat{j}$.

(C) Resultant force on coil is zero.

(D) Equation for the torque $\vec{\mu} \times \vec{B}$ where μ is magnetic moment of coil, is not valid here.

Q.34 The current density in a wire of radius a varies with radial distance r as $J = kr^2$, where k is a constant.

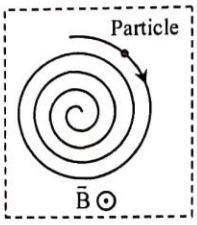
(A) Total current passing through the cross section of the wire is $I = \frac{\pi k a^4}{2}$

(B) Total current passing through the cross section of wire is $I = \frac{3\pi k a^3}{2}$

(C) The field at a distance r (> a) is $B = \frac{\mu_0 k a^4}{4r}$

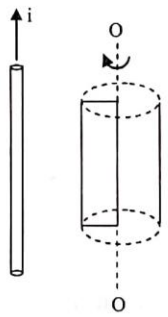
(D) The field at a distance r (< a) is $B = \frac{\mu_0 k r^3}{4}$

Q.35 A uniform magnetic field is directed out of the page perpendicularly. A charged particle, moving in the plane of the page, follows a clockwise sprial of decreasing radius as shown. a reasonable explanation is



(A) The charge is positive ansd showing down.
(B) The charge is negative and slowing down.
(C) The charge is positive and speeding up
(D) The charge is negative and speeding up

Q.36 A rectangular wire frame rotates with a constant angular velocity around one of its sides parallel to a current carrying & rectilinear conductor nearly as shown in diagram –

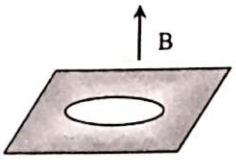


(A) When rectangular wire frame is in the plane passing through rectilinear conductor flux linked through rectangular wire frame is minimum
(B) When rectangular wire frame is in the plane passing through rectilinear conductor emf induced in rectangular wire frame is minimum
(C) When rectangular wire frame is in plane perpendicular to the plane passing through conductor then, emf is maximum
(D) When rectangular wire frame is in plane perpendicular to the plane passing through conductor then, flux is minimum

Q.37 A charged particle P leaves the origin with speed $v = v_0$, at some inclination with the x-axis. There is a uniform magnetic field B along the x-axis. P strikes a fixed target T on the x-axis for a minimum value of $B = B_0$. P will also strike T if
(A) $B = 2B_0$, $v = 2v_0$ (B) $B = 2B_0$, $v = v_0$ (C) $B = B_0$, $v = 2v_0$ (D) $B = B_0/2$, $v = 2v_0$

Q.38 When a current-carrying coil is placed in a uniform magnetic field with its magnetic moment anti-parallel to the field.
(A) Torque on it is maximum
(B) Torque on it is zero
(C) Potential energy is maximum
(D) Dipole is in unstable equilibrium.

Q.39 The electric charge Q (positive) is uniformly distributed on a thin dielectric ring of mass m. The ring lays on a frictionless table as shown in the figure. The magnetic field is perpendicular to the plane of ring varies from 0 to some value of B_0. Choose the correct statement -



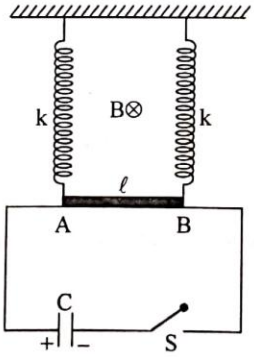
(A) The angular velocity of ring will be $\frac{QB_0}{2m}$, clockwise as viewed from above

(B) The angular velocity of ring will be $\frac{QB_0}{2m}$, anticlockwise as viewed from above

(C) The angular velocity of ring will be $\frac{QB_0}{4m}$, clockwise as viewed from above

(D) The angular velocity of ring will be $\frac{QB_0}{4m}$, anticlockwise as viewed from above

Q.40 A straight conducting bar AB of mass m and length ℓ is suspended horizontal by two non-conducting springs of spring constant k as shown in the figure. The bar is located in a region of uniform magnetic field of intensity B. The capacitor C is initially charged to the potential V. Springs are in equilibrium position with zero potential energy. At time t = 0, the switch S is closed and capacitor discharge. The bar starts oscillating in the vertical plane. (Assume that the time of discharge of the capacitor is much smaller than the time period of mechanical oscillation of the bar. Neglect the effect of gravity). Choose the correct statement(s) -



(A) The maximum speed of bar during oscillation is $\frac{B\ell CV}{3m}$

(B) The maximum speed of bar during oscillation is $\frac{B\ell CV}{m}$

(C) The amplitude of mechanical oscillation of bar is $\sqrt{\frac{B^2\ell^2C^2V^2}{2mk}}$

(D) The amplitude of mechanical oscillation of bar is $\sqrt{\frac{B^2\ell^2C^2V^2}{mk}}$

Q.41 A proton is fired form origin with velocity $\vec{v} = v_0\hat{j} + v_0\hat{k}$ in a uniform magnetic field $\vec{B} = B_0\hat{j}$. In the subsequent motion of the proton

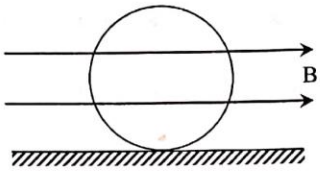
(A) its z coordinate can never be negative

(B) its x coordinate can never be positive

(C) its x and z coordinates cannot be zero at the same time

(D) its y coordinate will be proportional to its time of flight

Q.42 A conducting ring of mass 2 kg and radius 0.5 m is placed on a smooth horizontal plane . The ring carries a current of I = 4A. A horizontal magnetic field B = 10 T, coplanar with ring exist in the region. If the ring is released from rest then –



(A) angular acceleration of the ring is 40 πrad s^{-2}

(B) torque on the ring is 20 πNm

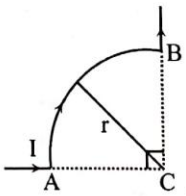
(C) angular acceleration of the ring is 20 πrad s^{-2}

(D) torque on the ring is 10 πNm

Q.43 Electric charge +q is uniformly distributed over the entire length of a ring of radius r rotating with constant angular velocity ω about its own axis. Assuming mass of ring to be m, its magnetic moment to be M and angular momentum to be L.

(A) $M = \frac{q\omega r^2}{2}$ (B) $M = \frac{2q\omega r^2}{5}$ (C) $\frac{M}{L} = \frac{q}{2m}$ (D) $\frac{M}{L} = \frac{2q}{m}$

Q.44 A wire carrying current I is shaped as shown. Section AB is a quarter circle of radius r. The magnetic field at C is directed



(A) along the bisector of the angle ACB, away from AB

(B) along the bisector of the angle ACB, towards AB

(C) perpendicular to the, plane of the paper, directed into the paper

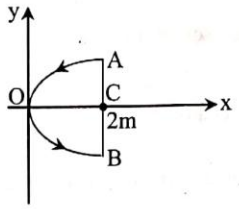
(D) at an angle $\pi/4$ to the plane of the paper

Passage Based Questions

Passage # 1 (Q.45 & 46)

A conducting wire is bend into a loop as shown in the figure. The segments AOB is parabolic given by the equation $y^2 = 2x$ while segment BA is a straight line parallel to the y-axis.

The magnetic field in the region is $\vec{B} = -8\hat{k}$ and the current in the wire is 2A.



Q.45 The torque on the loop will be -

(A) $16\sqrt{2}$ Nm (B) 16 Nm (C) $18\sqrt{2}$ Nm (D) Zero

Q.46 If the loop were rotated about the z-axis with an angular velocity of 1 rad/sec Then magnitude of emf induced across the straight segment AC will be -

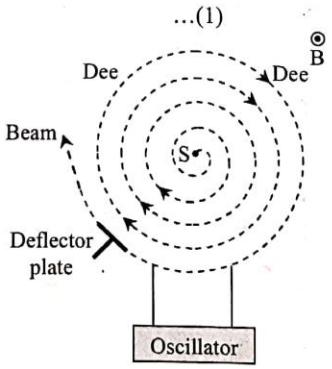
(A) 32 V (B) 8 V (C) 16 V (D) 4 V

Passage # 2 (Q. 47 to 49)

In the given figure of a cyclotron, showing the particle source S and the dees. A uniform magnetic field is directed up from the plane of the page. Circulating protons spiral outward within the hollow dees, gaining energy every time they cross the gap between the dees.

Suppose that a proton, injected by source S at the centre of the cyclotron in Fig., initially moves towards a negatively charged dee. It will accelerate toward this dee and enter it. Once inside, it is shielded from electric field by the copper walls of the dee; that is the electric field does not enter the dee. The magnetic field, however, is not screened by the (non magnetic) copper dee, so the proton moves in circular path whose radius, which depends on its speed, is given by

Eq ($r = mv/qB$) ...(1)



Let us assure that at the instant the proton emerges into the centre gap from the first dee, the potential difference between the dees is reversed. Thus, the proton again faces a negatively charged dee and is again accelerated. This process continues, the circulating proton always being in step, with the oscillations of the dee potential, until the proton has spiraled out to the edge of the dee system. There is deflector plate sends it out through a portal. The key to the operation of the cyclotron is that the frequency f at which the proton circulates in the field (and that does not depend on its speed) must be equal to the fixed frequency f_{osc} of the electrical oscillator, or

$f = f_{osc}$(resonance condition). ...(2)

This resonance condition says that, if the energy of the circulating proton is to increase, energy must be fed to it as a frequency f_{osc} that is equal to the natural frequency f at which the proton circulates in the magnetic field.

Combining Eq.1 and 2 allows us to write the resonance condition as

$qB = 2\pi m f_{osc}$ ...(3)

For the proton, q and m are fixed. The oscillator (we assume) is designed to work at a single fixed frequency f_{osc}. We then "tune" the cyclotron by varying B until eq. 3 is satisfied and then many protons circulate through the magnetic field, to emerge as a beam.

Q.47 Ratio of radius of successive semi circular path after every time period is-

(A) $\sqrt{1} : \sqrt{2} : \sqrt{3} : \sqrt{4}$ ..... (B) $\sqrt{1} : \sqrt{3} : \sqrt{5}$ .....

(C) $\sqrt{2} : \sqrt{4} : \sqrt{6}$ ..... (D) 1 : 2 : 3.....

Q.48 Change in kinetic energy of charge particle after every time period is:

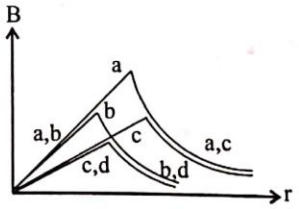
(A) 2qV (B) qV (C) 3qV (D) None of these

Q.49 If q/m for a charge particle is 10^6, frequency of applied AC is 10^6 Hz. Then applied magnetic field is:

(A) 2π tesla (B) π tesla (C) 2 tesla (D) cannot be defined

Passage # 3 (Q.50 & 51)

Curves in the graph shown give, as function of radial distance r (from the axis), the magnitude B of the magnetic field (due to individual wire) inside and outside four long wires a, b, c and d, carrying currents that are uniformly distributed across the cross section of the wires. Overlapping portions of the plots are indicated by double labels. All curves start from the origin.



Q.50 Which wire has the greatest radius ?

(A) a (B) b (C) c (D) d

Q.51 The current density in wire *a* is

(A) greater than in wire c

(B) less than in wire c

(C) equal to that in wire c

(D) not comparable to that of in wire c due to lack of information

Passage # 4 (Q.52 & 53)

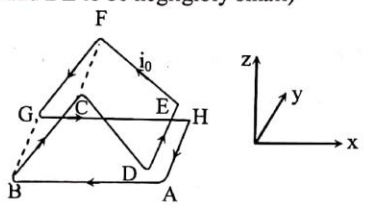
A charge Q of mass 2×10^{-15} kg is projected with velocity $\vec{v} = (5\,\hat{i} - 5\,\hat{j} + 3\,\hat{k}) \times 10^6\ ms^{-1}$ into uniform magnetic field $\vec{B} = -0.4\,\hat{k}$ T. The force on the charged particle at an instant is found to be 1.414 N in magnitude.

Q.52 The charge of the particle then must be -
(A) 0.5 μC (B) 1.0 μC (C) 1.5 μC (D) 2.0 μC

Q.53 Angular frequency ω of rotation of the particle is (in $rad.s^{-1}$)
(A) 1.0×10^8 for circular motion in (x-z) plane (B) 1.5×10^8 for circular motion in (x-y) plane
(C) 1.0×10^8 for circular motion in (x-y) plane (D) 1.5×10^8 for circular motion in (x-z) plane

Passage # 5 (Q.54 & 55)

A coil (ABCDEFGH) is in the form of prism having each side equal to length ℓ carries a current i_0 (Assume gap between parallel wires AH and DE to be negligibly small)

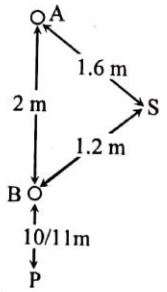


Q.54 The direction of magnetic field at the geometric centre of three dimensional prism shaped coil will be
(A) Along y-axis (B) along x-axis (C) along z-axis (D) none of these

Q.55 If an external magnetic field B_0 is applied along +ve z-axis then the force on the coil ABCDEFGH due to B_0 only will be equal to -
(A) zero (B) $LB_0\ell$ (C) $6LB_0\ell$ (D) $2LB_0\ell$

Passage # 6 (Q.56 & 57)

Two long straight parallel wires are 2 metres part, perpendicular to the plane of the paper. The wire A carries a current of 9.6 amps directed into the plane of the paper. The wire B carries a current such that the magnetic field of induction at the point P, at a distance of $\frac{10}{11}$ metre from the wire B, is zero. Answer the following questions.



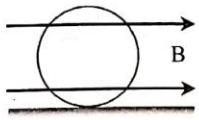
Q.56 The magnitude of direction of the current in B -
(A) 4.0 A (B) 3.0 A (C) 2.0 A (D) 1.0 A

Q.57 The magnitude of the magnetic field of induction at the point S.
(A) 1.1 μ T (B) 1.3 μ T (C) 1.4 μ T (D) 2.8 μ T

Column Matching Type Questions

Q.58 A conducting ring of mass m and radius r is placed on a smooth horizontal plane. The ring carries a current i. A horizontal magnetic field B is switched ON at t = 0 shown.

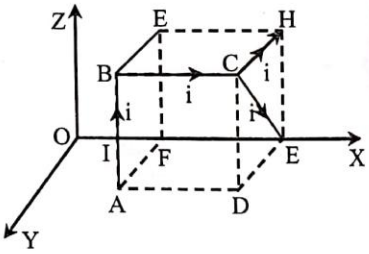
	Column-I		Column-II
(A)	Magnetic moment of the loop	(P)	$\frac{2i\pi r^2 B}{mr^2}$
(B)	Torque acting on the loop	(Q)	$i\pi r^2$
(C)	Angular acceleration of loop	(R)	$i\pi r^2 B$
(D)	Angular velocity of loop at time t	(S)	$\frac{2i\pi r^2 Bt}{mr^2}$



Q.59 Side of he cube is 'a' and wire AB, BC, CH and CE are insulated with each other and each having current I. then match the following. External magnetic field applied along positive x-axis as $\vec{B} = B_0 x\hat{i}$

	List-I (Magnitude of force due to external magnetic field only)		List-II
(P)	On AB	(1)	zero
(Q)	On BC	(2)	$2\sqrt{2}iB_0a^2$
(R)	On CH	(3)	iB_0a^2
(S)	On CE	(4)	$2iB_0a^2$

given that OF = a



Codes :

	P	Q	R	S
(A)	3	1	4	2
(B)	2	1	3	4
(C)	4	3	2	1
(D)	1	4	2	3

Q.60 A charged particle having non zero velocity is subjected to certain conditions given in column-I, column-II gives possible trajectories of the particle. Match the conditions in column-I with the results in column-II.

Column-I	Column-II
(A) In only uniform electric field	(P) the path of the charged particle may be a straight line
(B) In only uniform magnetic field	(Q) the path of the charged particle may be a parabola
(C) In uniform magnetic and uniform electric field	(R) the path of the charged particle may be circular
(D) Subjected to a net force of constant magnitude	(S) the path of the charged particle may be a helical with uniform or non uniform pitch

Q.61 Column-II gives four situations in which three or four semi infinite current carrying wires are placed in xy-plane as shown. The magnitude and direction of current is shown in each figure. Column-I gives statements regarding the x and y components of magnetic field at a point P whose coordinates are P(0, 0, d). Match the statements in column-I with the corresponding figures in column-II

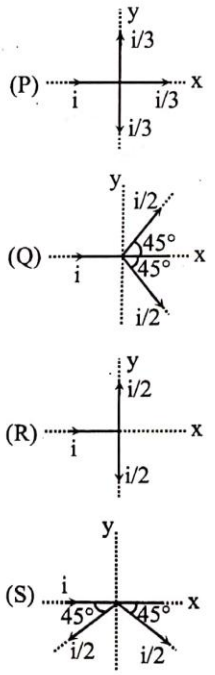
Column-I **Column-II**

(A) The x component of magnetic field at point P is zero in

(B) The z component of magnetic field at point P is zero in

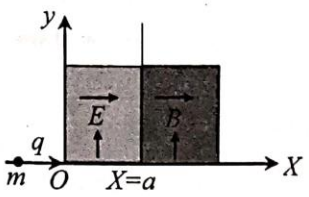
(C) The magnitude of magnetic field at point P is $\frac{\mu_0 i}{4\pi d}$ in

(D) The magnitude of magnetic field at point P is less than $\frac{\mu_0 i}{2\pi d}$ in



Numeric Response Type Questions

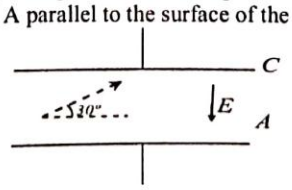
Q.62 A positively charged particle, having charge q is accelerated by a potential difference V. This particle moving along the x-axis enters a region where an electric field E exists. The direction of the electric field is along positive y-axis . The electric field exists in the region bounded by the lines x = 0 and x = a. Beyond the line x = a. (*i. e.* ,in the region x ≥ a) there exists a magnetic field of strength B, directed along the positive y–axis. Find :



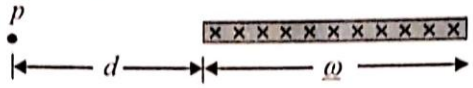
(a) At which point does the particle meets the line x = a

(b) The pitch of the helix formed after the particle enters the region x ≥ a Mass of the particle is m.

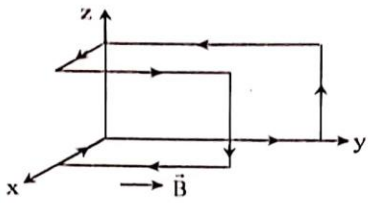
Q.63 A charged particle having charge 10^{-6} C and mass 10^{-10} kg is fired form the middle of the plate making an angle 30° with planc of the plate. Length of the plate is 0.17 m and it is separated by 0.1m. Electric field E = 10^{-3} N/ C is present between the plates. Just outside the plates magnetic field is present. Find the velocity of projection of charged particle and magnitude of the magnetic field perpendicular to the plane of the figure, if it has to graze the plate at C and A parallel to the surface of the plate. (Neglect gravity)



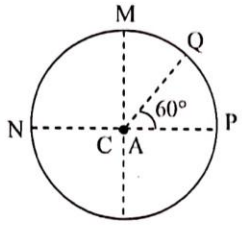
Q.64 Figure shows a cross – section of a long ribbon of width ω that is that is carrying a uniformly distributed total current i in the page. Calculate the magnitude and direction of the magnetic field $\vec{B}$ at a point P in the plane of the ribbon at a distance d from its edge.



Q.65 Given figure shows a coil with a edges of length 1 m and carrying a current of 1A. There exists in space a uniform magnetic field of 2T in positive y-direction. Find the torque on the loop.

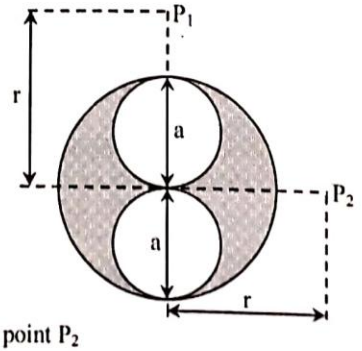


Q.66 In the given figure, AC is a current element of strength 0.4 A-m placed at the centre of a circle of radius 10 cm. Calculate magnetic field induction at the points P, Q, M and N.



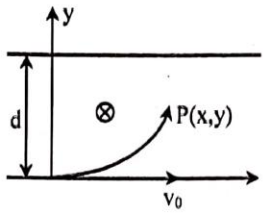
Q.67 Magnetic field $\vec{B} = -B_0 x\hat{k}$ exists in a region of space. A particle of specific charge α (charge per unit mass) enters this region of space. Its velocity and position of time t = 0, are $\vec{v} = v_0\hat{i}$ and (0, 0, 0). Find the maximum x-displacement of the particle.

Q.68 A long cylindrical conductor of radius a has two cylindrical cavities of diameter a through is entire length as shown in cross-section in figure. A current I is directed out of the page and is uniform throughout the cross-section of the conductor. Find the magnitude and direction of the magnetic field in terms of μ_0, I, r and a.



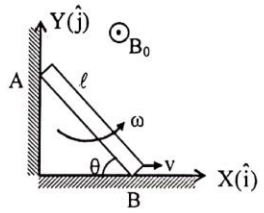
(a) at point P_1 and (b) at point P_2

Q.69 A non-uniform magnetic field $\vec{B} = B_0\left(1+\frac{y}{d}\right)\hat{k}$ is present in region of space in between $y = 0$ & $y = d$. The lines are shown in the diagram. A particle of mass 'm' and positive charge 'q' is moving. Given an initial velocity $\vec{v} = v_0\hat{i}$. Find the components of velocity of the particle when it leaves the field.

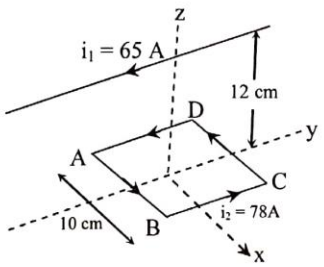


Q.70 A particle of mass m and having charge +q is projected from origin with velocity $\vec{v} = v_0\hat{i}$ in a region having magnetic field. $B = B_0\hat{i} + B_0\sqrt{3}\hat{j}$ x coordinate of particle when it touches n^{th} time the line $y = \sqrt{3}x$ is $\frac{\pi m \times n v_0}{a \times qB}$ then a is .....

Q.71 A thin conducting rod of length $\ell = 5$m is moved such that its end B moves along the X-axis while end A moves along the Y-axis. A uniform magnetic field $B = 6\hat{k}$ T exists in the region. At some instant, velocity of end B is 3 m/s and the rod makes an angle of $\theta = 37°$ with the X-axis as shown in the figure. Then, at this instant what is the emf induced (in volt) in the rod. ? If it is $3 \times$ n. Find the value of n.

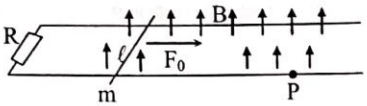


Q.72 Figure shows a square loop 10 cm on each side in the x-y plane with its centre at the origin. An infinite wire is at z = 12 cm above y-axis.



What is torque on loop due to magnetic force ? If torque is expressed as $x \times 10^{-5}$ N-m, fill value of x. (x is nearest integer)

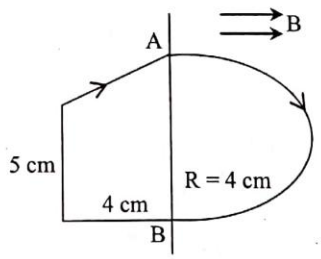
Q.73 The long, horizontal pair of rails shown in the figure is connected using resistance R. The distance between the rails is ℓ, the electrical resistance of the rails is negligible. A conducting wire of mass m and length ℓ can slide without friction on the pair of rails, in a vertical, homogeneous magnetic field of induction B.



A force of magnitude F_0 is exerted for sufficiently long time onto the conducting wire, so that the speed of the wire becomes nearly constant. The force F_0 is now removed at a certain point P. What distance (in m) does the conducting wire cover on rails from point P before stopping ? If it is 64 × n. Find the value of n.
(Given : $F_0 = 20$ N, m = 1.6 gm, R = 0.01 Ω, ℓ = 10 cm, B = 0.1 T)

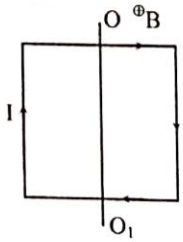
Q.74 A conducting rod of length vector $\vec{L} = \frac{3}{5}\hat{j} + \frac{4}{5}\hat{k}$ is moving with a velocity $\vec{v} = 2\hat{i}$ in a uniform magnetic field $\vec{B} = \hat{j} - 2\hat{k}$. Then find the magnitude of induced emf in rod.

Q.75 A coil of shape as shown in the figure is placed in a horizontal magnetic field of 1.956 Tesla perpendicular to field. 0.01 amp. current is flowing in the coil. It is free to rotate about axis AB. Mass per unit length of straight wires is λ and that of circular part is λ/2 where λ = 2.805 gm/cm. What will be its magnitude of angular acceleration at t = 0.

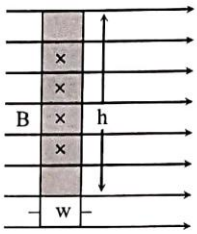


Q.76 There is a constant homogenous electric field of 200 V m^{-1} within the region x = 0 and x = 0.167 m pointing in the positive x-direction. There is a constant homogenous magnetic field $\vec{B}$ within the region x = 0.167 m & x = 0.334 m pointing in the z-direction. A proton at rest at the origin (x = 0, y = 0) is released. Find the strength of the magnetic field (in mT) B, so that the proton is deflected back to just reach x = 0, y = – 0.167 m. (mass of the proton = 1.67×10^{-27} kg)

Q.77 A square current carrying loop made of thin wire and having a mass m = 10g can rotate without friction with respect to the vertical axis OO_1, passing through the centre of the loop at right angles to two opposite sides of the loop. The loop is placed in a homogenous magnetic field with an induction B = 10^{-1} T directed at right angles to the plane of the drawing. A current I = 2A is flowing in the loop. Find the period of small oscillations that the loop performs about its position of stable equilibrium.

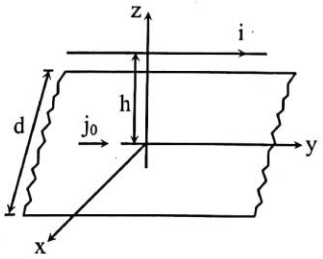


Q.78 A current i, indicated by the crosses in figure is established in a strip of copper of height h and width w. A uniform field of magnetic induction B is applied at right angles to the strip.

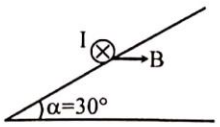


(a) Calculate the drift speed v_d for the electrons
(b) What are the magnitude and direction of the magnetic force F acting on the electrons?
(c) What would the magnitude & direction of homogenous electric field E have to be in order to counter balance the effect of the magnetic field ?
(d) What is the voltage V necessary between two sides of the conductor in order to create this field E? Between which sides of the conductor would this voltage have to be applied ?
(e) If no electric field is applied form the outside the electrons will be pushed somewhat to one side and therefore will give rise to a uniform electric field E_H across the conductor untill the force of this electrostatic field E_H balance the magnetic forces encountered in part (b). What will be the magnitude and direction of the field E_H ?
Assume that n, the number of conduction electrons per unit volume, is $1.1 \times 10^{29}/m^3$ and that $h = 0.02$ meter, $w = 0.1$ cm, $i = 50$ amp, and $B = 2$ webers/meter^2.

Q.79 A conductor carrying a current i is placed parallel to a current per unit width j_0 and width d, as shown in the figure. Find the force per unit length on the conductor.



Q.80 The figure shows a conductor of weight 1.0 N and length L = 0.5 m placed on a rough inclined plane marking an angle 30° with the horizontal so that conductor is perpendicular to a uniform horizontal magnetic field of induction B = 0.10 T. The coefficient of static friction between the conductor and the plane is 0.1. A current of I = 10 A flows through the conductor inside the plane of this paper as shown. What is the force needed to be the applied parallel to the inclined plane to sustaining the conductor at rest?



ANSWER KEY

Single Correct Option type Questions

1. (B)	**2.** (C)	**3.** (B)	**4.** (B)	**5.** (D)	**6.** (C)	**7.** (B)
8. (B)	**9.** (D)	**10.** (B)	**11.** (A)	**12.** (C)	**13.** (A)	**14.** (B)
15. (C)	**16.** (B)	**17.** (B)	**18.** (B)	**19.** (C)	**20.** (C)	**21.** (A)
22. (D)	**23.** (D)	**24.** (B)	**25.** (B)	**26.** (A)		

Statement Based Questions

27. (B)

Multiple Correct Option type Questions

28. (A,B,C)	**29.** (A,D)	**30.** (A,B,C)	**31.** (A,D)	**32.** (A,C,D)	**33.** (A,B,C,D)	**34.** (A,C,D)
35. (A)	**36.** (B,C,D)	**37.** (B,C,D)	**38.** (B,C,D)	**39.** (A)	**40.** (B,C)	**41.** (B,D)
42. (A,D)	**43.** (A,C)	**44.** (C)				

Passage Based Questions

45. (D)	**46.** (C)	**47.** (B)	**48.** (A)	**49.** (A)	**50.** (C)	**51.** (A)
52. (A)	**53.** (C)	**54.** (D)	**55.** (A)	**56.** (B)	**57.** (B)	

Column Matching Type Questions

58. $A \to Q$; $B \to R$; $C \to P$; $D \to S$ **59.** (A)

60. $A \to P,Q$; $B \to P,R,S$; $C \to P,S$; $D \to P,Q,R,S$

61. $A \to P,Q,R$; $B \to P,Q,R,S$; $C \to R$; $D \to P,Q,R,S$

Numeric Response Type Questions

62. (a) $y = \frac{Ea^2}{4V}$; (b) $p = \frac{\pi EA}{B}\sqrt{\frac{2m}{qV}}$ **63.** 2 m/s, 3.46 mT **64.** $B = \frac{\mu_0 i}{2\pi\omega}\ln\left(\frac{d+\omega}{d}\right)$, upwards

65. Zero **66.** Zero, 3.46×10^{-6} T, 4×10^{-6} T, zero **67.** $x_{max.} = \sqrt{\frac{2v_0}{B_0\alpha}}$

68. (a) $B = \frac{\mu_0 I}{\pi r}\left(\frac{2r^2-a^2}{4r^2-a^2}\right)$, to the left.; (b) $B = \frac{\mu_0 I}{\pi r}\left(\frac{2r^2+a^2}{4r^2+a^2}\right)$ **69.** $v_x = v_0 - \frac{3qB_0 d}{2m}$, $v_y = \sqrt{v_0^2 - v_x^2}$

70. 4 **71.** 7 **72.** 7 **73.** 5 **74.** 4 **75.** 2 **76.** 10

77. $T_0 = 2\pi\sqrt{\frac{m}{6IB}} = 0.57\,s$

78. (a) 1.4×10^{-4} m/s (b) 4.5×10^{-23} N (down) (c) 2.8×10^{-4} V/m (down)
(d) 5.7×10^{-6} V (top +, bottom –) (e) same as (c)

79. $\frac{\mu_0 i J_0}{\pi}\tan^{-1}\left(\frac{d}{2h}\right)(-\hat{k})$ **80.** $0.62\text{ N} < F < 0.88\text{ N}$

Chapter

26 Reflection

Single Correct Option Type Questions

Q.1 A plane mirror is placed in y-z plane facing towards negative x-axis. The mirror is moving parallel to y-axis with a speed of 2 cm/s. A point object 'p' is moving in front of the mirror with a velocity $(1\text{cm/s})\,\hat{i} + (1\text{cm/s})\,\hat{j}$. Then which of the following statements is incorrect ?

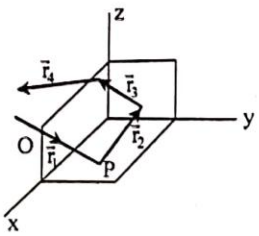
(A) The velocity of image is with $(-\hat{i}+\hat{j})$ cm/s

(B) The velocity of image with respect to mirror is $-(\hat{i}+\hat{j})$ cm/s

(C) The velocity of image with respect to object is $-(2\hat{i})$ cm/s

(D) The unit vector in the direction of reflected ray is $\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$

Q.2 Three plane mirrors are arranged so that they are mutually perpendicular as shown in figure. Let the line of intersection of the mirrors be the coordinate axes. A ray OP represented by vector $\vec{r}_1 = (x_1, y_1, z_1)$ is reflected from the mirror. Which of the following statement is **incorrect** ?



(A) The components of the reflected vector from mirror in x-y plane is $\vec{r}_2 = (x_1, y_1, -z_1)$

(B) If $\vec{r}_2$ is now reflected at the y-z plane, the components of the reflected vector is $\vec{r}_3 = (-x_1, y_1, -z_1)$

(C) If $\vec{r}_3$ is reflected at the z-x plane, the components of the reflected vector is $\vec{r}_4 = (-x_1, -y_1, -z_1)$

(D) For an incident ray that is reflected from the mirrors in some other order, the components of final ray $\vec{r}_4$ will change

Q.3 An optical device, which could be a mirror, or a lens, plane or spherical, is observed to give an image, sometimes real, sometimes virtual and sometimes diminished or sometimes enlarged, of an extended object placed on its axis. The optical device could be -

(A) a plane mirror, a concave mirror or a convex lens (B) a concave mirror or a convex lens

(C) a convex mirror or a concave lens (D) only a convex lens

Q.4 An object is moving with speed v_0 towards a spherical mirror with radius of curvature R, along the central axis of the mirror. The speed of the image with respect to the mirror is (U is the distance of the object from mirror at any given time t)

(A) $+\left(\frac{R}{U-2R}\right)v_0^2$ (B) $-\left(\frac{R}{R-2U}\right)^2 v_0$ (C) $-\left(\frac{R}{2U-2R}\right)^2 v_0$ (D) $+\left(\frac{R}{2U-2}\right)v_0^2$

Q.5 A point object is moving with velocity $\vec{u} = 2\hat{i} + \hat{j} - \hat{k}$ m/s in front of a stationary plane mirror. The magnitude of relative velocity of the image with respect to object is maximum if the normal of the plane mirror will be along -

(A) $2\hat{i} + \hat{j} + \hat{k}$ (B) $-2\hat{i} + \hat{j} - \hat{k}$ (C) $2\hat{i} + \hat{j} - \hat{k}$ (D) $2\hat{i} - \hat{j} - \hat{k}$

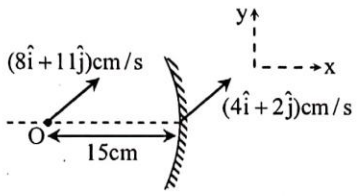
Q.6 A point object P moves towards a stationary convex mirror with a constant speed v, along the optical axis. The speed of the image -

(A) is always less than v
(B) may be greater than, equal to or less than v, depending upon the position of P
(C) is always greater than v
(D) none of these

Q.7 Two rays are incident on a spherical mirror of radius R = 5 cm parallel to its optical axis at distances $h_1 = 0.5$ cm and $h_2 = 3$ cm. Determine the distance Δx (approximately) between the points at which these rays intersect the optical axis after being reflected at the mirror -

(A) 0.2 cm (B) 1.5 cm (C) 0.6 cm (D) 1.0 cm

Q.8 A point object is located at a distance 15 cm from the pole of a concave mirror of focal length 10cm on its principal axis is moving with a velocity $(8\hat{i} + 11\hat{j})$ cm/s and velocity of mirror is $(4\hat{i} + 2\hat{j})$ cm/s as shown. If $\vec{v}$ is the velocity of image. Then find the value of $|\vec{v}|$ in (cm/s)



(A) 20 (B) 30 (C) 10 (D) 40

Q.9 A ray of light travelling along the positive z-axis is reflected twice -

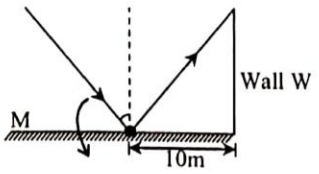
(i) for the first time, by a mirror whose normal is along $(\hat{i} + \hat{k})$

(ii) for the second time, by a mirror whose normal is along $(\hat{i} + \hat{k} + \hat{j})$, where the symbols have their usual meanings.

The final ray is along -

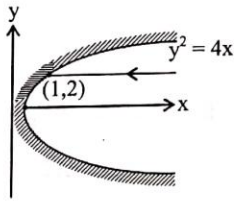
(A) $\hat{j} + \hat{k}$ (B) $\hat{k} + \hat{i}$ (C) $2\hat{j} + 2\hat{k} - \hat{i}$ (D) None of these

Q.10 A light ray is incident on a plane mirror M. The mirror is rotated in direction as shown in figure by an arrow at frequency $(9/\pi)$ revolution/sec. The light reflected by the mirror is received on the wall W at a distance of 10 m from axis of rotation. Speed of the spot on wall when angle of incident = 37° is



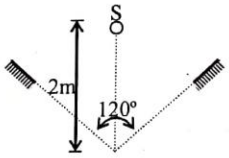
(A) 10 m/sec (B) 1000 m/sec (C) 360 m/sec (D) 500 m/sec

Q.11 A light ray parallel to x-axis is incident on a parabolic concave mirror in XY plane. The focus of this parabola is at (1, 0). The unit vector along the reflected ray will be



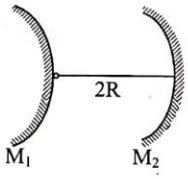
(A) $\hat{j}$ (B) $-\hat{j}$ (C) $\frac{\hat{i}+4\hat{j}}{\sqrt{17}}$ (D) $-\hat{i}$

Q.12 Area of triangle formed by S and its two images is



(A) $3\sqrt{3}$ m^2 (B) $\frac{3\sqrt{3}}{4}$ m^2 (C) $\frac{4}{3\sqrt{3}}$ m^2 (D) Can't be determined

Q.13 Two spherical mirror, one convex and other concave, each of same radius of curvature R are arranged coaxially at a distance 2R from each other. A small circle of radius a is drawn on the convex mirror near the pole as shown in figure. The radius of 2nd image (taking the first reflection at the concave mirror, then the reflection at the convex mirror) of the circle is $\left(\frac{3a}{30+x}\right)$, then value of x is



(A) 1 (B) 2 (C) 3 (D) 4

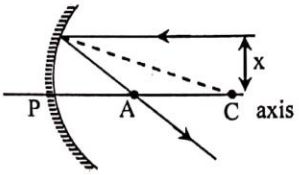
Q.14 The total number of images formed by two plane mirrors, inclined at an angle of 15°, and an object lying symmetrically is
(A) 24 (B) 23 (C) 22 (D) 25

Q.15 A plane mirror coincides with a plane having equation x = 3. A particle is moving along a line with direction ratios 3, 4, 5. If speed of the particle is $\sqrt{2}$, the velocity of its image is

(A) $\frac{3}{5}\hat{i}+\frac{4}{5}\hat{j}+\frac{1}{5}\hat{k}$ (B) $-\frac{3}{5}\hat{i}-\frac{4}{5}\hat{j}-\hat{k}$ (C) $\frac{3}{5}\hat{i}+\frac{4}{5}\hat{j}-\frac{1}{5}\hat{k}$ (D) $-\frac{3}{5}\hat{i}+\frac{4}{5}\hat{j}+\hat{k}$

Statement Based Questions

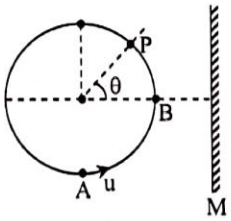
Q.16 **Statement-1 :** As 'x' increases, the distance of point of intersection of the reflected ray with axis from pole decrease.
Statement-2 : As the distance 'x' of a parallel ray from axis increases, angle of incidence decreases.



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

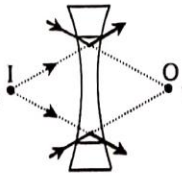
Multiple Correct Option Type Questions

Q.17 A particle is moving along a circle with a constant speed u, as shown in figure. M is a plane mirror, then

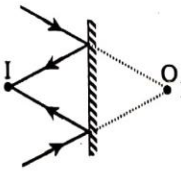


(A) relative velocity of image w.r.t. object becomes zero twice in one revolution
(B) path of image with respect to object is circle
(C) path of image with respect to object is straight line
(D) speed of image with respect to object when particle is at P is $2u \sin \theta$

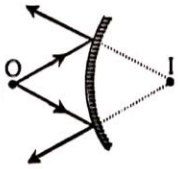
Q.18 The nature of object and image given with each of the optical condition is shown. Choose the correct option(s)

(A) Virtual image 

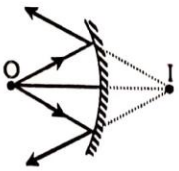
Virtual object

(B) Virtual image 

Real object

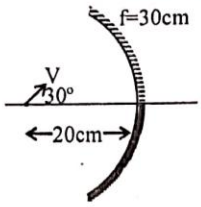
(C) Real Object 

Virtual image

(D) Real Object 

Virtual image

Q.19 A ball is projected with initial speed V at distance 20cm from pole of a concave mirror. Speed of image cannot be



(A) Greater than V (B) Less than V (C) Equal to V (D) Zero

Q.20 A point-object is kept at (1, 0, 0). A circular plane mirror of radius 1m is kept in yz plane such that its centre is at the origin. The reflecting side faces positive x-axis. At which of the following points can the image of the object be seen ?

(A) (– 0.5, 0, 0.5) (B) (2, 2, 2) (C) (1, 1.5, 1.5) (D) (1, –1, 1.5)

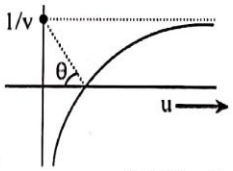
Q.21 An object is moving on principle axis in front of a spherical mirror, m is instantaneous transverse magnification the velocity of object is constant. Mirror is stationary. v and a are velocity and acceleration of image respectively. The correct statement (s) are

(A) $v \propto m^2$ (B) $v \propto m$ (C) $a \propto m^3$ (D) $a \propto m^4$

Passage Based Questions

Passage # 1 (Q.22 & 23)

For an optical element the graph between 1/v and u is given (Assume paraxial ray approximation has been used. Symbols have their usual meaning). For plotting the graph the following sign convention is used.



(a) Pole is taken as origin. (b) Direction of incident light is +ve
(c) Principle axis is used as one of the axis

Q.22 The nature of mirror is -

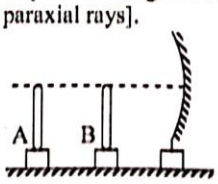
(A) Convex mirror (B) Concave mirror (C) Converging lens (D) Diverging lens

Q.23 Numerical value of cot θ is 4 -

(A) Numerical value of focal length is 2 (B) Numerical value of focal length is 1/2
(C) Numerical value of focal length is 4 (D) Numerical value of focal length is 1/4

Passage # 2 (Q.24 & 25)

A concave mirror M is mounted on an optical bench. Two pins A and B are placed on bench such that their tips also lie on the principal axis of the mirror as shown. The image of tip of one tip is formed on the tip of the other pin. Now if pin B is moved 80 cm towards left and pin A is moved 80cm towards right, image of tip of one pin is again on the tip of the other pin. The magnitude of transverse magnification of the larger image is three. [All the images are formed by paraxial rays].

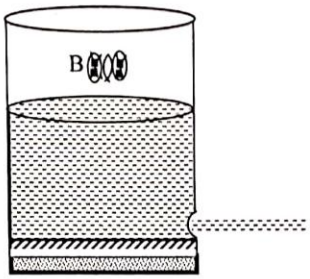


Q.24 The focal length of the mirror is -
(A) 30 cm (B) 60 cm (C) 40 cm (D) 15 cm

Q.25 The magnification of the image of the pin B in second case is -
(A) 3 (B) 4.5 (C) 1/4.5 (D) 1/3

Passage # 3 (Q.26 & 27)

In a cylindrical container of area 100 cm^2, water is filled upto a height 80m. there is a small orifice at the bottom of the container. The area of orifice is 1cm^2 . The base of the container is silvered and behaves like plane mirror.
An insect is crawling down on the wall of the container with velocity 2 cm /s and at t= 0 it is at 81 m from the base.
At t = 0 water starts flowing out from the orifice. (refractive index of water is 4/ 3)

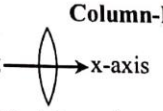
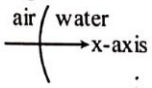
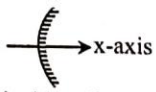
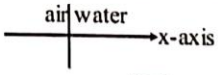
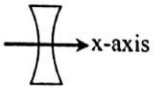


Q.26 The velocity of image of insect as observed by the insect at t = 200 sec.
(A) 2 cm/s (B) 6 cm/s (C) 3 cm/s (D) 8 cm/s

Q.27 After a certain time velocity of image of insect becomes constant. The time at which this happens will be
(A) 200 sec (B) 10 sec (C) 400 sec (D) 300 sec

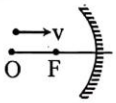
Column Matching Type Questions

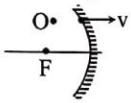
Q.28 In column-I certain combination of small object and image are given. Match them with possible refracting / reflecting body in column-II. In all cases, object is perpendicular to x-axis. Object can't be at zero distance from the interface.

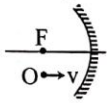
Column-I	Column-II
(A) Virtual image of virtual object	(P) Converging lens 
(B) Real image of real object	(Q) Light is incident from air on the spherical surface 
(C) Erect real image of same size as object	(R) Convex mirror 
(D) Erect and virtual image of larger size	(S) Light is incident from right to left 
	(T) Diverging lens 

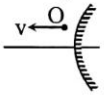
Q.29 In column-I possible instantaneous velocity vector of the object/mirror (as shown in figure) with respect to ground. The corresponding velocity vectors of images are the situations shown in column-II. Match column-I with the column-II.

Column-I

(A) 

(B) 

(C) 

(D) 

Column-II

(P)

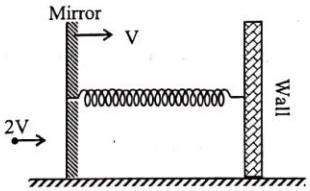
(Q)

(R)

(S)

(T) None of these

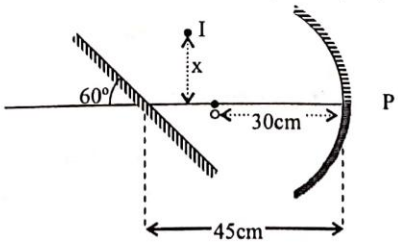
Q.30 A plane mirror is tied to the free end of an ideal spring. The other end of the spring is attached to a wall. The spring with mirror is held vertically to the floor, can slide along it smoothly. When the spring is at its natural length, the mirror is found to be moving at a speed of V with respect to ground frame. An object is moving towards the mirror with speed 2V with respect to ground frame. Then, Match the following :



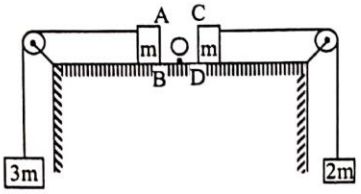
Column I	Column II
(A) Speed of image with respect to ground frame when spring is at natural length	(P) V
(B) Speed of image with respect to mirror when spring is at natural length	(Q) O
(C) Speed of image with respect to object when spring is at natural length	(R) 2V
(D) Speed of image with respect to ground frame when spring is at maximum compressed state	(S) 3V

Numeric Response Type Questions

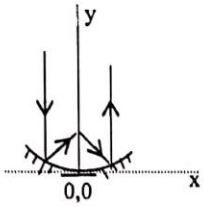
Q.31 A concave mirror of focal length 20cm and a plane mirror are kept as shown in the fig. Consider two reflections, first from concave mirror and second from plane mirror. If the image for an object kept at 30cm from concave mirror is formed at I then the value of x is $\left(\frac{60}{n}\sqrt{3}\right)$ cm. Find n



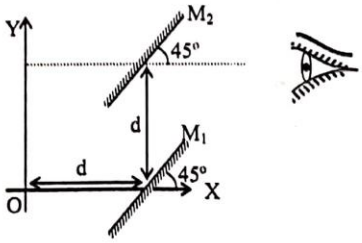
Q.32 Two blocks each of mass m lie on a smooth table. They are attached to two other masses as shown in the figure. The pulleys and strings are light. An object O is kept at rest on the table. The sides AB & CD of the two blocks are made reflecting. The acceleration of two images formed those two reflecting surfaces w.r.t. each other is $\left(\frac{17g}{x}\right)$ m/s^2. Find the value of x



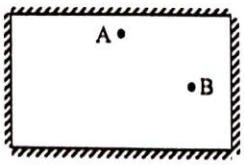
Q.33 A beam of light parallel to y - axis falls on reflecting surface $y = \frac{x^2}{16}$ as shown in the figure . Find the point where the beam will converge after reflection.



Q.34 Find the coordinates of the image formed that of an object placed at origin, which the eye will observe in mirror M_2.

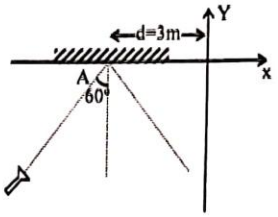


Q.35 How will you draw a beam of light to be sent from point A (see figure) contained in a mirror box for it to fall onto point B after being reflected once from all four walls? Points A and B are in one plane perpendicular to the walls of the box (i.e. in the plane of the drawing).



Q.36 A balloon is rising up along the axis of a concave mirror of radius of curvature 20 m. A ball is dropped from the balloon at a height 15 m from the mirror when the balloon has velocity 20 m/s. Find the speed of the image of the ball formed by concave mirror after 4 seconds? [Take : g = 10 m/s^2]

Q.37 Figure shows a torch producing a straight light beam falling on a plane mirror at an angle 60°. The reflected beam make a spot P on the screen along Y-axis. If at t = 0, mirror starts rotating about the hinge A with an angular velocity $\Omega = 1°$ per second clockwise. Find the speed of the spot on screen after time t = 15s.

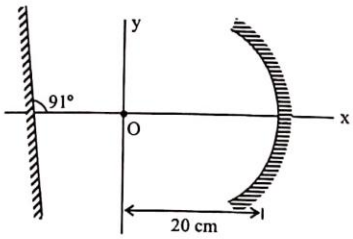


Q.38 A kid of height 1.1 ft is sleeping straight between focus and centre of curvature along the principal axis of a concave mirror of small aperture. His head is towards the mirror and is 0.5 ft from the focus of the mirror. How a plane mirror should be placed so that the image formed by it due to reflected light from concave mirror looks like a person of height 5.5 ft standing vertically. Draw the diagram. Find the focal length of the concave mirror.

Q.39 An observer whose least distance of distinct vision is 'd', views his own face in a convex mirror of radius of curvature 'r'. Prove that magnification produced can not exceed $\dfrac{r}{d+\sqrt{d^2+r^2}}$.

Q.40 A thief is running away in a car with velocity of 20 m/s. A police jeep is following him, which is sighted by thief in his rear view mirror which is a convex mirror of focal length 10 m. He observes that the image of jeep is moving towards him with a velocity of 1 cm/s. If the magnification of the mirror for the jeep at that time is 1/10. Find
(a) actual speed of jeep;
(b) rate at which magnification is changing
Assume that police jeep is on axis of the mirror.

Q.41 A point object is placed at the centre of curvature of a concave mirror (taken as origin). A plane mirror is also placed at a distance of 10 cm from the object as shown. Consider two reflection first at plane mirror and then at concave mirror. Find the coordinates of the image thus formed.



Q.42 A concave mirror has the form of a hemisphere with a radius of R = 60 cm. A thin layer of an unknown transparent liquid is poured into the mirror. The mirror-liquid system forms one real image and another real image is formed by mirror alone, with the source in a certain position. One of them coincides with the source and the other is at a distance of l = 30 cm from source. Find the possible value(s) refractive index μ of the liquid.

ANSWER KEY

Single Correct Option type Questions

1. (D) **2.** (D) **3.** (B) **4.** (B) **5.** (C) **6.** (A) **7.** (C)

8. (A) **9.** (C) **10.** (B) **11.** (C) **12.** (A) **13.** (C) **14.** (B)

15. (D)

Statement Based Questions

16. (C)

Multiple Correct Option type Questions

17. (A,C,D) **18.** (A,C,D) **19.** (B,C,D) **20.** (B,D) **21.** (A,C)

Passage Based Questions

22. (A) **23.** (B) **24.** (A) **25.** (D) **26.** (B) **27.** (C)

Column Matching Type Questions

28. $A \to R,T$; $B \to P,Q$; $C \to S$; $D \to P,Q$ **29.** $A \to R$; $B \to P$; $C \to Q$; $D \to S$

30. $A \to Q$; $B \to P$; $C \to R$; $D \to R$

Numeric Response Type Questions

31. 8 **32.** 6 **33.** 4 **34.** (– d, d) **36.** 80 m/sec. **37.** $\frac{2\pi}{15}$ m/sec.

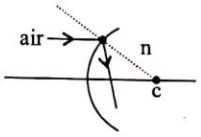
38. 2 feet **40.** (a) 21 m/sec., (b) 1×10^{-3} sec. **41.** $\frac{20}{3}$ cm, $\frac{\pi}{27}$ cm. **42.** 1.5° OR $(\sqrt{5}-1)$

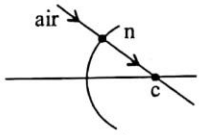
Chapter

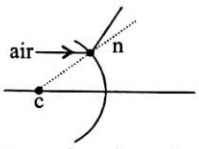
27 Refraction

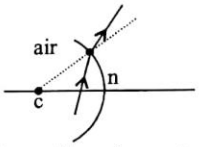
Single Correct Option Type Questions

Q.1 Different optical instruments (lens, slab) are formed using material having negative refractive index called meta materials. ('n' shows meta material) Which of the following ray diagram is **INCORRECT**?

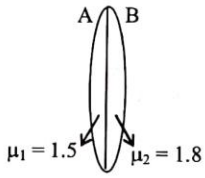
(A) 

(B) 

(C) 

(D) 

Q.2 A convex lens is made of two different materials having radius of curvature of surface A and surface B as 25 cm and 24 cm respectively. The effective focal length of lens is



(A) 75/4 cm (B) 75 cm (C) 50 cm (D) 30 cm

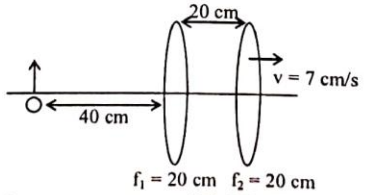
Q.3 The distance between object and screen is 96 cm. The ratio of length of two images formed by a convex lens placed between them is 4.84. the focal length f is nearly

(A) 22 cm (B) 20.6 cm (C) 24 cm (D) 24.2 cm

Q.4 A spherical glass bulb of diameter d is filled with water $\left(\mu = \frac{4}{3}\right)$. The bulb is viewed along its horizontal diameter. What is the apparent diameter? (Neglect the thickness of glass)

(A) 2d (B) $\frac{3d}{2}$ (C) $\frac{d}{2}$ (D) $\frac{7}{4}d$

Q.5 An object O is located 40 cm from the first of two thin converging lenses (each of focal length 20 cm), as shown in the figure below. If speed of the right lens is 7 cm/s rightwards, speed of final image is $\left(\frac{7x}{4}\right)$ cm/s at the instant shown, find the value of x.

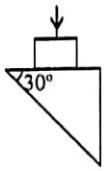


(A) 1.5 (B) 2.5 (C) 3.5 (D) 3

Q.6 An object is placed 1cm above the optical axis of a convex lens of focal length 40cm. The object distance is 60cm. If the object now starts moving perpendicularly away from the optical axis with a speed = 10 cm/s, the speed of the image is

(A) 5 cm/s (B) 10 cm/s (C) 20 cm/s (D) 40 cm/s

Q.7 A ray of light incident normally on the horizontal face of the slab and just fail to emerge from the diagonal face of the prism. If prism angle is 30°, refractive index of the prism is



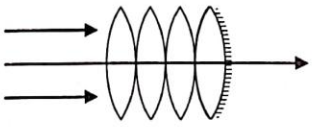
(A) $\sqrt{2}$ (B) 2

(C) slightly greater than 2 (D) slightly less than 2

Q.8 The limiting angle of incidence of a ray that can be transmitted by an equilateral prism of $\mu = \sqrt{\frac{7}{3}}$ will be

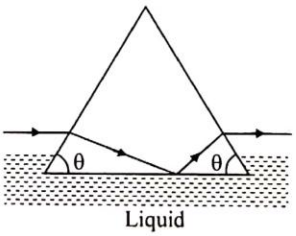
(A) 60° (B) 30° (C) 45° (D) None of these

Q.9 Four identical lenses are kept one beside the other on the same optical axis as shown in the figure. The right surface of rightmost lens is silvered. Focal length of each lens is 20 cm and radius of silvered surface is 20 cm. The focal length of the combined system is



(A) 2 cm (B) – 2 cm (C) 5 cm (D) – 5 cm

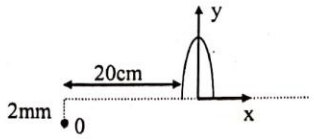
Q.10 An iso-scale glass prism stands with its (horizontal) base in water as shown in the figure. An incident ray of light, above and parallel to the liquid surface and perpendicular to the prism's axis, is internally reflected at the glass-liquid interface and subsequently re-emerges into the air. Refractive index of glass is μ_g and liquid is μ_ℓ, then which relation holds good



(A) $\mu_g^2 - \mu_\ell^2 \geq \cos^2\theta(\mu_g^2 + 1 - 2\mu_\ell)$ (B) $\mu_g = \mu_\ell \cos\theta$

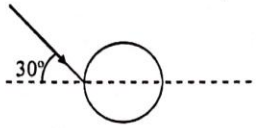
(C) $\mu_g^2 = \mu_\ell^2 \cos\theta$ (D) $\mu_g^2 - \mu_\ell^2 < \cos^2\theta(\mu_g^2 + 1 - 2\mu_\ell)$

Q.11 If an object is placed 20 cm in front of a half thin convex lens of focal length 10 cm, as shown in figure, then co-ordinate of image taking object position as origin.



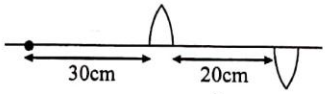
(A) [20 cm, 0.2 cm] (B) [40 cm, 0.4 cm] (C) [40 cm, – 0.2 cm] (D) [20 cm, 0.4 cm]

Q.12 A ray of light falls on the surface of spherical glass (having refractive index n) making angle 30° with normal then net angle of deviation between emergent and incident rays is



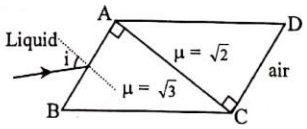
(A) $30° - 2\sin^{-1}\frac{1}{2n}$ (B) Zero (C) $60° - 2\sin^{-1}\frac{1}{2n}$ (D) $30° - 8\sin^{-1}\frac{1}{n}$

Q.13 Convex lens of focal length f is split into two half from its principal axis. The separation between two lens is 20cm and the separation between nearest lens and object is 30 cm as shown in the figure. If image by nearest lens is formed at infinity, the image of the object formed by second lens from its optical center is



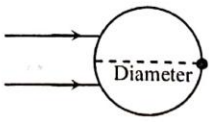
(A) 75 cm (B) 20 cm (C) 120 cm (D) Infinity

Q.14 A ray light from a liquid ($\mu = \sqrt{3}$) is incident on a system of two right angled prism of refractive indices $\sqrt{3}$ and $\sqrt{2}$ as shown. The ray suffers zero deviation when emerges into air from CD. The angle of incidence i is



(A) 45° (B) 35° (C) 20° (D) 10°

Q.15 When a narrow parallel beam of light falls on a solid transparent sphere kept in air parallel to a diameter it is found that the beam converge at the opposite end of that diameter, thus refractive index of the sphere must be

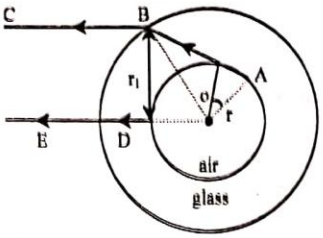


(A) 2 (B) $\sqrt{2}$ (C) $\frac{1}{\sqrt{2}}$ (D) $\frac{3}{2}$

Q.16 The magnifications for two positions of image of the same lens are 3 and 2, of a fix point object on a fix screen, when the distance between the two position of lens is 30 cm. The focal length of the lens is

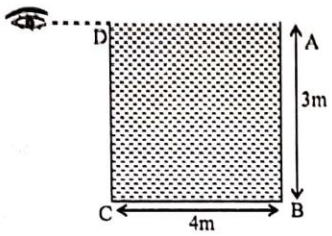
(A) 180 cm (B) 90 cm (C) 30 cm (D) 15 cm

Q.17 The adjacent figure shows cross section of a hollow glass tube of internal radius r, external radius R and index of refraction n. For two rays DE and ABC (in which DE lies on ODE and DE and BC are parallel), the separation r_1 will be



(A) $r_1 = (n-1)R$ (B) $r_1 = n^2R$ (C) $r_1 = nr$ (D) $r_1 = n^2r$

Q.18 The rectangular metal tank is filled with a liquid of refractive index μ. The observer, whose eye is in level with the top of the tank, can just see corner B. The value of μ is

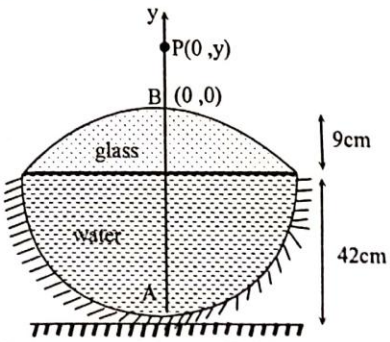


(A) $\frac{7}{4}$ (B) $\frac{5}{3}$ (C) $\frac{3}{2}$ (D) $\frac{5}{4}$

Q.19 The critical angle for a prism and its surrounding interface is 36°. The maxima angle of prism for which any emergent ray is possible is

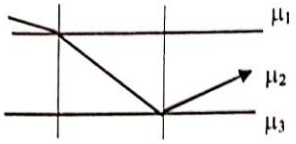
(A) 18° (B) 36° (C) 72° (D) 144°

Q.20 A point object is kept at point P (0, y) as shown in the figure. Find the value of y so that its image is also formed at point P. $\mu_g = \frac{3}{2}$, $\mu_w = \frac{4}{3}$. Radius of curvature of concave mirror is 130 cm and radius of curvature of curved part of glass is 30cm.



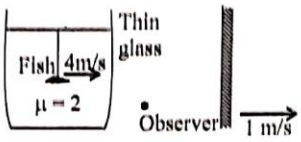
(A) 21 cm (B) 30 cm (C) 39 cm (D) 40 cm

Q.21 Light traveling through three transparent substances follows the path shown in the figure. Assuming that total internal reflection does take place on the bottom surface of medium 2. Arrange the refractive index in the increasing order.



(A) $\mu_1 < \mu_2 < \mu_3$ (B) $\mu_2 < \mu_1 < \mu_3$ (C) $\mu_1 < \mu_3 < \mu_2$ (D) $\mu_3 < \mu_1 < \mu_2$

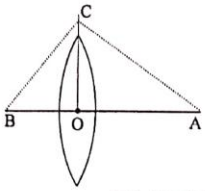
Q.22 Velocity of image of fish in the mirror with respect to ground is



(A) Zero
(B) 2 m/s towards mirror
(C) 2 m/s away from mirror
(D) 4 m/s towards mirror.

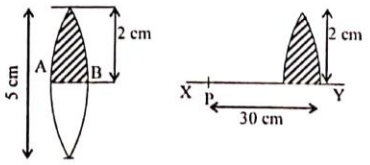
Q.23 A planoconvex lens made of a material of refractive index 1.5 is silvered on the convex surface. Calculate the radius of curvature of the curved surface
(Given : silvered lens which behaves as a mirror of focal length of –20 cm) :
(A) 10 cm (B) 20 cm (C) 30 cm (D) 60 cm

Q.24 If an object is placed at A (OA > f); Where f is the focal length of the lens the image is found to be formed at B. A perpendicular is erected at O and C is chosen on it such that the angle ∠BCA is a right angle. Then the value of f will be



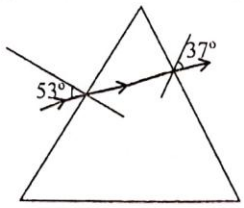
(A) AB/OC^2
(B) (AC)(BC)/OC
(C) (OC)(AB)/AC+BC
(D) OC^2/AB

Q.25 A converging lens of focal length 20 cm and diameter 5 cm is cut along the line AB. The part of the lens shown shaded in the diagram is now used to form an image of a point P placed 30 cm away from it on the line XY. Which is perpendicular to the plane of the lens. The image of P will be formed.



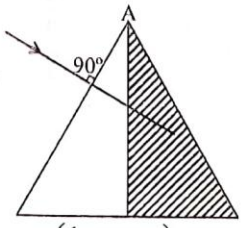
(A) 0.5 cm above XY (B) 1 cm below XY (C) on XY (D) 1.5 cm below XY

Q.26 A ray incident at an angle 53° on a prism emerges at an angle at 37° as shown. If the angle of incidence is made 50°, which of the following is a possible value of the angle of emergence.



(A) 35° (B) 42° (C) 40° (D) 38°

Q.27 A ray of light is incident normally on the first refracting face of the isosceles prism of refracting angle A. The ray of light comes out at grazing emergence. If one half of the prism (shaded position) is knocked off, the same ray will



(A) emerge at an angle of emergence $\sin^{-1}\left(\frac{1}{2}\sec A/2\right)$

(B) not emerge out of the prism

(C) emerge at an angle of emergence $\sin^{-1}\left(\frac{1}{2}\sec A/4\right)$

(D) None of these

Statement Based Questions

Q.28 **Statement-1 :** A lens L (shown in figure), kept in surrounding medium X, has a power +10D. If the same lens is kept in a surrounding medium Y, its power is found to be +12.5D. Also if the same lens is placed in a surrounding medium Z, its power is now measured to be –3.5D, then $\mu_z > \mu_x > \mu_y$.

Statement-2 : In different surrounding, power of given lens has different values but the same sign.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.29 **Statement-1 :** When two lenses are combined closely to form a achromatic doublet, both lens are of opposite nature and are made of different materials.
Statement-2 : Two opposite nature lens always have different dispersive powers.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.30 **Statement-1 :** Instead of prism, if white light incidents on a glass slab with certain angle, then no dispersion can be observed.

Statement-2: When white light passes through a glass slab with certain angle, lateral displacement of all colours are same with respect to original path of white light.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.31 **Statement-1 :** Two prisms made of same materials and having refractive index μ, μ' and prism angle A, A′ respectively when combined in opposite manner, then they will show dispersion but no mean deviation if $\frac{A'}{A} = -\frac{\mu - 1}{\mu' - 1}$.

Statement-2 : When light passes through combination of above two prism, net deviation is given by $\delta_{net} = (\mu - 1)A + (\mu' - 1)A'$ and no deviation means $(\mu - 1)A + (\mu' - 1)A' = 0$

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.32 **Statement-1 :** When an object, emitting white light is placed on the principal axis of a converging lens, at near focal point centre of image is violet and margin is red while at far focal point centre of image is red and margin is violet.

Statement-2 : Due to spherical nature of lens, every part of lens have different prism angle so every part of lens deviates light ray in different angles.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

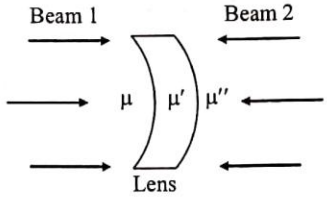
Q.33 **Statement-1 :** An observer is located at some distance from an object. The object, illuminated by monochromatic light, is viewed by the observer through a plane glass slab of a certain thickness that is smaller than the distance between the object and the observer, as the glass slab is placed more and more closer to the object, the apparent position of the object as seen by the observer will shift more and more towards the observer.

Statement-2 : If the refractive index of glass slab is more than that of surrounding medium in which the object and the observer are located, apparent position of the object will always be closer to the observer than its actual position.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

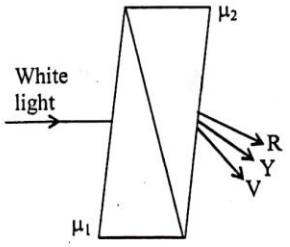
Q.34 The lens (thin) shown here is surrounded by different media on both sides. Radii of curvature of both the surfaces are equal



(A) Focal length of the lens is independent of μ' for both the beams
(B) If the lens is converging for beam 1 it will also be converging for beam 2
(C) If $\mu > \mu''$, lens is converging for beam 2
(D) if $\mu \le \mu''$, lens is converging for beam 1

Q.35 A light source is submerged inside water. It is moving in upward direction due to buoyancy force. Which of the following is **INCORRECT**?
(A) Percentage of light transfering from water to air is increasing
(B) Percentage of light transfering from water to air is constant
(C) Base area of light cone is increasing
(D) Base area of light cone is decreasing

Q.36 A beam of white light is incident on a combinations of thin prisms with equal angles. In the out going beam the rainbow colours are observed as shown. μ stands for refractive index and θ for angle of dispersion. Then



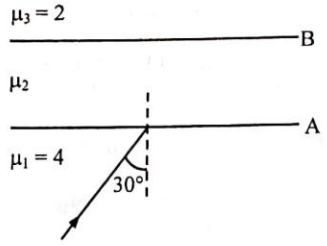
(A) $\mu_1 < \mu_2$ (B) $\mu_2 = \mu_1$ (C) $\theta_1 > \theta_2$ (D) $\mu_1 > \mu_2$

Q.37 An image of a bright square is obtained on a screen with the aid of a convergent lens. The distance between the square and the lens is 40 cm. The area of the image is nine time larger than that of the square. Select the correct statement(s) :
(A) Image is formed at a distance 120 cm from lens.
(B) Image is formed at a distance 360 cm from lens.
(C) Focal length of lens is 30 cm.
(D) Focal length of lens is 36 cm.

Q.38 The x-z plane separates two media A and B of refractive index $\mu_1 = 1.5$ and $\mu_2 = 2$. A ray of light-travels from A to B. Its direction in the two media, are given by unit vectors $\vec{u}_1 = a\hat{i} + b\hat{j}$ and $\vec{u}_2 = c\hat{i} + d\hat{j}$, then (positive y-axis medium A & – ve y-axis medium B)

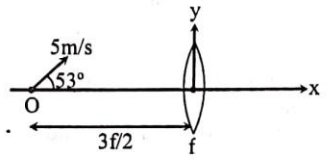
(A) $\frac{a}{c} = \frac{4}{3}$ (B) $\frac{a}{c} = \frac{3}{4}$ (C) $\frac{b}{d} = \frac{4}{3}$ (D) $\frac{b}{d} = \frac{3}{4}$

Q.39 A light ray is incident on lower medium boundary at an angle 30° with the normal. Which of following statements (s) are incorrect -



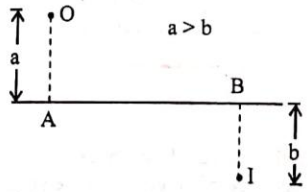
(A) If $\mu_2 > 2$ then total deviation is 60°
(B) If $\mu_2 < 2$ then total deviation is 60°
(C) If $\mu_2 > 2$ then total deviation is 120°
(D) If $\mu_2 < 2$ then total deviation is 120°

Q.40 A point object is placed on the principal axis of a convex lens (focal length f) at a distance of $\frac{3f}{2}$. Which of the following is correct about velocity of image -



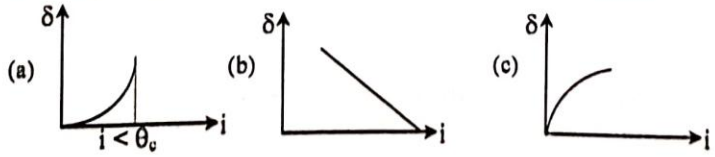
(A) x component is 12 m/s towards right
(B) y component is 8 m/s towards –y direction
(C) angle with x-axis is less than 53°
(D) angle with x-axis is more than 53°

Q.41 A luminous point object is placed at O, whose image is formed at I as shown in figure. Line AB is optic axis. Which of the following statements are correct ?



(A) If the lens is used to obtain the image, the lens must be a converging lens and position of its optical centre can be found out.
(B) If the mirror is used to obtain the image, the mirror must be a convex mirror whose pole will be at point of intersection of line OI with the optic axis.
(C) If the mirror is used to obtained the image, the mirror will be concave mirror and its centre of curvature can be found out.
(D) I is a real image.

Q.42 Following are graphs of angle of deviation versus angle of incidence.

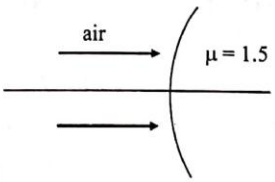


Based on the above graphs mark the correct options.
(A) Graph (a) may be a part of the graph for ray of light that travels from denser to rarer medium.
(B) Graph (b) may be for ray of light that is totally internally reflected from a denser to rarer medium boundary.
(C) Graph (c) may be a part of the graph for ray of light that travels from rarer to denser medium.
(D) Graph (b) may be a part of the graph for ray of light that is reflected from a plane mirror.

Q.43 In displacement method, the distance between object and screen is 96 cm. The ratio of height of two images formed by a converging lens placed between them is 4.
(A) Ratio of the height of object to the height of shorter image is 2
(B) Distance between the two positions of the lens is 32 cm
(C) Focal length of the lens is $\frac{64}{3}$ cm
(D) When the shorter image is formed on screen distance of the lens from the screen is 32 cm.

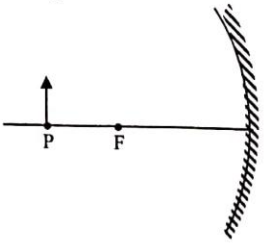
Q.44 Both ends of glass rod with an index of refraction 1.6 are ground and polished to convex hemispherical surfaces. The radius of curvature at the left end is 6 cm and at right end is 12 cm. The length of the rod between the vertexes is 25 cm. The object for the surface at the left end is an arrow that lies 23 cm to the left of the vertex of this surface. The arrow is 1.50 mm tall and right angles to the axis. Choose the correct option is-
(A) The object distance for the surface at right end of rod is – 3.3 cm.
(B) Object for the surface at right end of rod is virtual
(C) Final image is formed 1.9 cm to right of vertex at right end of rod.
(D) Final image is real.

Q.45 Parallel rays of light are falling on convex spherical surface of radius of curvature R = 20 cm. Refractive index of the medium is $\mu = 1.5$. After refraction from the spherical surface parallel rays



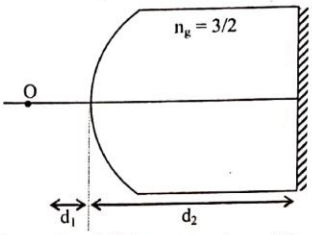
(A) actually meet at some point
(B) appears to meet after extending the refracted rays backwards
(C) meet (or appears to meet) at a distance of 30 cm from the spherical surface
(D) meet (or appears to meet) at a distance of 60 cm from the spherical surface

Q.46 The diagram below shows an object located at point P, 0.25 meter from a concave spherical mirror with principal focus F. The focal length of the mirror is 0.10 meter. How does the image initially change as the object begin to move from point P toward point F ?



(A) Its distance from the mirror decreases
(B) The size of image decreases
(C) Its distance from the mirror increases
(D) The size of images increases

Q.47 In the figure shown a point object O is placed in air on the principal axis. The radius of curvature of the spherical surface is 60 cm. I_f is the final image formed after all the refractions and reflections.

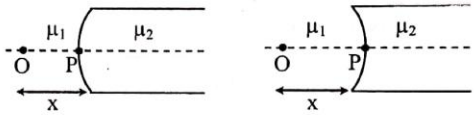


(A) If $d_1 = 120$ cm, then the 'I_f' is formed on 'O' for any value of d_2.
(B) If $d_1 = 240$ cm, then the "I_f' is formed on 'O' only if $d_2 = 360$ cm.
(C) If $d_1 = 240$ cm, then the 'I_f' is formed on 'O' for all values of d_2.
(D) If $d_1 = 240$ cm, then the 'I_f' cannot be formed on 'O'.

Passage Based Questions

Passage # 1 (Q.48 to 50)

A curved surface of radius R separates two media of refractive indices μ_1 and μ_2 as shown in figures(A) and (B) respectively



Figure(A) Figure(B)

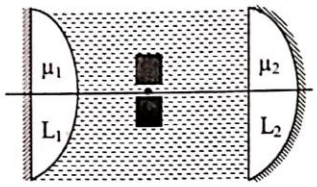
For a real object a image is virtual if the light rays diverge after refraction and real if they converge or become parallel after refraction.

Q.48 A point object is kept at point O in figure (A) then -
(A) real image is formed for all position of object if $\mu_2 > \mu_1$
(B) real image is formed only when $x > R$
(C) real image will form irrespective of μ_1 and μ_2
(D) real image is formed if $x > \dfrac{\mu_1 R}{\mu_2 - \mu_1}$ for $\mu_2 > \mu_1$

Q.49 If the point object is kept at O at a distance x in figure (A) then -
(A) virtual image is formed for any position of O for $\mu_2 < \mu_1$
(B) virtual image can be formed only if $x > R$ and $\mu_2 < \mu_1$
(C) virtual image can be formed only if $x < R$ and $\mu_2 < \mu_1$
(D) virtual image can never be formed

Q.50 If an object is kept at O at distance x from pole of figure(B) then -
(A) If $\mu_2 < \mu_1$ then virtual image is formed for any value of x
(B) If $\mu_2 < \mu_1$ then virtual image is formed for $x < \dfrac{\mu_1 R}{\mu_1 - \mu_2}$
(C) If $\mu_2 < \mu_1$ then real image is formed for any value of x
(D) If $\mu_2 < \mu_1$ then real image is always formed

Passage # 2 (Q.51 to 53)



A cylindrical tube filled with water ($\mu_w = 4/3$) is closed at its both ends by two silvered Plano convex lenses as shown in the figure. Refractive index of lenses L_1 and L_2 are 2.0 and 1.5 while their radii of curvature are 5 cm and 9 cm respectively. A point object is placed somewhere at a point O on the axis of cylindrical tube. It is found that the object and image coincide each other.

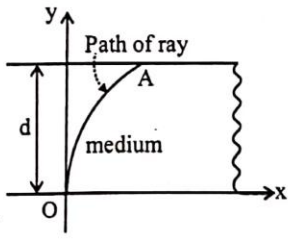
Q.51 The position of object w.r.t of lens L_1 is -
(A) 8 cm (B) 10 cm (C) 12 cm (D) 14 cm

Q.52 The position of object w.r.t. lens L_2 is -
(A) 8 cm (B) 10 cm (C) 12 cm (D) 14 cm

Q.53 The length of the cylindrical tube is -
(A) 16 cm (B) 18 cm (C) 20 cm (D) 22 cm

Passage # 3 (Q.54 & 55)

A long rectangular slab of transparent medium of thickness d is placed on table with length parallel to x-axis and width parallel to the y-axis. A ray of light traveling along y-axis at origin. The refractive index μ of the medium varies as $\mu = \sqrt{1 + e^{x/d}}$. The refractive index of the air is 1.

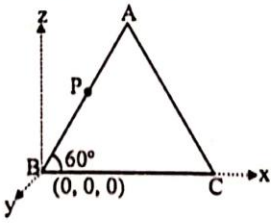


Q.54 Determine the x-coordinate of the point A, where the ray intersect the upper surface of the slab air boundary -
(A) d(ln 2) (B) 2d(ln 2) (C) $\frac{d(\ln 2)}{2}$ (D) None of these

Q.55 Write down the refractive index of the medium at A -
(A) $\sqrt{6}$ (B) $\sqrt{5}$ (C) $\sqrt{7}$ (D) $\sqrt{8}$

Passage # 4 (Q.56 to 58)

An equilateral prism ABC (RI = μ) is placed in air with its base side BC lying horizontally along X-axis as shown in the figure. A ray given by $\sqrt{3}\,z + x = 10$ is incident at a point P on face AB of prism.



Q.56 Find the value of μ for which the ray grazes the faces AC.

(A) $\frac{2}{\sqrt{3}}$ (B) $\sqrt{3}$ (C) $\frac{3\sqrt{3}}{2}$ (D) None of these

Q.57 Find direction of the finally refracted ray if $\mu = 3/2$.

(A) at 45° to x-axis (B) parallel to z axis (C) at 30° to z-axis (D) None of these

Q.58 Find the equation of ray coming out of prism if bottom BC is silvered for $\mu = \frac{3}{2}$?

(A) $z + \sqrt{3}\,x = 10$ (B) $z + x = 10$ (C) $\sqrt{3}\,z + x = 10$ (D) None of these

Passage # 5 (Q.59 to 61)

A thin convex lens L_1 of focal length f_1 and another thin convex lens L_2 of focal length f_2 are kept co-axially at such a distance apart that rays incident parallel to the optic axis on lens L_1 emerge parallel to the optic axis from lens L_2. Such an arrangement is called a 'beam expander' and it commonly used to increase the width of a beam. It is found that L_1 from a 'beam expander' with L_2 when they are at a distance 50 cm apart. It is also possible to form a 'beam expander' with lenses one of which is convex and the other concave. Let us have an arrangement of lens L_1 with another lens L_3 (concave) of focal length 10 cm. L_1 & L_3 are kept co-axially at a suitable distance 'd' apart such that rays incident parallel to optic axis on L_1 emerge parallel to the axis from L_3. This arrangement is shown in figure (A). With L_1 & L_3 forming a beam expander, let us locate an object AB at distance x from L_1, as shown in fig. (B) It is found that for $x < 20$ cm, the image of object AB formed by lens L_1 is virtual whereas for $x > 20$ cm, it is real. Let us now place AB such that $x = 30$ cm. Let I_1 be the image of object AB formed by lens L_1 and I′ be the final image.

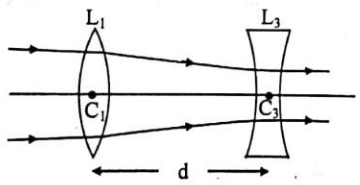


fig. (A)

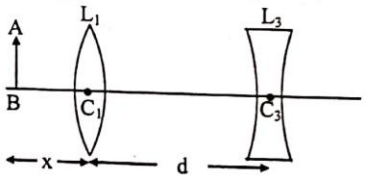


fig. (B)

Answer the following questions

Q.59 Focal length of lens L_2 is

(A) 40 cm (B) 30 cm (C) 20 cm (D) 10 cm

Q.60 I_1, the image of object AB formed by lens L_1, will act as a virtual object for lens L_3 which forms an image I′. Relative to I_1, I′ is

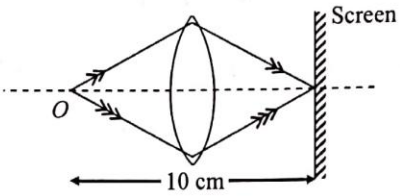
(A) Virtual, inverted and reduced four times in size (B) Virtual, erect and two times in size
(C) Real, inverted and four times in size (D) Virtual, erect and reduced two times in size

Q.61 The final image I′, relative to object AB, is

(A) Erect and twice in size (B) Erect and half in size
(C) Inverted and twice in size (D) Inverted and half in size

Passage # 6 (Q.62 & 63)

An object O is placed in front of a convex lens such that the lens forms a sharp image on the screen. The distance between the object and screen is 10 cm. The lens is made of glass of refractive index $\mu_g = \frac{3}{2}$. The surrounding medium is air with refractive index 1.



Q.62 If the surrounding air is replaced by water $\left(\mu_w = \frac{4}{3}\right)$, and still a sharp image is formed on the screen, then the focal length of convex lens (in air) f satisfies the condition -

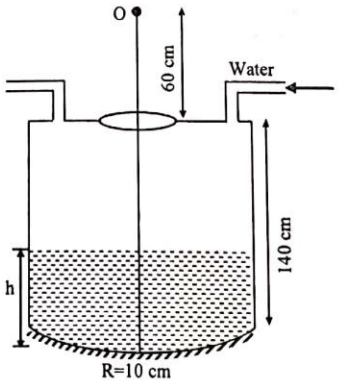
(A) $f \le 2.5$ cm (B) $f \le 0.625$ cm (C) $f \le 1.25$ cm (D) $f \le 5$ cm

Q.63 If focal length of convex lens in air is $\frac{20}{9}$ cm and surrounding medium is air, then magnification is -

(A) -2 (B) -3 (C) $-\frac{1}{2}$ (D) $-\frac{1}{3}$

Passage # 7 (Q.64 & 65)

A tank of depth 140 cm has silvered concave bottom of radius of curvature R = 10 cm. At the top of tank a thin small equiconvex lens made up of glass of refractive index 1.5 and focal length 40 cm is mounted. There is provision to fill water (μ = 4/3) in the tank to desired heights. A point object is placed at a distance 60 cm above lens.



Q.64 If height of water in tank is h = 50 cm, final image formed is –

(A) 30 cm above lens (B) 40 cm above lens (C) At object itself (D) Real

Q.65 If height of water in tank is h = 80 cm, final image formed is -

(A) 30 cm above lens (B) 40 cm above lens (C) At object itself (D) Real

Passage # 8 (Q.66 & 67)

It is possible to take a high quality photograph of a very fast moving object by illuminating the object a small fraction of a second. You may have come across photographs of a bullet penetrating a banana or an apple in many text books or magazines. This is called 'Stop Action' photography because the fast moving object travels a very short distance during the time of illumination. Harold Edgerton, the inventor of stroboscope, was a pioneer of this kind of photography. A normal photographic plate works properly if it receives an energy of 4 J during the exposure. To release this energy in a very small fraction of time, huge amount of power is required. Such huge power can not be generated directly from a battery because of its high internal resistance. To produce such power a capacitor is used. The time in which a capacitor discharges can be very short. Although, theoretically it would take a long time for a capacitor to discharge completely, it discharges almost completely in about 10 time constants. Consider the following situation.

A capacitor of 200 μF, storing 4 J energy is made to discharge through a flash light in 2 ms. The time constant of this circuit is 0.2 ms. This setup is used to take the picture of a bullet moving at a speed of 100 m/s. Assume that the flash light acts as a resistor and there is no other resistance in the circuit.

Q.66 The image of the moving bullet is formed on the photographic plate through a converging lens. If we use a lens of power 10 diopters, the lens to photographic plate distance is 15 cm and the bullet moves perpendicular to the principal axis, what is the distance covered by bullet as seen on photographic plate ?
(A) 1 cm (B) 5 cm (C) 10 cm (D) 20 cm

Q.67 What is the order of energy delivered to the flash light in 0.2 ms (approx.) ?
(A) 0.4 J (B) 1.83 J (C) 2.74 J (D) 3.45 J

Passage # 9 (Q.68 to 70)

A turnip sits before a thin converging lens, outside the focal point of the lens. The lens is filled with a transparent gel so that it is flexible; by squeezing its ends toward its center [as indicated in figure(a)], you can change the curvature of its front and rear sides.

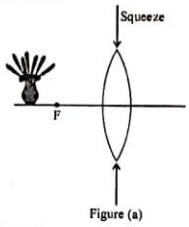


Figure (a)

Q.68 When you squeeze the lens, the image.
(A) moves towards the lens (B) moves away from the lens
(C) shifts up (D) remains as it is

Q.69 The lateral height of image.
(A) increases (B) decreases (C) remains same (D) data insufficient

Q.70 Suppose that the image must be formed on a card which is at a certain distance behind the lens [figure(b)], while you move the turnip away from the lens, then you should

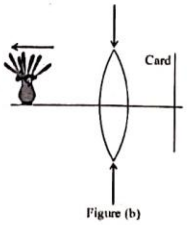


Figure (b)

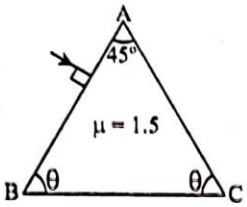
(A) decrease the squeeze of the lens (B) increase the squeeze of the lens
(C) keep the card and lens as it is. (D) move the card away from the lens

Column Matching Type Questions

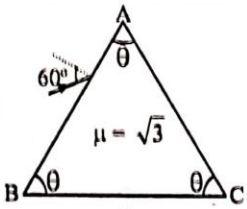
Q.71

Column I

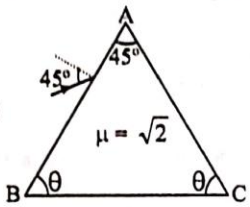
(A)



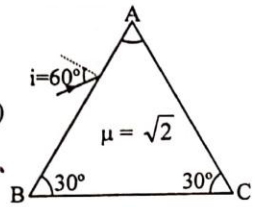
(B)



(C)



(D)



Column II

(P) At surface AC, TIR will take place

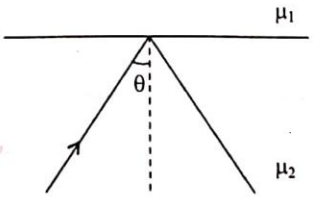
(Q) At surface AC, light will be refracted

(R) Ray refracted at AB will be parallel to base BC

(S) Ray refracted at AB will not be parallel to base BC

(T) Light will graze the surface AC.

Q.72 A ray of light strikes at the boundary separating two media at angle θ. μ_1 and μ_2 are refractive indices of media with ($\mu_2 > \mu_1$).



Column I

(A) When $\theta < \sin^{-1}\left(\frac{\mu_1}{\mu_2}\right)$ then deviation in the path of ray is

(B) Maximum deviation in the path of ray for refraction at boundary

(C) Maximum deviation in the path of ray for reflection at the boundary

(D) Deviation in the path at grazing angle of incidence

Column II

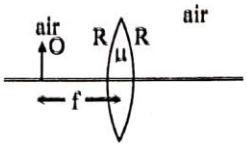
(P) $\frac{\pi}{2} - \sin^{-1}\left(\frac{\mu_1}{\mu_2}\right)$

(Q) $\pi - 2\sin^{-1}\left(\frac{\mu_1}{\mu_2}\right)$

(R) Zero

(S) $\sin^{-1}\left(\frac{\mu_1}{\mu_2}\sin\theta\right) - \theta$

Q.73 An object O (real) is placed at focus of an equi-bioconvex lens as shown in figure. The refractive index of lens is $\mu = 1.5$ and the radius of curvature of either surface of lens is R. The lens is surrounded by air . In each statement of List-I some changes are made to situation given above and information regarding final image formed as a result is given in List-II. The distance between lens and object is unchanged in all statements of List-I. Match the statement ins List-I with resulting image in List-II.

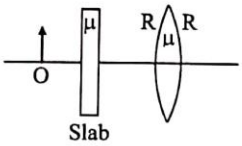


List-I **List-II**

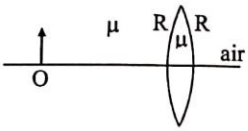
(P) If the refractive index of the lens is doubled (that is, made 2μ) then — (1) Final image is real

(Q) If the radius of curvature is doubled (that is, made 2R) then — (2) Final image is virtual

(R) If a glass slab of refractive index $\mu = 1.5$ is introduced between the object and lens as shown , then — (3) Final image becomes smaller in size in comparison to size of image before the change was made



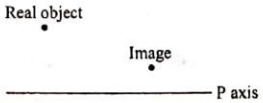
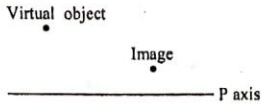
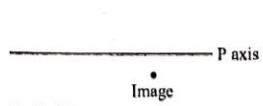
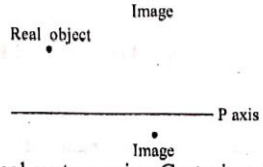
(S) If the left side of lens is filled with a medium of refractive index $\mu = 1.5$ as shown, then — (4) Final image is of same size of object



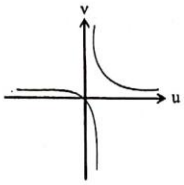
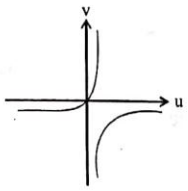
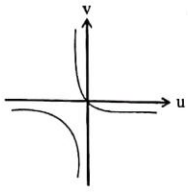
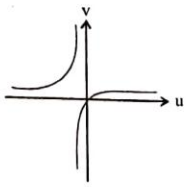
Codes :

	P	Q	R	S
(A)	1	(2,4)	(2,3)	3
(B)	(1,2)	(2,3)	(2,3)	(2,3)
(C)	(1,2)	(2,4)	2	3
(D)	(1,3)	(1,3)	(2,3)	(1,3)

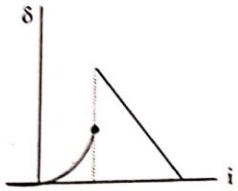
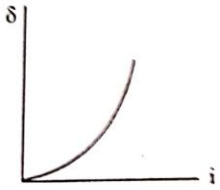
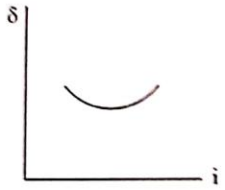
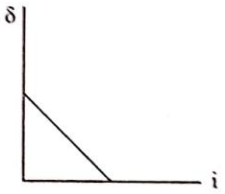
Q.74 In the I column, optical system are given. Match the optical system with the image and object combination possible. The nature of image is not known and the optical system can be at any position.

Column I	Column II
(A) Convex mirror	(P) 
(B) Concave mirror	(Q) 
(C) Converging lens	(R) 
(D) Diverging lens	(S) 

Q.75 Match the correct u - v graph with optical system using Cartesian sign conventions.

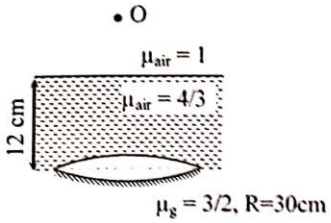
Column I	Column II
(A) Convex mirror	(P) 
(B) Convex lens	(Q) 
(C) Concave mirror	(R) 
(D) Concave lens	(S) 

Q.76 The entries of Column-I describe the path of rays and entries of Column-II, the deviation and angle of incidence plots. Match the entries

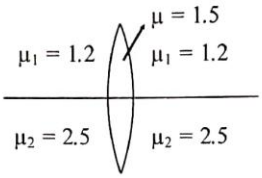
Column I	Column II
(A) A ray is falling on a plane smooth mirror	(P) 
(B) A ray is going from a rarer to denser medium	(Q) 
(C) A ray is going from a denser to rarer medium	(R) 
(D) A ray is falling on a prism	(S) 

Numeric Response Type Questions

Q.77 Figure show a mirrored equiconvex lens placed at 12 cm below water. Find position of object above the surface of water (in cm) such that its image coincides with itself.

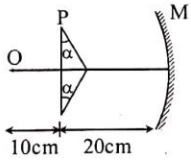


Q.78 A thin lens of material of refractive index $\mu = 1.5$ and focal length of 20 cm (when placed in air) is taken and two mediums of different refractive indices $\mu_1 = 1.2$ and $\mu_2 = 2.5$ are there covering upper and lower halves of the lens, respectively as shown in figure. If an object is placed on the principal axis, then its two images will form one after refraction from upper part and other after refraction from lower part. Consider the object to be at ∞, the separation between two images formed is x (in cm). Find the value of $\frac{x}{13}$.

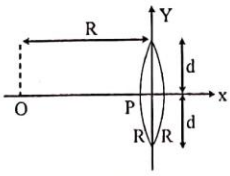


Q.79 A lens is held directly above a coin lying on a table and forms an image of it. After the lens has been vertically a distance equal to its focal length, it forms another image of the coin equal in size to previous image. If the diameter of the coin is 4.0 cm, what is the diameter (in cm) of the image ?

Q.80 Point O is the point object kept on the principal axis on a concave mirror M of radius of curvature 20 cm. P is a prism of angle $\alpha = 1.8°$. Light falling on the prism and then fall on the mirror. The distance between the images formed by the concave mirror due to this light is 'x' (in cm). Find the value of $100\ x/\pi$. (Take $\mu = 3/2$ for prism)



Q.81 A biconvex thin lens of radius of curvature R is made up of variable refractive index $\mu = 2\left(1+\frac{|y|}{d}\right)$. Assume very small aperture 2d << R. A point object O is placed at a distance R = 7.5 m on the principal axis from the lens (as shown). Due to variable refractive index of lens, there are infinite number of image on the principal axis. These image are spreaded over the length ℓ. Find the value of ℓ (in m).

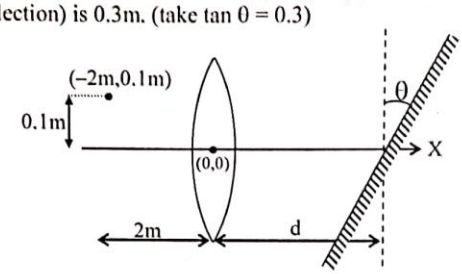


Q.82 A narrow light is incident on a plane-parallel having a refractive index of $n = \frac{17}{16}$ at an angle of 30° to the normal. As a result it is partially reflected and refracted. The refracted beam is reflected by the rear surface of the plate and then undergoes refraction again, emerging from the plate with a displacement of $4\sqrt{3}$ cm parallel to the primary reflected beam. Find the thickness of the plate in mm.

Q.83 A vessel, whose bottom is flat and perfectly reflecting, is filled with water (refractive index = 4/3) upto a height = 40 cm. A point object in air above is moving towards the water surface with a constant speed = 4 m/s. What is the relative speed of its final image (in m/s), as seen by the object itself, at a moment when the object is 30 cm above the water surface ?

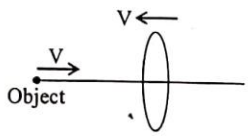
Q.84 Two converging lens have focal length f = 10 cm and f ′ = 20 cm respectively. The optical axes of the lenses coincide. This lens system is used to form an image of an object kept at a certain distance from the first lens. If the size of the final image does not depend on the distance of the object from the first lens. What is the distance (in cm) between the two lens ?

Q.85 A convex lens of focal length 1.5m is placed in a system of coordinate axis such that its optical center is at origin and principal axis coinciding with the x-axis. An object and a plane mirror are arranged on the principal axis as shown in figure. Find the value of d(in m) so that y-coordinate of image (after one refraction through lens and one reflection) is 0.3m. (take tan θ = 0.3)



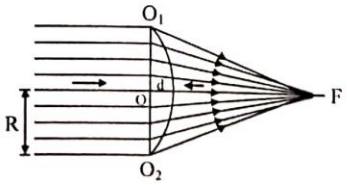
Q.86 A ray of light enters a spherical liquid drop (refractive index = $\sqrt{3}$) from air at an angle of incidence $\theta(\neq 0)$. it suffers two internal reflections (not TIR) inside the drop and finally comes out of the drop. If $\theta(\neq 0)$ is such that the deviation of the ray with respect to its original direction is minimum, find the value of $12 \sin^2 \theta$.

Q.87 In the diagram shown, the lens is moving towards the object with a velocity 2 m/s and the object is also moving towards the lens with the same speed. What is speed of the image with respect to earth when the object is at a distance 2f from the lens? (f is the focal length) :

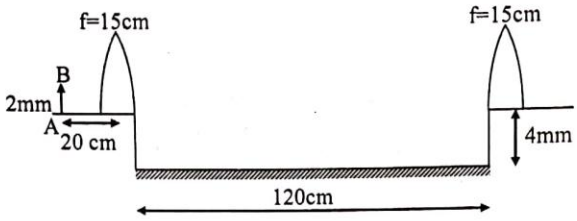


Q.88 A convex lens of focal length f = 10 cm is cut through a dimeteral plane into two semicircular halves. In doing so, glass of 0.5 mm thickness is lost. The two halves are then joined together. This lens is placed symmetrically 5 cm in front of a slit which is illuminated with light of wavelength λ = 5000 Å. A screen is placed on the other side of the lens at a distance of 90 cm from the lens, perpendicular to the optical axis of the lens. Find total number of bright fringes formed.

Q.89 Determine the thickness d (in cm) in the centre of a plano convex lens of refractive index μ = 1.5 for which a parallel beam of light, which is incident perpendicularly on the flat surface gets focused at F (See figure), if OF = focal length (f) = 12 cm., and $OO_1 = OO_2 = R = 5$ cm.



Q.90 A convex lens of focal length 15 cm is split into two halves and the two halves are placed at a separation of 120 cm. Between the two halves of convex lens a plane mirror is placed horizontally and at a distance of 4 mm below the principal axis of the lens halves. An object AB of length 2 mm is placed at a distance of 20 cm from one half lens as shown in figure. The final image of the point A is formed at a distance of $\frac{n}{3}$ mm from the principle axis. Determine the value of n.

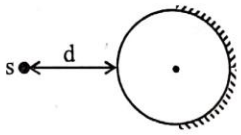


Q.91 A sphere of radius R made of material of refractive index $\frac{3}{2}$ is placed in a medium of refractive index $\frac{4}{3}$. An object is placed KR distance from the sphere. Its final real image is formed at equidistant from the diametrically opposite end of the sphere. Find K.

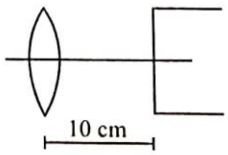
Q.92 There are two spherical surfaces of radii 30 cm and 60 cm. They can be arranged in different ways to get different converging lens. If all lenses are made of glass of $\mu = \frac{3}{2}$. Then find the ratio of maximum and minimum focal lengths obtained.

Q.93 A thick equi-convex lens of refractive index 1.5 and radius of curvature R is placed on a horizontal plane mirror, The space between lens and mirror is filled with a liquid of refractive index μ. An object is held at a distance D vertically above the lens and it is found that its own image coincides with it. Find the value of $\mu + \frac{R}{D}$.

Q.94 A very expensive diamond is polished into a perfect sphere of radius 5 cm. The back surface of the sphere is then covered with silver. How far in front of the sphere should a source of light s be placed in order for the image to coincide with the source. The index of refraction of diamond is 2.4. If the distance is 5x cm then x is



Q.95 Focal length of a thin convex lens is 30 cm. At a distance of 10 cm from the lens there is a plane refracting surface of refractive index 3/2. The parallel rays incident on lens converge at a distance of B × 10 cm from the lens, then value of B is

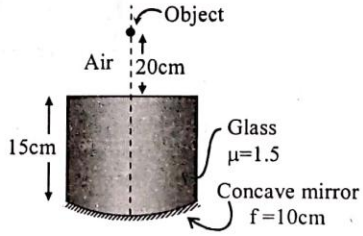


Q.96 A capillary tube is made of glass with the index of refraction 3 and outer radius of the tube is 30 cm. The tube is filled with a liquid with the index of refraction 2. What should be the minimum internal radius of the tube r so that any ray that hits the tube would enter the liquid. If it is 5 × n cm. Find n. (Ray of light is incident in the plane of cross-section)

Q.97 A plane mirror is suspended vertically at the centre of a large thin-walled spherical flask filled with water. The diameter of the flask is 10 inches. An observer whose eye is 35 inches from the mirror as shown in figure tries to see an image of his own eye. What is distance of the image from the eye (in inches). The effect of the thin glass walls of the flask be neglected.
If it is n × 3. Find the value of n.
Take $\mu_{water} = \frac{4}{3}$.

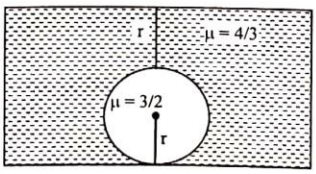
Q.98 Visible light of variable wavelength is incident normally on a thin sheet of plastic film in air. The reflected light is a minimum only for
$\lambda = 512$ nm and $\lambda = 640$ nm in the visible spectrum. What is the minimum thickness (in μm) of the film ($\mu = 1.28$) ?

Q.99 After all possible reflection and refractions the final image is located at a distance 'x' cm from air-glass interface. Then value of $\frac{7x}{2}$ is

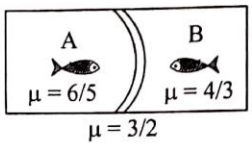


Q.100 The xz plane is the boundary between two transparent medium. Medium-I with $y \geq 0$ has refractive index μ and medium-II with $y \leq 0$ has a refractive index 1. A ray of light in medium-I, given by vector $\vec{n} = \hat{i} - \sqrt{3}\,\hat{j}$ is incident on the plane of separation. If the reflected and refracted rays make an angle of 90° with each other, then the value of μ is $\sqrt{k}$. Find the value of k.

Q.101 A glass sphere having refractive index (3/2) is having small irregularity at its centre. It is placed in a liquid of refractive index $\frac{4}{3}$ such that surface of liquid is r high above sphere where r is radius of sphere. If irregularity is viewed from above normally, the distance is K cm from centre where eye will observe the irregularity. Then find the value of K. (r = 10 cm)

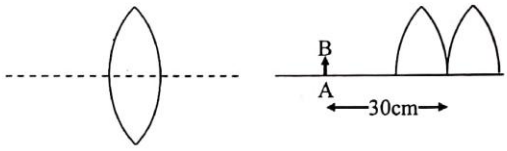


Q.102 An aquarium is divided into two parts by a thin curved glass sheet of radius of curvature 30 cm and refractive index 3/2. Left hand side is filled with liquid having refractive index 6/5 and right hand side with having refractive index 4/3. There are two fishes each 6 cm away from glass sheet on the principal axis of glass sheet. Find the apparent position (in cm) of fish B as seen by the fish A.

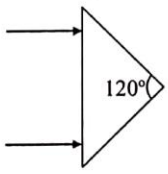


Q.103 A double convex lens forms a real image of an object of on a screen which is fixed. Now lens is given a constant velocity v = 1 m/s along its axis and away from the screen. For the purpose of forming image always on the screen the object is also required to be given appropriate velocity. Find the velocity (in m/s) of the object at the instant its size is doubled the size of the image.

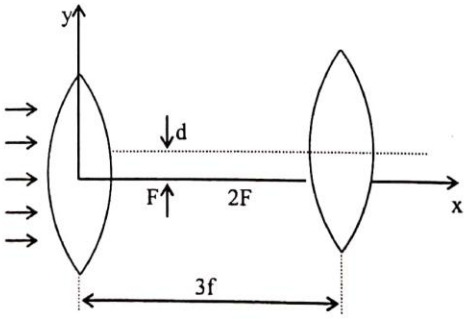
Q.104 If a thin convex lens of focal length 20 cm is cut into two pieces from a plane passing through the pole, then both the pieces (touching each other) kept as shown in figure. If a object AB of length 2 cm is kept at distance of 30 cm. Find the height (in cm) of the image.



Q.105 An isosceles prism of angle 120°C has a refractive index 1.44. Two parallel monochromatic rays enter the prism parallel to each other in air as shown. The rays emerge from the opposite faces make an angle K [$\sin^{-1}$ (0.72) – 30°] with each other. Then find the value of K.

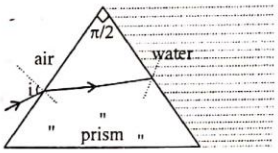


Q.106 In the figure shown, the focal length of the two thin convex lenses is the same = f. They are separated by a horizontal distance 3f and their optical axes are displaced by a vertical separation 'd' (d << f), as shown. Taking the origin of coordinates O at the centre of the first lens, find the x and y coordinates of the point where a parallel beam of rays coming from the left finally get focused?

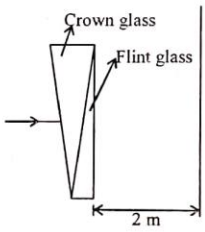


Q.107 A equilateral prism provides the least deflection angle 46° in air. Find the refracting index of an unknown liquid in which same prism gives least deflection angle of 30°.

Q.108 A light ray is incident on a right angled triangular prism and refracted at the first surface. If the refractive index of prism is $\mu_g = 1.5$ & refractive index of water $\mu_w = 4/3$. Calculate the smallest angle of incidence at the first surface for which the refracted ray does not undergo internal reflection at the second surface.



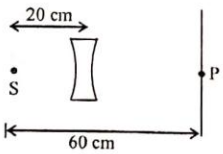
Q.109 The refractive indices of the crown glass for violet and red lights are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. A prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other thin flint glass prism is combined with the crown glass prism such that the net mean deviation is 1.5° anticlockwise.



(i) Determine the angle of the flint glass prism.

(ii) A screen is placed normal to the emerging beam at a distance of 2m from the prism combination. Find the distance between red and violet spot of the screen. Which is the topmost colour on screen.

Q.110 A point source of light is placed 60 cm away from screen. Intensity detected at point P is I. Now a diverging lens of focal length 20 cm is placed 20 cm away from S between S and P. The lens transmits 75% of light incident on it. Find the new value of intensity at P.



Q.111 A parallel beam of light falls normally on the first face of a prism of small angle. At the second face it is partly transmitted and partly reflected, the reflected beam striking at the first face again, and emerging from it in a direction making an angle 6°30' with the reversed direction of the incident beam. The refracted beam is found to have undergone a deviation of 1°15' from the original direction. Find the refractive index of the glass and the angle of the prism.

ANSWER KEY

Single Correct Option type Questions

1. (D)	**2.** (A)	**3.** (B)	**4.** (B)	**5.** (D)	**6.** (C)	**7.** (C)
8. (C)	**9.** (B)	**10.** (A)	**11.** (A)	**12.** (C)	**13.** (A)	**14.** (A)
15. (A)	**16.** (A)	**17.** (C)	**18.** (D)	**19.** (C)	**20.** (C)	**21.** (D)
22. (C)	**23.** (D)	**24.** (D)	**25.** (D)	**26.** (D)	**27.** (A)	

Statement Based Questions

28. (C)	**29.** (C)	**30.** (C)	**31.** (D)	**32.** (B)	**33.** (D)

Multiple Correct Option type Questions

34. (A,C)	**35.** (A,C)	**36.** (C,D)	**37.** (A,C)	**38.** (A)	**39.** (B,C)	**40.** (A,B,C)
41. (A,C,D)	**42.** (A,B,D)	**43.** (A,B,C,D)	**44.** (A,B,C,D)	**45.** (A,D)	**46.** (C,D)	**47.** (A,B)

Passage Based Questions

48. (D)	**49.** (A)	**50.** (B)	**51.** (B)	**52.** (A)	**53.** (B)	**54.** (B)
55. (B)	**56.** (A)	**57.** (B)	**58.** (C)	**59.** (B)	**60.** (A)	**61.** (B)
62. (B)	**63.** (A,C)	**64.** (C,D)	**65.** (C,D)	**66.** (C)	**67.** (A)	**68.** (D)
69. (C)	**70.** (B)					

Column Matching Type Questions

71. $A \to P,S$; $B \to Q,R$; $C \to Q,S$; $D \to P,S$

72. $A \to S$; $B \to P$; $C \to Q$; $D \to R$

73. (B)

74. $A \to P,R$: $B \to Q,S$: $C \to Q,S$: $D \to P,R$

75. $A \to P$: $B \to S$: $C \to R$: $D \to Q$

76. $A \to S$: $B \to Q$: $C \to P$: $D \to R$

Numeric Response Type Questions

77. 9	**78.** 5	**79.** 8	**80.** 5	**81.** 6	**82.** 75	**83.** 8
84. 30	**85.** 5	**86.** 9	**87.** 2	**88.** 5	**89.** 2	**90.** 8
91. 8	**92.** 3	**93.** 2	**94.** 5	**95.** 4	**96.** 3	**97.** 7
98. 1	**99.** 5	**100.** 3	**101.** 5	**102.** 5	**103.** 3	**104.** 1

105. 2 **106.** (5f, 2d) **107.** $\frac{8}{5\sqrt{2}}$ **108.** $\sin^{-1}\frac{\sqrt{17}}{6}$ **109.** (1) 2°, (2) $\frac{4\pi}{9}$ mm

110. 0.27 I **111.** $\mu = \frac{13}{8}$, $A = 2^\circ$

Chapter 28

Wave Optics

Single Correct Option Type Questions

Q.1 A transparent slab of thickness t and refractive index μ is inserted in front of upper slit of YDSE apparatus. The wavelength of light used is λ. Assume that there is no absorption of light by the slab. Mark the INCORRECT statement -

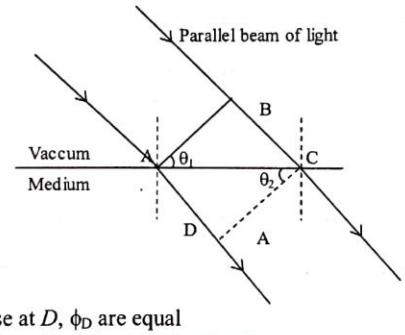
(A) The intensity of dark fringes will be zero, if slits are identical

(B) The change in optical path due to insertion of plate is μt

(C) For marking intensity maximum at the centre of screen, the thickness could be $\frac{5\lambda}{(\mu-1)}$

(D) For marking intensity zero at the centre of screen, the thickness could be $\frac{5\lambda}{2(\mu-1)}$

Q.2 Figure shows a parallel beam of light travelling in vacuum and incident on surface of medium of refractive index μ. Mark the INCORRECT statement -



(A) Phase at C . ϕ_C and phase at D, ϕ_D are equal

(B) Angle θ_1 and θ_2 are angles of incidence and refraction respectively

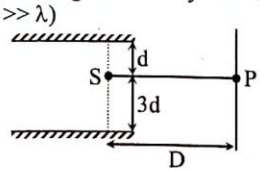
(C) $AD = \mu\,(BC)$

(D) Phase at A, ϕ_A and phase at B, ϕ_B are equal

Q.3 In young double slit experiment $\frac{d}{D} = 10^{-4}$ and wavelength of light is used 6000Å. At a point P on the screen resulting intensity is equal to the intensity due to individual slit I_0. Then the distance of point P from the central maximum is

(A) 2 mm (B) 1 mm (C) 0.5 mm (D) 4 mm

Q.4 Consider the optical system shown in the figure that follows. The point source of light S is having wavelength equal to λ. The light is reaching screen only after reflection. For point P to be 2nd maxima, the value of λ would be - ($D >> d$ and $d >> \lambda$)

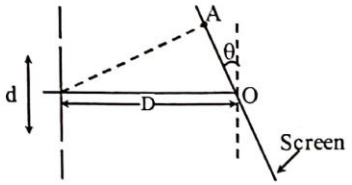


(A) $\frac{12d^2}{D}$ (B) $\frac{6d^2}{D}$ (C) $\frac{8d^2}{D}$ (D) $\frac{24d^2}{D}$

Q.5 Interference fringes were produced using white light in a double slit arrangement. When a mica sheet of uniform thickness of refractive index 1.6 (relative to air) is placed in the path of light from one of the slits, the central fringe moves through some a distance. This distance is equal to the width of 30 interference bands if light of wavelength 4800 Å is used. The thickness (in μm) of mica is -

(A) 90 (B) 12 (C) 14 (D) 24

Q.6 In a standard YDSE setup if the screen is kept tilted as shown, find the distance OA if first maximum is formed at A. Wavelength of light emitted by source is λ -



(A) $\frac{D\lambda\sec\theta}{d+\lambda\tan\theta}$ (B) $\frac{D\lambda\sec\theta}{d+\lambda\sin\theta}$ (C) $\frac{D\lambda\cos\theta}{d+\lambda\tan\theta}$ (D) $\frac{D\lambda\sec\theta\tan\theta}{d+\lambda\tan\theta}$

Q.7 Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\frac{\pi}{2}$ at point A and π at point B. Then the difference between the resultant intensities at A and B is -

(A) 2I (B) 4I (C) 5I (D) 7I

Q.8 In a YDSE apparatus, d = 2 mm, λ = 600 nm, D = 1 m. The slits individually produce same intensity on the screen. Find the position (distance from central maximum) of point where intensity is $\frac{3}{4}$ times of the maximum intensity on screen.

(A) 0.01 mm (B) 13×10^{-4} mm (C) 0.05 mm (D) 1.5×10^{-4} mm

Q.9 When a thin transparent sheet of refractive index $\mu = \frac{3}{2}$ is placed near one of the slits in Young's double slit experiment, the intensity at the centre of the screen reduces to half of the maximum intensity. The minimum thickness of the sheet should be -

(A) $\frac{\lambda}{4}$ (B) $\frac{\lambda}{8}$ (C) $\frac{\lambda}{2}$ (D) $\frac{\lambda}{3}$

Q.10 Coherent light consisting of two wavelengths λ_1 = 4500 Å & λ_2 = 6000 Å is sent through both slits of a Young's double slit apparatus

(A) Central maxima for both wavelengths will not coincide

(B) The third order bright fringe of λ_1 will coincide with the fourth order bright fringe of λ_2

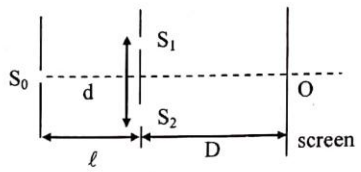
(C) The third order bright fringe of λ_2 will coincide with fourth order bright fringe of λ_1

(D) The fringes of wavelength λ_1 will be wider than the fringes of wavelength λ_2

Q.11 The figure shows a schematic diagram showing the arrangement of Young's double slit experiment

$d << l$ and $d << D$, $\frac{\lambda}{d} << 1$

Choose the correct statement related to wavelength of light used.

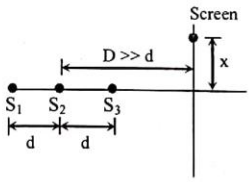


(A) Larger the wavelength of light larger the fringe width.
(B) If white light is used in YDSE, then the violet color forms its first maxima closest to the central maxima.
(C) The central maxima of all the wavelengths coincide.
(D) All the above statements are correct.

Q.12 In young's double slit experiment. Assume intensity of each source is I_0 and K_1 is equal to difference of maximum and minimum intensity. Now intensity of one source is made $\frac{I_0}{4}$ and K_2 is again difference of maximum and minimum intensity. Then $\frac{K_1}{K_2} =$

(A) 4 (B) 3 (C) $\frac{3}{4}$ (D) 2

Q.13 Three coherent point sources S_1, S_2 and S_3 are placed on a line perpendicular to the screen as shown in the figure. The wavelength of the light emitted by the sources is λ. The distance between adjacent sources is $d = 3\lambda$. The distance of S_2 from the screen is D ($>> \lambda$). Find the minimum (non zero) distance x of a point P on the screen at which complete darkness is obtained.



(A) $\frac{2\sqrt{2}D}{7}$ (B) $\frac{\sqrt{17}D}{8}$ (C) $4\sqrt{5}D$ (D) $\frac{4\sqrt{2}D}{7}$

Q.14 The refractive index of material of a convex lens is changing with time as $\mu = \mu_0 (1+ \alpha \sin \omega t)$ .At $t = 0$ the focal length of the lens is f and μ_0, α, ω are constant (α, is very small). A luminous point object is placed on principal axis at distance 3f from the optical centre. The image appears to oscillate simple hamonically the amplitude of image is

(A) $\frac{3\alpha f\mu_0}{2(\mu_0 - 1)}$ (B) $\frac{9\alpha f\mu_0}{4(\mu_0 - 1)}$ (C) $\frac{9\alpha f\mu_0}{2(\mu_0 - 1)}$ (D) None

Q.15 In the Young's double slit experiment, thin sheet of mica is placed over one of the two slits. As a result, the centre of the fringe pattern on the screen shifts by an amount corresponding to 30 dark bands. The wavelength of monochromatic light, used in this experiment is 480 nm, and the refractive index of the mica is 1.60. The thickness of mica sheet is

(A) 0.0090 mm (B) 0.0120 mm (C) 0.0240 mm (D) 0.0360 mm

Q.16 In YDSE, what is the minimum slit separation d for interference to produce at least one more maximum other than the central maximum ? (λ is the wavelength of incident electromagnetic wave)

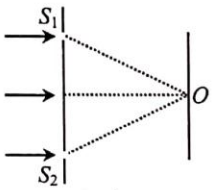
(A) $d \geq 5\lambda$ (B) $d \geq 3\lambda$ (C) $d \geq \lambda$ (D) There is no minimum d

Q.17 A double-slit apparatus is used to observe an interference pattern projected on a screen from a stationary light source. If the light source is instead moved toward the double slits at constant speed along the axis of symmetry, what will be observed on the screen ?

(A) The interference pattern will remain unchanged
(B) The fringes will move farther apart to a new fixed direction
(C) The fringes will move closer together to a new fixed distance.
(D) The fringes will continue to move further and farther apart as the source is brought closer.

Statement Based Questions

Q.18 **Statement-1 :** In YDSE, as shown in figure, central bright fringe is formed at O. If a liquid is filled between plane of slits and screen, the central bright fringe is shifted in upward direction.



Statement-2 : If path difference at O increases y-coordinate of central bright fringe will change.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.19 **Statement-1 :** In Young's experiment, the fringe width for dark fringes is equal to that for white fringes.
Statement-2 : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Q.20 **Statement-1 :** In Young's double slit experiment having two identical slit, if width of one of slit is increased, then intensities of both bright and dark fringes will increase.
Statement-2 : On increasing the width of one of slit in YDSE, there will be no point on the screen which is physically dark (zero intensity).

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

Q.21 A thin paper of thickness 0.02 mm having refractive index 1.45 is pasted across one of the slit in a Young's double slit experiment. The paper transmits 4/9 of light falling on it. (λ_{light} = 600 nm).

(A) Amplitude of light wave transmitted through the paper will be 2/3 time of incident wave.

(B) The ratio of maximum and minimum intensity in the fringe pattern will be 25.

(C) The total number of fringe crossing the centre if an identical paper is pasted on the other slit is 15.

(D) The ratio of maximum and minimum intensity in the pattern will be 5.

Q.22 A double-slit apparatus is set up and green light is used to form the interference pattern. The green light is then replaced by red light which of the following changes may allow the spacing of the bright bands on the screen to remain unaffected by the change of light colour ?

(Given that the distance between the slits is d and that between the plane of the slits and the screen is D) -

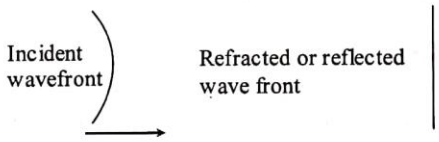
(A) Decrease 'D'

(B) Increase 'd'

(C) Increase 'd' and decrease 'D'

(D) Increase the brightness of the light source

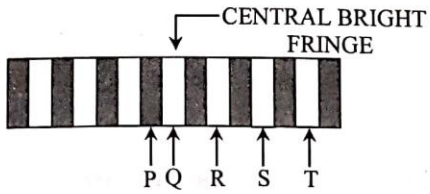
Q.23 Figure shows an incident wavefront and refracted or reflected wavefront after a single optical device -



which of the following may be the optical device-

(A) concave lens (B) convex lens (C) concave mirror (D) convex mirror

Q.24 The figure shows the interference pattern obtained in double-slit experiment using light of wavelength 600 nm. P, Q, R, S and T are marked on five fringes -



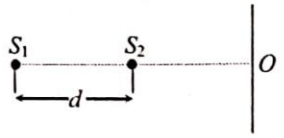
(A) The third order bright fringe is R.

(B) The third order bright fringe is T

(C) The fringe resulting from a phase difference of 4π is S

(D) If ΔX_A and ΔX_C represent path differences between waves interfering at P and R respectively then $(|\Delta X_C| - |\Delta X_A|)$ is equal to 300 nm.

Q.25 Two point monochromatic and coherent sources of light of wavelength λ are placed on the dotted line in front of an infinite screen. The source emit waves in phase with each other. The distance between S_1 and S_2 is 'd' while their distance from the screen is much larger -



(A) if d is $\frac{3\lambda}{2}$, at O minima will be observed

(B) if d is $\frac{11\lambda}{6}$, then intensity at O will be $\frac{3}{4}$ of maximum intensity

(C) if d is 3λ, O will be a maxima

(D) if d is $\frac{7\lambda}{6}$, the intensity at O will be $\frac{3}{4}$ of maximum intensity

Q.26 In YDSE the lower slit is covered by a thin glass sheet. Which of the following option(s) may restore central maximum at perpendicular bisector of original slits?

(A) Turning incident rays anticlockwise

(B) Displacing upper slit up a little

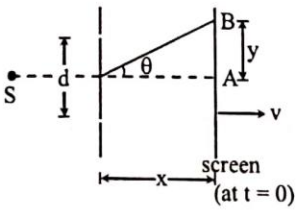
(C) Using a thin prism in between plane of slit & screen

(D) Using a converging lens in between plane of slit & screen with bisector of slit as its optical axis

Q.27 In a YDSE set up the separation between the slits is 3×10^{-3} m. The distance between the slits and the screen is 1.5 m. Light of wavelength in the visible range (4000 Å – 8000 Å) is allowed to fall on the slits. The wave length in the visible region that will be present on the screen at a distance of 1.5×10^{-3} m from central maxima is

(A) 4500 Å (B) 5000 Å (C) 6000 Å (D) 7500 Å

Q.28 In YDSE arrangement shown here the screen starts moving towards right at t = 0 as shown. Position of any point 'B' on the screen can be specified by y or by an angle θ as shown. Choose the correct statement(s) –



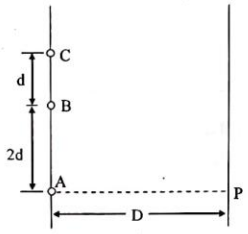
(A) At any point on the screen (for a given y) fringe order decreases with time

(B) At any point on the screen (for a given θ) fringe order decreases with time

(C) At any point B on the screen (for a given y), at t = 0 3rd order minima was positioned. After some time 3rd order maxima may be obtained at that point

(D) Position (for a given y) where 3rd order maxima is positioned at t = 0. 2nd order minima is positioned at time $t = \frac{x}{v}$

Q.29 In the figure A, B and C are three slits each of them individually producing the same intensity I_0 at P when they are illuminated by parallel beam of light of wavelength λ. It is given that $BP - AP = \frac{\lambda}{2}$. Also given that $d << D$, then wavelength λ and resultant intensity I at P will be ($\lambda << d$) -



(A) $\lambda = \frac{2d^2}{D}$ (B) $\lambda = \frac{4d^2}{D}$ (C) $I = 2I_0$ (D) $I = I_0$

Q.30 - In a Young's double slit experiment

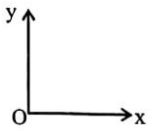
(A) if a point source is placed symmetrically from both the slits then interference will be observed on the screen

(B) if a point source is placed un-symmetrically from both the slits then interference will be observed on the screen

(C) if two slits are illuminated by two independent sources then the interference will be observed on the screen

(D) intensity of light at two slits should be same for better interference

Q.31 Two coherent sources A & B emitting light of wavelength λ are placed at positions $(-D, 0)$ and $(-D, 3\lambda)$ respectively $D >>> \lambda$ -



(A) number of minima on y axis is 6

(B) number of minima is more than number of maxima on y axis

(C) number of maxima on x axis is 3

(D) number of maxima on x axis is more than number of minima on x axis

Q.32 Which of the following is correct?

(A) Young's double slit experiment uses in coherent source

(B) Incoherent sources may having variable phase difference.

(C) Young's double slit experiment uses in incoherent source

(D) Incoherent sources must having same phase difference.

Passage Based Questions

Passage # 1 (Q.33 to 35)

The YDSE apparatus is modified by placing an isotropic transparent plate of high melting point in front of one of the slits. The refractive index of the plate is $\mu_r = 1.5$ at room temperature and its thickness is $t = 2\ \mu m$. The refractive index of plate will increase when temperature increases and temperature coefficient of refractive index of the plate (i.e., the fractional change in refractive index per unit rise in temperature) is $3\times10^{-3}/°C$. The incident light is having wavelength $\lambda = 6000$ Å. The separation between the slits is $d = 0.2$ cm, and separation between the slit and the screen is 2m.

Based on above information, answer the following questions :

Q.33 Before insertion of plate, mid-point of screen is location of central maxima, then this point after the insertion of slab is -

(A) a point of central maxima
(B) a point of maxima but not the central maxima
(C) a point of minima
(D) neither a point of maxima nor of minima

Q.34 If the plate is heated so that it temperature rises by 100°C, then how many fringes will cross a particular point on the screen ? (Neglect the thermal expansion of plate) -

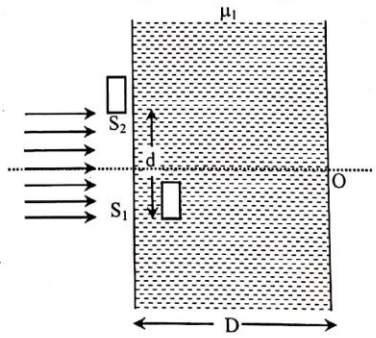
(A) 1000 (B) 1 (C) 100 (D) $\frac{1}{100}$

Q.35 If intensity of uncovered slit is I_0 and that of covered slit is $\frac{I_0}{2}$, then intensity at mid-point of the screen is -

(A) $I_0\left[\frac{3}{2}-\frac{1}{\sqrt{2}}\right]$ (B) $I_0\times\frac{3}{2}$ (C) $4I_0$ (D) $I_0\left[1-\frac{1}{\sqrt{2}}\right]$

Passage # 2 (Q.36 to 38)

A young double slit apparatus is immersed in a liquid of refractive index μ_1. The slit plane touches the liquid surface. A parallel beam of monochromatic light of wavelength 5000 Å is incident normally on the slits.



Q.36 Find the fringe width-

(A) $\frac{D\lambda}{\mu_2 d}$ (B) $\frac{D\lambda}{\mu_1 d}$ (C) $\frac{\mu_1 d}{D\lambda}$ (D) $\frac{\mu_2 d}{D\lambda}$

Q.37 If one of the slits (say s_2) is covered by a transparent slab of refractive index μ_2 and thickness t as shown, then find the new position of central maxima.

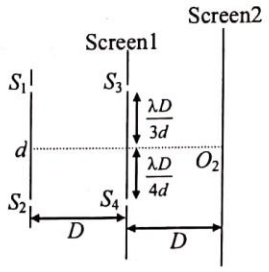
(A) $\frac{D(\mu_2-1)t}{d\mu_1}$ (B) $\frac{D(\mu_2+1)t}{d\mu_1}$ (C) $\frac{d\mu_1}{D(\mu_2-1)t}$ (D) $\frac{d\mu_1}{D(\mu_2+1)t}$

Q.38 Now the other slit S_1 is also covered by a slab of same thickness and refractive index μ_3 as shown in the figure due to which the central maxima recovers its position. Find the value of μ_3-

(A) $\mu_3 = \mu_2 + \mu_1 + 1$ (B) $\mu_3 = \mu_2 - \mu_1 + 1$ (C) $\mu_3 = \mu_2 + \mu_1 - 1$ (D) None of these

Passage # 3 (Q.39 to 41)

In YDSE two slits S_1 and S_2 are giving light of wavelength λ and intensity I_0 and are in the same phase. Two pin holes S_3 and S_4 are made in screen 1 as shown in figure.



Q.39 The ratio of intensity at S_3 and S_4 will be -

(A) $\frac{1}{2}$ (B) 2 (C) 1 (D) ∞

Q.40 The ratio of maximum and minimum intensity on screen 2 is -

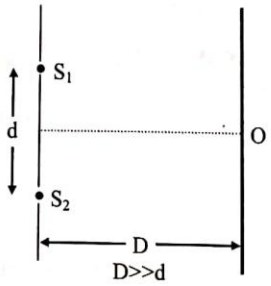
(A) $\left(\frac{\sqrt{2}+1}{\sqrt{2}-1}\right)$ (B) $\left(\frac{\sqrt{2}+1}{\sqrt{2}-1}\right)^2$ (C) $\frac{4}{1}$ (D) None of these

Q.41 The intensity of light at a point equidistant from S_3 and S_4 on screen 2 is -

(A) $3I_0$ (B) $9I_0$ (C) $(3+\sqrt{6})I_0$ (D) zero

Passage # 4 (Q.42 to 44)

In Young's experiment, light of wavelength 6000Å is incident on the double slits. Intensity of central maximum, formed at O is I_0, and the angular fringe-width is 0.1°. If a thin transparent plate 'A' is placed in the path of one of the interfering beams, it is found that smallest thickness of the plate, for which intensity at O becomes half of maximum, is 250 nm. Also, the zero order fringe earlier at O now forms 0.5 mm from O. However, instead of plate 'A', if a plate 'B' made of another material is placed in the path of one of the interfering beams, smallest thickness of B for which intensity at O becomes zero is 300 nm. Neglect absorption of light by the plate. Answer the following questions :



Q.42 Refractive index of plate 'A' is

(A) 1.4 (B) 1.5 (C) 1.6 (D) 1.82

Q.43 Refractive index of plate 'B' is

(A) 2 (B) 1.8 (C) 1.65 (D) 1.48

Q.44 Distance of screen from the double slits is

(A) 1.1 m (B) 1.4 m (C) 0.8 m (D) 1.5 m

Passage # 5 (Q.45 to 47)

Two coherent point light sources are placed at $x = -d/2$ and $x = d/2$. These sources are surrounded by a spherical screen having equation $x^2 + y^2 + z^2 = R^2$ (where $R >> d$). The sources emit monochromatic light of wavelength λ (= d/3).

Waves from both the sources reach screen and superimpose. When waves reaching any point on the screen have a constant path difference of $n\lambda$ (where λ is wavelength of light and n is some integer), the superposition of these waves is constructive in nature (i.e. maximum intensity) n may be called as order of maximum.

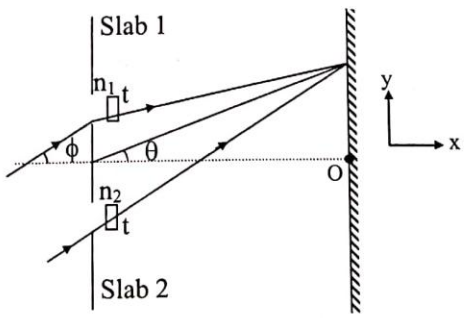
Q.45 The number of maximas on the screen
(A) 7 (B) 12 (C) 6 (D) None of these

Q.46 As screen is a bounded one, therefore the length of maxima is finite. Which of the following data is correct about shape and length of second order maxima ?
(A) hyperbola, $\frac{2\pi R\sqrt{5}}{3}$ (B) circle, $\frac{2\pi R\sqrt{5}}{3}$
(C) hyperbola, $\frac{2\pi R}{3}$ (D) circle, $\frac{2\pi R}{3}$

Q.47 Which of the statements is incorrect about the interference experiment explained above
(A) if radius of spherical screen is doubled the intensity of maxima will become one fourth
(B) all maximas are equally spaced along x-axis
(C) the equation of first order maximum is $y^2 + z^2 = (8/9) R^2$ and $x = R/3$.
(D) None of these

Column Matching Type Questions

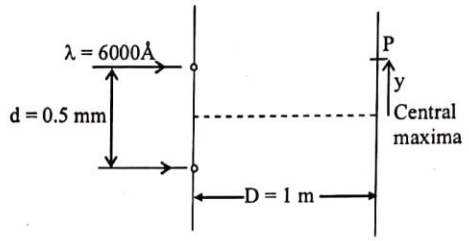
Q.48 Young's double slit experimental arrangement is shown in the diagram. 'θ' represents angular position of point on the screen. Also, not that two slabs made up of material of refractive indices n_1 and n_2 and each of thickness t = 0.2 mm are placed in front of the slits.



Match the following. Column I lists values of different parameters shown in diagram. Column II lists various possibilities.

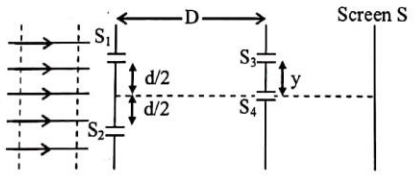
Column-I	Column-II
(A) Central maxima must be above point O	(P) If $\phi = 30^\circ$ and $n_1 = n_2$
(B) Central maxima must be below point O	(Q) If $\phi = 30^\circ$ and $n_1 > n_2$
(C) Central maxima may or must be at origin O	(R) If $\phi = 30^\circ$ and $n_1 = 1.3$, $n_2 = 1.5$
(D) Central maxima may be below point O	(S) If $\phi = 0^\circ$ and $n_1 = n_2$

Q.49 In YDSE light of wavelength λ = 6000Å is used screen distance D = 1 m and slit separation d = 0.5 mm. Intensity of light on screen emerging from slits are individually I_0 and $4I_0$. Column I indicates distance of certain point P on screen from central maxima.



List-I	List-II
(A) y = 2 mm	(P) Intensity = $7I_0$ at P
(B) y = 2.2 mm	(Q) Intensity = $3I_0$ at P
(C) y = 2.6 mm	(R) P lies between 2nd minima and 2nd maxima
(D) y = 2.8 mm	(S) P lies between 3rd minima and 2nd maxima
	(T) None

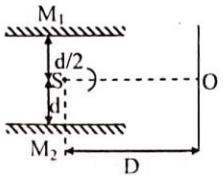
Q.50 The below diagram shows the set-up for a variation of a Young's Double Slit Experiment . Plane parallel beams of two wavelengths λ_1 = 2000 Å and λ_2 = 7500 Å are incident on two slits S_1 and S_2 (assume S_1 and S_2 to be of identical dimension) the superposed waves from S_1 and S_2 are then incident on a second opaque screen with two slits S_3 and S_4 as shown. Superposed waves from S_3 and S_4 are then incident on a far-away screen S take D/d = 2 × 10^3, y = 0.5 mm and assume all slits to be of identical size and both beams λ_1 = 2000 Å and λ_2 = 7500 Å of identical intensity I_0



Column -I	Column -II
(A) Intensity of light of wavelength λ_1 = 2000Å at slit S_3	(P) I_0
(B) Intensity of light of wavelength λ_2 = 7500 Å at slit S_3	(Q) $2I_0$
(C) The maximum intensity for λ_1 = 2000Å deserved at screen "S"	(R) $4I_0$
(D) The maximum intensity for λ_2 = 7500 Å deserved at screen "S"	(S) $5.8I_0$
	(T) None

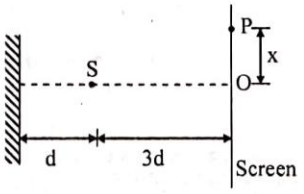
Numeric Response Type Questions

Q.51 M_1 and M_2 are plane mirrors and kept parallel to each other. At point O there will be a maxima for wavelength. Light from monochromatic source S of wavelength λ is not reaching directly on the screen. Then λ is $\frac{n \times d^2}{2D}$. Find the value of n [D >> d, d >> λ]

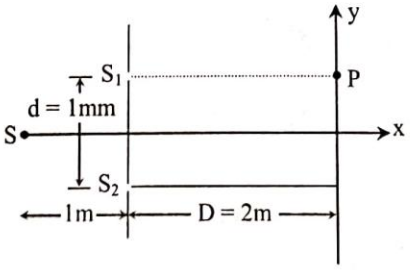


Q.52 A source of wavelength λ is placed in front of a plane mirror as shown in figure. Find minimum distance x from O on the screen where minimum of intensity will occur. But $x \neq 0$. Given $d = \lambda$

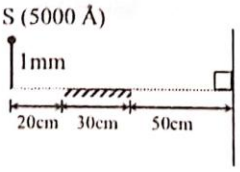
If it is $\frac{3\sqrt{7 \times n}}{2}\lambda$. Find the value of n.



Q.53 In a modified YDSE the source S of wavelength 5000Å oscillates about axis of setup according to the equation $y = 0.5 \sin\left(\frac{\pi}{6}\right) t$, where y is in millimeter and t in second. At what time t will the intensity at P, a point exactly in front of slit S_1, be maximum for the first time ?

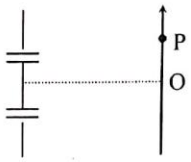


Q.54 Find the total number of fringes formed on screen in the Lloyd's mirror arrangement shown. If it is $n \times 2$. Find the value of n.

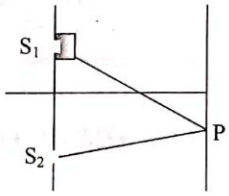


Q.55 Young's double slit experiment is conducted in a medium of refractive index 4/3. Light of 600 nm wavelength falls on the slits having 0.45 mm separation. The lower slit S_2 is covered by a thin glass sheet of thickness 10.4 μm and refractive index 1.5. The interference pattern is observed a screen placed 1.5 m from the slits as shown in the figure. Find the location of central maxima (bright fringe with zero path difference on the y-axis) in mm

[All wavelength in the problem are for the given medium of refractive index 4/3. Ignore dispersion.]

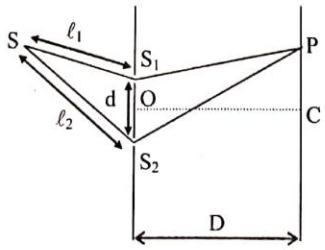


Q.56 In a young's double slit experiment one of the slits is covered by a thin film of thickness $t = 0.04$ mm, and refractive index $\mu = 1.2 + \frac{9\times10^{-4}\,m^2}{\lambda^2}$, where, λ is the wave length in meter. A beam of light consisting two wavelength $\lambda_1 = 400$ nm and $\lambda_2 = 600$ nm falls normally on the plane of the slits. Find the distance between two central maxima in millimeter. Distance of screen from slits is 400 times the separation between the slits.



Q.57 In a young double slit experiment . The two slits are illuminated by a monochromatic light source S of wavelength λ = 500 nm. Distance between slits and screen is D = 2m and distance between two slits $S_1S_2 = 10\mu m$, $\ell_1 = 20\ \mu m$ and $\ell_2 = 30\ \mu m$ as shown in the figure.

If number of maxima will appear on the screen is 13 K. Find the value of K.



ANSWER KEY

Single Correct Option type Questions

1. (B)	**2.** (C)	**3.** (A)	**4.** (C)	**5.** (D)	**6.** (A)	**7.** (B)
8. (C)	**9.** (C)	**10.** (C)	**11.** (D)	**12.** (D)	**13.** (B)	**14.** (B)
15. (C)	**16.** (A)	**17.** (A)				

Statement Based Questions

18. (D)	**19.** (C)	**20.** (B)

Multiple Correct Option type Questions

21. (A,B,C)	**22.** (A,B,C)	**23.** (B,C)	**24.** (B,C,D)	**25.** (A,B,C,D)	**26.** (A,B,C)	**27.** (B,C,D)
28. (A,D)	**29.** (B,D)	**30.** (A,B,D)	**31.** (A,B,C)	**32.** (A,B)		

Passage Based Questions

33. (D)	**34.** (B)	**35.** (A)	**36.** (B)	**37.** (A)	**38.** (B)	**39.** (A)
40. (B)	**41.** (C)	**42.** (C)	**43.** (A)	**44.** (C)	**45.** (A)	**46.** (B)
47. (D)						

Column Matching Type Questions

48. $A \rightarrow P,Q$; $B \rightarrow T$; $C \rightarrow R, S$; $D \rightarrow R,T$

49. $A \rightarrow Q,R$; $B \rightarrow P,R$; $C \rightarrow P,R,S$; $D \rightarrow Q,R,S$

50. $A \rightarrow Q$; $B \rightarrow P$; $C \rightarrow S$; $D \rightarrow R$

Numeric Response Type Questions

51. 3	**52.** 3	**53.** 1	**54.** 6	**55.** 4	**56.** 5	**57.** 3

Chapter 29

Modern Physics -1

Atomic structure, Photoelectric effect & X-rays

Single Correct Option Type Questions

Q.1 Suppose potential energy between electron and proton at separation 'r' is given by U = K ln (r), where K is a constant. For such a hypothetical hydrogen atom, the ratio of energy difference between energy levels (n = 1 and n = 2) and (n = 2 and n = 4) is -

(A) 1 (B) 2 (C) 3 (D) 4

Q.2 A particle of mass 'm' is projected from ground with velocity 'u' making angle 'θ' with the vertical. The de-Broglie wave length of the particle at the highest point is :

(A) ∞ (B) $\frac{h}{mu\sin\theta}$ (C) $\frac{h}{mu\cos\theta}$ (D) $\frac{h}{mu}$

Q.3 Consider three statement :

1. In photo electric effect, even for monochromatic incident radiation, the photoelectrons are emitted with a spread of velocities.
2. Photoelectrons are emitted without delay once the incident light reaches the surface of the emitter.
3. Frequency of monochromatic light (well above the cutoff frequency), that is incident on a emitter in a photoelectric effect, is increased while keeping the intensity constant. It results in decrease in magnitude of stopping potential.

Correct order of the true/false for the above statements is

(A) T T F (B) F T T (C) T F T (D) F F T

Q.4 The photon radiated from hydrogen corresponding to 2nd line of Lyman series is absorbed by a hydrogen like atom 'X' in 2nd excited state. As a result the hydrogen like atom 'X' makes a transition to n^{th} orbit. Then,

(A) $X = He^{+}$, n = 4 (B) $X = Li^{++}$, n = 6 (C) $X = He^{+}$, n = 6 (D) $X = Li^{++}$, n = 9

Q.5 If first excitation potential of a hydrogen like atom is V electron volt, then the ionization energy of this atom will be :

(A) V electron volt (B) $\frac{3V}{4}$ electron volt

(C) $\frac{4V}{3}$ electron volt (D) cannot be calculated by given information.

Q.6 The ratio of De-Broglie wave length of a photon and an electron of mass 'm' having the same kinetic energy E is : (Speed of light = C)

(A) $\sqrt{\frac{2mc^2}{E}}$ (B) $\sqrt{\frac{mc^2}{E}}$ (C) $\frac{2mc^2}{E}$ (D) $\frac{mc^2}{E}$

Q.7 A parallel beam of uniform, monochromatic light of wavelength 6600 Å has an intensity of 900 Wm^{-2}. The number of photons in 1 mm^3 of this radiation are

(A) 10000 (B) 1000 (C) 100000 (D) 5000

Q.8 Photons with an energy of 5.6eV eject photoelectrons from metal with a work function of 5.2 eV. The maximum impulse transmitted to the surface of the metal when an electron is ejected is $X \times 10^{-25}$ $kgms^{-1}$. Then write the greatest integer value of X :

(A) 5 (B) 4 (C) 3 (D) None of these

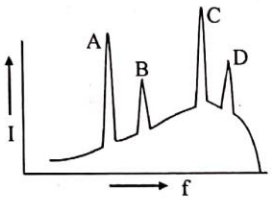
Q.9 What is the energy of an electron in a hydrogen atom in the ground state if the potential energy of electron is taken to be zero in the first excited state?

(A) – 6.8 eV (B) 6.8 eV (C) 3.6 eV (D) zero

Q.10 X-rays of high penetrating power are called hard X-ray. Hard X-rays have energy of the order of 10^5 eV. The minimum potential difference through which the electrons should be accelerated in an X-ray tube to obtain X-ray of energy 10^5 eV is :

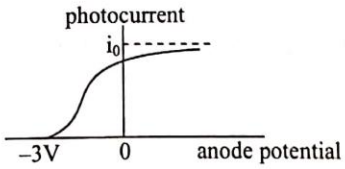
(A) 10^5 eV (B) 50 kV (C) 50 keV (D) 10^5 V

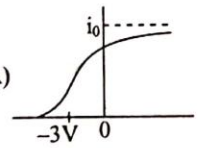
Q.11 Correct match for the graph between intensity and frequency for X-rays will be :

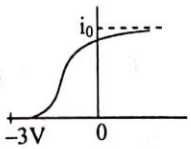


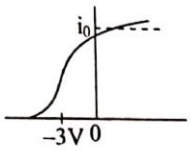
(A) $A \to K_\alpha$, $B \to K_\beta$, $C \to L_\alpha$, $D \to L_\beta$
(B) $A \to K_\beta$, $B \to K_\alpha$, $C \to L_\alpha$, $D \to L_\beta$
(C) $A \to L_\alpha$, $B \to L_\beta$, $C \to K_\alpha$, $D \to K_\beta$
(D) $A \to L_\beta$, $B \to L_\alpha$, $C \to K_\beta$, $D \to K_\alpha$

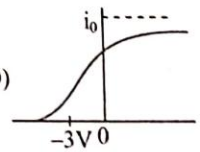
Q.12 Figure shows the anode potential vs photo-current graph when photons of 6 eV are incident on cathode in a photoelectric experiment set-up. In the same experiment set-up, If photons of 8eV and same intensity are incident on cathode, then anode-potential vs photo-current graph will be (assume 100 % efficiency of photons to eject photo-electrons in both cases)



(A)


(B)


(C)


(D)


Q.13 When light of intensity 1 W/m^2 and wavelength 5×10^{-7} m is incident on a surface. It is completely absorbed by the surface. If 100 photons emit one electron and area of the surface is 1 cm^2, then the photoelectric current will be -

(A) 2m A (B) 0.4 μA (C) 4.0 mA (D) 4 μA

Q.14 A sensor is exposed for time t to a lamp of power P placed at a distance ℓ. The sensor has an opening that is 4d in diameter. Assuming all energy of the lamp is given off as light, the number of photons entering the sensor if the wavelength of light is λ is -

(A) $N = \frac{P\lambda d^2 t}{hc\ell^2}$ (B) $N = \frac{4P\lambda d^2 t}{hc\ell^2}$ (C) $N = \frac{P\lambda d^2 t}{4hc\ell^2}$ (D) $N = \frac{P\lambda d^2 t}{16hc\ell^1}$

Q.15 Choose correct statement regarding photoelectric effect.
(A) No matter how small intensity, if photoelectric emission takes place, the emission is instantaneous
(B) The maximum kinetic energy of a photoelectron depends upon the intensity of incident light, if frequency of incident light is kept constant
(C) Threshold frequency depends upon the intensity of incident light.
(D) The photoelectric current is inversely proportional to the intensity of incident light and is independent of its frequency.

Q.16 The series limit of Balmer series of hydrogen is 3646 Å. The atomic number of element which gives x - rays of wavelength down to 1 Å will be
(A) 29 (B) 35 (C) 25 (D)28

Q.17 At what minimum kinetic energy of a moving hydrogen atom will its inelastic head on collision with another stationary hydrogen atom produce a photon emitted by one of the atoms. Both the of the atom are supposed to be in ground state prior to collision. (momentum of photon is negligible and no heat is lost)
(A) 10.2 eV (B) 20.4 eV (C) 13.6 eV (D) none

Q.18 A particle moves in a closed orbit around the origin, due to a force which is directed towards the origin. The de Broglie wavelength of the particle varies cyclically between two values λ_1 and λ_2 with $\lambda_1 > \lambda_2$. Which of the following statement are true ?
(A) The particle could be moving in an circular orbit with origin as centre
(B) The particle could be moving in an parabolic orbit with origin as its focus
(C) When the de Broglie wave length is λ_1, the particle is nearer the origin than when its value is λ_2.
(D) When the de Broglie wavelength is λ_2, the particle is nearer the origin than when its value is λ_1.

Q.19 The de-Broglie wavelength of an electron in the first Bohr orbit is
(A) equal to the circumference of first orbit (B) equal to $\frac{1}{2}$ × (circumference of first orbit)
(C) equal to $\frac{1}{4}$ × (circumference of first orbit) (D) equal to $\frac{3}{4}$ × (the circumference of first orbit)

Q.20 The stopping potential for the photo electrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelengths equal to that of incident radiation for the above photoelectric effect :
(A) n = 3 to 1 (B) n = 3 to 2 (C) n = 2 to 1 (D) n = 4 to 1

Q.21 The frequency and the intensity of a beam of light falling on the surface of photoelectric material are increased by a factor of two. Treating efficiency of photoelectron generation as constant, this will :
(A) Increase the maximum energy of the photoelectrons, as well as photoelectric current by a factor of two
(B) Increase the maximum kinetic energy of the photo electrons and would increase the photoelectric current by a factor of two.
(C) Increase the maximum kinetic energy of the photoelectrons by a factor of greater than two and will have no effect on the magnitude of photoelectric current produced.
(D) Not produce any effect on the kinetic energy of the emitted electrons but will increase the photoelectric current by a factor of two

Q.22 Cut off potentials for a metal in photoelectric effect for light of wavelength λ_1, λ_2 and λ_3 is found to be V_1, V_2 and V_3 volts if V_1, V_2 and V_3 are in Arithmetic Progression and λ_1, λ_2 and λ_3 will be :

(A) Arithmetic progression (B) Geometric progression

(C) Harmonic progression (D) None

Q.23 In a photoelectric experiment, the collector plate is at 2.0 V with respect to the emitter plate made of copper $\varphi = 4.5$ eV. The emitter is illuminated by a source of monochromatic light of wavelength 200 nm :

(A) The minimum kinetic energy of the photoelectrons reaching the collector is 0

(B) The maximum kinetic energy of the photoelectron reaching the collector is 3.7 eV.

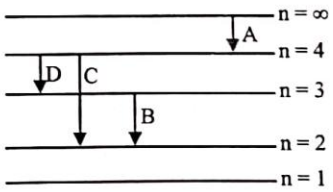
(C) If the polarity of the battery is reversed then answer to part A will be 0

(D) If the polarity of the battery is reversed then answer to part B will be 1.7 eV

Q.24 In a hypothetical system a particle of mass m and charge –3q is moving around a very heavy particle having charge q. Assuming Bohr's model to be true to this system, the orbital velocity of mass m when it is nearest to heavy particle is :

(A) $\frac{3q^2}{2\varepsilon_0 h}$ (B) $\frac{3q^2}{4\varepsilon_0 h}$ (C) $\frac{3q}{2\varepsilon_0 h}$ (D) $\frac{3q}{4\varepsilon_0 h}$

Q.25 Consider the following electronic energy level diagram of H-atom. Photons associated with shortest and longest wavelengths would be emitted from the atom by the transitions labeled :



(A) D and C respectively (B) C and A respectively

(C) C and D respectively (D) A and C respectively

Q.26 In a hydrogen atom, the binding energy of the electron in the nth state is E_n, then the frequency of revolution of the electron in the nth orbits is :

(A) $2E_n/nh$ (B) $2E_n n/h$ (C) E_n/nh (D) $E_n n/h$

Q.27 In hydrogen and hydrogen like atoms, the ratio of difference of energies $E_{4n} - E_{2n}$ and $E_{2n} - E_n$ varies with its atomic number z and n as :

(A) z^2 / n^2 (B) z^4 / n^4 (C) z / n (D) $Z^0 n^0$

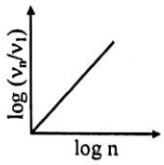
Q.28 Difference between nth and (n + 1)th Bohr's radius of 'H' atom is equal to it's (n – 1)th Bohr's radius. The value of n is :

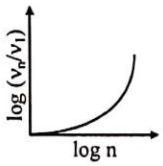
(A) 1 (B) 2 (C) 3 (D) 4

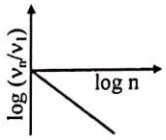
Q.29 The electron in a hydrogen atom makes transition from M shell to L. The ratio of magnitudes of initial to final centripetal acceleration of the electron is :

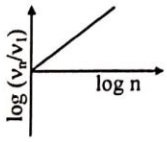
(A) 9 : 4 (B) 81 : 16 (C) 4 : 9 (D) 16 : 81

Q.30 The frequency of revolution of electron in n^{th} Bohr orbit is ν_n. The graph between log n and log (ν_n / ν_1) may be :

(A) 

(B) 

(C) 

(D) 

Q.31 The electron in hydrogen atom in a sample is in n^{th} excited state, then the number of different spectrum lines obtained in its emission spectrum will be :

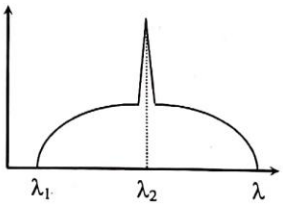
(A) 1 + 2 + 3 + ... + (n – 1) (B) 1 + 2 + 3 + ... + (n)

(C) 1 + 2 + 3 + ... + (n + 1) (D) 1 × 2 × 3 × ..... × (n – 1)

Statement Based Questions

Q.32 **Statement-1:** Variation of intensity of X-rays is plotted against λ. On increasing the acceleration potential, $(\lambda_2 - \lambda_1)$ increases.

Statement-2 : λ_{min} will decrease but λ_2 will be same, as wavelength of characteristic X-rays is independent of the accelerating potential. Choose the correct statement from the following.



(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 true and statement-2 is NOT is correct explanation for statement.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

Multiple Correct Option Type Questions

Q.33 Pick out the correct statement(s) :

(A) A moving electron in isolation cannot spontaneously change into an x-ray photon in free space.

(B) If maximum frequency of Balmer and Paschen series is f_1 and f_2 respectively, then frequency of first line of Balmer series is $(f_1 - f_2)$.

(C) In Moseley's equation $\sqrt{\nu} = a(z - b)$, constant 'a' has dimension of frequency equal to $\frac{1}{2}$.

(D) X-rays can produce photoelectric effect.

Q.34 An electron of the kinetic energy 10eV collides with a hydrogen atom in 1st excited state. Assuming loss of kinetic energy in the collision to be quantized which of the following statements is **incorrect**.
(A) The collision may be perfectly inelastic
(B) The collision may be inelastic
(C) The collision may be elastic
(D) The collision must be inelastic

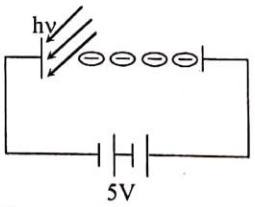
Q.35 When a hydrogen atom is excited from ground state to first excited state then
(A) its kinetic energy increases by 10.2 eV.
(B) its kinetic energy decreases by 10.2 eV.
(C) its potential energy increases by 20.4 eV.
(D) its angular momentum increases by 1.05×10^{-34} J-s.

Q.36 The electron in a hydrogen atom jump back from an excited state to ground state, by emitting a photon of wavelength $\lambda_0 = \frac{16}{15R}$, where R is Rydberg constant, In place of emitting one photon electron can come back to ground state by
(A) emitting three photon of wavelength $\lambda_1, \lambda_2, \lambda_3$ such that $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} + \frac{1}{\lambda_3} = \frac{15R}{16}$
(B) emitting two photon of wavelength λ_1,& λ_2 such that $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{15R}{16}$
(C) emitting two photon of wavelength λ_1,& λ_2 such that $\lambda_1 + \lambda_2 = \frac{16}{15R}$
(D) Emitting three photons of wavelength λ_1, λ_2, & λ_3 such that $\lambda_1 + \lambda_2 + \lambda_3 = \frac{16}{15R}$.

Q.37 In an experiment of photoelectric effect, light from a point source of monochromatic light of wavelength 3000 Å is incident on a metal surface. The kinetic energies of photo-electrons range from zero to 4.0×10^{-19} J, then -
(A) Stopping potential for this light is 2.5 V
(B) Threshold wavelength for the material is 7590Å
(C) Stopping potential will be doubled on reducing the distance and the wavelength of light source to half
(D) Saturation current will be doubled on reducing the distance of source to half

Q.38 A collimated beam of light of flux density 30 kWm^{-2} is incident normally on a 100 mm^2 completely absorbing screen. If P is the pressure exerted on the screen and Δp is the momentum transferred to the screen during a 1000 s interval then -
(A) $P = 10^{-3}$ Nm^{-2} (B) $P = 10^{-4}$ Nm^{-2} (C) $\Delta p = 10^{-4}$ $kgms^{-1}$ (D) $\Delta p = 10^{-5}$ $kgms^{-1}$

Q.39 Photons of energy 5eV are incident on cathode. Electrons reaching the anode have kinetic energies varying from 6eV to 8eV.



(A) Work function of the metal is 2eV
(B) Work function of the metal is 3eV
(C) Current in the circuit is equal to saturation value
(D) Current in the circuit is less than saturation value.

Q.40 A particular hydrogen like atom has its ground state binding " energy 122.4 eV. Its is in ground state. Then :
(A) Its atomic number is 3
(B) An electron of 90 eV can excite it
(C) An electron of kinetic energy nearly 91.8 eV can be brought to almost rest by this atom
(D) An electron of kinetic energy 2.6 eV may emerge from the atom when electron of kinetic energy 125 eV collides with this atom.

Q.41 Choose the correct statement (s) for hydrogen and deuterium atoms (considering motion of nucleus) :
(A) The radius of first Bohr orbit of deuterium is less than that of hydrogen
(B) The speed of electron in the first Bohr orbit of deuterium is more than that of hydrogen
(C) The wavelength of first Balmer line of deuterium is more than that of hydrogen
(D) The angular momentum of electron in the first Bohr orbit of deuterium is more than that of hydrogen

Q.42 A neutron collides head-on with a stationary hydrogen atom in ground state. Which of the following statements are correct (Assume that the hydrogen atom and neutron has same mass) :
(A) If kinetic energy of the neutron is less than 20.4 eV collision must be elastic
(B) If kinetic energy of the neutron is less than 20.4 eV collision must be inelastic
(C) Inelastic collision may be take place only when initial kinetic energy of the neutron is greater than 20.4 eV.
(D) Perfectly inelastic collision can not take place

Passage Based Questions

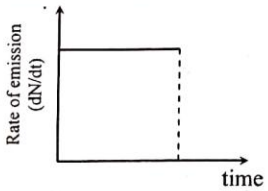
Passage # 1 (Q.43 to 45)

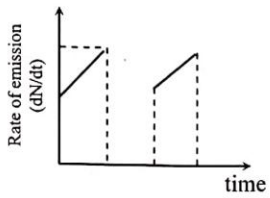
A light of wavelength λ is incident on a metal sheet of work function $\phi = 2$ eV. The wavelength λ varies with time as $\lambda = 3000 + 40t$, where λ is in Å and 't' is in second. The power incident on metal sheet is constant at 100 W. This signal is switched on and off for time intervals of 2 minutes and 1 minutes respectively. Each time the signal is switched on, the λ start from initial value of 3000 Å. The metal plate is grounded and electron clouding is negligible. The efficiency of photoemission is 1% (hc = 12400 eVÅ, 1eV = 1.6×10^{-19} J)

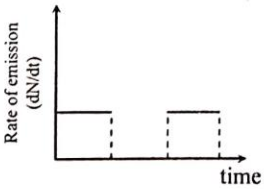
Q.43 The time after which photoemission will stop is
(A) 120 s (B) 80 s (C) 60 s (D) 180 s

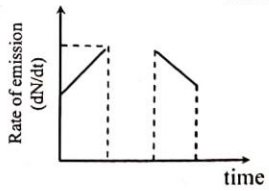
Q.44 The total number of photoelectrons ejected in one hour is
(A) 3.71×10^{17} (B) 3.71×10^{21} (C) 3.71×10^{25} (D) 3.71×10^{7}

Q.45 The variation of rate of emission vs time is

(A) 

(B) 

(C) 

(D) 

Passage # 2 (Q.46 & 47)

Electromagnetic radiation

$E = a(1 + \cos \omega t) \cos \omega_0 t$ where a is a constant, $\omega = 8\pi \times 10^{14}\ s^{-1}$ and $\omega_0 = 3.6\pi \times 10^{15}\ s^{-1}$ is incident on lithium surface. The work function of lithium is 2.4 eV.

Q.46 The frequency corresponding to maximum kinetic energy is -

(A) $18 \times 10^{14}\ s^{-1}$ (B) $3 \times 10^{15}\ s^{-1}$ (C) $4 \times 10^{10}\ s^{-1}$ (D) $8 \times 10^{12}\ s^{-1}$

Q.47 The maximum kinetic energy of electron emitted is -

(A) 7.4 eV (B) 9.8 eV (C) 0.72 eV (D) 5.0 eV

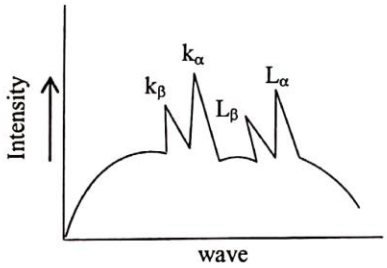
Passage # 3 (Q.48 & 49)

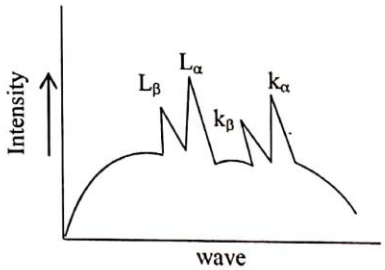
X - ray are produced in Coolidge tube. It consists of a thick glass bulb evacuated to about 10^{-6} cm of Hg so that no discharge can pass in it . A cathode serves as source of electron is made up of tungsten filament heated by a low voltage current. A cylindrical metal shield S surrounds the filament and S kept at negative potential with respect to the filament is focuses the electron emitted form the filament on the target T. The target is mounted on the surface of a copper block fixed to the end of a copper rod . The rod is fitted with fins for air cooling or cooled by circulating water A potential difference of about 20.000 V is applied across the tube to accelerate the electrons. The accelerated electrons strike to the target and produces continuous and characteristic x - rays.

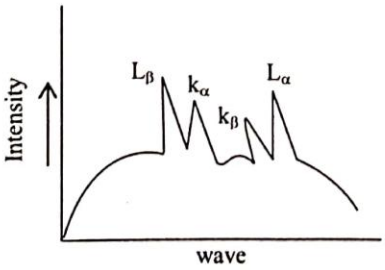
Q.48 In the Coolidge tube experiment Platinum is used as target material for the emission of k- series x-ray. The K, L and M energy level of this element are 7.8×10^4 eV, 1.2×10^4 eV and 3×10^3 eV respectively $C = 3 \times 10^8$ m/s , 1 eV = 1.6×10^{-19} and $h = 6.23 \times 10^{-34}$ J -s . The wavelength of k_α lines will be

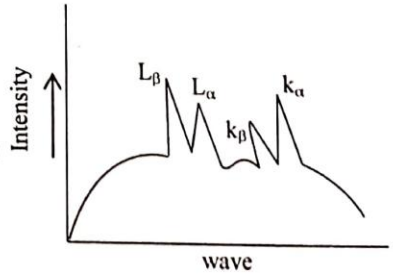
(A) 0.188 A (B) 0.376 (C) 0.999 A (D) 0.25A

Q.49 Mar k the correct graph which shows the rough variation of intensity of x - ray with wavelength λ.

(A)


(B)


(C)


(D)


Column Matching Type Questions

Q.50 In the experimental setup for a photocell, the wavelength of the light incident on the cathode is initially 0.6 times the threshold wavelength for the material of the cathode. Certain changes in the experiment setup are given in column-I and their possible effects are given in column-II.

Column -I	Column-II
(A) The intensity of the incident light is doubled but the frequency remains unaltered	(P) Saturation photocurrent remains the same
(B) Both the intensity and wavelength of the incident light are doubled	(Q) Photocurrent may falls to zero
(C) The intensity of the incident light is doubled and its wavelength is made half	(R) Stopping potential increases
(D) The intensity of the incident light remains the same and the wavelength is made half	(S) Saturation photocurrent increases
	(T) Stopping potential remain unaltered

Numeric Response Type Questions

Q.51 A certain species of ionized atoms (hydrogen like) produces an emission line spectrum according to Bohr model. A group of lines in the spectrum form a series in which the smallest energy is 4.896 eV and the maximum energy is 13.6 eV. The atomic number of atom is.....?

Q.52 A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. The excited atom can make a transition to the first excited state by successively emitting two photons of energy 10.2 and 17.0 eV respectively. Alternately, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 eV and 5.95 eV respectively. Determine the value of 'n'. (Ionization energy of H-atom = 13.6eV)

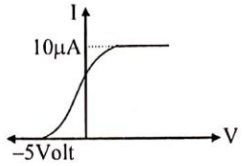
Q.53 A hydrogen-like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. Find Z.

Q.54 A hydrogen-like atom (described by the Bohr model) is observed to emit six wavelengths, originating from all possible transitions between a group of levels. These levels have energies between –0.85 eV and –0.544 eV (including both these values). Find the atomic number of the atom. (Take hc = 1240 eV-nm, ground state energy of hydrogen atom = –13.6 eV)

Q.55 If an excited He^+, ion emits two photons in succession with wavelength 1026.7 and 304 Å while making a transition to its ground state. Taking value of $R = 1.097 \times 10^7$/m, find the quantum number of excited state of He^+ ion.

Q.56 Two metallic plates A and B, each of area 5×10^{-4} m^2, are placed parallel to each other at a separation of 1 cm. Plate B carries a positive charge of 33.7×10^{-12} C. A monochromatic beam of light, with photons of energy 5eV each, starts falling on plate A at t = 0 so that 10^{16} photons fall on it per square meter per second. Assume that one photoelectron is emitted for every 10^6 incident photons. Also assume that all the emitted photoelectrons are collected by plate B and the work function of plate A remains constant at the value 2eV. If the number of photoelectrons emitted upto t = 10 s is ($x \times 10^7$), find x.
Neglect the time taken by the photoelectrons to reach plate B. Take $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N-m^2

Q.57 In the photoelectric experiment, if we use a monochromatic light, the I – V curve is as shown. If work function of the metal is 2eV, estimate the power of light used. (Assume efficiency of photo emission = 10^{-3}%, i.e. number of photoelectrons emitted are 10^{-3}% of number of photons incident on metal.)



Q.58 When a metallic surface is illuminated with monochromatic light of wavelength λ, the stopping potential is $5V_0$. When the same surface is illuminated with light of wavelength 3λ, the stopping potential is V_0. If work function of the metallic surface is $\frac{hc}{\lambda x}$ then 'x' is :

Q.59 A hydrogen atom is in its excited state with energy –1.51 eV. The angular momentum of the electron in this state is $\frac{xh}{2\pi}$ then write the value of 'x'.

Q.60 When a surface 1 cm thick is illuminated with light of wavelength λ, the stopping potential is V_0, but when the same surface is illuminated by light of wavelength 3λ, the stopping potential is $\frac{V_0}{6}$. Then the threshold wavelength for metallic surface will be $n\lambda$. Find n.

Q.61 On a certain metal light of frequency $\nu = 5\nu_0$ falls then maximum velocity of electrons emitted is 8×10^6 m/s, where ν_0 is threshold frequency of metal. If $\nu = 2\nu_0$ then the maximum velocity of photoelectron in 10^6 m/s will be.

Q.62 Calculate the value of retarding potential in volt needed to stop the photoelectron ejected from a metal surface of work function 1.29 eV with light frequency of 5.5×10^{14} sec^{-1} (nearly)

Q.63 There are two sources of light each emitting with a power of 100W.One emits X - rays of wavelength 1 nm and the other visible light at 500 nm. The ratio of number of photons of visible light to the photons of X - rays of the given wavelength is 100k. Find the value of K.

Q.64 If the potential difference across the Coolidge tube is increased to 1.4 time of initial potential difference the cut of wavelength of x - ray becomes 0.2 . The value of $\lambda_1 - \lambda_2$ in this condition is $\frac{2k}{100}$ Find the value of k. (λ_1 is initial wavelength and λ_2 is final wavelength)

Q.65 If the attractive potential between electron and proton were given by $V(r) = V_0 \ln\left(\frac{r}{r_0}\right)$ (where V_0, r_0 are constants), the radius r_n of the nth Bohr orbit in Hydrogen atom would be proportional to n^K. Then find the value of K.

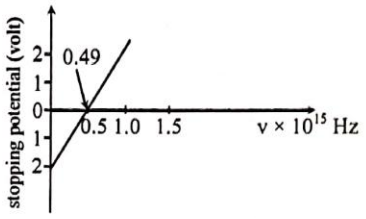
Q.66 A parallel beam of uniform, monochromatic light of wavelength 2640 A has an intensity of 200 W/m^2. The number of photons in 1 mm^3 of this radiation are .....

Q.67 663 mW of light from a 540 nm source is incident on the surface of a metal. If only 1 of each 5×10^9 incident photons is absorbed and causes an electron to be ejected from the surface, the total photocurrent in the circuit is .....

Q.68 Light of wavelength 330 nm falling on a piece of metal ejects electrons with sufficient energy which required voltage V_0 to prevent a electron from reading collector. In same setup, light of wavelength 220 nm, ejects electrons which require twice the voltage V_0 to stop them in reaching a collector. Find the numerical value of voltage V_0. (Take plank's constant, $h = 6.6 \times 10^{-34}$ Js and $1\ eV = 1.6 \times 10^{-19}$ J)

Q.69 A small 10W source of ultraviolet light of wavelength 99nm is held at a distance 0.1 m from a metal surface. The radius of an atom of the metal is approximately 0.05 nm. Find
(i) The average number of photons striking an atom per second
(ii) The number of photoelectrons emitted per unit area per second if the efficiency of liberation of photoelectrons is 1 %.

Q.70 The surface of cesium is illuminated with monochromatic light of various wavelengths and the stopping potentials for the wavelengths are measured. The results of this experiment is plotted as shown in the figure. Estimate the value of work function of the cesium and Plank's constant.



Q.71 A hydrogen atom in a state having a binding energy 0.85 eV makes a transition to a state of excitation energy 10.2 eV. The wave length of emitted photon is ..... nm

Q.72 A hydrogen atom is in 5th excited state. When the electron jumps to ground state the velocity of recoiling hydrogen atom is ..... m/s and the energy of the photon is .....eV.

Q.73 The ratio of series limit wavelength of Balmer series to wavelength of first line of Paschen series is .....

Q.74 An electron joins a helium nucleus to form a He+ ion in ground state. The wavelength of the photon emitted in this process if the electron is assumed to have had no kinetic energy when it combines with nucleus is ..... nm

Q.75 A hydrogen like atom has its single electron orbiting around its stationary nucleus. The energy to excite the electron from the second Bohr orbit to the third Bohr orbit is 47.2 eV. The atomic number of this nucleus is .....

Q.76 A single electron orbits a stationary nucleus of charge Ze where Z is a constant and e is the electronic charge. It requires 47.2 eV to excite the electron from the 2nd Bohr orbit to 3rd Bohr orbit. Find
(i) the value of Z
(ii) energy required to excite the electron from the third to the fourth orbit
(iii) the wavelength of radiation required to remove the electron from the first orbit to infinity
(iv) the kinetic energy, potential energy and angular momentum in the first Bohr orbit
(v) the radius of the first Bohr orbit

Q.77 A hydrogen like atom (atomic number Z) is in higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energy 22.95 eV and 5.15 eV respectively. Alternatively, the atom from the same excited state can make transition to the second excited state by successively emitting two photons of energies 2.4 eV and 8.7 eV respectively. Find the value of n and Z.

Q.78 An electron of mass "m" and charge "e" initially at rest gets accelerated by a constant electric field E. The rate of change of deBroglie wavelength of this electron at time t is .....

Q.79 A small plate of a metal (work function = 1.17 eV) is placed at a distance of 2m from a monochromatic light source of wave length 4.8×10^{-7} m and power 1.0 watt. The light falls normally on the plate. Find the number of photons striking the metal plate per square meter per sec. If a constant uniform magnetic field of strength 10^{-4} tesla is applied parallel to the metal surface. Find the radius of the largest circular path followed by the emitted photoelectrons.

Q.80 Electrons in hydrogen like atoms (Z = 3) make transitions from the fifth to the fourth orbit & from the fourth to the third orbit. The resulting radiation are incident normally on a metal plate & eject photo electrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volts. Calculate the work function of the metal & the stopping potential for the photoelectrons ejected by the longer wavelength. (Rydberg constant = 1.094×10^7 m^{-1})

Q.81 A beam of light has three wavelengths 4144Å, 4972Å & 6216Å 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. Assume that there is no loss of light by reflection and that each energetically capable photon ejects one electron. Calculate the number of photoelectrons liberated in two seconds.

Q.82 A small 10 W source of ultraviolet light of wavelength 99 nm is held at a distance 0.1 m from a metal surface. The radius of an atom of the metal is approximately 0.05 nm. Find
(i) the number of photons striking as atom per second
(ii) the number of photoelectrons emitted per second if the efficiency of liberation of photoelectrons is 1%

Q.83 A neutron with kinetic energy 25 eV strikes a stationary deuteron. Find the deBroglie wavelengths of both particles in the frame of their centre of mass

Q.84 Two identical nonrelativistic particles move at right angles to each other, possessing DeBroglie wavelengths, λ_1 and λ_2. Find the DeBroglie wavelength of each particle in the frame of their centre of mass.

Q.85 A stationary He^+ ion emitted a photon corresponding to the first line its Lyman series. That photon liberated a photoelectron from a stationary hydrogen atom in the ground state. Find the velocity of the photoelectron

Q.86 A gas of identical hydrogen like atoms has some atoms in the lowest (ground) energy level A & some atoms in a particular upper (excited) energy level B & there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level by the absorbing monochromatic light of photon energy 2.7 eV. Subsequently, the atoms emit radiation of only six different photon energies. Some of the emitted photons have energy 2.7 eV. Some have energy more and some have less than 2.7 eV.

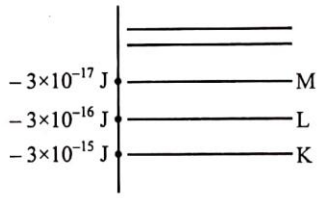
(i) Find the principal quantum number of the initially excited level B.

(ii) Find the ionization energy for the gas atoms.

(iii) Find the maximum and the minimum energies of the emitted photons.

Q.87 A mono chromatic light source of frequency ν illuminates a metallic surface and ejects photoelectrons. The photoelectrons having maximum energy are just able to ionize the hydrogen atoms in ground state. When the whole experiment is repeated with an incident radiation of frequency $(5/6)\nu$, the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength of 1215 Å. Find the work function of the metal and the frequency ν.

Q.88 Simplified picture of electron energy levels in a certain atom is shown in the figure. The atom is bombarded with high energy electrons. The impact of one of these electron has caused the complete removal of K-level is filled by an electron from the L-level with a certain amount of energy being released during the transition. This energy may appear as X-ray or may all be used to eject an M-level electron from the atom :



Find :

(i) The minimum potential difference through which electron may be accelerated from rest to cause the ejection of K-level electron from the atom.

(ii) Energy released when L-level electron moves to fill the vacancy in the K-level.

(iii) Wavelength of the X-ray emitted

(iv) K.E. of the electron emitted from the M-level

Q.89 In a photo electric effect set-up, a point source of light of power 3.2×10^{-3} W emits mono energetic photons of energy 5.0 eV. The Source is located at a distance of 0.8m from the centre of a stationary metallic sphere of work function 3.0 eV & of radius 8.0×10^{-3} m. The efficiency of photo electrons emission is one for every 10^6 incident photons. Assume that the sphere is isolated and initially neutral, and that photo electrons are instantly swept away after emission.

(i) Calculate the number of photo electrons emitted per second

(ii) Find the ratio of the wavelength of incident light to the De-Broglie wave length of the fastest photo electrons emitted.

(iii) Evaluate the time t.

ANSWER KEY

Single Correct Option type Questions

1. (A)	**2.** (B)	**3.** (A)	**4.** (D)	**5.** (C)	**6.** (A)	**7.** (A)
8. (A)	**9.** (A)	**10.** (D)	**11.** (C)	**12.** (D)	**13.** (D)	**14.** (A)
15. (A)	**16.** (B)	**17.** (B)	**18.** (D)	**19.** (A)	**20.** (A)	**21.** (C)
22. (C)	**23.** (B)	**24.** (A)	**25.** (C)	**26.** (A)	**27.** (D)	**28.** (D)
29. (D)	**30.** (C)	**31.** (B)	**32.** (A)			

Multiple Correct Option type Questions

33. (A,B,C,D)	**34.** (A,D)	**35.** (B,C,D)	**36.** (A,B)	**37.** (A,B)	**38.** (B,D)	**39.** (A,D)
40. (A,C,D)	**41.** (A)	**42.** (A,C)				

Passage Based Questions

43. (B)	**44.** (B)	**45.** (B)	**46.** (A)	**47.** (D)	**48.** (A)	**49.** (C)

Column Matching Type Questions

50. A → S,T ; B → Q,S ; C → R,S ; D → P,R

Numeric Response Type Questions

51. 4	**52.** 6	**53.** 4	**54.** 3	**55.** 6	**56.** 5	**57.** 7
58. 6	**59.** 3	**60.** 5	**61.** 4	**62.** 1	**63.** 5	**64.** 4

65. 1 **66.** 885 **67.** 5.76×10^{-11} A **68.** 15/8 V **69.** $\frac{5}{16}, \frac{10^{20}}{80\pi}$

70. 2 eV, 6.53×10^{-34} J-s **71.** 487.06 nm **72.** 4.26 m/s, 13.2 eV

73. 7 : 36 **74.** 22.8 nm **75.** 5 **76.** (i) 5, 16.5 eV, 36.4 A, 340 eV, – 680 eV, $\frac{h}{2\pi}$ 1.06×10^{-11} m

77. z = 3, n = 7 **78.** $-\frac{h}{eEt^2}$ **79.** 4.8×10^{16}, 40 cm **80.** 1.99 eV, 0.760 V

81. 1.1×10^{12} **82.** (i) 5/16 photon/sec, (ii) 5/1600 electrons/sec **83.** $\lambda_{deutron} = \lambda_{neutron} = 8.6$ pm

84. $\lambda = \frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2 + \lambda_2^2}}$ **85.** 3.1×10^6 m/s **86.** (i) 2 ; (ii) 23.04×10^{-19} J; (iii) 4 → 1, 4 → 3

87. 6.8 eV, 5×10^{15} Hz

88. (i) 1.875×10^4 V; (ii) 2.7×10^{-15} J ; (iii) 0.737 Å ; (iv) 2.67×10^{-15} J

89. (i) 10^5 s^{-1}; (ii) 286.18 ; (iv) 111 s

Chapter

30

Modern Physics -2

Nuclear physics & Radioactivity

Single Correct Option Type Questions

Q.1 Nuclei of radioactive element A are produced at rate 't^2' at any time t. The element A has decay constant λ. Let N be the number of nuclei of element A at any time t. At time $t = t_0$, $\frac{dN}{dt}$ is minimum. Then the number of nuclei of element A at time $t = t_0$ is

(A) $\frac{2t_0 - \lambda t_0^2}{\lambda^2}$ (B) $\frac{t_0 - \lambda t_0^2}{\lambda^2}$ (C) $\frac{2t_0 - \lambda t_0^2}{\lambda}$ (D) $\frac{t_0 - \lambda t_0^2}{\lambda}$

Q.2 The radionuclide ^{238}U decays by emitting an alpha particle.

$$^{38}U \rightarrow {}^{234}Th + {}^{4}He$$

The atomic masses of the three isotopes are.

^{238}U	238.05079 amu
^{234}U	234.04363 amu
^{4}He	4.00260 amu

What is the maximum kinetic energy of the emitted alpha particle. Express your answer in Joule.
(1 amu = 1.67×10^{-27} kg)

(A) 6.8×10^{-14} J (B) 6.8×10^{-13} J (C) 4.3×10^{-14} J (D) 4.3×10^{-13} J

Q.3 Choose the correct statement.

(A) The nuclear force between two nucleons depends upon charge on each nucleon.
(B) The nuclear force is not a central force
(C) The nuclear force between the two nucleons increases rapidly as size of nucleus increases.
(D) Nuclear force is a conservative force.

Q.4

	$A \xrightarrow{\lambda_1}$	$B \xrightarrow{\lambda_2}$	C
t = 0	N_0	0	0
t	N_1	N_2	N_3

In the above radioactive decay C is stable nucleus. Then :

(A) rate of decay of A will first increase and then decrease
(B) number of nuclei of B will first increase and then decrease
(C) if $\lambda_2 > \lambda_1$, then activity of B will always be higher than activity of A
(D) if $\lambda_1 >> \lambda_2$, then number of nucleus of C will always be less than number of nucleus of B.

Q.5

	$A \xrightarrow{\lambda}$	$B \xrightarrow{2\lambda}$	C
t = 0	N_0	0	0
t	N_1	N_2	N_3

The ratio of N_1 to N_2 when N_2 is maximum is :

(A) at no time this is possible (B) 2
(C) 1/2 (D) $\frac{\ell n\, 2}{2}$

Q.6 The radii of nuclei of two atoms are in ratio $\frac{3}{2}$. Assuming them to be Hydrogen like atom, the ratio of their orbital radius for K shell will be (assume no. of proton = No. of neutron for each atom)

(A) $\frac{27}{8}$ (B) $\frac{8}{27}$ (C) $\frac{4}{9}$ (D) None

Q.7 Consider the following statements :

(i) Nuclear fission is normally followed by emission of β^- - particles.

(ii) Emission of α-particle is normally followed by emission of γ-rays.

(iii) In carbon-carbon cycle of fusion reaction which powers the large stars, two carbon combine nuclei to form a magnesium nucleus :

The correct order of True / False in above statements is

(A) T T T (B) T T F (C) F T T (D) T F T

Q.8 In a sample of radioactive nuclide;

(A) a nucleus emits α, β radiations simultaneously.

(B) only α, β can be emitted simultaneously by a nucleus.

(C) α, β, γ may be obtained simultaneously from the sample.

(D) all the three α, β, γ one after the other will be obtained from a nucleus.

Q.9 The mass of proton is 1.0073 u and that of neutron is 1.0087 u (u = atomic mass unit). Mass of helium nucleus = 4.0015 u. The binding energy of the ${}_2^4He$ is (1u = 931 MeV/c^2) :

(A) 1.99 u (B) 0.0305 J (C) 0.0305 erg (D) 28.4 MeV

Q.10 Radius of a nucleus is given as $R = R_0A^{1/3}$. A proton from a large distance is to be projected towards the nucleus ${}_ZX^A$ so that it can enter into the nucleus. Neglecting nuclear force outside the nucleus, the speed of the proton with which it should be projected should be just more than :

(A) $\frac{ze^2}{2\pi\varepsilon_0 mR_0^2A^{2/3}}$ (B) $\frac{ze^2}{2\pi\varepsilon_0 mR_0A^{1/3}}$ (C) $\frac{ze}{2\pi\varepsilon_0 mR_0A^{2/3}}$ (D) $\frac{ze^2}{32\pi\varepsilon_0 mR_0A^{1/3}}$

Q.11 At time t = 0, N_1 nuclei of decay constant λ_1 & N_2 nuclei of decay constant λ_2 are mixed. The decay rate of the mixture at time 't' is :

(A) $N_1N_2e^{-(\lambda_1+\lambda_2)t}$ (B) $\left(\frac{N_1}{N_2}\right)e^{-(\lambda_1-\lambda_2)t}$

(C) $\left(N_1\lambda_1e^{-\lambda_1t} + N_2\lambda_2e^{-\lambda_2t}\right)$ (D) $N_1\lambda_1N_2\lambda_2e^{+(\lambda_1+\lambda_2)t}$

Q.12 A radionuclide has a half-life of 1.6×10^3 years. If a sample contains 3.0×10^{16} such nuclei at a certain instant, the activity of the sample at the this time in (curie) 'Ci' is 11×10^{-x} Ci then write the value of 'x'. (given 1 Ci = 3.7×10^{10} dps)

(A) x = 6 (B) x = 4 (C) x = 2 (D) x = 8

Q.13 Which of the following statement is correct in connection with hydrogen spectrum

(A) The longest wavelength in the Balmer series is longer than the longest wavelength in Lyman series

(B) The shortest wavelength in the Balmer series is shorter than the shortest wavelength in the Lyman series

(C) The longest wavelength in both Balmer and Lyman series are equal

(D) The longest wavelength in Balmer series is shorter than the longest wavelength in the Lyman series.

Q.14 An electron and a proton are separated by a large distance and the electron approaches the proton with K.E. of 2 eV. If the electron is captured by the proton to form a hydrogen atom in the ground state, wavelength of photon emitted will be -

(A) 793 Å (B) 1098 Å (C) 704.5 Å (D) 1291.6 Å

Q.15 In certain experiment it has been found that the ratio of the current in a L-R discharging circuit to the activity of a radioactive sample at any instant remains constants with time. The time constant of L-R circuit is 0.4 sec, the average life of radioactive sample is

(A) 0.2 sec (B) 0.4 sec (C) 0.6 sec (D) 0.5 sec

Q.16 During negative β decay, an anti-neutrino is also emitted along with the ejected electron. Then

(A) only linear momentum will be conserved

(B) total linear momentum and total angular momentum but not total energy will be conserved

(C) total linear momentum and total energy but not total angular momentum will be conserved

(D) total linear momentum, total angular momentum and total energy will be conserved

Q.17 The binding energies of nuclei X and Y are E_1 and E_2 respectively. Two atoms of X fuse to give one atom of Y and an energy Q is released. Then :

(A) $Q = 2E_1 - E_2$ (B) $Q = E_2 - 2E_1$ (C) $Q = 2E_1 + E_2$ (D) $Q = 2E_2 + E_1$

Q.18 Half life for certain radioactive element is 5 min. Four nuclei of that element are observed at a certain instant of time. After five minutes.

Statement-1 : It can be definitely said that two nuclei will be left undecayed

Statement-2 :: After half life i.e. 5 minutes, half of total nuclei will disintegrate. So only two nuclei will be left undecayed. Then :

(A) Statement-1 is correct & Statement-2 is correct explanation of Statement-1

(B) Both are correct, But Statement-2 is not correct explanation of Statement-1

(C) Statement-1 is incorrect & Statement-2 is correct.

(D) Both are incorrect

Q.19 An unstable element is produced in a nuclear reactor at a constant rate. If its half life is 100 years, the time in years is required to produce 50% of the equilibrium quantity is 20X then the value of X is ?

(A) 12 (B) 10 (C) 5 (D) 2.5

Q.20 An electron in hydrogen atom first jumps from second excited state to first excited state and then, from first excited state to ground state. Let the ratio of wavelength, momentum and energy of photons in the two cases be x, y and z, then select the wrong answer/(s) :

(A) $z = 1/x$ (B) $x = 9/4$ (C) $y = 5/27$ (D) $z = 5/27$

Q.21 The probability that particular nucleus of $_{38}Cl$ will undergo β - decay in time interval 10^{-3} sec (the half life of $_{38}Cl$ is 37.2 min) is

(A) 3.1×10^{-7} (B) 2.25×10^{-6} (C) 3.36×10^{-5} (D) 1.73×10^{-7}

Q.22 Which of the following statement is correct?

(A) The rest mass of a stable nucleus is less than the sum of the rest masses of its separated nucleons.

(B) The rest mass of a stable nucleus is greater than the sum of the rest masses of separated nucleons.

(C) In nuclear fission, energy is released by fusing two nuclei of medium mass (approximately 100 amu)

(D) In nuclear fission, energy is released by fragmentation of a very heavy nucleus

Q.23 Consider the following energies
1. The minimum energy needed to excite a hydrogen atom from its ground state = E_1
2. Energy needed to ionize a hydrogen atom from ground state = E_2
3. Energy released in ^{235}U – fission = E_3
4. Energy needed to remove a neutron from a $^{12}C_{nucleus}$ = E_4

Choose correct statement :
(A) $E_1 < E_2 < E_3 < E_4$ (B) $E_1 < E_3 < E_2 < E_4$ (C) $E_1 < E_2 < E_4 < E_3$ (D) $E_2 < E_1 < E_4 < E_3$

Q.24 A nuclear reactor containing U^{235} produces 10MW. Calculate the fission rate assuming that 200 MeV of useful energy is released in one fission ?
(A) 3.1×10^{17} sec^{-1} (B) 6×10^{8} sec^{-1} (C) 1.5×10^{17} sec^{-1} (D) 2×10^{17} sec^{-1}

Multiple Correct Option Type Questions

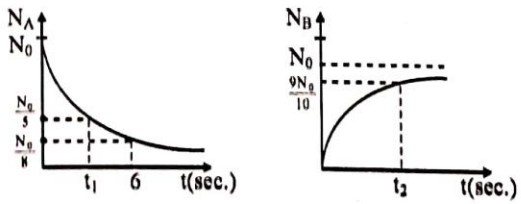
Q.25 At t = 0, a sample of radionuclide A has the same decay rate as a sample of radionuclide B has at t = 60 min. The disintegration constants of A and B are λ_A and λ_B respectively, with $\lambda_A < \lambda_B$.
(A) The half life of radionuclide A is greater than that of B.
(B) At t = 60 min, number of atoms in sample of material A is greater than that of sample B.
(C) The two samples will never have the same decay rate simultaneously.
(D) After some time, the two samples will have the same decay rate simultaneously for an instant.

Q.26 A fusion reaction consists of combining four protons into an α-particle. The mass of α-particle is 4.002603u and that of proton is 1.007825u
(A) the equation $4p_1^1 \rightarrow He_2^4$ does not satisfy conservation of charge
(B) the correct reaction equation may be $4p_1^1 \rightarrow He_2^4 + 2\beta^+ + 2\nu$ where β^+ is positron and ν is the neutrino (zero rest mass and uncharged)
(C) loss of mass in the reaction is 0.028697 u
(D) the energy equivalent of the mass defect is 26.7 MeV

Q.27 X-ray from a tube with a target A of atomic number Z shows strong K_α lines for target A and two weak K_α lines for impurities. The wavelength of K_α lines is λ_0 for target A and λ_1 and λ_2 for two impurities respectively. $\frac{\lambda_0}{\lambda_1} = 4$ and $\frac{\lambda_0}{\lambda_2} = \frac{1}{4}$. The screening constant of K_α lines is unity. Select the correct alternative(s) :
(A) The atomic number of first impurity is 2Z – 1 (B) The atomic number of first impurity is 2Z + 1
(C) The atomic number of second impurity is $\frac{Z+1}{2}$ (D) The atomic number of second impurity is $\frac{Z}{2} + 1$

Q.28 If a nucleus $^{A}_{Z}x$ emits an α particle & a β particle in succession, then the daughter nucleus will have which of the following configurations?
(A) A – 4 nucleons (B) 4 nucleons (C) A – z – 3 neutrons (D) Z – 2 protons

Q.29 In a decay process A decays to B, A ⟶ B
Two graphs of number of nucli of A and B versus time is given then :



(A) $t_2 - t_1 = 4$ (B) $t_2 - t_1 = 2$ (C) $t_1 = 2 \log_2 5$ (D) $t_2 = \log_2 100$

Q.30 When a hydrogen atom is excited from ground state to first excited state then ($h = 6.6 \times 10^{-34}$ J–s)-

(A) its kinetic energy increases by 10.2 eV.

(B) its kinetic energy decreases by 10.2 eV.

(C) its potential energy increases by 20.4 eV.

(D) its angular momentum increases by 1.05×10^{-34} J-s

Q.31 A positronium atom consists of a positron and electron revolving around their common centre of mass. Then as compared to hydrogen atom positronium atom has –

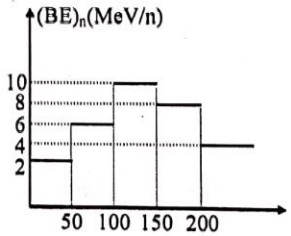
(A) Ground state energy half of hydrogen atom

(B) Rydberg constant half of hydrogen atom

(C) radius of first orbit of electron double that in case of hydrogen atom

(D) velocity of electron in first orbit same as in case of hydrogen atom

Q.32 Consider of hypothetical binding energy per nucleon curve. Which of the following fission or fusion may occur ?



(A) $X^{250} \rightarrow Y^{160} + Z^{90}$

(B) $X^{220} \rightarrow Y^{180} + Z^{40}$

(C) $X^{40} + Y^{70} \rightarrow Z^{110}$

(D) $X^{40} + Y^{120} \rightarrow Z^{160}$

Q.33 A mumesic atom is a hydrogen atom with electron replaced by muon whose mass is 210 times of mass of electron (mass of proton $m_p = 1836\ m_e$, Charge –e on mumesic)

(A) Bohr radius of the mumesic atom is 0.0023 Å

(B) Ground state energy of mumesic atom is 2856 eV

(C) angular momentum in ground state is $\frac{h}{2\pi}$

(D) angular momentum in ground state is $\frac{(210)h}{2\pi}$

Q.34 If potential energy in hydrogen atom with electron in ground state is taken to be 13.6 eV, then -

(A) Potential energy in the first excited state would be 34 eV

(B) Total energy in the first excited state would be 37.4 eV

(C) Kinetic energy in the first excited state would be 44.2 eV

(D) Total energy in the ground state would be 27.2 eV

Q.35 If fission of U^{236} takes place into two nuclei of equal masses and KE of each nuclei is 100 MeV. Binding energy per nucleon of U^{236} is 8.0 MeV. Then choose the correct statement(s) -

(A) Nuclei near A = 118 has mass less than half that of U^{236}

(B) Nuclei near A = 118 has mass greater than half that of U^{236}

(C) BE of nuclei A = 118 may be around 7.2 $\frac{\text{MeV}}{\text{Nucleon}}$

(D) BE of nuclei A = 118 may be around 8.8 $\frac{\text{MeV}}{\text{Nucleon}}$

Q.36 Polonium ${}_{84}Po^{210}$ emits α-particles and is converted into ${}_{82}Pb^{206}$. This reaction is used for producing electric power in a space mission. Po^{210} has half life of 138.6 days. Assuming an efficiency of 10%. Now choose correct statement(s) -

Given : $M(Po^{210}) = 209.98264$ amu ; $M(\alpha) = 4.0026$ amu $M(Pb^{206}) = 205.97440$ amu ; 1 amu = 931 MeV energy

(A) K.E of α particle is greater then K.E of ${}_{82}Pb^{206}$ (B) Decay constant of Po^{210} is 0.005 day^{-1}

(C) Q-value of α-decay process is 8.4×10^{-13} Joule (D) None of these

Q.37 During a positive beta decay

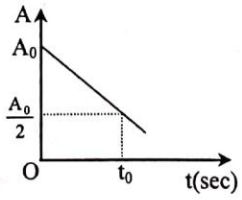
(A) The atomic number of the atom decreases by one

(B) Sometimes a neutrino may also come along with it

(C) A proton gets converted into a neutron

(D) The binding energy of the remaining nucleus increases

Q.38 A radioactive nuclide decays with a constant λ. Let $A = \log\left|\frac{dN}{dt}\right|$, where $\left|\frac{dN}{dt}\right|$ is the number of radioactive decay acts taking place per second. Suppose the experiment starts at t = 0 and the curve between A and t is shown in the adjacent figure.



Now, choose the correct statements (s) from the following.

(A) Decay constant of the radioactive sample is $\frac{A_0}{2t_0}$.

(B) Number of radioactive nuclei at the start of the experiment was $\frac{t_0}{A_0}e^{A_0}$.

(C) Number of radioactive nuclei after half-life is $\frac{t_0}{A_0}e^{A_0}$.

(D) Half-life of the radioactive sample is t_0.

Q.39 If the radius, speed, energy and time period of revolution of an e^- in Bohr's atom and r, v, E and T respectively, the quantities remaining proportional to n^3 are

(A) rv (B) $\frac{r}{v}$ (C) T (D) $\frac{ET}{r}$

Q.40 Suppose frequency of emitted photon is f_0 when electron of a stationary hydrogen atom jumps from a higher state m to a lower state n. If the atom is moving with a velocity v(<<c) and emits a photon of frequency f during the same transition, then which of the following statements are possible.

(A) f may be equal to f_0
(B) f may be greater than f_0
(C) f may be less than f_0
(D) f cannot be equal to f_0

Q.41 Energy liberated in the de-excitation of hydrogen atom from 3rd level to 1st level falls on a photo-cathode. Later when the same photo-cathode is exposed to a spectrum of some unknown hydrogen like gas, excited to 2nd energy level, it is found that the de-Broglie wavelength of the fastest photoelectrons, now ejected has decreased by a factor of 3. For this new gas, difference of energies of 2nd Lyman line and 1st Balmer line is found to be 3 times the ionization energy of the hydrogen atom. Select the correct statement (s) :

(A) The gas is lithium
(B) The gas is helium
(C) The work function of photo-cathode is 8.5 eV.
(D) The work function of photo-cathode is 5.5 eV

Q.42 The photon radiated from hydrogen corresponding to 2nd line of Lyman series is absorbed by hydrogen like atom 'X' in 2nd excited state. As a result the hydrogen like atom 'X' makes a transition to n^{th} orbit

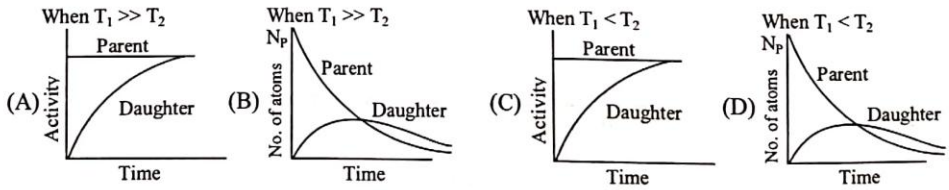
(A) $X = He^+$
(B) $X = Li^{++}$
(C) $n = 6$
(D) $n = 9$

Q.43 For a proton and α-particle λ_1 and λ_2 are De-broglie wavelength respectively-

(A) If they have same momentum, then $\lambda_1 = \lambda_2$
(B) If they have same kinetic energies, then $\lambda_1 = 2\lambda_2$
(C) If they are accelerated through same potential difference then $\lambda_1 = 2\sqrt{2}\,\lambda_2$
(D) λ_1 can never be less than λ_2

Q.44 A nucleus A decays into B with half life T_1 and B decays into C with half life T_2. Graph is drawn between number of atoms / activity versus time.

Select the correct graph (s) (parent nucleus A & daughter nucleus is B.)



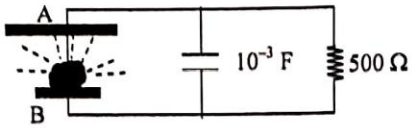
Q.45 Consider a particle at rest which may decay into two (daughter) particles or into three (daughter) particles. Which of the following is/are true? (There are no external forces)

(A) The velocity vectors of the daughter particles must lie in a plane
(B) Given the total kinetic energy of system and the mass of each daughter particle, it is possible to determine the speed of each daughter particle
(C) Given the speed (s) of all but one daughter particle it is possible to determine the speed of the remaining particle
(D) The total momentum of the daughter particles is zero

Passage Based Questions

Passage # 1 (Q.46 & 47)

An artificial radioactive battery consists of N_0 number of atoms of a radioactive element emitting α - particles with a disintegration constant $\lambda = 1$ per sec. Half of the fraction of 'α' particles emitted are captures at the anode A. Rest remains in the surrounding of radioactive substance kept on the cathode B. A capacitor C and a resistance R are connected across the battery. Charge on a particle is denoted by q_0 (Given $C = 10^{-3}$ F, $R = 500\ \Omega$ and at $t = 0$, number of atoms are N_0)



Q.46 Current through a battery as a function of time.

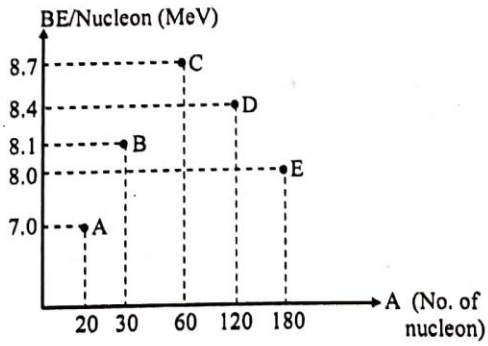
(A) $\frac{N_0 q_0}{2} e^{-2t}$ (B) $\frac{N_0 q_0}{2}(1-e^{-2t})$ (C) $\frac{N_0 q_0}{2} e^{-t}$ (D) $\frac{N_0 q_0}{2} 1-e^{-t}$

Q.47 The charge on the capacitor as function of time is given as

(A) $\frac{q_0 N_0 e^{-t}}{2}(1-e^{-t})$ (B) $\frac{q_0 N_0}{2}(1-e^{-2t})$ (C) $\frac{q_0 N_0}{2}(1-e^{-t})$ (D) $q_0 N_0 (1-e^{-2t})$

Column Matching Type Questions

Q.48 Consider the positions of different nuclei on the binding energy per nucleon graph as shown -



Column-I (Reactions)	Column-II (Q-values (MeV))
(A) $2B \rightarrow C$	(P) zero
(B) $2B + C \rightarrow D$	(Q) 102
(C) $E \rightarrow C + D$	(R) non-zero
(D) $3A \rightarrow C$	(S) 36
	(T) 90

Numeric Response Type Questions

Q.49 If the frequency of k_α x-ray emitted from the element with atomic number 31 is f, if the frequency of k_α x-ray emitted from the element with atomic number 51, is given by $\frac{25}{x}$ f then x is (assume that screening constant for K_α is 1)

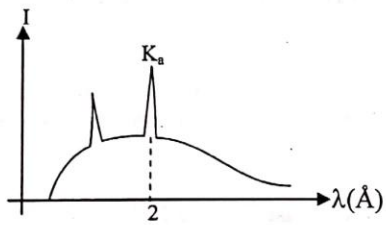
Q.50 The Ra^{226} nucleus undergoes α-decay according to equation $Ra_{88}^{226} \rightarrow Rn_{86}^{222} + He_2^4$. If the Q value of reaction is Q = x MeV then write the [X]. Where [X] represents the greatest integer of x.
(Given : m(Ra_{88}^{226}) = 226.025406u, m(Rn_{86}^{222}) = 222.017574u, m(He_2^4) = 4.002603u]

Q.51 An ionization counter is used to investigate the disintegration rate of a certain radioactive sample. At the start of the experiment, the counter gives 141 pulses in 20s. After 3 days it gives 100 pulses in 20s. Its half life is (in days).

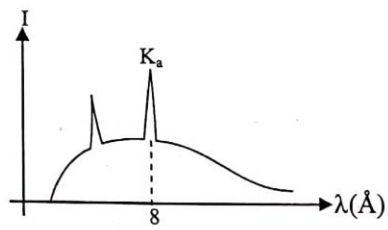
Q.52 A box contains 100 mg of radioactive sample of half-life 270 days. After 540 days the mass of radioactive material is left '5n' mg then 'n' is

Q.53 The voltage applied to an X-ray tube is 20 kV. The minimum wavelength of X-ray produce, is given by $\frac{3\ln}{50}$ Å then n will be ($h = 6.62 \times 10^{-34}$ Js, $c = 3 \times 10^8$ m/s. $e = 1.6 \times 10^{-19}$)

Q.54 Intensity v/s wavelength of x-rays graphs are given for two different target elements. If number of protons in an atom of target element-1 is 37 then number of protons in an atom of target element-2 will be :



Target element-1



Target element-2

Q.55 A Neutron is moving with speed 'v' towards a hydrogen atom which is in ground state. If hydrogen atom is also moving towards neutron with same speed. Then minimum KE of each so that an inelastic collision may occur will be ... eV. (Approx your answer to nearest integer) (Take masses of both are almost equal)

Q.56 Photon corresponding to the first five transition of Balmer series of hydrogen atom are incident on a metal plate, which has a work function of 3eV. What will be number of photo electrons emitted if corresponding to each wavelength the number of photons available are 2. Consider one electron to be emitted for each photon.

Q.57 The nuclei of two radioactive isotopes of same substance A^{236} and A^{234} are present in the ratio 4 : 1 in an ore obtained from Mars. Their half lives are 30 min and 60 min respectively. Both isotopes are alpha emitters and the activity of the isotope with half life 30 min is one Rutherford . Calculate after how much time (in min) their activities will become identical. If it is 60 × n. Find the value of n.

Q.58 In a sample initially there are equal number of atoms of two radioactive isotopes A and B. 3 days later the number of atoms of A is twice that of B. Half life of B is 1.5 days. What is half life of isotope A ? (in days)

Q.59 The reaction ${}^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{7}_{4}Be + {}^{1}_{0}n$ is endothermic. Assuming that Li nuclei is free and at rest. The minimum kinetic energy (in keV) of incident proton so that this reaction occurs is n × 235. Find the value of n.
Take Q value of this reaction as –1645 keV

Q.60 A radioactive element decays simultaneously through two decays processes A and B, having half lives t_1 and t_2 respectively where $t_1 = 3t_2$. The ratio of the decay constant of the process A to that of the decay constant of the decay of element is $\frac{1}{a}$ then a is

Q.61 A radioactive sample contains two radio nuclides A and B having decay constant λ hr^{-1} and 2λ hr^{-1}. Initially 25% of total decay comes from A. How long (in hr) will it take before 75% of total decay comes from A. [Take $\lambda = \ell n\, 3$]

Q.62 A radioactive decay counter is switched on at t = 0. A β-active sample is present near the counter. The counter registers the number of β-particles emitted by the sample. The counter registers 1×10^5 β-particles at t = 36 s and 1.11×10^5 β-particles at t = 108 s. Find $T_{1/2}$ of this sample.

Q.63 An isotopes of Potassium ${}^{40}_{19}K$ has a half life of 1.4×10^9 year and decays to Argon ${}^{40}_{18}Ar$ which is stable.
(i) Write down the nuclear reaction representing this decay.
(ii) A sample of rock taken from the moon contains both potassium and argon in the ratio 1/7. Find age of rock

Q.64 At t = 0, a sample is placed in a reactor. An unstable nuclide is produced at a constant rate R in the sample by neutron absorption. This nuclide β^- decays with half life τ. Find the time required to produce 80% of the equilibrium quantity of this unstable nuclide.

Q.65 Suppose that the sun consists entirely of hydrogen atom and releases the energy by the nuclear reaction, $4{}^{1}_{1}H \longrightarrow {}^{4}_{2}He$ with 26 MeV of energy released. If the total output power of the sun is assumed to remain constant at 3.9×10^{26} W, find the time it will take to burn all the hydrogen. Take the mass of the sun as 1.7×10^{30} kg.

Q.66 The positron is a fundamental particle with the same mass as that of the electron and with a charge equal to that of an electron but of opposite sign. When a positron and an electron collide, they may annihilate each other. The energy corresponding to their mass appears in two photons of equal energy. Find the wavelength of the radiation emitted.
[Take : mass of electron = $(0.5 / C^2)$ MeV and $hC = 1.2 \times 10^{-12}$ MeV.m where h is the Plank's constant and C is the velocity of light in air]

Q.67 U^{238} and U^{235} occur in nature in an atomic ratio 140 : 1. Assuming that at the time of earth's formation the two isotopes were present in equal amounts. Calculate the age of the earth.
(Half life of $u^{238} = 4.5 \times 10^9$ yrs and that of $U^{235} = 7.13 \times 10^8$ yrs)

Q.68 The kinetic energy of an α-particle which flies out of the nucleus of a Ra^{226} atom in radioactive disintegration is 4.78 MeV. Find the total energy evolved during the escape of the α-particle.

Q.69 A small bottle contains powdered beryllium Be & gaseous radon which is used as a source of α-particles. Neutrons are produced when α-particles of the radon react with beryllium. The yield of this reaction is (1/4000) i.e. only one α-particle out of 4000 induces the reaction. Find the amount of radon (Rn^{222}) originally introduced into the source, if it produces 1.2×10^6 neutrons per second after 7.6 days. [$T_{1/2}$ of R_n = 3.8 days]

Q.70 An experiment is done to determine the half-life of radioactive substance that emits one β-particle for each decay process. Measurement show that an average of 8.4 β are emitted each second by 2.5 mg of the substance. The atomic weight of the substance is 230. Find the half life of the substance

Q.71 A wooden piece of great antiquity weight 50 gm and shows C^{14} activity of 320 disintegrations per minute. Estimate the length of the time which has elapsed since this wood was part of living tree, assuming that living plants show a C^{14} activity of 12 disintegrations per minute per gm. The half life of C^{14} is 5730 yrs.

Q.72 Show that in a nuclear reaction where the outgoing particle is scattered at an angle of 90° with the direction of the bombarding particle, the Q-value is expressed as

$$Q = K_P\left(1+\frac{m_P}{M_O}\right) - K_I\left(1+\frac{m_I}{M_O}\right)$$

Where, I = incoming particle, P = product nucleus, T = target nucleus, O = outgoing particle

Q.73 A radionuclide with disintegration constant λ is produced in a reactor at a constant rate α nuclei per sec. During each decay energy E_0 is released. 20% of this energy is utilized in increasing the temperature of water. Find the increase in temperature of m mass of water in time t. Specific heat of water is S. Assume that there is no loss of energy through water surface.

Q.74 A neutron of kinetic energy 65 eV collides inelastically with a singly ionized helium atom at rest. It is scattered at an angle of 90° with respect of its original direction.

(i) Find the allowed values of the energy of the neutron & that of the atom after collision.

(ii) If the atom gets de-excited subsequently by emitting radiation, find the frequencies of the emitted radiation. (Given : Mass of He atom = 4 × (mass of neutron), ionization energy of H atom = 13.6 eV)

ANSWER KEY

Single Correct Option type Questions

1. (A)	**2.** (B)	**3.** (B)	**4.** (B)	**5.** (B)	**6.** (B)	**7.** (B)
8. (C)	**9.** (D)	**10.** (B)	**11.** (C)	**12.** (A)	**13.** (A)	**14.** (A)
15. (B)	**16.** (D)	**17.** (B)	**18.** (D)	**19.** (C)	**20.** (B)	**21.** (A)
22. (A)	**23.** (C)	**24.** (A)				

Multiple Correct Option type Questions

25. (A,C)	**26.** (A,B,C,D)	**27.** (A,C)	**28.** (A,C)	**29.** (B,C,D)	**30.** (B.C.D)	**31.** (A,B,C,D)
32. (A,C)	**33.** (C)	**34.** (A,B,D)	**35.** (A,D)	**36.** (A,B,C)	**37.** (A,C,D)	**38.** (A,C)
39. (B,C)	**40.** (A,B,C)	**41.** (B,C)	**42.** (B,D)	**43.** (A,B,C)	**44.** (A,D)	**45.** (A,D)

Passage Based Questions

46. (C) **47.** (A)

Column Matching Type Questions

48. $A \rightarrow R,S$; $B \rightarrow P$; $C \rightarrow R,T$; $D \rightarrow Q,R$

Numeric Response Type Questions

49. 9	**50.** 4	**51.** 6	**52.** 5	**53.** 2	**54.** 19	**55.** 5
56. 4	**57.** 3	**58.** 3	**59.** 8	**60.** 4	**61.** 4	

62. ($T_{1/2} = 10.8$ sec)

63. (i) ${}^{40}_{19}K \longrightarrow {}^{40}_{18}Ar + {}_{+1}e^{0} + \nu$, (ii) 4.2×10^{9} years

64. $t = \left(\frac{\ell n5}{\ell n2}\right)\tau$

65. $8/3 \times 10^{18}$ sec

66. 2.48×10^{-12} m

67. 6.04×10^{9} yrs

68. 4.87 MeV

69. 3.3×10^{-6} g

70. 1.7×10^{10} years

71. 5196 yrs

73. $\Delta T = \dfrac{0.2E_0\left[\alpha t - \frac{\alpha}{\lambda}(1 - e^{-\lambda t})\right]}{mS}$

74. (i) Allowed values of energy of neutron = 6.36 eV and 0.312 eV ; allowed values of energy of He atom = 17.84 eV and 16.328 eV, (ii) 18.23×10^{14} Hz, 9.846×10^{15} Hz, 11.6×10^{15} Hz