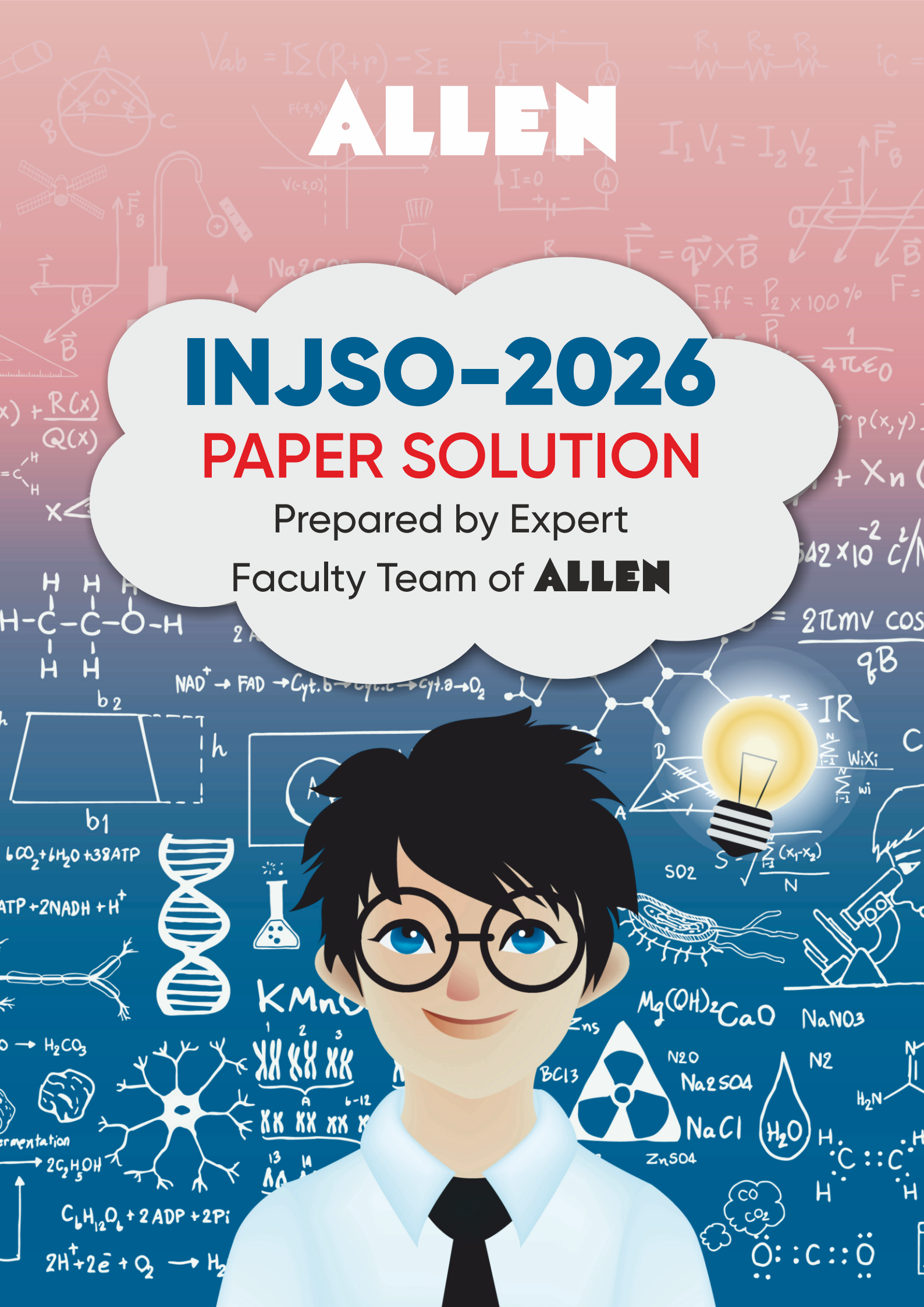
ALLEN

INJSO-2026

PAPER SOLUTION

Prepared by Expert

Faculty Team of ALLEN



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ANSWER KEY

Indian National Junior Science Olympiad

INJSO 2026

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	D	C	B	C	D	C	C	C	B	B
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	B	B	B	C	C	A,B	A,C	A,C,D	A,C	A,B
Que.	21	22	23	24						
Ans.	A,C,D	B,C,D	D	B,D						

Indian National Junior Science Olympiad-2026

Date of Examination : 01st February, 2026

SOLUTIONS

SECTION-I

1. Which of the following statements are correct with respect to nerve impulse conduction in brain slice cultured in artificial medium?

I. Conduction relies on electrical signals

II. Conduction is driven by sodium-potassium pump activity

III. Myelin slows down the conduction

IV. Conduction requires ATP hydrolysis

(A) I and II only (B) I, III and IV only (C) II and IV only (D) I, II and IV only

Ans. (D)

Sol. I, II and IV only

2. Nucleic acids can be resolved on an agarose gel by their electrophoretic mobility. They are visualised by a dye that binds quantitatively to the bases when they are paired (double stranded). Only in the bound form does the dye fluoresce brightly under UV light. What unique advantage does fluorescent dyes (Fds) impart in the detection of nucleic acids, compared to chromogenic dyes (Cds, like methylene blue or safranin), to visualize DNA on an agarose gel?

(A) Fds enable visualization by binding specifically to DNA based on molecular weight

(B) Fds are inert and do not diffuse into the gel matrix, unlike Cds.

(C) Fds provide a better signal -to-noise ratio compared to Cds.

(D) Fds do not alter the structure of DNA as much as Cds.

Ans. (C)

Sol. Fds provide a better signal -to-noise ratio compared to Cds.

3. In a practical examination a student collects several different types of fungal species from diverse habitats, labels them as samples P to S, and notes down the following:

Sample	Observation
P	Releases digestive enzymes onto decaying wood
Q	Unicellular
R	Lives symbiotically with algae on tree bark, tolerating extreme environments.
S	Causes rust disease in plants and significant crop loss

A classmate observe the same samples, notes down some remarks, and re-labels them as samples I-IV.

Sample	Remarks
I	Has filamentous hyphae to increase the surface area for nutrient absorption
II	Shows obligate biotrophy (they cannot be cultured in a laboratory on artificial media, but can be maintained on live host).
III	Primarily reproduces asexually by budding.
IV	Pioneer species in ecological succession and contributes to soil formation.

Which of the following options show the correct combinations depicting the same species?

(a) P-III, Q-IV, R-II, S-I (b) P-I, Q-III, R-IV, S-II

(c) P-IV, Q-III, R-II, S-I (d) P-IV, Q-II, R-I, S-III

Ans. (b)

Sol. P-I, Q-III, R-IV, S-II

4. For the formation of human gametes, the primordial germ cells in ovaries undergo meiotic division. Considering this, which or the following combination of cell types and chromatid number are correct?

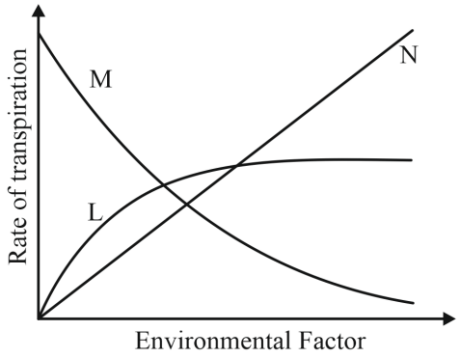
	Cell 1	Cell 2	Chromatid number per cell
1.	Oogonium	Primary polar body	46
2.	Secondary oocyte	Ootid	23
3.	Primary oocyte	Primary polar body	46
4.	Primary polar body	Secondry polar body	23
5.	Oogonium	Primary oocyte	46
6.	Secondary oocyte	Oogonium	46
7.	Primary oocyte	Secondary oocyte	92
8.	Secondary polar body	Ovum	23

(A) 1,3,5 (B) 2,3,4 (C) 1,6,8 (D) 3,4,8

Ans. (C)

Sol. 1,6,8

5. Tran pi ration is the process by which water is lost from the aerial parts or plants, primarily through the stomata. The rate of transpiration is influenced by several environmental factors some or which are enlisted in the table below. The graph below shows three factors-L, M and which affect the rate of transpiration in plants. Identify the correct combinations of L, M and N based on the patterns as seen in the graph.



	L	M	N
(A)	Humidity	Light intensity	Wind speed
(B)	Temperature	Wind speed	Humidity
(C)	Wind speed	Temperature	Light intensity
(D)	Light intensity	Humidity	Temperature

Ans. (D)

Sol.

Light intensity	Humidity	Temperature

6. When a slightly soluble ionic compound is added to water, some of it dissolves to form a solution, establishing equilibrium between the pure solid and a solution of its ions.

For the dissolution of calcium phosphate, one main component of kidney stones, the equilibrium can be written as follows, with the solid salt on the left:

$$Ca_3(PO_4)_{2(s)} \rightleftharpoons 3Ca^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$$

The equilibrium constant for the dissolution of a sparingly soluble salt like calcium phosphate. is the solubility product (K_{sp}) of the salt. The activity of pure $Ca_3(PO_4)_2$ is a constant at given salt concentration. The solubility product expression for calcium phosphate is:

$$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$$

At 25ºC and pH 7.00, K_{sp} for calcium phosphate is 2.07×10^{-33}, indicating that the concentrations of Ca^{2+} and PO_4^{3-} ions in solution that are in equilibrium with solid calcium phosphate are very low.

The solubility of calcium phosphate gets changed in presence of other salts containing similar ions as in calcium phosphate. Adding common cation or anion shifts solubility equilibrium in the direction predicted by Le Chatelier's principle.

The solubilities of calcium phosphate re measured in different solutions at 25°C.

Choose the correct option from the table given below:

	Solubility of $Ca_3(PO_4)_2$ in moles/litre			
	Aqueous solution	0.01 M clcium chloride solution	0.025 M calcium nitrate solution	0.05 M sodium phosphate solution
(A)	1.14×10^{-7}	1.97×10^{-11}	4.38×10^{-15}	1.11×10^{-15}
(B)	1.14×10^{-7}	1.11×10^{-15}	4.38×10^{-15}	1.97×10^{-11}
(C)	1.14×10^{-7}	4.38×10^{-15}	1.11×10^{-15}	1.97×10^{-11}
(D)	1.14×10^{-7}	4.38×10^{-15}	1.11×10^{-15}	1.97×10^{-15}

Ans. (C)

Sol. $Ca_3(PO_4)_{2(s)} \rightleftharpoons 3Ca^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$

In aqueous solution

$K_{sp} = (3S)^3 (2S)^2$

$= 108S^5 = 2.07 \times 10^{-33}$

$S = 1.14 \times 10^{-7}$

In 0.01 M $CaCl_2$ solution :

$K_{sp} = (0.01)^3 (2S)^2 = 2.07 \times 10^{-33}$

$= (2S)^2 = 2.07 \times 10^{-27}$

$= S = 2.27 \times 10^{-14}$

In 0.025 M $Ca(NO_3)_2$ solution :

$K_{sp} = (0.025)^2 (2S)^2 = 2.07 \times 10^{-33}$

$(2S)^2 = 1.32 \times 10^{-28}$

$S = 5.74 \times 10^{-15}$

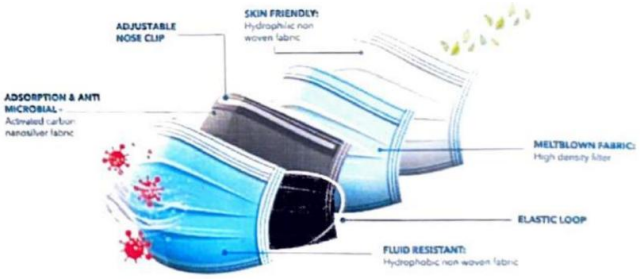
In 0.05 M Na_3PO_4 solution :

$K_{sp} = (3S)^3 (0.05)^2 = 2.07 \times 10^{-33}$

$S = 3.13 \times 10^{-11}$

7. After the last pandemic, mask have become an extended part of our body. If you ever try to cut open a pollution mask, you shall find it consists of two or more layers of fabric, and between the layers exist activated carbon granules or a filter sheet, which serve as a purifier. It allows clean air to reach our nostrils by adsorbing the dust and smoke particles. The activated carbon element or the filter sheet is the adsorbent, while the dust and smoke particles are adsorbates.

This process creates a film of the adsorbate on the surface of the adsorbent. The process of adsorption is distinctly a surface phenomenon. Adsorption is usually an exothermic process. And when molecules get adsorbed, they lose their freedom of motion. This adsorption process differs from absorption in which fluid (the absorbate) is dissolved by or permeates a liquid or solid (the absorbent).



Now, in view of the following thermodynamic parameters described below:

(i) Gibbs free energy change (ΔG) which is the criterion for determining whether a chemical reaction or physical transformation will occur on its own under constant temperature and pressure conditions.

(ii) Enthalpy change (ΔH) which is a measure of the heat gained or lost by a system during a process under constant pressure.

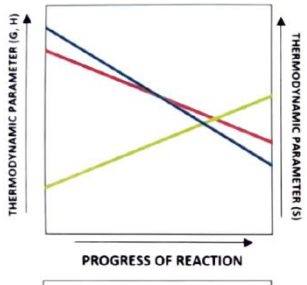
(iii) Entropy change (ΔS) a positive change in entropy indicates a system is becoming more disordered, while negative change indicates a move toward greater order.

And they are also related by the equation: $\Delta G = \Delta H - T\Delta S$

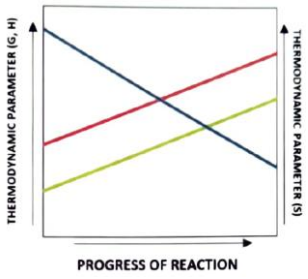
[where, T = absolute temperature];

Which of the following graphs represent the adsorption process on the system, where the following lines represent each thermodynamic property.

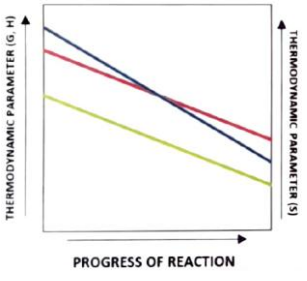
(A)



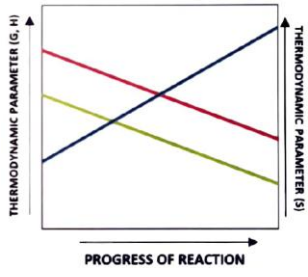
(B)



(C)



(D)



Ans. (C)

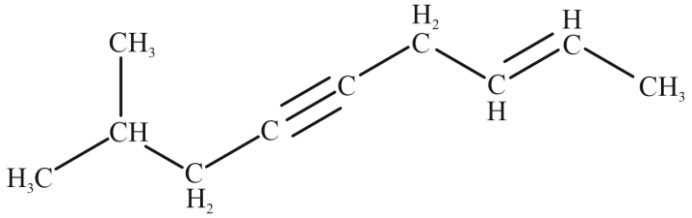
Sol. For adsorption process:

ΔH = negative

ΔS = negative

ΔG = negative

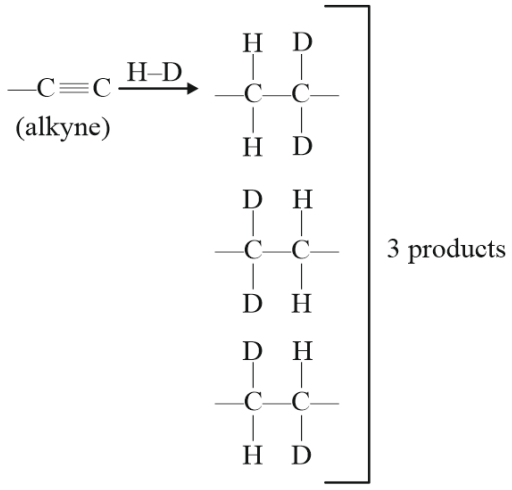
8. Hydrogenation of alkenes and alkynes is executed by exposing them to excess hydrogen gas in presence of a metal catalyst like Nickel. The molecule below was exposed to excess gas H-D in presence of nickel catalyst. How many unique products are formed? [D = deuterium. Assume reaction goes to completion. Ignore formation of stereoisomers]

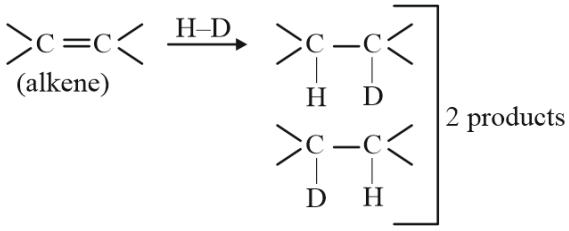


(A) 3 (B) 4 (C) 6 (D) 8

Ans. (C)

Sol.





$\therefore$ Total $3 \times 2 = 6$ Products

(neglecting scrabing of H —H to from H_2, D_2, HD

9. One day in a university chemistry laboratory. Priya was preparing an aqueous urea solution for her experiment. She carefully weighed out exactly 900 grams of water and added the required amount of urea to achieve a mole fraction of 0.05. As she observed the clear solution, she wondered about it concentration. Checking her notes, Priya found that the density of the solution was noted as 1.03 g dm^{-3}. What is the molarity of her freshly prepared urea solution?

(A) 2.64 (B) 2.56 (C) 3.27 (D) 3.01

Ans. (B)

Sol. Mole fraction of urea $= \dfrac{\text{Mole of Urea}}{\text{Mole of Urea} + \text{Mole of water}} = \dfrac{n}{n + \frac{900}{18}} = 0.05$

$\therefore n = \dfrac{2.5}{0.95} = 2.63$

$\therefore$ wt. of solution formed $= (2.63 \times 60) + 900 = 1057.9$ gm

Volume of solution $= \dfrac{1057.9}{1.03} = 1027.1$ ml

Molarity of solution $= \dfrac{2.63 \times 1000}{1027.1} = 2.56$

10. A large number of different proteins contain nearly the same percentage of nitrogen (N). The factor or conversion of weight of N to weight of protein is 6.25 (proteins contain about 16% nitrogen). A sample of protein is heated with excess sulphuric acid in a closed container. The nitrogen atoms in it are converted to soluble ammonium salt. The solution is cooled, and concentrated sodium hydroxide is added to make the solution alkaline. This liberates a colourless pungent gas which is passed through excess of acid of known concentration. The unreacted acid is titrated with sodium hydroxide of known concentration to obtain the amount of nitrogen present in the protein sample. A 3.00 g sample of health supplement is analysed for its protein content by the above method. The colourless gas was passed through 100.0 mL of 0.1 M HCI. After completion of the reaction, the remaining acid required 35.0 mL of 0.05 M NaOH solution. The percent of protein in the sample and the sequence of reactions are

(A) 72% -- {decomposition, displacement, neutralisation, neutralisation}

(B) 24 % -- {decomposition, displacement, neutralisation, neutralisation}

(C) 72% -- {decomposition, neutralisation, displacement, neutralisation, neutralisation}

(D) 24% -- {decomposition, neutralisation, displacement, neutralisation, neutralisation}

Ans. (B)

Sol. Protein $\xrightarrow[H_2SO_4]{\Delta}$ $(NH_4)_2SO_4$ (Decomposition)

$(NH_4)_2SO_4 + NaOH \longrightarrow NH_3 + Na_2SO_4$ (Displacement)

$NH_3 + \underset{\text{100 ml, 0.1 M}}{HCl} \longrightarrow NH_4Cl$ (Neutralisation)

$HCl + \underset{\text{35 ml, 0.05 M}}{NaOH} \longrightarrow NaCl + H_2O$ (Neutralisation)

(unreacted)

Millimoles of HCl taken $= M \times V = 0.1 \times 100 = 10$ mm

Millimoles of HCl left = Milliole of NaOH used $= 0.05 \times 35 = 1.75$ mm

Millimoles of HCl used for $NH_3 = 10 - 1.75 = 8.25$ mm

Millimoles of $NH_3 = 8.25$ mm

$\therefore$ millimoles of N in protein = 8.25 mm

wt. of N in protein $= 8.25 \times 14 \times 10^{-3}$ gm $= 0.1155$ gm

$\therefore$ wt. of protein $= \frac{\text{wt. of N}}{16} \times 100 = \frac{\text{wt. of N}}{16} = \frac{0.1155}{16} \times 100 = 0.72$ gm

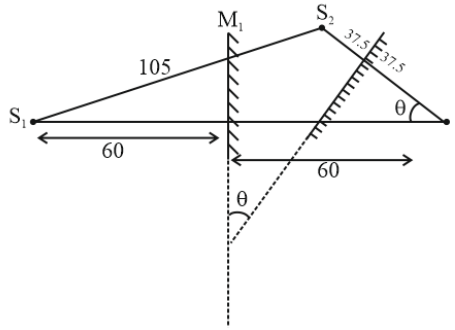
$\therefore$ wt.% of protein in the sample $= \frac{0.72}{3} \times 100 = 24\%$

11. Two point-sources of light lying on a plane of the paper are separated by 105 cm. Two plane mirrors are placed at a perpendicular distance of 60 cm and 37.5 cm respectively from the two sources. The mirrors are oriented in such a way that the images of the two light sources of light formed by them coincide with each other. The angle included by the two non-reflecting faces of the mirrors is.

(A) 90º (B) 120º (C) 60º (D) 0º

Ans. (B)

Sol.



In $\Delta S_1S_2S_1'$

$\cos\theta = \frac{(120)^2 + (75)^2 - (105)^2}{2 \times 120 \times 75}$

$\cos\theta = \frac{1}{2}$

$\theta = 60°$

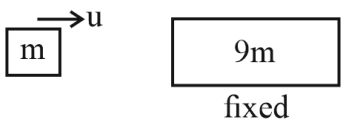
So angle between non-reflecting surfaces = 180 – θ = 120º.

12. A bullet of mass m is fired horizontally into a fixed wooden block of mass 9 m. It pierces through a distance S_0 in the block and stops. In another case, an identical block that is free to move on a smooth horizontal surface is hit by an identical bullet fired into the block horizontally. The bullet covers distance S into the block and after that, they travel with common velocity. Assuming same masses same initial velocity of the bullet and same constant resistive force, determine $\frac{S_0}{S}$.

(A) $\frac{3}{4}$ (B) $\frac{10}{9}$ (C) $\frac{19}{10}$ (D) $\frac{4}{3}$

Ans. (B)

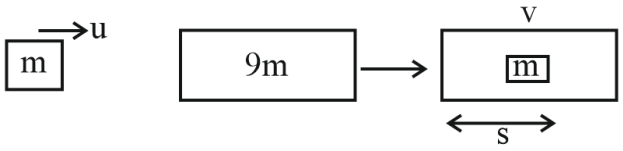
Sol. Case-1



Let resistive face be F_0 then

$F_0S_0 = \frac{1}{2}mu^2$ .....(1)

Case-2



By COLM

$mu = (10\ m)v$

$v = \frac{u}{10}$ ……(2)

By WET

F_0S = Loss of K.E.

$F_0S = \frac{1}{2}mu^2 - \frac{1}{2} \times 10\ mv^2$

$F_0S = \frac{1}{2}mu^2 - \frac{1}{2} \times 10\ \frac{m \times u^2}{100}$

$F_0S = \frac{9}{20}\ mu^2$ ……..(3)

eq.(1) / eq.(3)

$\frac{S_0}{s} = \frac{1}{2} \div \frac{9}{20} = \frac{10}{9}$

13. This question is on combustion, temperature change and phase change.

Combustion : Combustion is a chemical reaction in which a substance reacts with oxygen to produce heat and light, like when wood bums in a fire. If 1 gram of gasoline bums. i.e, undergoes combustion, it releases 45000 J of heat.

Temperature Change: A temperature change happens when heat energy is gained or lost, such as water warming up when heated on a gas stove. To increase the temperature of 1 kg of water through 1 °C, the heat to be supplied is 4200 J.

Phase Change: A phase change occurs when a substance changes its state, like ice melting into water or water boiling into steam. To convert 1 kg of water at 100 °C into 1 kg steam at 100 °C the heat to be supplied is 2250 kJ. During the phase change, there is no change in the temperature of water,

In an experiment, 1 kg of water is taken in a pot on a gas stove which produces heat energy by combustion of gasoline. On lighting the stove, only 40% of heat is transferred to water. Initial temperature of water is 25ºC. The amount of gasoline required to heat the water up to 100ºC and boil of 250 g of it is

(A) 33.00 g (B) 48.75 g (C) 40.25 g (D) 75.30 g

Ans. (B)

Sol. $\Delta Q = m_1 s\,\Delta T + m_2 L$

$\Delta Q = 1 \times 4200 \times 75 + (.250) \times 2250 \times 10^3$

$= 877500$ J

Heat required to be produced by combustion

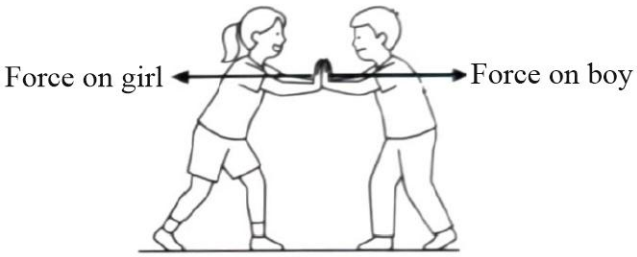
$\Delta Q' = \Delta Q \times \frac{100}{40} = 2193750$ J

Required mass of gasoline

$= \frac{\Delta Q'}{45000}$

$= 48.75$ g.m

14. Two ice skaters, a boy of mass 60 kg and a girl of mass 45 kg are initially at rest on a flat ice bed. They push each other to gain some velocity. As a result, the boy picks a speed of 1.5 m/s. Consider the following statement.



Statement-1 : The speed of girl is 1.5 ms^{-1}.
Statement-2 : The speed of girl is 2.0 ms^{-1}.
Statement-3 : work done by the boy while pushing the girl is 90 J.
Statement-4 : Work done by the girl while pushing the boy is less than work done by the boy pushing the girl.
Choose the correct options.

(A) Statements 1, 3 and 4 are only correct.
(B) Statements 1 and 4 only correct.
(C) Statement 2, 3 and 4 only correct.
(D) Statements 2 and 3 only correct.

Ans. (C)

Sol. By COLM $\rightarrow M_G V_G = M_B V_B$

$V_G = \frac{60 \times 1.5}{45} = 2$ m/s

Work done by boy = kinetic energy of girl

$= \frac{1}{2} M_G V_G^2$

$= \frac{1}{2} \times 45 \times (2)^2$

$= 90$ J

Work done by girl = kinetic energy of boy $= \frac{1}{2} M_B V_B^2$

$= \frac{1}{2} \times 60 \times (1.5)^2$

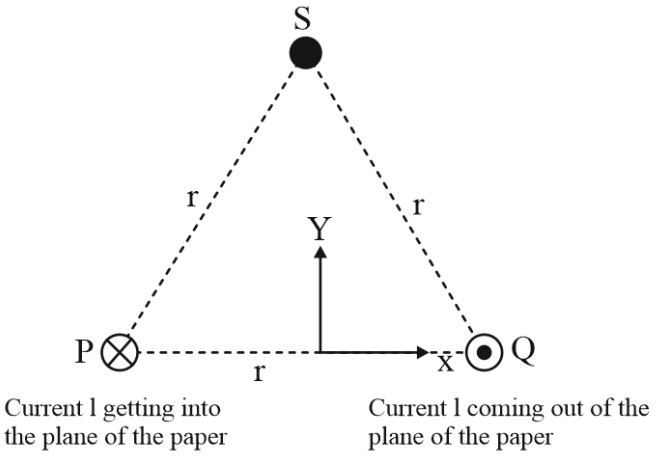
$= 67.5$ J

15. Two long conducting wires carry equal currents but in opposite direction. These are separated by distance r. The wire at P carries current into plane of the paper and that at Q carries current coming out of the plane of the paper. S is a point in the plane of the paper at an equidistance (r) from both the wires. Select the correct statements from the following.

Statement-I : The directions of magnetic fields produced at S by the two wires are at 120º with each other.

Statement-2 : The net magnetic field at S is towards negative y – direction.

Statement-3 : If the current in the wire at P is reversed, then the magnetic field at S will be along positive x-direction.

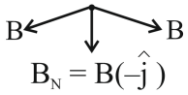


(A) Statements 1, 2, 3 are correct.
(B) Statements 1 and 3 only are correct.
(C) Statements 1 and 2 are correct.
(D) Statement 2 and 3 only are correct.

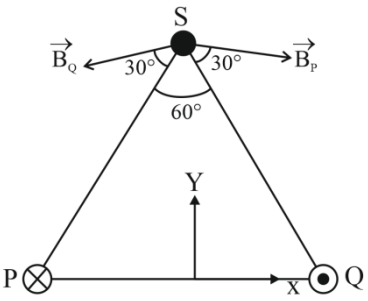
Ans. (C)

Sol. By right hand thumb rule directions of $\overrightarrow{B_P}$ and $\overrightarrow{B_Q}$ are inclined at 120°

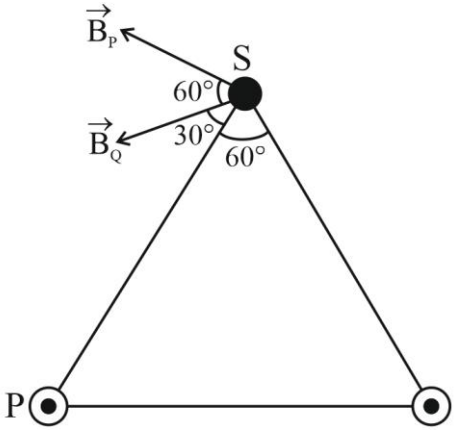
Net magnetic field at 's'



$B_N = B(-\hat{j})$



If current in p is reversed



Net magnetic field at 's' will be toward negative x-axis

SECTION-II

16. During prolonged fasting in a healthy individual, the body tries to maintain blood glucose levels. If a healthy person fasts for longer than 18 hours. which of the following statement/s correctly describe the body's process(es) for maintaining optimum glucose levels?

(A) Glycogen stores are depleted due to increased mobilisation.

(B) Adipose tissue is broken down, and free fatty acids are used energy.

(C) The body shows reduced insulin sensitivity since there is no glucose.

(D) Fermentative metabolism begins in the liver.

Ans. (A and B)

Sol. Glycogen stores are depleted due to increased mobilisation.

Glycogen stores are depleted due to increased mobilisation.

17. In the Western Ghats, farms with installed wind turbines were operated for using wind as a renewable energy source. The operation of wind turbines reduced the number of predatory birds in that area. Which of the following is likely to have happened due to the fall in number of predatory bird?

(A) The lizard population will result in fewer beetles.

(B) The frog population will increase due to a decline in the number of snakes.

(C) Higher number of frogs will result in fewer beetles.

(D) Wind turbines will eventually result in fewer flowering plants.

Ans. (A,C)

Sol. The lizard population will result in fewer beetles.

Higher number of frogs will result in fewer beetles.

18. The nitrogen cycle maintains the balance of nitrogen in the biosphere through several microbial transformations and human-induced alterations. Which of the following statements most accurately describe these processes and their ecological consequences? Choose the correct statements,

(A) During nitrification, chemoautotrophic bacteria such as Nitrosomonas and Nitrobacter oxidize ammonia into nitrite and nitrate; under excessive fertilizer input, this step accelerates nitrate leaching and enhances the risk of eutrophication in aquatic systems.

(B) Denitri fication involves the reduction of nitrates by soil microbes into ammonium compounds that remain available for plant uptake, thereby preventing nitrogen loss and maintaining soil fertility even under limited oxygen conditions.

(C) Ammonification releases ammonia from dead plants and animals through microbial decay. But when fossil fuels or plant matter are burned, this natural process is skipped, and instead nitrogen oxides (NOx) are released into the air, leading to acid rain and ozone formation near the ground.

(D) Biological nitrogen fixation, mediated by Rhizobium in legume root nodules and by free-living bacteria such as Azotobacter, converts N_2 to ammonia; yet prolonged use of synthetic nitrogen fertilizers down-regulates this symbiotic process by reducing plant-bacterial signalling and altering soil microbial community structure.

Ans. (A,C,D)

Sol. During nitrification, chemoautotrophic bacteria such as Nitrosomonas and Nitrobacter oxidize ammonia into nitrite and nitrate; under excessive fertilizer input, this step accelerates nitrate leaching and enhances the risk of eutrophication in aquatic systems.

Ammonification releases ammonia from dead plants and animals through microbial decay. But when fossil fuels or plant matter are burned, this natural process is skipped, and instead nitrogen oxides (NOx) are released into the air, leading to acid rain and ozone formation near the ground.

Biological nitrogen fixation, mediated by Rhizobium in legume root nodules and by free-living bacteria such as Azotobacter, converts N_2 to ammonia; yet prolonged use of synthetic nitrogen fertilizers down-regulates this symbiotic process by reducing plant-bacterial signalling and altering soil microbial community structure.

19. Oral rehydration salts (ORS) is a low-cost, simple mixture of sugar, salt, which when dissolved in water helps treat dehydration by replenishing fluids and electrolytes lost due to diarrhoea and vomiting. ORS works by enhancing the absorption of water and essential minerals like sodium and potassium in the small intestine, helping to restore the body's fluid balance. The mixture is provided in powder or tablet form and must be mixed with fresh drinking water before consumption. An experiment is done by the students of Class X in the school laboratory under the supervision of a guide teacher to find out the percentage composition of sodium chloride and potassium chloride present in a very common branded powdered ORS which is readily available in the market. A sachet of powdered ORS contains 21.80 g of powder. In this sachet, total quantity of sodium chloride and potassium chloride is 4.10 g. Whole sachet is dissolved in 250 ml of distilled water.

The solution is acidified with dilute nitric acid. In this solution, 170 mL of 0.495 M $AgNO_3$ solution is added. The precipitate is filtered off, and a strip of copper weighing 50.0 g is dipped into the filtrate. After a given tin1c interval, the strip weighs 51.5 g.

From the above experiment, find one or more correct result(s) which arc obtained by the (lass X students:

(A) Percentage composition of sodium chloride present in ORS powder = 11.93 %, quantity of deposited silver = 2.1246 g.

(B) Percentage composition of sodium chloride present in ORS powder = 6.88 %, percentage composition of potassium chloride present in ORS powder = 11.93 %.

(C) Quantity of deposited silver 2.1246 g, percentage composition of potassium chloride present in ORS powder = 6.88 %.

(D) Percentage composition of sodium chloride present in ORS powder 6.88 %, quantity of deposited silver = 2.1246 g.

Ans. (A, C)

Sol. Wt. of ORS powder = 21.8 gm

Total wt. of NaCl and KCl in powder = 4.1 gm

Milli moles of $AgNO_3$ dissolved = MV = $0.495 \times 170 = 84.15$ mm = m.m of Ag^+

When Cu strip is dissolved

$$Cu + 2Ag^+ \longrightarrow Cu^{2+} + 2Ag$$

Wt. gain by the strip per mole reaction = $(2 \times 107.868 - 63.546) = 152.19$ gm

$\therefore$ Mole of Ag^+ displaced by Cu = $\frac{(51.5-50)\times 2}{152.19}$ = 0.0197 mole = 19.7 millimoles

$\therefore$ Wt. of Ag deposited on strip = 19.7 × 107.868 mg = 2.124 gm

$\therefore$ millimoles of Ag^+ used for precipitation of AgCl = 84.15 – 19.7 = 64.45 mm
= m.m of NaCl + m.m. of KCl

Let m.m of NaCl and KCl are x and y respectively.

$\therefore$ x + y = 64.45 …(1)

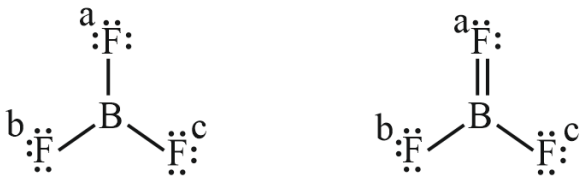
And 58.5 x + 74.5 y = 4100 …(2)

On solving: x = 43.85, y = 20.60

$\therefore$ Wt% of NaCl is ORS = $\frac{43.85\times 10^{-3}\times 58.5}{21.8}\times 100 = 11.8\%$

$\therefore$ Wt% of KCl is ORS = $\frac{20.6\times 10^{-3}\times 74.5}{21.8}\times 100 = 7\%$

20. Two structures have been assigned to BF_3



Structure-I

Structure-II

Formal charge of an atom in a molecule is the hypothetical charge the atom would have if we could redistribute the electrons in the bonds evenly between the atoms in the bond.

Formal charge (F) of an atom in the molecule is determined using the formula

F = V – (S/2) – U

Where V is valence electrons, S is shared electrons, and U is unshared electrons.

The oxidation number in small covalent molecules represents the hypothetical charge an atom would possess if all bonds were considered completely ionic, with electrons assigned to the more electronegative atom in each bond. Unlike formal charge, which assumes equal sharing of electrons. oxidation number helps in understanding electron transfer and chemical reactivity in compounds.

Choose the correct statements.

(A) Formal charge and the oxidation number of boron in the BF_3 in **Structure I** is 0 and +3 respectively, while formal charge and the oxidation number of boron in the BF_3 in **Structure II** , is –1 and +3 respectively.

(B) Formal charge and the oxidation number of fluorine atom a in **Structure I** is 0 and –1 respectively. while formal charge and the oxidation number of fluorine atom a in **Structure II** is + 1 and –1 respectively.

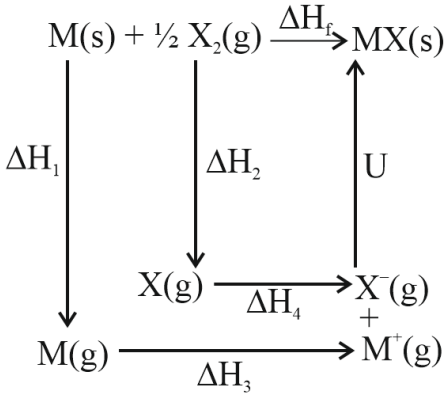
(C) Formal charge of fluorine atom a in **Structure I & II** is –1 and –1 respectively. while oxidation number of fluorine atom b in **structure I and II** is –1 and –1 respectively.

(D) **Structure-I** is better representation of BF_3.

Ans. (A, B)

Sol. Theoretical

21. The Born-Haber cycle is used to determine the lattice energy, which cannot be directly measured. Hess's law of constant heat summation is applied here. Hess's law states that the total enthalpy change in a chemical reaction remains the same, irrespective of the route taken, whether in a single step or in a series of steps. The Born-Haber cycle for formation of alkali metal halides may be represented as in the diagram below, where ΔH_1 is the enthalpy change for sublimation of the metal, ΔH_2 is enthalpy change for dissociation $\frac{1}{2} X_2 \rightarrow X$, ΔH_3 is the ionisation energy for $M \rightarrow M^+$, ΔH_4 is the electron affinity for $X \rightarrow X$, U is the lattice energy for the formation of solid MX and ΔHr is enthalpy change for formation of MX directly from the elements.



By Hess's law $\Delta H_r = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4 + U$

Given the data below, what are the reasons for the high heat of formation of LiF over NaCl?

Reaction	Energy change (kJ mol^{-1})	Reaction	Energy change (kJ mol^{-1})
$Li_{(s)} \rightarrow Li_{(g)}$	161	$Na_{(s)} \rightarrow Na_{(g)}$	108
$Li_{(g)} \rightarrow Li^+_{(g)}$	X_1	$Na_{(s)} \rightarrow Na^+_{(g)}$	X_2
$\frac{1}{2}F_{2(g)} \rightarrow F_{(g)}$	77	$\frac{1}{2}Cl_{2(g)} \rightarrow Cl_{(g)}$	122
$F_{(g)} \rightarrow F_{(g)}$	Y_1	$Cl_{(g)} \rightarrow Cl^-_{(g)}$	Y_2
$Li^+_{(g)} + F^-_{(g)} \rightarrow LiF_{(g)}$	–1047	$Na^+_{(g)} + Cl^-_{(g)} \rightarrow NaCl_{(s)}$	–788
$Li^+_{(g)} + \frac{1}{2}F_{2(g)} \rightarrow LiF_{(g)}$	–617	$Na_{(s)} + \frac{1}{2}Cl_{2(g)} \rightarrow NaCl_{(g)}$	–411

(A) It is easier to ionize sodium compared to lithium.

(B) Electron affinity of fluorine is greater than that of chlorine

(C) LiF lattice energy is significantly higher than that of NaCl

(D) F-F bond is easier to break than Cl–Cl bond

Ans. (A, C, D)

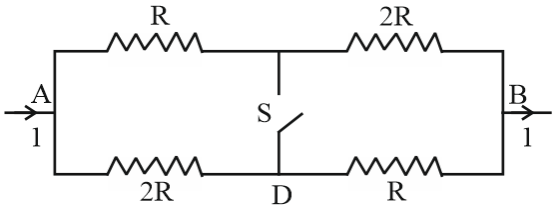
Sol. (A) Ionization energy = Li > Na

(B) Electron affinity = Cl > F

(C) Lattice energy = LiF > NaCl

(D) Bond energy = $Cl_2 > F_2$

22. A current I is driven into a combination of resistors as shown in the figure. Initially switch is open then it is closed. Identify the correct statements.



(A) Power consumed by R at the top left of the circuit before closing the switch is $\frac{I^2R}{2}$.

(B) Power consumed by R before closing the switch is $\frac{I^2R}{4}$.

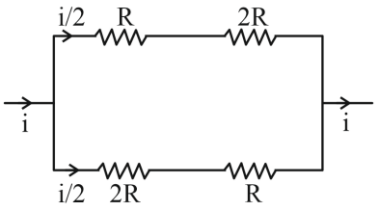
(C) Power consumed by R before closing the switch is $\frac{4I^2R}{9}$.

(D) The current that flows through the key after closing the switch is $\frac{I}{3}$.

Ans. (B, C, D)

Sol. Before closing the switch

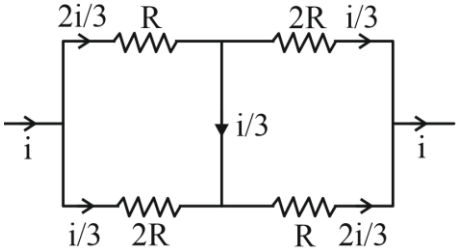
Power consumed by R



$P_R = (i/2)^2 \cdot R = \frac{i^2R}{4}$

<u>After closing the switch:</u>

$P_R = \left(\frac{2i}{3}\right)^2 \cdot R = \frac{4i^2R}{9}$



23. A passenger gets down from a train compartment to have a cup of tea in a crowded shop on the platform just in front or the door of her compartment. When she is having tea. the train starts with an acceleration of 0.03 m s^{-2}. She starts running to catch the same door that she got down aflcr finishing. the tea. Assuming her speed of running to be uniform and neglecting the small distance between tea stall and door of the compartment, identify the correct possibilities.

(A) She can never catch the coach with a uniform speed. She must accelerate.

(B) If we assume that she runs with an average speed of 3 ms^{-1}, right from the beginning then she will have at least 50 s to finish the tea and run to reach the compartment door.

(C) The length of the platform should be at least 150 m from the tea shop for the passenger to safely reach the door of the compartment and catch the train.

(D) If she takes 60 s to finish her tea, the minimum speed required to catch the train by reaching the compartment door is 3.6 ms^{-1}.

Ans. (D)

Sol. For the passenger to catch the train, her position must be equal to the train's position at some point in time ($x_{passenger} = x_{train}$).

$$v(t - t_0) = \frac{1}{2}at^2$$

Rearranging this into a standard quadratic equation for time t:

$$\frac{1}{2}at^2 - vt + vt_0 = 0$$

For a physical solution to exist (meaning she actually catches the train) the roots of this quadratic equation must be real. This requires the discriminant (Δ) to be greater than or equal to zero.

$$\Delta = b^2 - 4ac \geq 0$$

Here, $a_{quad} = \frac{1}{2}a$, $b = -v$, and $c = vt_0$.

$$(-v)^2 - 4\left(\frac{1}{2}a\right)(vt_0) \geq 0$$

$$v^2 - 2avt_0 \geq 0$$

Since velocity $v > 0$, we can divide by v:

$$v - 2at_0 \geq 0$$

$$v \geq 2at_0$$

This gives us the formula for the minimum speed (v_{min}) required to catch the train after a delay of t_0:

3. Evaluate the options

A. Incorrect. As shown above, it is mathematically possible to catch the train with uniform speed provided the speed satisfies $v \geq 2at_0$.

B. Incorrect. If we assume $v = 3$ m/s, the condition becomes
$3 \geq 2(0.03)t_0 \Rightarrow 3 \geq 0.06t0 \Rightarrow t_0 \leq 50$ s.
This means she has at most 50 seconds to finish tea, not "at least".

C. Incorrect. The required length depends on the specific speed and wait time. It is not a fixed universal value of 150 m for all scenarios.

D. Correct. Let's test the values given in this option.

- Given wait time $t_0 = 60$ s
- Using our derived formula: $v_{min} = 2at_0$
- $v_{min} = 2 \times 0.03$ m/s$^2 \times 60$ s
- $v_{min} = 0.06 \times 60$
- $v_{min} = 3.6$ m/s

This matches the value in option D perfectly.

Answer: The correct possibility is D.

24. A square metal plate (of each side equal to 10a and thickness a) and a cube of wood (each side equal to 10a) are joined together with negligible amount of adhesive to form a cuboid. A liquid is taken in a sufficiently tall vessel with cross-sectional area marginally greater than $100a^2$. First, the cuboid is allowed to float with the metal surface at the top and the liquid level in the vessel is marked. The height of the submerged portion of the wood in this case is h1 . Now, the cuboid is taken out and floated again with metal plate lying at the bottom of the wooden block. The water level in the vessel is marked again. The height of the submerged portion of only the wood in the case is h_2. Use the following data to identify the correct statements.

The density of metal 8ρ

The density of wood is ρ.

The density or liquid is 2.ρ.

Walls of the vessel are smooth. Select correct statements.

(A) $h_1 - h_2$ is zero

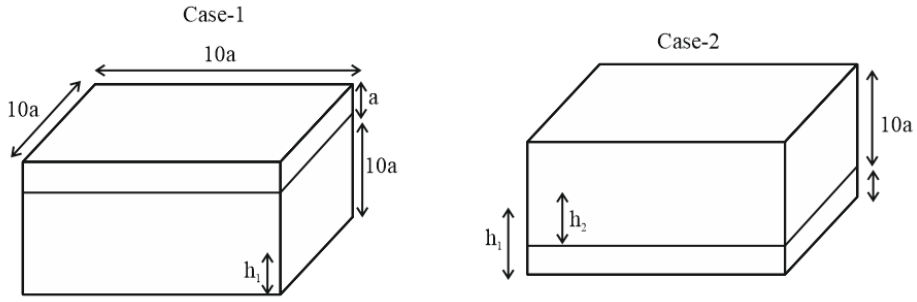
(B) $h_1 - h_2$ is a

(C) The water level in the vessel drop on flipping the cuboid.

(D) The water level in the vessel remains the same on flipping the cuboid.

Ans. (B,D)

Sol.



In both cases

$Mg = \rho_L V_L g$

$$V_L = \frac{M}{\rho_L}$$

$$h = \frac{M}{\rho_L 100a^2} = h_1$$

From diagram $h_1 - h_2 = a$

Since volume of displaced liquid is same in both cases so water level remain same in both cases.

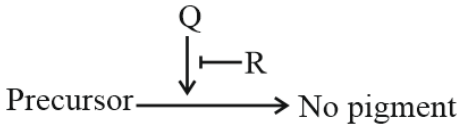
Section III

(Long answer/theory question)

25. In nature. some characters (phenotypes) observed in an organism are results of interactions or alleles of more than one gene. One such interaction is dominant suppression which occurs when a dominant allele of one gene completely suppresses the phenotypic expression of other gene.

This phenomenon is evident in chickens. There are two types of chickens, one with white feathers and the other with coloured ones. This trait is governed by interaction between the alleles of two genes.

The dominant allele. 'Q' of one gene is responsible for coloured feathers; while the dominant allele, 'R' of the other gene. is responsible for controlling the expression of the first gene. Allele 'Q' is dominant over ·q· and the homozygous recessive genotype (qq) leads to growth of white feathers. Interestingly, the dominant allele. 'R' of the other gene has a suppressive eftect on the colour-producing action of 'Q' but the recessive allele. 'r' has no such effect. The following figure depicts the actions of 'Q' and 'R'.



Q.1 At a breeding centre, pure-breeding chickens of particular phenotypes were allowed to mate. (Jure breeding organisms have identical alleles for a given gene(s). In an experimental setup, if pure breeding chicken with coloured feathers were allowed to mate with pure-breeding chickens, the croos result in the production of all white-feathered dihybrid as the F1 generation, When the chickens of Fl were interbred (selfing), the F2 generation produced 629 birds. In the table given below, column A shows the most likely numbers of birds with coloured feathers, while colun1n B shows the most likely numbers of birds with white feathers. Based on the information given. choose the correct pair of number of birds from column A with the one from column B and write it a the space given for writing the answer.

(2 Marks)

A	B
Birds with coloured feathers	Birds with white feathers
a. 118	w. 354
b. 158	x. 471
c. 275	y. 511
d. 40	z. 589

Answer: The correct matching pair from column A and B is _____

Q.2 The breeding centre working with these birds has been meticulously keeping genotypic) records of the birds from generation to ger1eration. For a certain experiment, more white chickens than colored ones are desired in Fi. Which genotype of the coloured birds will produce more white chickens then the coloured ones, when mated with birds of F_1 the experiment from the previous question?

Write down the cross(es) required and find out the correct genotype. All the conventions of writing crosses must be followed and the alphabets and symbols used must be clearly defined. The uppercase and lowercase letters must be clearly legible.

Q.3 A private poultry farm requested the breeding centre for only coloured chickens in large quantities. The newly recruited personnel at the breeding centre formed mating pairs of only coloured birds. However, the progeny birds were comprised of both coloured and white one. Find out the genotype of male and female birds selected as mating pairs that resulted in the progeny with coloured and white birds.
Write down the details of the required cross(es) and find out the correct genotypes of male and female birds. All the conventions of writing crosses must be followed and the alphabets and symbols used must be clearly defined. The uppercase and lowercase letters must be clearly legible. **(4 Marks)**

Sol. (1) In cross qqRR × QQrr
Offsprings in F_1 generation are QqRr.
On selfing 13 : 3 ratio of white : coloured
So, 511(white) out of 629 and 117(coloured) out of 629
(2) In cross Qqrr × QqRr
White : coloured ratio are $\frac{5}{8}:\frac{3}{8}$ respectively
So, F_1 generation Qqrr
(3) Male : Qqrr
Female : Qqrr

26. Using several combinations of biochemical techniques, Zaira developed a multi-step strategy to purify the Mg^{2+}. dependent Taq Polymerase enzyme to >95% purity, from the thermophilic bacterium, Thermus aquaticus (isolated from hot springs). Although these bacteria usually contain about 10^7 total number of protein molecules per cell (which include a mixture of structural proteins, enzymes of different metabolic pathways and recycling enzymes like nucleases and proteases) against only 100 copies of the Taq DNA polymerase enzyme per cell, they are still considered to be a great source of the thermostable polymerase.
Based on this information, solve the problem sets provided :
Zaira grew a 100 ml culture of T aquaticus in a laboratory up to a density of 10^8 cells/ml.
Using this freshly grown 100 mL bacterial culture. Zaira lysed the cells to extract and purify the Taq protein. In the multistep protein purification process, she was able to recover and retain only 5% of the total Taq protein at each step. However, the loss of the total non-target protein was about 1000-fold at each step. Based on this information:

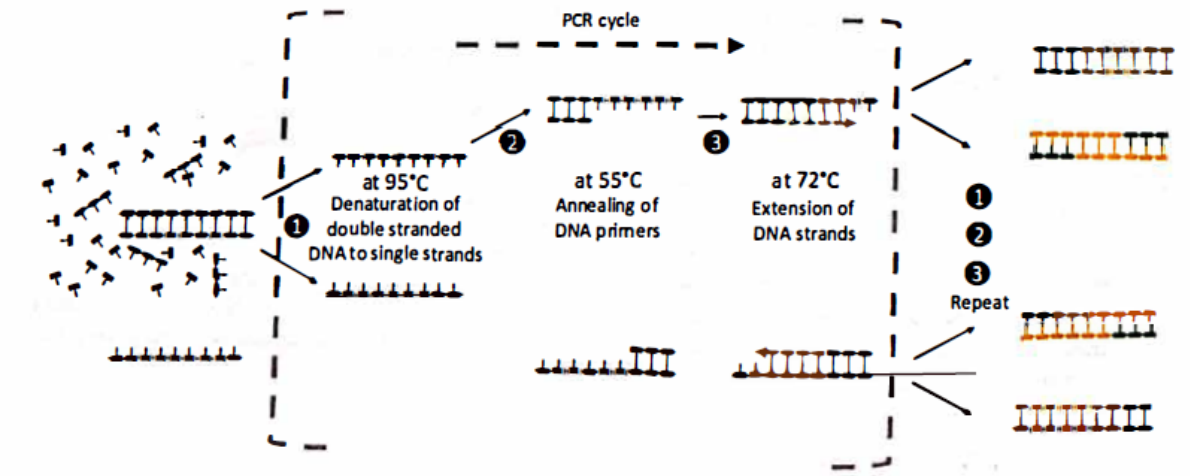
Q.1 Calculate the total number or non-target proteins in the cell versus the target protein in the table below (column 'a' in the table below).

Q.2 Based on the loss of protein during the process at each step, determine the minimum number of purification steps Zaira would have to perfrom, to be able to get a least 95% pure Taq (in columns 'b-h' in the table below) :
(Show your calculations of the answers to the best accuracy, but should be entered into the table as single units with two decimal places and corresponding indices –e.g. 5.04×10^2)
Show your calculations in the space below (for each step) :

Number of molecues of proteins	In 100 mL	After step 1	After step 2	After step 3	After step 4	After step 5	After step 6	After step 7
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Non-target protein (P)								
Taq protein (Q)								
Total protein (P + Q)								
Percentage of pure Taq protein								

Minimum number of purification steps required to get at least 95% pure Taq is _____

(ii) A diagrammatic representation of PCR is given below (template - red and blue. primer- green single nucleotides - blue, newly synthesized strands yellow, and the DNA pol enzyme that catalyses the reaction is not depicted).



In order to PCR-amplify the Tubulin gene from human DNA template, Zaira and Trbulin specific primes (short pieces of single standard DNA that can pair in a sequence specific manner (aneal) to the tubulin gene and prime the polymerisation of that gene alone). She used her own preparation of the ~ 95% pure Taq enzyme as the main source of DNA polymerised when doing the PCR. Let us refer to this PCR reaction as the Standard Reaction.

Q.3 Besides setting up the default standard reaction, where she added all the ingredients required for a regular PCR as shown (i.e., Nucleotides, PCR primes and Buffer), she kept 2 additional reaction tubes, which had all conteins similar, except that : to one reaction tube, she added BSA (Bovine serum Albumin-a non-specific protein which is not involved in the PCR reaction) and to the other she added EDTA (a metal chelator). Pick the statement that correctly reasons the outcome of each reaction compared to the standard reaction (control), where neither was added :

(A) BSA can bind non-specifically to primers in the reaction thereby inhibiting the PCR → PCR expected to be poorer than the standard.

EDT A will chelate Mg^{2+} and inhibit the polymerase enzyme → PCR expected to be poorer than the standard.

(B) BSA competes with contaminating proteases, thereby prolonging the half-life of the Taq polymerase → PCR expected to be better than the standard.
EDTA chelates Mg^{2+} that protects the human template DNA from D Nases → PCR expected to be better than the standard.

(C) BSA can bind non-specifically to primers in the reaction thereby inhibiting the PCR → PCR expected to be poorer than the standard.
EDTA chelates Mg^{2+} that protects the human template DNA from DNases → PCR expected to be better than the standard.

(D) BSA competes with Taq for the action of contaminating proteases, thereby prolonging the half of the Taq polymerase → PCR expected to be better than the standard.
EDTA will chelate Mg^{2+} and inhibit the polymerase enzyme → PCR expected to be poorer than the standard.

Q.4 To ensure that Zaira wasn't amplifying any contaminating DNA from any of the other reagents in the reaction, she executed a control reaction. In case her standard reaction is positive for PCR, pick which of the following control reactions, if negative (lack of DNA amplification), will provide the information she seeks:

(A) Control tube without Taq polymerase
(B) Control tube with 3-times the amount of Taq polymerase
(C) Control tube without any added nucleotides
(D) Control tube without the human template DNA

Q.5 Zaira· found out that her Standard Reaction did not work, and she suspected the nucleotides might have gotten inactivated over time - either partially or completely. as they were bought 6 months ago. She approached her mentor to help her differentiate these two possibilities. The mentor asked her to do 4 different reactions listed below (from P to S). Based on the description lit' each reaction (P-S), if the respective outcome is positive (PCR works, DNA gets amplified), match the statements (E or F) that can help Zaira conclude unambiguously about her two hypotheses (if it doesn't match either hypothesis, then label as NONE):

(P) Repeating the standard reaction tube containing the ingredients for PCR along with the human DNA (her template or choice). but with twice the amount of nucleotides she had previously used.

(Q) A reaction similar to the standard reaction but using the specific pre-amplified tubulin DNA as template from a previous PCR reaction (That had worked. done by her mentor).

(R) Repeat any PCR reaction (that used a commercially prepared Taq Pol) that she knows had worked previously. but do it this time with the Taq Pol she had purified.

(S) Repeat the standard reaction tube with all the ingredients+ human DNA template for PCR, but with a fresh batch of nucleotides.

E.	The nucleotides she used in the original standard reaction were completely functional.
F.	The nucleotides she used in the original standard reaction were partially inactivated.

Sol. (1) Non-target proteins 10^{17}

Target proteins 10^{12}

(2)

Number of molecues of proteins	In 100 mL	After step 1	After step 2	After step 3	After step 4	After step 5	After step 6	After step 7
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Non-target protein (P)	1×10^{17}	1×10^{14}	1×10^{11}	1×10^{8}	1×10^{5}			
Taq protein (Q)	1×10^{12}	5×10^{10}	2.50×10^{9}	1.25×10^{8}	6.25×10^{6}			
Total protein (P + Q)	1×10^{17}	1×10^{14}	1×10^{11}	1×10^{8}	1×10^{5}			
Percentage of pure Taq protein	0.000001%	0.05%	2.44%	55.56%	98.42%			

Minimum number of purification steps required to get at least 95% pure Taq is 4

(3) (D) BSA competes with Taq for the action of contaminating proteases, thereby prolonging the half of the Taq polymerase → PCR expected to be better than the standard.

EDTA will chelate Mg^{2+} and inhibit the polymerase enzyme → PCR expected to be poorer than the standard.

(4) (D)Control tube without the human template DNA

(5) P → F

Q → none

R → none

S → E

27. Tubulin constitutes 6% of the total protein of a cell and exists as a heterodimer composed of α-tubulin (molar mass ≈ 50,000 Da) and β-tubulin (molar mass ≈ 55,000 Da). Biochemical analysis shows that there is 0.5 mg of total protein per million cells. Using this value, estimate the average number of tubulin heterodimeric molecules per cell. Show the complete sequence of calculations required to arrive at each answer.

Tubulin mass per 10^6 cells: _____

Tubulin mass per cell: _____

Moles of tubulin per cell:

Average number of tubulin molecules per cell: _____

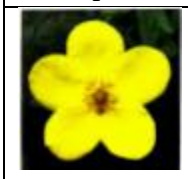
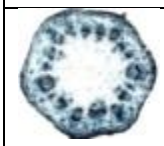
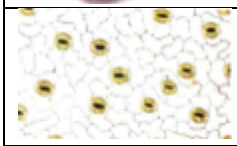
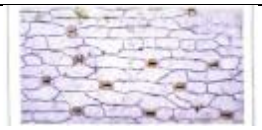
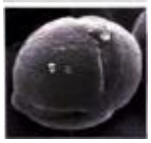
Sol. Tubulin mass per 10^6 cells: 0.03 mg

Tubulin mass per cell: 3×10^{-8} mg/cell

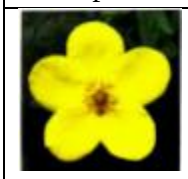
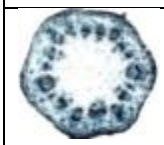
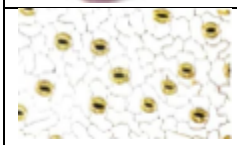
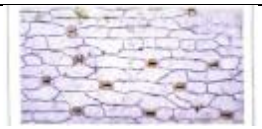
Moles of tubulin per cell: 2.857×10^{-6} mole/cell

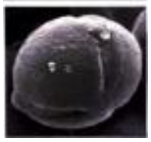
Average number of tubulin molecules per cell: 1.72×10^{8} molecule/cell

28. Plants are classified as monocot and dicot based on certain character. Identify the following plant part as monocot (M) or dicot (D)

Plant part	Monocot/Dicot	Plant part	Monocot/Dicot
			
			
			
			
 Electron micrograph of a pollen		 Elecrton micrograph of a pollen	

Sol.

Plant part	Monocot/Dicot	Plant part	Monocot/Dicot
	Dicot		Monocot
	Dicot		Monocot
	Monocot		Dicot
	Dicot		Monocot

 Electron micrograph of a pollen	Monocot	 Elecrton micrograph of a pollen	Dicot

29. The glucometer is a vital tool for persons managing diabetes, as it enables accurate monitoring of blood glucose levels. The operation of a glucometer relies on enzymatic reactions, specifically utilising the enzyme glucose oxidase. When a blood sample comes into contact with the sensor region or a test trip, glucose oxidase catalyses the conversion of glucose in the blood to gluconic acid and hydrogen peroxide. This reaction uses blood water and oxygen and is nearly irreversible. The quantity of hydrogen peroxide formed during this process is directly proportional to the concentration of glucose present in the blood sample. The generation of hydrogen peroxide leads to the production of an electric current. The device then calculates the corresponding blood glucose level based on this magnitude of this electrical current.

Every component,, within the glucometer is designed to contribute towards the precision and reliability if the measurement. To maintain consistent and reliable results, regular calibration and maintenance of the glucometer are essential.

The following steps outline the typical procedure for using a glucometer :

1. Insert Test Strip: Insert a test strip into the glucometer as per the instructions provided with the device.
2. Clean the Finger: Use the supplied wet swab to clean the surface of the finger you intend to prick.
3. Lancing: Use the lancet to gently prick your finger, typically near the tip, to produce a small drop of blood.
4. Blood Sample: Carefully touch the blood drop to the designated area on the test strip.
5. Measurement: The test strip draws the blood sample into contact with the embedded enzyme.
6. Reading Display : Within seconds, the glucometer displays your blood sugar level on its screen.

   By following these straightforward steps, users can efficiently monitor their blood glucose levels at home. helping in diabetes management.

   By following these straightforward steps, users can efficiently monitor their blood glucose levels at home. helping in diabetes management

   Based on the description given above answer the following questions:

Q.1 Describe the chemical reaction in a word equation

Q.2 What type of reaction is taking place

Q.3 What is the physical process that allows for blood components to come into contact with the sensors?

Q.4 What is the chemical reason this method to be accurate despite blood containing other sugar or carbohydrates?

Ranga wanted to test the accuracy of his glucometer. He bought glucose from a store and made a series of standard glucose solutions. Then he used the glucometer available in his house and measured the glucose values. The concentration of the solutions he made, and the corresponding values are given in the table below.

	Standard concentration of Glucose solution (mg/dL)	Values obtained on glucometer (mg/dL)
Trial 1	50	50
Trial 2	100	100
Trial 3	150	155
Trial 4	200	212
Trial 5	250	265
Trial 6	300	319
Trial 7	350	373

To make his solution Ranga made a stock of 250 ml of 500 mg/dL solution which he diluted subsequently to obtain the required solutions.

Q.5 What was the amount of glucose (in mg) used to make the stock solution?

Q.6 What is the amount of water and glucose stock solution that he had to mix to obtain 15 mL of 150 mg/dL solution?

Q.7 Plot a single graph that Ranga can use to clearly show the deviation between the standard values and the values measured with the glucometer.

Q.8 Ranga calculated the average percentage deviation of the measurement. What is the value?

Sol. **1.** Glucose + Oxygen + Water $\longrightarrow$ Gluconic Acid + Hydrogen Peroxide

Explain: Glucose Oxidise catalyses the conservation of glucose into Gluconic acid and hydrogen peroxide. This reaction uses blood oxygen and water.

2. Oxidation Reaction

Explain: Use of O_2 to convert Glucose into Gluconic Acid Hydrogen peroxide.

3. Capillary action

Explain: The test strip draws the blood sample into contact with the Embedded Enzyme, which is the physical process of capillary action.

4. The use of a specific enzyme [Glucose oxidase]

Explain: Enzyme are highly specific to their substrates, which means that glucose oxidase will primarily reach with glucose and not other sugars or carbohydrates.

5. $v = 250\text{ ml} = 250\text{ ml} \times \dfrac{1\text{ dL}}{100\text{ ml}} = 2.5\text{ dL}$

Amount = concentration × volume

$= c \times v = 500\text{ mg/dL} \times 2.5\text{ dL} = 1250\text{ mg}$

6. $v_2 = 15\ ml = 0.15\ dL$

$c_1v_1 = c_2v_2$

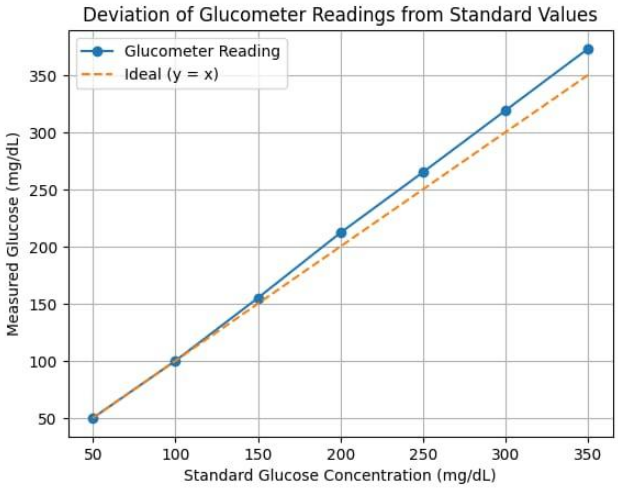
$v_1 = \dfrac{150 \times 0.15}{500} = 0.45\ dL$

$v_1 = 4.5\ ml$

volume of water = $v_2 - v_1 = 15\ ml - 4.5\ ml = 10.5\ ml$

He had mixed 4.5 ml of Glucose stock solution with 10.5 ml of water.

7.



8. Avg. deviation = $\dfrac{0+0+3.33+6+6+6.33+6.57}{7} = \dfrac{28.23}{7}\% = 4.03\%$

30. Lead Accumulator: Structure and Function

A lead accumulator, commonly referred to as a car battery, is a rechargeable electrochemical cell that transforms chemical energy into electrical energy. The cell's electrode system comprises negative electrodes made from pure spongy lead (Pb), while the positive electrodes consists of lead dioxide (PbO_2). Both types of electrodes are immersed in diluted sulphuric acid (H_2SO_4), which has a concentration of 38% by mass and a specific gravity of 1.33 g/cm^3.

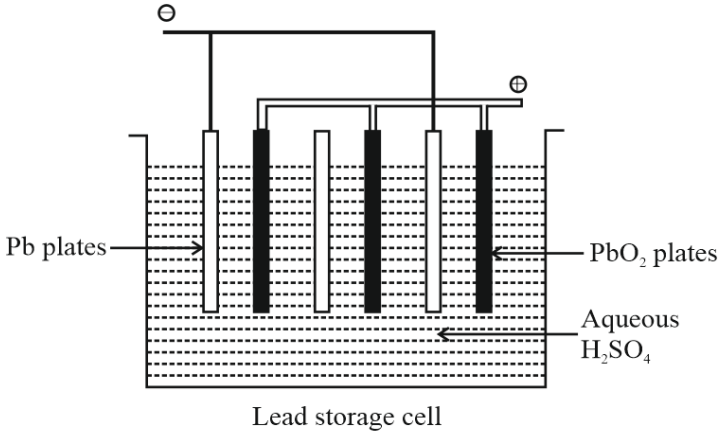


Figure-1 : Schematic diagram of Lead Accumulator

Thin plastic layers serve as separators between the electrodes, effectively preventing them from making direct contact with each other. All internal components are securely housed in a protective plastic casing, as depicted in figure-1. The typical dimensions of a lead acuumulator

are 300 mm in length, 150 mm in breadth and 200 mm in height. Approximately 80% of the cell's volume is occupied by the sulphuric acid electrolyte.

Electrochemical Reactions During Discharge and Charge

During the discharge process, the lead electrode reacts with sulphuric acid, resulting in the fonnation of lead (II) sulphate. Similarly, the lead dioxide electrode reacts with sulphuric acid to produce lead (II) sulphate and water as the final products. These reversible chemical reactions facilitate the release of stored electrical energy. When the accumulator is recharged, a direct current applied, reversing the reactions at the respective electrodes. This process restores the electrodes to their original chemical states and also returns the sulphuric acid to its initial concentration, enabling repeated cycles of charging and discharging.

Determination of EMF

$$E = E^0 - \frac{RT}{nF} \ln Q$$

Here, E^0 represents the standard EMF of the cell, defined as the difference in reduction potentials between the two half-cells under standard conditions. Standard conditions are specified as solutions with a concentration of one molar (M), gases at one atmosphere pressure, and a temperature of 25°C (298 K). Assume that sulphuric acid at all concentrations is dissociated completely and activity of water is 1.0 under all conditions.

$$E = E^0 - \frac{0.0591}{n} \log Q$$

Q.1 Write reactions at anode, cathode and overall reaction taking place in Lead Accumulator at the time discharging leading to the products as mentioned in the description.

Q.2 What is the molar concentration of sulphuric acid (H_2SO_4) used as an electrolyte in the Lead accumulator?

Q.3 Calculate EMF of the lead accumulator battery whose electrode system is shown in the **figure 1**.
(Given : Standard reduction potential of $Pb^{2+}/PbO_2 = 0.126V$
Standard reduction potential of PbO_2/Pb^{2+} in the presence of standard $H_2SO_4 = 1.45V$

Q.4 The specific gravity or the electrolyte (sulphuric acid) is a direct indicator for the state of a lead-acid battery. The EMF of the battery drops when the specific gravity of H_2SO_4 is at 1.17g/cc or less. This indicates that the battery needs charging. Calculate the charge in units (Ampere-hour) A.h delivered by the car battery when its specific gravity falls from 1.33 g/cm^3(38% by mass) to 1.17 g/cm^3(23.43% by mass) Given : 3600C = 1 Ampere hour ; Farady constant = 96500 C] Assume no change in the volume of the solution.

Sol. 1. At cathode:

$PbO_2 + 2e^- + 4H^+ \longrightarrow Pb^{2+} + 2H_2O$

At anode

$Pb \longrightarrow Pb^{2+} + 2e^-$

Overall cell reaction during discharging:

$Pb + PbO_2 + 4H^+ \longrightarrow 2Pb^{2+} + 2H_2O$

OR

$Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)} \longrightarrow 2PbSO_{4(s)} + 2H_2O(\ell)$

2. Wt.% of H_2SO_4 in solution = 38

Let we have 100 gm solution

So, wt. of H_2SO_4 = 38 gm

Volume of solution = $\frac{100}{1.33}$ ml

Molarity of H_2SO_4 = $\frac{38/98}{(100/1.33}$ × 1000 = 5.16 M

3. For the cell

$EMF = E^o - \frac{RT}{nF} \ln Q$

For given reaction

$T = 298, n = 2, Q = \frac{1}{[H_2SO_4]^2} = \frac{1}{(5.16)^2}$

$E^o = E^\circ_{Pb^{4+}/Pb^{2+}} - E^\circ_{Pb^{2+}/Pb} = 1.455 - (0.126)$

$E^o = 1.581$ V

$\therefore EMF = 1.581 - \frac{8.314\times298}{2\times96500}\ln\left(\frac{1}{5.16}\right)^2 = 1.623$ V

4. Volume of electrolytic solution inside battery

= (300 × 150 × 200) × $\frac{80}{100}$ mm^3 = 7200 ml = 7.2 lt.

Initial wt. of H_2SO_4 in solution = 7200 × 1.33 × $\frac{38}{100}$ = 3638.88 gm

Final wt. of H_2SO_4 in solution = 7200 × 1.17 × $\frac{23.43}{100}$ = 1973.74 gm

w.t. of H_2SO_4 consumed during discharging = 3638.88 – 1973.74 = 1665.14 gm

moles of H_2SO_4 consumed = $\frac{1665.14}{98}$ = 17 moles

$\therefore$ Charge delivered = 17 × 96500 amp. sec.

= $\frac{17\times96500}{60\times60}$ amp.hr

= 455.69 amp.hr

31. Inorganic Reactions **(5 Marks)**

A chemistry students named Mira was performing a set of experiment in her school laboratory. She started with a white powder (A). When she added dilute hydrochloric acid to it, the mixture began to fizz, releasing a colourless gas (Y) and forming a solution of another compounds (B). Curious about the gas, Mira passed Y through limewater. The lime water immediately turned milky forming a white precipitate (D). When she continued passing more of gas. Y, the milky mixture surprisingly cleared up and turned into a colourless solution of E.

Later that day, she mixed the same original powder (A) with ammonium chloride and heated the mixture strongly. This produced compound B again, along with two gases: one was Y, the same gas from earlier, and the other was pungent-smelling gas (F)

To confirm its identity, Mira brought a glass rod dipped in a concentrated hydrochloric acid near the gas F. Instantly, dense white fumes (G) appeared.

1. Draw the Lewis structure of gas 'Y'
2. Draw the Lewis structure of gas 'F'
3. What is the molecular formula of 'E'
4. What type of reaction leads to formation of G?
5. The difference in molecular weight of A and B is 63.5, identify A and B?

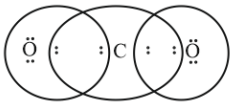
Sol. $\underset{A}{K_2CO_3} + 2HCl \rightarrow \underset{B}{2KCl} + H_2O + \underset{Y}{CO_2}$

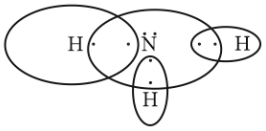
$\underset{\text{lime water}}{Ca(OH)_2} + \underset{Y}{CO_2} \rightarrow \underset{D}{CaCO_3}\downarrow + H_2O$

$\underset{Y}{CO_2} + \underset{D}{CaCO_3} + H_2O \rightarrow \underset{E}{Ca(HCO_3)_2}$

$\underset{A}{K_2CO_3} + 2NH_4Cl \rightarrow \underset{B}{2KCl} + \underset{F}{2NH_3} + CO_2 + H_2O$

$NH_3 + HCl \rightarrow \underset{G}{NH_4Cl}$





1. $Y = CO_2$
2. $F = NH_3$
3. $E = Ca(HCO_3)_2$
4. $G = NH_4Cl$
5. $A = K_2CO_3$ (MW = 138) ; $B = KCl$ (MW = 74.5)
   Difference of molecular weight of A and B is 138 – 74.5 = 63.5

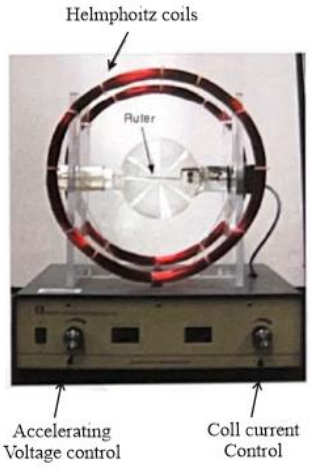
32. This question is based on a experiment to determine the ratio of the charge to mass of an electron. The ratio has a great physical significance in the field of charge particle dynamics. A brief description of the experiment and theoretical background is provide for your information and understanding. The data that has been collected using the apparatus is also provide. Suing the information and data find the charge to mass ratio of electron by plotting a graph Graph plotting is an important skill to analyses the data. A good graph should utilize at least 75% of the given area and have its axes property labelled.

Theoretical Background: The charge-to-mass ration $\left(\frac{e}{m}\right)$ of an electron is one of the fundamental constant in physics. It was first measure by J.J. Thomson in 1987 using the deflection of cathode rays in electric and magnetic fields. In this experiment we determine $\frac{e}{m}$ by observing the motion of electrons in a uniform magnetic field produced by a pair of coils.

$$ev = \frac{1}{2}mv^2 \quad \ldots\ldots\ldots (1)$$

where is the charge of the electron, m is tis mass and ν is its velocity after acceleration.

When this electron beam enters a region of uniform magnetic field (B) perpendicular to its velocity, it experiences a magnetic Lorentz force that causes it to move in a circular path. The required centripetal force for circular motion is provide by the magnetic force.



$$evb = \frac{mv^2}{r}$$

$$\therefore \quad eB = \frac{mv}{r} = \frac{mv}{r} \qquad \ldots. (2)$$

Here p is the momentum of the electron.

The magnetic field at the centre of pa pair of identical circular coils (each having N turns and radius R), carrying current l, and separated by a distance equal to R is

$$B = \mu_0 \left(\frac{4}{5}\right)^{\frac{3}{2}} \left(\frac{N\ell}{R}\right) \qquad \ldots. (3)$$

These coils are called Helmholtz coils. This arrangement ensures that the magnetic field near the centre is nearly uniform, allowing the electrons to follows a circular trajectory.

experimental Method: In the laboratory setup, electrons emitted from a heated cathode are accelerated through a known potential difference v and enter the magnetic field regions between the Helmholtz coils. The electron beam form a circular path whose radius r can be measured using a fluorescent screen. By keeping the coil current ℓ (hence B) constant and varying V, a series of (V, r) data pairs are obtained as provided in the table. From these , $\frac{e}{m}$ can be calculated

(10 marks)

1. Show that the ratio $\frac{e}{m} = \frac{2V}{B^2r^2}$ (1 marks)
2. For the given values of current, calculate value of magnetic field using equation (3). (1 marks)
3. Identify two parameters that can be used to plot a straight-line graph to obtain $\frac{e}{m}$. enter their values in the empty columns in the table. (3 marks)
4. Plot a linear graph and obtain the ratio $\frac{e}{m}$ from its slope.

Data : Apparatus Parameters

(a) Number of tums per coil, N = 130

(b) Coil radius, R = 0.150 m

(c) Current flowing through the coils, I = 1.40 A (constant)

(d) Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ T mA^{-1}

Trail No.	accelerating Voltage, V (V)	Measure diameter, d (cm)			
1	100	6.2			
2	120	6.8			
3	140	7.4			
4	160	8			
5	180	8.3			
6	200	8.8			
7	220	9.6			
8	240	10			
9	260	10.4			
10	280	10.7			

Ans. (*)

Sol. Q1. Show that

$$\frac{e}{m} = \frac{2V}{B^2r^2}$$

From theory:

$$eV = \frac{1}{2}mv^2 \ (1)$$

Magnetic force provides centripetal force:

$$evB = \frac{mv^2}{r} \Rightarrow v = \frac{eBr}{m}$$

Substitute v into (1) :

$$eV = \frac{1}{2}m\left(\frac{eBr}{m}\right)^2$$

$$eV = \frac{e^2B^2r^2}{2m}$$

$$\boxed{\frac{e}{m} = \frac{2V}{B^2r^2}}$$

Q2. Magnetic field of Helmhotz coils

$$B = \mu_0 \left(\frac{4}{5}\right)^{\frac{3}{2}} \frac{NI}{R}$$

Substitute given values:

- N = 130
- I = 1.40 A
- R = 0.150 m
- $\mu_0 = 4\pi \times 10^{-7}$

$$\boxed{B = 1.22 \times 10^{-3}\ T}$$

(This value is constant for all readings.)

Q3. Parameters for straight-line graph

From $V = \frac{e}{2m} B^2 r^2$

A straight line is obtained by plotting:

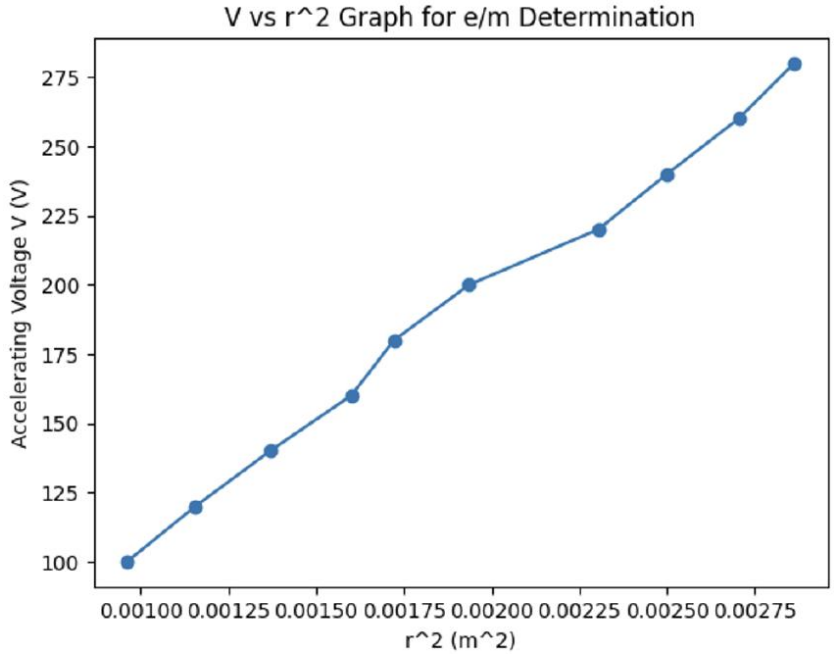
- Y-axis: V
- X-axis: r^2

Slope:

$$\text{Slope} = \frac{e}{2m} B2$$

Q4. Filled observation table

Trial	V(v)	d(cm)	r(m)	$r^2(m^2)$	e/m (C/kg)
1	100	6.2	0.0310	0.000961	1.75×10^{11}
2	120	6.8	0.0340	0.001156	1.74×10^{11}
3	140	7.4	0.0370	0.001369	1.72×10^{11}
4	160	8.0	0.0400	0.001600	1.68×10^{11}
5	180	8.3	0.0415	0.001722	1.76×10^{11}
6	200	8.8	0.0440	0.001936	1.74×10^{11}
7	220	9.6	0.0480	0.002304	1.60×10^{11}
8	240	10.0	0.0500	0.002500	1.61×10^{11}
9	260	10.4	0.0520	0.002704	1.62×10^{11}
10	280	10.7	0.0535	0.002862	1.64×10^{11}



Graph (exam description)

- Plot V vs r^2
- Graph is a straight line
- Confirms $V \propto r^2$

From slope S:

$$\frac{e}{m} = \frac{2S}{B^2}$$

Final Result

$$\boxed{\frac{e}{m} \approx (1.7 \pm 0.1) \times 10^{11}\,C\,kg^{-1}}$$

Which agrees well with the accepted value:

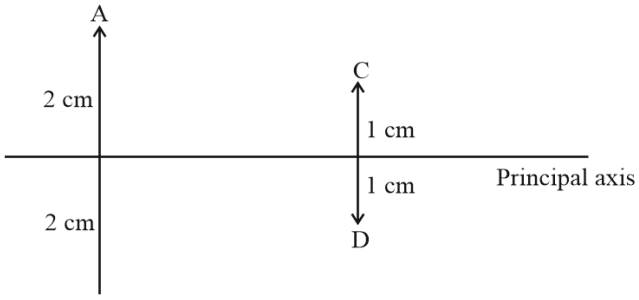
1.76×10^{11} C kg^{-1}

33. Object and Image: The figure given below is a part of several ray diagram. Out of the two arrow lines AB and CD, anyone can be object and the other is its image (i.e. if AB is an object, CD is its image and vice versa).

You are given a concave mirror, a convex mirror a biconcave lens and a biconvex lens as optical devices. Radius of curvature of both the mirrors and of all the surfaces of both the lenses is 30 cm. Both the lenses are thin and are made up of glass of refractive index, n = 1.5. Each one of these optical devices can have AB and CD as either object or image.

In case of a lens, according to the Cartesian coordinates system, its focal length is related to refractive index n and radii of curvature of the two surfaces R_1 and R_1 as

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



Q.1 Considering CD as object, find the positions of the converging optical devices that can give the AB as image. Fill the table with the required values. The axial distance is the distance between AB and CD.

Converging Optical device	Object	Image	Arrangement (Sequence of AB, CD and optical device from Left to Right)	u cm	v cm	Expression for Axial distance |v–u|,	Axial distance (value, cm)
	CD	AB					
	CD	AB					
	CD	AB					
	CD	AB					

Q.2 Considering AB as object, find the positions of the optical devices that can give the CD as image. Fill the table with the required values.

Converging optical device	Object	Image	Arrangement (Sequence of AB, CD and optical devices from Left to Right)	u cm	v cm	Expression for Axial distance	Axial Distance (value, cm)
Concave Mirror	AB	CD					
Convex mirror	AB	CD					
Concave lens	AB	CD					
Convex lens	AB	CD					

Sol.

Converging Optical device	Object	Image	Arrangement (Sequence of AB, CD and optical device from Left to Right)	u cm	v cm	Expression for Axial distance |v–u|,	Axial distance (value, cm)
Concave mirror	CD	AB	AB, CD, mirror	–22.5	–45	|–45 + 22.5|	22.5
Concave mirror	CD	AB	AB, mirror, CD	7.5	–15	|–15 – 7.5|	22.5
Convex lens	CD	AB	AB, lens, CD	45	–90	|–90 – 45|	135
Convex lens	CD	AB	AB, CD, lens	–15	–30	|–30 + 15|	15

Q.2 Considering AB as object, find the positions of the optical devices that can give the CD as image. Fill the table with the required values.

Converging optical device	Object	Image	Arrangement (Sequence of AB, CD and optical devices from Left to Right)	u cm	v cm	Expression for Axial distance	Axial Distance (value, cm)

Concave Mirror	AB	CD	AB, CD, mirror	– 45	–22.5	|–22.5 + 45|	22.5
Convex mirror	AB	CD	AB, mirror, CD	–15	+7.5	|7.5 + 15|	22.5
Concave lens	AB	CD	AB, CD, lens	–30	–15	|–15 + 30|	15
Convex lens	AB	CD	AB, Lens, CD	–90	+45	|45 + 90|	135

34. In cold climates, our bodies expend extra energy to, warm the cold air we inhale to our body temperature (around 37°C). This thermoregulatory process burns an additional 100 to 200 calories per day, even without doing any physical activity. The colder the air, the greater the energy demand, as the body maintains core temperature through shivering and increased metabolism-esentially making us burn calories just be breathing and staying warm.

Metabolism is a continuous process in the body and remains active even when we are sleeping. The energy released through metabolism is used to support the functioning of internal organs as well as activities such as as walking, running and other physical tasks. Energy expenditure during activities is often expressed in units called METs, which stands for Metabolic Equivalent to Taks.

1 MET = the energy you expand while resting, sitting quietly or sleeping.

It is approximately 4.2 kJ per kg of body weight per hour.

A tourist in Ooty is fasting on the day when the least temperature is 6°C. He wants to manage the day with 2 bananas, I apple and few glasses of plain water. He spends a good 14 hours inside the room where the temperature is maintained at 20°C. During this time, he hardly does any physical activities and inhales 6 litres of air per minute. He spends time with other tourists about 6 hours in the lounge, sit out, roof top where the temperature is 9°C, and inhales 6 litres of air per minute. When temperature hits 12°C he joins others for a hike. He manages to complete the task in four hours, including two hours of slow walk, one hour of rigorous walk and a total of one hour rest. On an average he inhales 25 litres of air per minute during these 4 hours.

Use the following data to answer the following questions.

a. Mass of the tourist 70 kg.
b. Useful energy released by digesting a banana is 4.40 kJ.
c. Useful energy released by digesting an apple is 400 kJ.
d. No energy is released by water.
e. Normal body temperature is 37°C.
f. Density of air 1.2 kg/m^3.
g. Energy required to increase the temperature of 1 kg air through 1°C is 1 kJ.
h. Energy expended during slow walk is 3 MET.
i. Energy expended during rigorous walk is 6 MET.
j. To burn one gram of fat one needs to spend 40 kJ of energy.

Questions

Q.1 How much total useful energy does the tourist obtain from eating 2 bananas and 1 apple during the day?

Q.2 While inside the room at 20°C (for 14 hours), how much energy does his body spend in heating the inhaled air to 37°C, given that he inhales 6 litres of air minute?

Q.3 During the 6 hours spent in roof top at 9°C, how much energy is required to warm all the air he inhales from 9°C to 37°C?

Q.4 During the 4-hour hike, he inhales 25 litres of air per minute. If the temperature is 12°C, how much energy does his body use to warm the inhaled air to 37°C during the entire hike?

Q.5 How much energy he expends during this day for physical activities and for functioning of internal organs?

Q.6 Using all the above energy expenditures, determine whether the energy obtained from food is sufficient. If not, how many grams of fat must his body burn to meet the shortage, given that burning 1 gram of fat provides 40 kJ?

Sol. **Q.1 Total useful energy obtained from food.**

The tourist consumes 2 bananas and 1 apple.

Total Energy = $(2 \times \text{Energy}_{\text{banana}}) + (1 \times \text{Energy}_{\text{apple}})$

Total Energy = (2 × 440 kJ) + 400 kJ

Total Energy = 880 + 400 = 1280 kJ

Q2. Energy spent heating air (Inside room)

- **Conditions:** T_{room} = 20º C, Duration t = 14 hours, Rate = 6L/min.
- **Temperature difference (ΔT) :** 37 ºC – 20 ºC = 17 ºC
- **Total volume of Air Inhaled:**
  6L/min × 60 min/hr × 14 hrs = 5040 L
- Mass of Air:
  5040 L × 0.0012 kg/L = 6.048 kg
- Energy Required :
  E = Mass × Specific Heat × ΔT
  E = 6.048 kg × 1 kJ/kg . ºC × 17ºC
  E = 102.816 kJ

Q.3. Energy spent heating air (roof top)

- **Conditions:** T_{roof} = 9ºC, Duration t = 6 hours, Rate = 6L/min. (from text description)
- **Temperature difference (ΔT) :** 37 ºC – 9ºC = 28ºC
- **Total volume of Air Inhaled:**
  6L/min × 60 min/hr × 6 hrs = 2160 L
- **Mass of Air:**
  2160 L × 0.0012 kg/L = 2.592 kg
- **Energy Required :**
  E = 2.592 kg × 1 kJ/kg . ºC × 28ºC
  E = 72.576 kJ

Q.4. Energy spent heating air (Hike)

- **Conditions:** T_{hike} = 12ºC, Duration t = 4 hours, Rate = 25L/min. (average)
- **Temperature difference (ΔT) :** 37ºC – 12ºC = 25ºC

- **Total volume of Air Inhaled:**
  25L/min × 60 min/hr × 4 hrs = 6000 L
- **Mass of Air:**
  6000 L × 0.0012 kg/L = 7.2 kg
- **Energy Required :**
  E = 7.2 kg × 1 kJ/kg . ºC × 25ºC
  E = 180 kJ

Q.5 Energy expended for metabolic functions and physical activities.

We calculate the energy for each activity period using the MET values provided
(1 MET = 294 kJ/hr for this tourist)

1. **Room (14 hours): Resting → 1 MET**
   14 hrs × 1 MET = 14 MET – hours
2. **Lounge/Roof (6 hours): Sitting → 1 MET**
   6 hrs × 1 MET = 6 MET – hours
3. **Hike (4 hours total)**
   - **Slow walk (2 hours):** 3 MET → 2 × 3 = 6 MET – hours
   - **Rigorous walk :** 6 MET → 1 × 6 = 6 MET – hours
   - **Rest (1hour) :** 1 MET → 1 × 1 = 1 MET – hours
   - **Total MET-hours for the day:**
     14 + 6 + 6 + 6 + 1 = 33 MET-hours
   - Total Energy:
     33 × 294 kJ = 9702 kJ

Q.6 Energy sufficiency and fat burning

First, we calculate the total energy Expenditure by summing the metabolic energy (Q5) and the air heating energy (Q2, Q3, Q4)

Total expenditure = Metabolic + Heating (Room) + Heating (Roof) + Heating (H)

Total expenditure = 97.2 + 102.816 + 72.576 + 180

Total Expenditure = 10057.392 kJ

Comparison: The energy from food is 1280 kJ. Since 1280 kJ < 10057.392 kJ, the food is not sufficient.

Fat to be burnt:

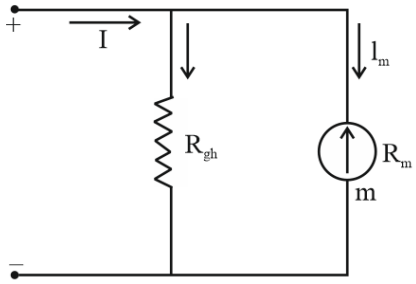
- Energy shortage: 10057.392 – 1280 kJ = 8777.392 kJ
- Fat Conversion: 1 gram fat = 40 kJ
- Mass of fat needed:

$$\frac{8777.392}{40} = 219.4348 \text{ grams}$$

Answer: The tourist must burn approximately 219.43 grams of fat.

35. A basic de (direct current) ammeter circuit consists of a galvanometer in which pointer deflection is directly proportional to the amount of current passing through the meter. The current producing full-scale deflection in galvanometer is very small. When large currents are to be measured, a major part of the current is by passed through a small resistance (R_{sh}) called shunt, connected in parallel with meter, as shown in the figure.

If R_m is the resistance of meter and l_m is the meter current and l_{sb} is the current through shunt. At any instant,



$I = I_{sh} + I_m$

$I_m R_m = I_{sh} R_{sh}$

Problem : Now consider a typical multirange de anmeter circuit shown in figure 2. It consists of a single meter having resitance $R_m = 50\ \Omega$, in parallel with series of resistors R_a, R_b and R_c can be selected in different combination by rotary switch S that can be represented by an arrow. The arrow may be turned about its midpoint and accordingly the arrowhead can touch the points 1, 2 or 3. The position of switch S determines the total resistance in series and parallel with the meter. The two terminals of the ammeter in the figure have been with a positive sign(+) and a negative (–)

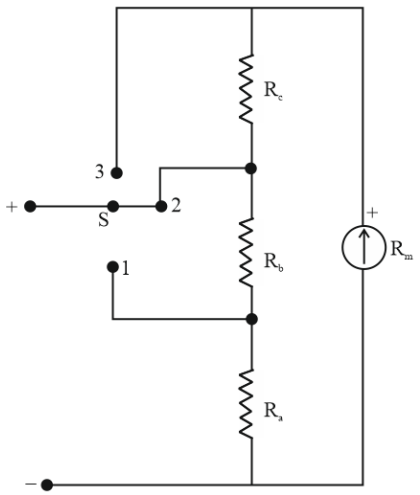
The position of the arrowhead switch S and the corresponding operating range of the ammeter are related as shown in the following table.

Arrowhead in S	Operating range of ammeter
Position 3	0 – 2 mA
Position 2	0 – 10 mA
Position 1	0 – 50 mA

If the current required for full-scale deflection is $I_M = 1$ mA

Q.1 Calculate value of R_a, R_b and R_c

Q.2 Calculate the effective ammeter resistance when operating in the following ranges



(i) 0 – 2 mA
(ii) 0 – 10 mA
(iii) 0 – 50 mA

Sol. Given (unchanged)

- Meter resistance: $R_m = 50\ \Omega$
- Full scale deflection current of meter: $I_m = 1$ mA
- Hence full scale meter voltage: $V_m = I_m R_m = 0.001 \times 50 = 0.05$ V

This 0.05 V must appear across the entire parallel combination at full scale in every range.

Correct interpretation of switch positions (key point)

From your clarification and the figure:

Position 1 (0-50 mA range)

- R_b and R_c are in series with the meter.
- This series branch is in parallel with R_a

Equivalent branches

- Branch 1 : R_a
- Branch 2: $R_m + R_b + R_c$

Position 2 (0-10 mA range)

- R_c is in series with the meter.
- Parallel with $R_a + R_b$

Equivalent branches

- Branch 1 : $R_a + R_b$
- Branch 2: $R_m + R_c$

Position 3 (0-2 mA range)

- Meter alone in one branch
- Parallel with $R_a + R_b + R_c$

Equivalent branches

- Branch 1 : $R_a + R_b + R_c$
- Branch 2: R_m

Q.1 Find R_a, R_b, R_c

Position 3 (0-2 mA) easiest, start here

Total current at FSD:

$I = 2$ mA

Meter current:

$I_m = 1$ mA $\rightarrow I_{ah} = 1$ mA

Voltage across both branches:

$V = 0.05$ V

So shunt resistance:

$$R_a + R_b + R_c = \frac{0.05}{0.0001} = 50\ \Omega$$

$R_a + R_b + R_c = = 50\ \Omega$ …(1)

Position 2 (0-10 mA)

Total current

$I = 10$ mA $\Rightarrow I_{sh} = 9$ mA

Series resistance with meter:

$R_m + R_c = 50 + R_c$

Voltage across meter branch:

$V = I_m (R_m + R_c) = 0.0001 (50 + R_c)$

This equals voltage cross shunt branch:

$0.001 (50 + R_c) = 0.009 (R_a + R_b)$

$50 + R_c = 9 (R_a + R_b)$ …(2)

Position 1 (0-50 mA)

Total current

$I = 50 \text{ mA} \Rightarrow I_{sh} = 49 \text{ mA}$

Series resistance with meter:

$R_m + R_b + R_c = 50 + R_b + R_c$

Voltage equality:

$0.001 (50 + R_b + R_c) = 0.049 R_a$

50 + his equals voltage cross shunt branch:

$0.001 (50 + R_c) = 0.009 (R_a + R_b)$

$50 + R_b + R_c = 49 R_a$ …(3)

Solve equations (1), (2), (3)

From (1):

$R_c = 50 – R_a – R_b$

Substitute into (2)

$50 + (50 – R_a + R_b) = 9 (R_a + R_b)$

$100 = 10R_a + 10R_b \Rightarrow R_a + R_b = 10\ \Omega$

So, $R_c = 50 – 10 = 40\ \Omega$

Now use (3) :

$50 + R_b + 40 = 49R_a \Rightarrow 90 + R_b = 49 R_a$

But $R_b = 10 – R_a$:

$90 + 10 – R_a = 49R_a$

$100 = 50 R_a \Rightarrow \boxed{R_a = 2\Omega}$

Then:

$\boxed{R_b = 8\Omega}$, $\boxed{R_c = 40\Omega}$

Final answer for Q.1

$\boxed{R_b = 8\Omega,\ R_b = 8\Omega, R_c = 40\Omega}$

$50 + R_b + R_c = 49 R_a$ …(3)

Q.2. Effective ammeter resistance in each range

Effective resistance = parallel combination of the two branches.

(i) 0.2 mA

Branches:

- $R_m = 50\ \Omega$
- $R_a + R_b + R_c = 50\ \Omega$

$$R_{eff} = \frac{50 \times 50}{50 + 50} = \boxed{25\Omega}$$

(ii) 0 - 10 mA

Branches:

- $R_m + R_c = 90\ \Omega$
- $R_a + R_b = 10\ \Omega$

$$R_{eff} = \frac{90 \times 10}{100} = \boxed{9\Omega}$$

(iii) 0 - 50 mA

Branches:

- $R_m + R_b + R_c = 98\ \Omega$
- $R_a = 2\ \Omega$

$$R_{eff} = \frac{98 \times 2}{100} = \boxed{1.96\Omega}$$

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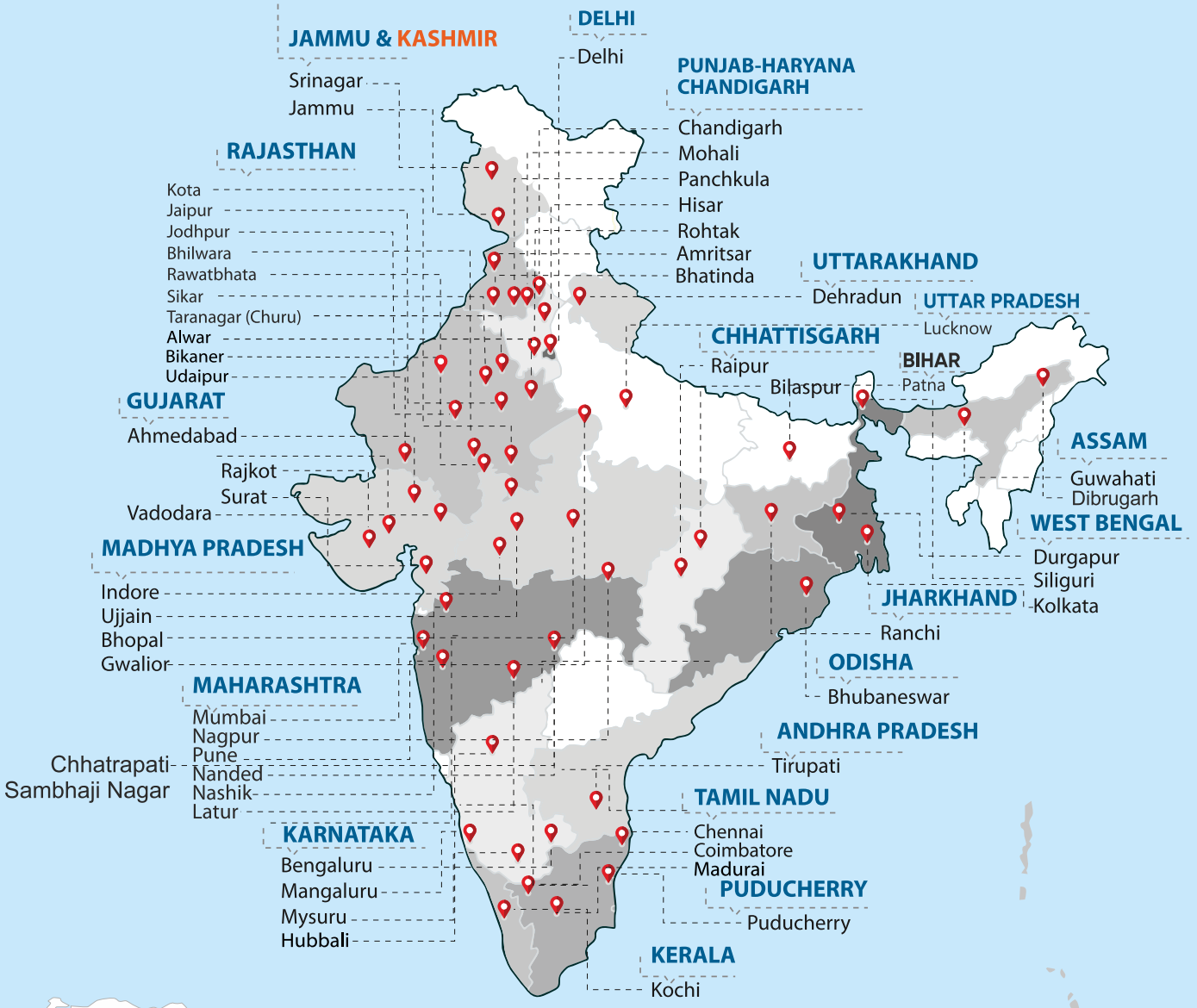

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