Date: 28/01/2023

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Answers & Solutions

Time : 3 hrs. *for* M.M. : 180

Indian National Junior Science Olympiad (INJSO) - 2023

GENERAL INSTRUCTIONS :

- Section I of this question paper has **15** questions.
  - For each question in this section, **only one** of the four options is a correct answer.
  - For each question, a correct answer will earn 3 marks, a wrong answer will earn (–1) mark, and an unattempted question will earn 0 marks.
  - If you mark more than one option, it would be treated as a wrong answer.
- Section II contains **9** questions worth 5 marks each. There is no negative marking.
  - For each of these questions one or more option(s) may be correct.
  - You will get full credit for each question only if you mark all correct options and no wrong option. There are no partial marks for these 9 questions.
- Section III contains **11** questions.
  - For all the questions in this section, the process involved in arriving at the solution is more important than the final answer. Valid assumptions / approximations are perfectly acceptable. Please write your method clearly, explicitly stating all the reasonings / assumptions / approximations.
  - In case you fall short of writing space for any question, you can ask for an extra sheet. You can ask for maximum of two extra sheets.

Section I : Single Correct MCQ

1. One of the major challenges in creating "Dolly" the first cloned organism/animal, was the process of creating an enucleated egg (nucleus removed), as the artificial removal of the nucleus damaged the egg cell. The cloning of Dolly in 1996 was achieved by inserting the nucleus of a mammary epithelial cell, precisely into such an enucleated egg cell. If you were to choose to activate a naturally occurring molecular mechanism of enucleation in an egg cell, which of the following cell type would you study to mimic the mechanism?

   (A) Neurons / Neuroblasts

   (B) Erythrocytes / Erythroblasts

   (C) Muscle cell / Myoblasts

   (D) Bone tissue cells / Osteoblasts

Answer (B)

Sol. Enucleation is the process by which nucleus is extruded by budding off from the erythroblast, hence mature erythrocytes are enucleated cells.

2. Which of these phenomena has not yet been observed in wild chimpanzees?

   (A) Demonstration of the ability to use stone and/or wooden tools

   (B) Demonstration of the ability to use of fire to process food

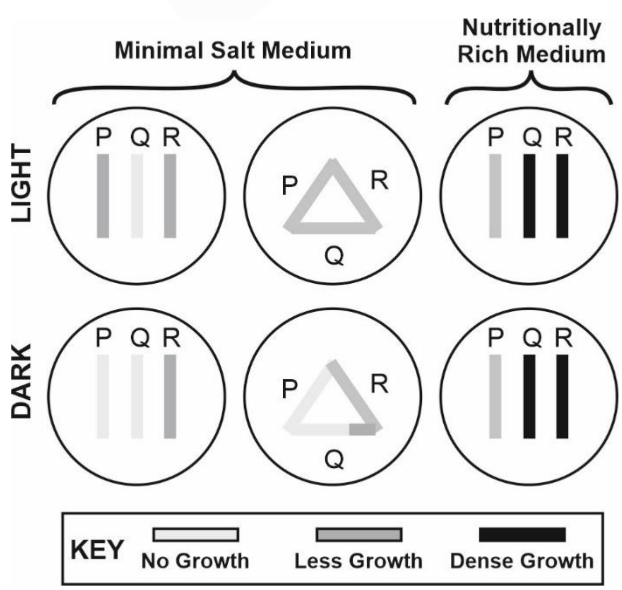
   (C) Demonstration of the ability to communicate using primitive language

   (D) Demonstration of ability to grieve in groups at the death of a member

Answer (B)

Sol. The latest researches show that chimpanzees have all the cognitive abilities necessary for unique human behaviour of cooking. They cannot process food with the use of fire because they have never learned to control fire.

3. Some microbes produce diffusible metabolites that can be used by other microbes for their growth. Three such microorganisms were tested for their nutritional growth requirements (under +/– light, scheme below) either on minimal salt media (lacking any organic sources of carbon and nitrogen) OR on complete or rich media containing salts with organic carbon and nitrogen.



Based on the growth patterns shown after 24 hrs, pick the correct option:

(A) P - Autotrophs, Q - Heterotroph, R - Heterotroph

(B) P - Photoautotroph, Q - Chemoheterotroph, R - Chemoautotroph

(C) P - Chemoautotrophs, Q – Chemoautotrophs, R - Heterotroph

(D) P - Photoautotroph, Q - Chemoheterotroph, R - Saprophyte

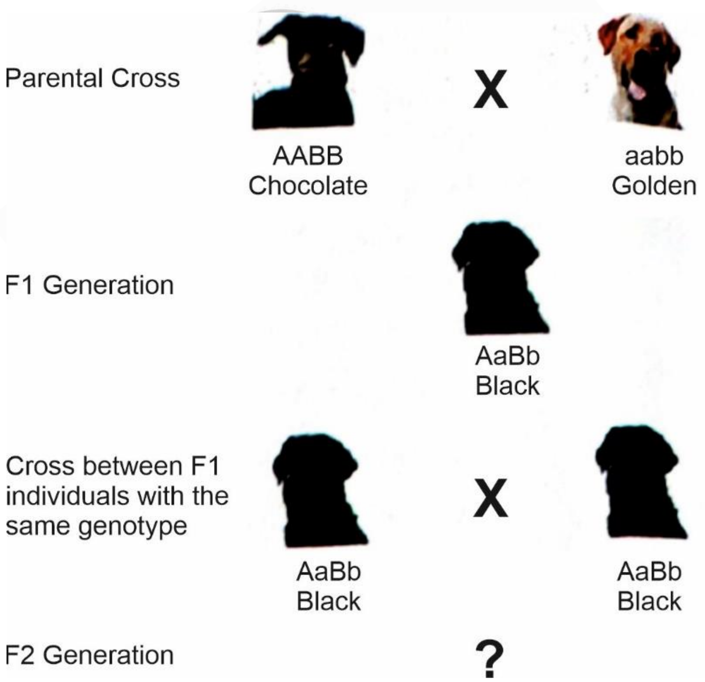
Answer (B)

Sol. Photoautotrophs can show growth in the presence of light even on minimal media.

Chemoheterotrophs cannot show growth on minimal media.

Chemoautotrophs show dense growth on nutritionally rich media where organic matter is predominant.

4. A breed of dogs show Black, Chocolate and Golden coat colors due to the interaction of products of two genes, one that produces pigment and another that distributes the pigment to hair follicles. The final coat color is due to the interaction of products of these two genes. In this kind of gene interaction, the alleles of one gene in homozygous recessive condition masks/suppresses the expression of the allele of another gene either in dominant or recessive state. This kind of interaction is known as the epistasis. The gene that masks the expression is epistatic and the one that gets masked is hypostatic. Assume that the allele that produces pigment is represented by 'A', so the 'a' would be the allele that cannot produce pigment and the allele that is responsible for pigment distribution is 'B' and the allele that is responsible for reduced distribution is 'b'.



Now, consider the following pictorial demonstration of a cross.

Which of the following ratios will be obtained in the F2 progeny due to this kind of interaction?

(A) 9:3:4 (Black:Chocolate:Golden)

(B) 12:3:1 (Black:Chocolate:Golden)

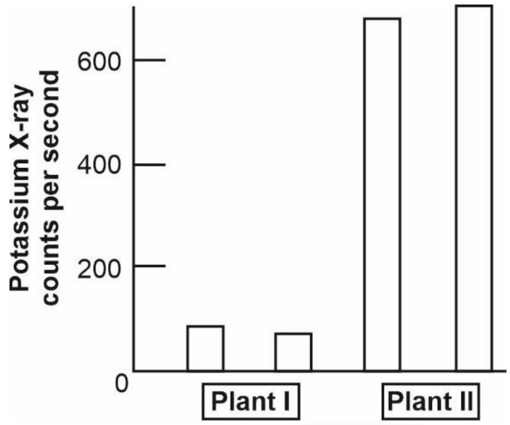
(C) 15:1 (Chocolate:Golden)

(D) 9:6:1 (Chocolate:Black:Golden)

Answer (A)

Sol. It is the case of recessive epistasis where recessive alleles in homozygous condition mask the expression of dominant gene. The ratio here comes out to be 9 : 3 : 4 (Black : Chocolate : Golden).

5. Movement of ions in and out of guard cells in plants is responsible for the stomatal activity (i.e. opening and closing of stomata). An experiment was carried out on two broad bean plants (Plant I and II) using a radioactive isotope of potassium. The concentration of potassium ions in the two guard cells of each plant was measured using a radioactivity counter. The graph below shows the K^+ concentration (indicated as potassium X-ray counts per sec) in each of the guard cells in respective plants, I and II.



Based on the results, which of the following is true?

(A) I has open stomata most likely for transpiration.

(B) II has open stomata most likely due to exposure to light.

(C) II has open stomata most likely due to absence of light.

(D) I has open stomata for uptake of carbon dioxide.

Answer (B)

Sol. High amount of potassium accumulates in guard cells due to exposure to light causing the stomata to open.

6. Two salts **X** and **Y** are heated strongly in two test tubes separately to study their decomposition process, and following observations are made during the experiments.

- Salt **X** evolves gases that are acidic in nature.
- One of the evolved gases from salt **X** helps in burning of a candle.
- A yellow-colored residue is formed after complete decomposition of salt **X**.
- Salt **Y** completely decomposes to produce gases.
- Salt **Y** generates a gas that makes you laugh.

That salts **X** & **Y**, respectively, are…

(A) Zinc carbonate & Silver nitrate

(B) Ammonium carbonate & Barium nitrate

(C) Lead nitrate & Ammonium nitrate

(D) Potassium iodide & Sodium nitrate

Answer (C)

Sol. $\underset{X}{2Pb(NO_3)_2(s)} \xrightarrow{\Delta} \underset{(Yellow)}{2PbO(s)} + 4NO_2(g) + \underset{\text{Supporter of combustion}}{O_2(g)}$

$\underset{Y}{2NH_4NO_3(s)} \xrightarrow{\Delta} N_2O(g) + 2H_2O(g)$

N_2O = Laughing gas

NO_2 = Acidic in nature

7. Wood pulp contains multiple compounds, including several polymers. Hydrolysis of one of the polymers produces compound α. This compound α undergoes anaerobic decomposition by microbes and produces compounds β and γ.

Compounds α, β and γ, respectively, are;

(A) Cellulose, ethanol, water
(B) Glucose, ethanol, carbon dioxide
(C) Lactose, lactic acid, carbon dioxide
(D) Starch, ethanoic acid, carbon dioxide

Answer (B)

Sol. $\underset{\text{(Present in wood pulp)}}{\text{Cellulose}} \xrightarrow{\text{Hydrolysis}} \underset{(\alpha)}{\text{Glucose}} \xrightarrow[\text{decomposition}]{\text{Anaerobic}} \underset{(\beta)}{\text{Ethanol}} + \underset{(\gamma)}{\text{Carbon dioxide}}$

8. Read the statements given below:

(i) Dissolution of glucose in water is an exothermic process.
(ii) Mixing of calcium oxide in water is an endothermic process.
(iii) Melting of ice into water is an endothermic process.
(iv) Dilution of sulphuric acid in water is an endothermic process.
(v) Boiling of water is an exothermic process.

Of the above, the true statement/s is/are:

(A) (iii)
(B) (v) and (i)
(C) (iv) and (v)
(D) (i), (ii) and (iv)

Answer (A)

Sol.

Endothermic process (ΔH = +ve)	**Exothermic process (ΔH = –ve)**
• Dissolution of glucose in water	• Mixing of calcium oxide in water
• Melting of ice into water	• Dilution of sulphuric acid in water
• Boiling of water	

9. Find the number of moles of hydrogen gas liberated when 39 g of potassium is treated with 7.8 g of water.

(A) 0.22 mol
(B) 0.43 mol
(C) 0.50 mol
(D) 1.0 mol

Answer (A)

Sol. $2K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g) + \text{Heat}$

Number of moles of K $= \dfrac{39\text{ g}}{39\text{ g mol}^{-1}} = 1\text{ mol}$

Number of moles of $H_2O = \dfrac{7.8\text{ g}}{18\text{ g mol}^{-1}} = 0.433\text{ mol}$

Here, H_2O is acting as limiting agent

$\because$ 2 moles of water liberate 1 mole of hydrogen gas

$\therefore$ 0.433 mol of water liberate $= \dfrac{1}{2} \times 0.433$

$= 0.216$

$\simeq 0.22$ mol of hydrogen gas

10. A closed container has a mixture of 48 g of sodium hydroxide, 52 g of water and 132 g ammonium sulphate. Find the number of moles of oxygen atoms present in that container

(A) 5 (B) 7

(C) 8 (D) 10

Answer (C)

Sol. Number of moles of $NaOH = \frac{48}{40}\ \text{mol} = 1.2\ \text{mol}$

Number of moles of $H_2O = \frac{52}{18}\ \text{mol} = 2.89\ \text{mol}$

Number of moles of $(NH_4)_2SO_4 = \frac{132}{132}\ \text{mol} = 1\ \text{mol}$

Number of moles of oxygen atoms in 1.2 mol NaOH = 1.2 mol

Number of moles of oxygen atoms in 2.89 mol H_2O = 2.89 mol

Number of moles of oxygen atoms in 1 mol $(NH_4)_2SO_4$ = 4 × 1 = 4 moles

Total number of moles of oxygen atoms = (4 + 2.89 + 1.20) mol

= 8.09 moles

≃ 8 moles

11. Angular size of an object is the angle subtended by that object for that distance and size. From the surface of the Earth, the Sun and the Moon appear to be of the same size, because both subtend nearly the same angle at the surface of the Earth.

If someone observes the Moon from the equator of the Earth, it takes nearly 2 minutes for the full disc of the Moon to sink below the horizon. Angular size of the Earth, when observed from the Moon is nearly….

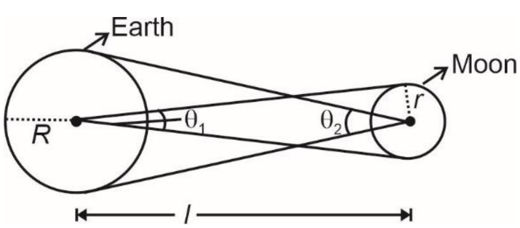
(A) 0.5° (B) 1°

(C) 1.5° (D) 2°

Answer (D)

Sol. Angle subtended by moon in 2 min $= \frac{360}{24 \times 60} \times 2$

$\theta_1 = 0.5°$



$\theta_1 = \frac{r}{l}, \quad \theta_2 = \frac{R}{l}$

$\frac{\theta_1}{\theta_2} = \frac{r}{l} \times \frac{l}{R} = \frac{1}{4} \quad \left\{\because \frac{r}{R} = \frac{1}{4}\right\}$

$\theta_2 = 0.5 \times 4 = 2°$

12. Two identical iron balls of mass 10 g each are moving in space at speeds 10 m/s and 5 m/s along the same direction with the faster one following the slower one. The balls collide, stick together, and continue to move as a single object. The loss of kinetic energy during collision increases the temperature of the combined object. Rise in temperature of the combined object is roughly …

Note:

- Specific heat capacity of iron is 451 J/(kg K).
- Neglect any other process that may change the temperature.
- Initial temperature of both the balls is assumed to be the same.

(A) 0.007 K (B) 0.014 K

(C) 0.07 K (D) 0.14 K

Answer (A)

Sol. $\Delta KE = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2 = \frac{1}{2} \times \frac{10 \times 10}{10 + 10} \times 10^{-3}(10 - 5)^2$

$= \frac{1}{2} \times 5 \times 10^{-3}(5)^2$

$= \frac{125}{2} \times 10^{-3}\ \text{J}$

Now, $\Delta T = \frac{Q}{mc} = \frac{125}{2} \times 10^{-3} \times \frac{1}{20 \times 10^{-3}} \times \frac{1}{451}$

$\Delta T = 0.0069 \approx 0.007\ \text{K}$

13. A car X starts moving with initial velocity *u* and acceleration *a*. Simultaneously from the same point, another car Y moves in the same direction with initial velocity *u*/2 and acceleration 2*a*. All velocities and accelerations are in the same direction. Which of the following is true?

(A) Cars X & Y will have the same speed when car Y overtakes car X

(B) Cars X & Y will have the same speed at some instance, but car Y will overtake car X at different instance

(C) Cars X & Y will have the same speed at some time but will never cross each other

(D) Car Y will overtake car X but the two will never have the same speed

Answer (B)

Sol. $\rightarrow a$

$\boxed{X} \rightarrow u$

$\boxed{Y} \rightarrow \frac{u}{2}$

$\rightarrow 2a$

Let after time *t* car Y overtakes car X

Distance travelled by car X

$s = ut + \frac{1}{2}at^2$ ...(i)

Same distance must be travelled by car Y in same time

$s = \frac{u}{2}t + \frac{1}{2}(2a)t^2$ ...(ii)

By equating (i) and (ii)

$$ut + \frac{1}{2}at^2 = \frac{u}{2}t + \frac{1}{2}(2a)t^2$$

$$\Rightarrow \quad \frac{u}{2}t = \frac{1}{2}at^2 \Rightarrow t = \frac{u}{a}$$

$$v_X = u + at_1 \qquad \ldots\text{(iii)}$$

$$v_Y = \frac{u}{2} + 2at_1 \qquad \ldots\text{(iv)}$$

As per question

$$v_X = v_Y$$

Therefore, $t_1 = \dfrac{u}{2a}$

14. A thin convex lens forms real image of an object on a screen. If you add another thin lens, in contact with the convex lens, it is now observed that a real image is formed at a longer distance. Which of the following statements is correct?

(A) The new lens added is a convex lens with a shorter focal length than the first lens

(B) The new lens added is a convex lens with a longer focal length than the first lens

(C) The new lens added is a concave lens with a shorter focal length than the first lens

(D) The new lens added is a concave lens with a longer length than the first lens

Answer (D)

Sol. $P_{eff} = P_1 + P_2$

To decrease P_{eff}, P_2 should be negative so concave lens is added.

So, $\dfrac{1}{f_{eff}} = \dfrac{1}{f_1} - \dfrac{1}{f_2}$

$$\frac{1}{f_{eff}} = \frac{f_2 - f_1}{f_1 f_2}$$

For, $f_{eff} > 0$

$f_2 - f_1 > 0$

So, $f_2 > f_1$

Therefore, the new lens added is a concave lens with a longer focal length than the first lens.

15. Evaporation of water, in the form of sweat is an essential mechanism in human beings for maintaining normal body temperature. For human body, the specific heat capacity is 3.5 kJ/(kg K) and heat of vaporization of sweat at body temperature of 37°C is nearly 2.3 MJ/kg.

On consuming a certain prescribed diet, the body temperature of Balvinder of mass 82 kg is expected to increase by 2°C. To prevent this, Balvinder drinks N bottles of mineral water (250 mL water in each) kept at ambient temperature (37°C). Assume that the entire amount of this water is converted into sweat, which vaporizes. *N* is nearly ...

(A) 1 (B) 2

(C) 3 (D) 4

Answer (A)

Sol. $\Delta Q_1 = 82 \times 3500 \times 2$

$$\Delta Q_2 = N \times \frac{250}{1000} \times 2.3 \times 10^6$$

According to the question

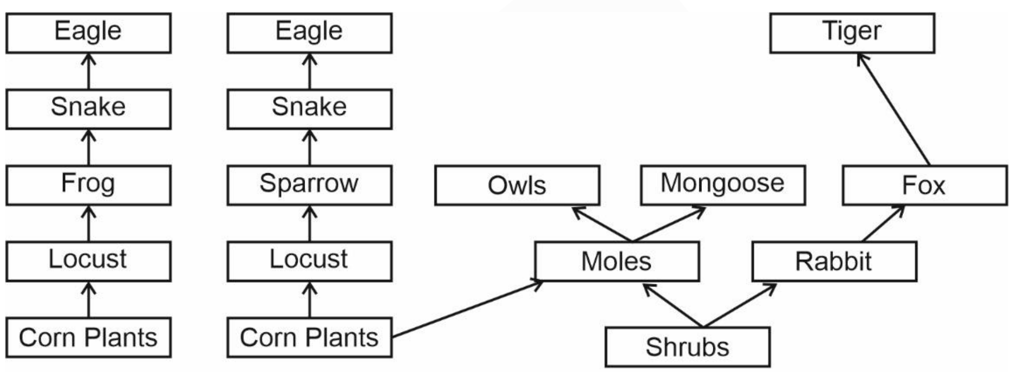
$\Delta Q_2 = \Delta Q_1$

$$\Rightarrow \quad N \times \frac{1}{4} \times 2.3 \times 10^6 = 82 \times 3500 \times 2$$

$\Rightarrow \quad N = 0.998 \approx 1$

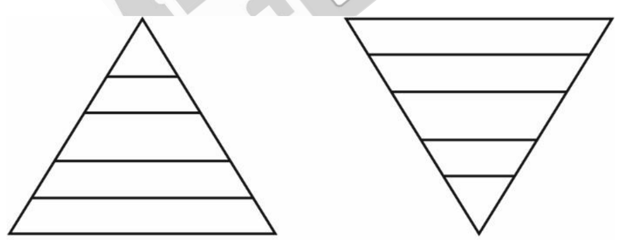
Section II : Multiple Correct MCQ

16. A food chain and a food web from ecosystems 1 and 2 are represented below.



Ecosystem I Ecosystem II

Consider the two pyramids shown below and from the options, identify what they would represent:



M N

(A) M could be the number pyramid of food web 2 while N could be the number pyramid of food chain 1

(B) M could be the energy pyramid of food web 2 and N could be the energy pyramid of food chain 1

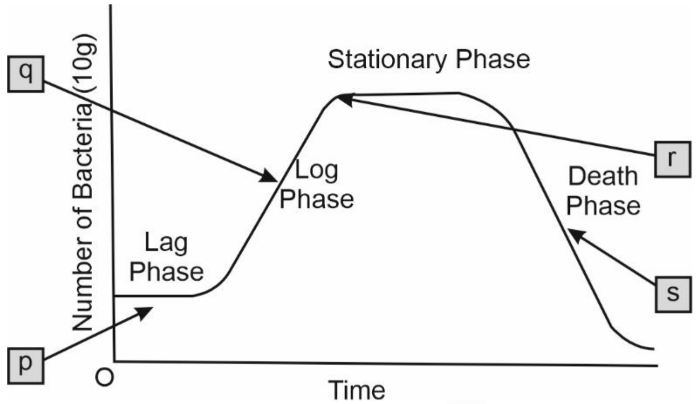
(C) M could be the number pyramid as well as energy pyramid for food chain 1

(D) M could be the number pyramid as well as energy pyramid of food web 2

Answer (C, D)

Sol. M could be the number pyramid for food chain-1 and food web-2 and it is also the pyramid of energy for food chain-1 and food web-2 as the pyramid of energy is always upright.

17. In the laboratory, bacteria are grown in a liquid nutrient medium. They reproduce asexually by successive cycles of binary fission. When such populations are grown in a flask, bacteria show a predictable growth pattern known as a growth curve. The following graph represents such a typical growth curve with the different phases of growth, as indicated.



Choose the correct option(s) that describe(s) the condition for each annotated point on the graph:

(i) Lowest concentration of nutrients, highest growth rate.

(ii) Highest number of bacterial cells, lower concentration of nutrients.

(iii) Lowest number of dividing bacterial cells, slow growth rate.

(iv) Highest growth rate, lesser toxic by-products.

(v) Highest concentration of nutrients, highest number of bacterial cells.

(vi) Highest concentration of nutrients, low numbers of bacterial cells.

(vii) Highest concentration of toxic by-products, least number of dividing bacterial cells.

(A) p-(vii) q-(iv) r-(ii) s-(iii)
(B) p-(vi) q-(i) r-(vii) s-(iii)
(C) p-(vi) q-(iv) r-(ii) s-(vii)
(D) p-(vi) q-(ii) r-(iii) s-(vii)

Answer (C, D)

Sol. Lag phase shows highest concentration of nutrients and low number of bacterial cells. Exponential (log) phase shows highest growth rate and low concentration of nutrients. Stationary phase shows highest concentration of toxic by - products and least number of dividing bacterial cells and death phase shows least growth rate and lowest number of dividing bacterial cells because of the low concentration of nutrients.

18. In temperate regions, woody plants undergo dormant condition to adapt to the extreme winter season. Physiologically they show periodic changes in the cellular activity. For example, cambium tissue is actively dividing in normal conditions. During winter dormancy, cells show changes in the protoplasm, their metabolic activity and cellular content. Which of the following feature/s can be seen in dormant cambium cell as compared to actively dividing cell.

(A) Very few Golgi bodies

(B) Lesser amount of rough endoplasmic reticulum

(C) Large vacuole occupying much of the cell volume

(D) Increased hydration of cellulose microfibrils of the cell wall

Answer (A, B)

Sol. Dormant cambial cells show very few dictyosomes (Golgi bodies), lesser rough endoplasmic reticulum, more smooth endoplasmic reticulum and many small vacuoles. These also show decreased hydration of cellulose microfibrils.

19. Following table gives information on naturally occurring stable isotopes of three elements and the number of neutrons in these isotopes. Identify the position for the elements in the Modern Periodic Table. Select the correct option/s.

Element code	**Number of stable Isotopes**	**Atomic mass (a.m.u.)**	**Number of neutrons**
α	2	120.90	70
		122.90	72
β	5	69.92	38
		71.92	40
		72.92	41
		73.92	42
		75.92	44
γ	2	106.90	60
		108.90	62

(A) Element α belongs to group 15 and period 5, Element β belongs to group 4 and period 4

(B) Element β belongs to group 14 and period 4, Element γ belongs to group 1 and period 5

(C) Element α belongs to group 14 and period 5, Element β belongs to group 13 and period 4

(D) Element α belongs to group 15 and period 5, Element γ belongs to group 11 and period 5

Answer (D)

Sol.

Element code	**Atomic number (Z = A – n)**	**Element**	**Group number**	**Period number**
α	51	Sb	15	5
β	32	Ge	14	4
γ	47	Ag	11	5

Isotopes of Sb : $^{121}_{51}Sb$ and $^{123}_{51}Sb$

Isotopes of Ge : $^{70}_{32}Ge$, $^{72}_{32}Ge$, $^{73}_{32}Ge$, $^{74}_{32}Ge$ and $^{75}_{32}Ge$

Isotopes of Ag: $^{107}_{47}Ag$ and $^{109}_{47}Ag$

20. With a solution of $I^{-}_{(aq)}$, chlorine (Cl_2) would react more vigorously at similar conditions and concentrations than bromine (Br_2) because,

(A) Atomic radius of bromine atom is larger than chlorine atom.

(B) Electronegativity of bromine is greater than chlorine.

(C) Shielding of nuclear charge within the chlorine atom is less than that in bromine atom.

(D) Nuclear charge in chlorine atom is less than that in bromine atom.

Answer (A, C)

Sol. $2I^-(aq) + Cl_2 \longrightarrow 2Cl^- + I_2$

$2I^-(aq) + Br_2 \longrightarrow 2Br^- + I_2$

- Since, standard reduction potential of chlorine (E° = 1.36 V) is more than bromine (E° = 1.09 V), that's why I^- reacts more vigorously with Cl_2 than Br_2.
- Atomic radius of Cl is less than Br, so the tendency to gain electrons is more in Cl as compared to Br.
- Bromine has additional shell as compared to chlorine which increases the shielding of nuclear charge.

21. A member of alkene series **X** has a molecular mass 28 amu. A small quantity of **X** (150 cm^3) is burnt in just sufficient air (containing 20% oxygen) to form carbon dioxide and steam. If all the measurements are made at 1 atm pressure and 100°C, then the composition of the products formed and the unreacted air is

(A) 300 cm^3 CO_2, 300 cm^3 steam, and 450 cm^3 the unreacted air, respectively

(B) 5.9×10^{21} molecules of CO_2, 5.9×10^{21} molecules of steam, 1800 cm^3 the unreacted air, respectively

(C) 5.9×10^{25} molecules of CO_2, 5.9×10^{25} molecules of steam, 450 cm^3 the unreacted air, respectively

(D) 300 cm^3 CO_2, 300 cm^3 steam, and 1800 cm^3 the unreacted air, respectively

Answer (B, D)

Sol. $X \Rightarrow C_2H_4$

$$\underset{150\text{ mL}}{C_2H_4(g)} + \underset{450\text{ mL}}{3O_2(g)} \longrightarrow 2CO_2(g) + 2H_2O(g)$$

150 mL of X will produce 300 mL of CO_2 and 300 mL of steam on complete combustion

Amount of air required for complete combustion $= \dfrac{450 \times 100}{20}$

$= 2250$ mL

Amount of unreacted air = 2250 – 450 = 1800 mL

Now, using ideal gas equation

PV = nRT

$$n_{CO_2} = \frac{PV}{RT}$$

$$= \frac{1 \times 0.3}{0.082 \times 373}$$

= 0.0098 mole

Molecules of CO_2 = Molecules of H_2O (steam) = $0.0098 \times 6.022 \times 10^{23}$

$= 5.9 \times 10^{21}$

22. A pulse of sound is generated at the centre of a room of rectangular cross section having dimensions 20 m × 20 m × 30 m. Speed of sound is 350 m/s. Consider all possibilities of hearing echoes of this pulse. Some of the instances of time when echoes can be detected at the location of the source are …

(A) 81 ms

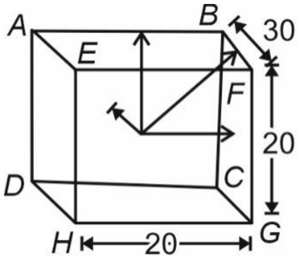
(B) 86 ms

(C) 96 ms

(D) 103 ms

Answer (A, B, D)

Sol.



Echo from wall *ABCD* or *EFGH*

$$t=\frac{2d}{v}=\frac{2\times\frac{30}{2}}{350}=85.71\approx 86\text{ ms}$$

Echo from wall *BFGC*, *AEHD*, *AEFB* or *DHGC*

$$t=\frac{2\times\frac{20}{2}}{350}=57.14\text{ ms}$$

Second echo = 2 × 57.14 = 114.28 ms (not in options)

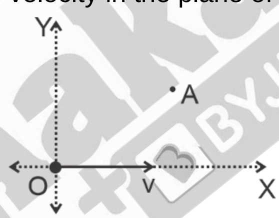
Echo from edge *BF*, *CG*, *DH* or *AE*

$$t=\frac{2\times 10\sqrt{2}}{350}=80.8\text{ ms}\approx 81\text{ms}$$

Echo from edge *AB*, *EF*, *HG* or *DC*

$$t=\frac{2\times\sqrt{10^2+15^2}}{350}\approx 103\text{ ms}$$

23. The figure shows an electron projected from O, with velocity v along the positive X-axis. After a short time, the same electron is found at point A, with its velocity in the plane of the figure. Choose the correct option/s.



(A) The above motion can be due to presence of a uniform electric field along the negative Y direction.

(B) Motion of electron from O to A can be due to presence of uniform magnetic field perpendicular to XOY plane and outwards.

(C) Motion of electron from O to A can be possible due to presence of both, a uniform magnetic field and a uniform electric field with proper magnitudes and directions.

(D) In the figure given, the path of the electron from O to A will necessarily be along a straight line.

Answer (A, B, C)

24. Prajakta is riding her cycle on a level road. She applies brake and the cycle slows down. Select the correct statement/s.

(A) If she applies only the front brake, the force due to both the tyres reduce her cycle's speed.

(B) If she applies only the front brake, the force due to ground reduces her cycle's speed.

(C) If she applies only the rear brake, the force due to the rear tyre reduces her cycle's speed.

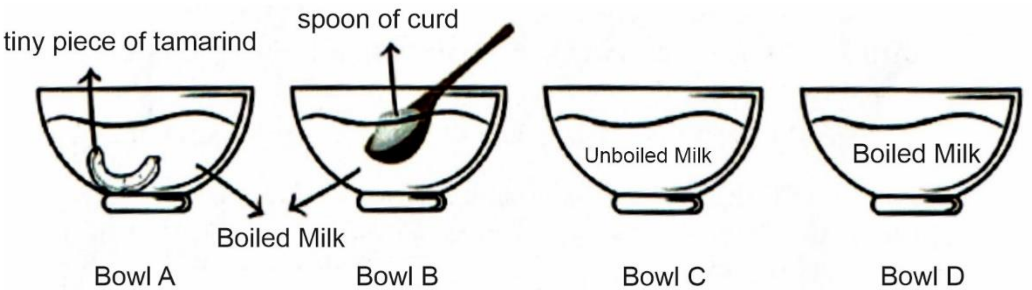
(D) If she applies only the rear brake, the force due to ground reduces her cycle's speed.

Answer (B, D)

Sol. Only friction is responsible for slowing down of cycle. Hence, force due to ground reduces her cycle's speed.

Section III : Descriptive Questions

25. Four bowls of milk were incubated at room temperature under different conditions (schematic below – either boiled or unboiled milk was mixed and incubated either with a ripe piece of tamarind OR a spoon full of curd). The results of curd formation after 20 hrs is tabulated below, where a number of characteristics are recorded (the more the number of '+' signs, the better the firmness of the curd formed, rancid = unpleasant/old taste): **[8 Marks]**



Bowl	Coagulation of milk into curd like solids	Total Acidity	Flavour
A	+ +	Medium	Good
B	+ + +	Medium	Great
C	+ +	High	Rancid smell
D	+ / –	Low	Rancid smell

(a) Based on your knowledge of milk to curd formation, interpret which of the following is true?

(A) Lactic acid and other bacteria are already present in the milk.

(B) Controlled/desired fermentation of milk occurred in Bowls A, B and C.

(C) The spoon of curd introduces lactic acid bacteria into the milk.

(D) Bacteria from the air settled into sample D and prevented curd formation.

(b) A scientist claimed that the acid from tamarind helped in the curdling of milk. If you were the experimenter and had the option comparing unboiled/untreated samples versus those boiled for 10 min, which of the following observations would help you evaluate that the claim is false:

	Experiment	Outcome
A	The juice/tamarind extract from that same piece was boiled and added (instead of whole piece)	didn't curdle the milk
B	The juice/tamarind extract from the same piece of tamarind was added directly.	curdled the milk.
C	Tamarind extract was added to the boiled milk sample versus unboiled milk.	resulted in the unboiled milk curdling faster.
D	A raw piece of tamarind added to the boiled milk.	resulted in slower fermentation and curd formation.

(c) Below are a few facts about the nature of milk and clues to the curdling process:

(i) Milk is made up of proteins which in turn are made up of amino acids that contain varying amounts of weak acids-COOH and weak bases-NH2 depending on the amino acid content. These help act like a buffer that resists sudden changes of pH in milk.

(ii) As bacteria grow in milk, they can either break down these proteins (putrefaction) or utilize lactose to produce acids that contribute to the spoilage of milk.

(iii) Upon acid accumulation, proteins slowly tend to lose their overall structure, leading to aggregation and coagulation of milk. This is similar to the coagulation of egg albumin protein upon heating.

Based on this and the experiments above, which of the following statements is/are true?

(A) Milk protein acts like a buffer and hence takes a long time to curdle, as bacterial acids produced, accumulate slowly.

(B) Tamarind normally contain bacteria that utilize lactose to produce acids, which accumulate slowly eventually leading to curdling of milk.

(C) Weak acids are released from the small piece of tamarind and take a long time to denature the milk protein that leads to the curdling of milk.

(D) Tamarind tends to inhibit spoilage of milk as the acids prevent putrefaction of milk proteins due to coagulation.

Sol. (a) Answer (C)

Curd of bowl B showed high coagulation and great flavour which means that the spoon of curd introduced lactic acid bacteria into the milk.

(b) Answer (C)

As the experiment initially involved tamarind extract addition to boiled milk only so to evaluate the claim of the scientist we should add tamarind extract to unboiled milk too, so that when unboiled milk curdled faster, we can falsify the claim of one scientist that acid from tamarind helped in curdling.

(c) Answer (A, C)

Milk protein can act as buffer and hence take longer time to curdle milk.

Tamarind produce tartaric acid (weak acid) which can take longer time to denature protein.

26. The effects that organisms in a community have on each other are referred to as ecological interactions. Different types of ecological interactions exist based on the types of relationships between the same (intraspecific interactions) or different species (interspecific interactions). Consider the following situations: **[8 Marks]**

Situation I: The African buffalo feeds on the grasses growing in the Savannas. The buffalo's hide (skin) is infested with ticks. Oxpecker birds ride on the buffalo and feed on the ticks. While grazing, this large mammal unknowingly destroys insects and their nests present on the grounds. These insects which fly around after they are disturbed are eaten by egret birds in the vicinity:

Situation II: Carnivores such as timberwolves hunt and kill herbivorous mammals. Grizzly bears in the vicinity attempt to take over the wolf's prey/kill.

Situation III: Some kinds of detrivorous mites that need to feed on dung but cannot fly in search of fresh dung attach themselves to the bodies of dung beetles which are not only good at flying but are also good at locating fresh dung.

(a) For each of the situation (I - III), fill in the table to indicate the various type/s of interaction/s present, where '+' indicates positive effect, '–' indicates negative effect and '0' indicates no effect. Put tick marks (✓) against the appropriate interaction to indicate presence and cross mark (×) to indicate absence.

Serial No.	Effect on species 1	Effect on species 2	Type of interaction	Situation I	Situation II	Situation III
1	+	–	Predation			
2	+	–	Herbivory			
3	0	–	Amensalism			
4	+	0	Commensalism			
5	–	–	Competition			
6	+	–	Parasitism			
7	+	+	Mutualism			

(b) Antagonistic interactions are those in which one species benefits and the other is harmed. Choose the antagonistic interactions from the list of interactions given in the table in Q.26(a) and provide the solutions in the answersheet with the corresponding serial numbers. Antagonistic interaction/s is/are:

(c) Fill in the table below with the type of antagonistic interaction/s observed in each of the situations I, II and III (as referred in the table – Q26a) and also indicate the species/organism that is benefited (indicated by + in the table) and the species that is harmed (indicated by – in the table). Indicate the absence of an antagonistic interactions by writing NONE in the table under the column type of antagonistic interaction.

Situation	Type of antagonistic interaction	Species 1 (+)	Species 2 (–)
I			
Situation	Type of antagonistic interaction	Species 1 (+)	Species 2 (–)
II			

Situation	Type of antagonistic interaction	Species 1 (+)	Species 2 (–)
III			

Sol. (a)

Serial No.	Effect on species 1	Effect on species 2	Type of interaction	Situation I	Situation II	Situation III
1	+	–	Predation	✓	✓	×
2	+	–	Herbivory	✓	×	×
3	0	–	Amensalism	✓	×	×
4	+	0	Commensalism	✓	×	✓
5	–	–	Competition	×	✓	×
6	+	–	Parasitism	✓	×	×
7	+	+	Mutualism	✓	×	×

(b) Antagonistic interactions can be seen in predation (serial number 1), Herbivory (serial number 2) and parasitism (serial number 6).

- **Predation :** Ticks and Oxpecker, Insects and egret birds } Situation I
  Timberwolves and herbivorous mammals } Situation II
- **Herbivory :** African buffalo feeding on grass (Situation I)
- **Parasitism :** African buffalo and ticks (Situation I)

(c)

Situation	Type of antagonistic interaction	Species 1 (+)	Species 2 (–)
I	• Predation	Oxpecker	Ticks
		Egret	Insects
	• Herbivory	Buffalo	Grass
	• Parasitism	Ticks	Buffalo
Situation	Type of antagonistic interaction	Species 1 (+)	Species 2 (–)
II	Predation	Timberwolves	Herbivorous mammals
Situation	Type of antagonistic interaction	Species 1 (+)	Species 2 (–)
III	None	–	–

27. Our body organs are adapted to gravitational force present on earth's surface. Our circulatory system, skeletal system, muscle structure and functions all are adapted according to normal gravitational force on the earth's surface. Longer stay in space results in many physical and physiological changes in human body. Astronauts staying on the International Space Station (ISS) for extended periods of time face changes in regular bodily functions. **[6 Marks]**

For example, weight-bearing parts, balancing mechanisms, body fluids do not have to counter gravitational force in microgravity condition.

(a) Which one of the following changes in circulatory system occur(s) in case of an astronaut staying on ISS?

A. Heart shape changes under the influence of microgravity. It gets vertically elongated resulting in increased cardiac output.

B. Longer stay in space leads to gain in ventricular muscle mass as heart has to work harder to pump blood all over the body.

C. Heart rate of an individual on ISS is similar to the rate while lying down on the earth.

D. Astronaut continuously feel light headedness (dizziness) due to postural hypotension* during their stay in space but the feeling diminishes after landing on earth.

* Postural hypotension is a condition of low blood pressure that happens when standing after sitting or lying down.

(b) The skeletal system also gets affected due to microgravity. The functioning of osteoblasts (that make and regulate bone matrix) and osteoclasts (that breakdown and absorb bone matrix) are programmed as per the gravitational load present on the earth. During prolonged stay on ISS, both these types of cells show altered function. The 'weightless' condition results in 2-4% loss of bone matter. Interestingly, 97% of this loss is from part/s like: (Put a tick in correct box/es)

A	Wrist bones (Carpels)	
B	Hip bone	
C	Skull	
D	Rib cage	
E	Vertebral column	

(c) The International space station is revolving 400 km above the surface of the Earth. As you might have seen (in some movies or TV), the astronauts feel weightless inside the space station. What is the value of gravitational acceleration due to the earth *g* as measured at the space station?

Sol. (a) **Answer (A)**

Heart shape of astronaut changes from oval to a round ball under the influence of microgravity. It gets vertically elongated resulting in increased cardiac output.

(b) In space, astronauts experience spaceflight osteopenia. This bone loss typically happens in the legs, hips and spines of astronauts so, the loss of bone matter from hip bone and vertebral column will be seen majorly.

(c) $g' = \dfrac{g}{\left(1+\dfrac{400}{6400}\right)^2}$

$= \dfrac{256}{289} g$

$= 0.886 \times 10$

$= 8.86 \text{ m/s}^2$

28. A plasmid is an extrachromosomal DNA present in bacteria, imparting them with additional function, for example those imparted by antibiotic resistance genes. In recombinant DNA technology, a foreign gene of interest is usually inserted at a site present within the antibiotic resistance gene. This helps screen the bacterial cells that contain the engineered recombinant plasmid. **[8 Marks]**

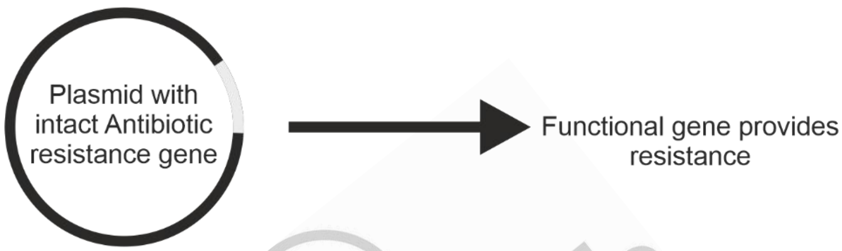


Figure 1 : Original plasmid

Figure 2 : Process of creating recombinant plasmid

In an experiment, plasmid pBR322 is used, which has both tetracycline (tet) and ampicillin (amp) resistance genes. A foreign gene is inserted in this plasmid at a site present within the tetracycline resistance gene.

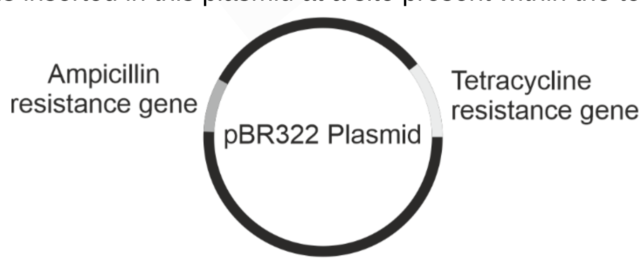


Figure 3 : pBR322 plasmid used for the experiment

(a) Bacterial cultures with these recombinant plasmids were grown on solid media plates each containing a different combination of antibiotics. Based on the observations after the growth period, state which of the following statements would be true/false-

i. Bacterial cells with recombinant plasmid grow on media containing both ampicillin and tetracycline.

ii. Bacterial cells with recombinant plasmid grow on media containing ampicillin only.

iii. Bacterial cells that lose the plasmid grow on media containing tetracycline only.

iv. Bacterial cells with recombinant plasmids will grow on media containing tetracycline only.

(b) Growth of the bacterial culture on ampicillin containing media would not be observed in which of the following cases of the same experiment-

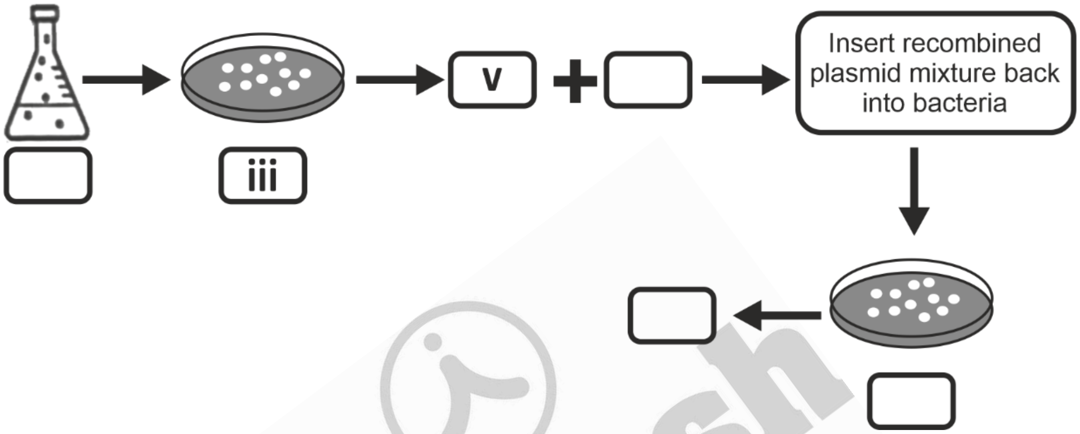
A. A successful recombination where the DNA gets inserted at the expected locus.

B. A failed recombination where the DNA gets inserted outside both the antibiotic resistance genes.

C. No recombination at all.

D. Complete loss of plasmid from all the cells.

(c) As per the sequential flow of the above experiment, insert the corresponding roman numerals for each of the following statements at the correct places in the diagram below, as shown by the examples in the figure.



i. Foreign gene
ii. Bacterial culture plated on media plate containing ampicillin
iii. Bacterial culture plated on media containing both ampicillin & tetracycline
iv. Bacterial cells with pBR322
v. Purify plasmid and cut at Tet gene for genetic engineering
vi. Isolate the bacteria with the desired recombinant plasmid

Sol. (a) (i) False

Due to insertion of foreign gene at a site present within the tetracycline resistance gene causes its inactivation and thus recombinant bacterial cells will not grow in tetracycline containing medium.

(ii) True

Only tetracycline resistance gene has been inactivated and thus bacterial cells have normal ampicillin resistance gene.

(iii) False

Plasmid contains antibiotic resistance genes and without plasmid, bacterial cells will not be able to resist the action of antibiotics.

(iv) False

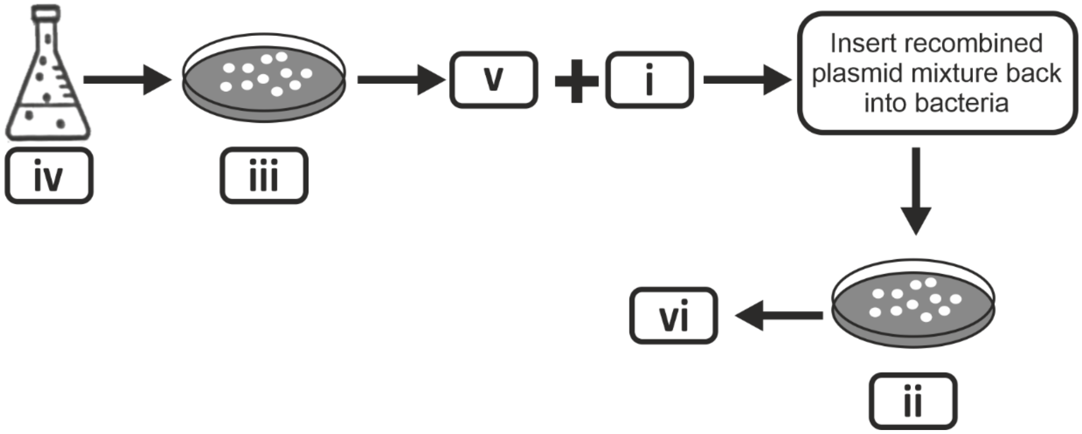
Recombinant plasmid has inactivated tetracycline resistance gene due to insertional inactivation.

(b) **Answer (A, D)**

Successful recombination of foreign gene at a site within the ampicillin containing gene causes its inactivation.

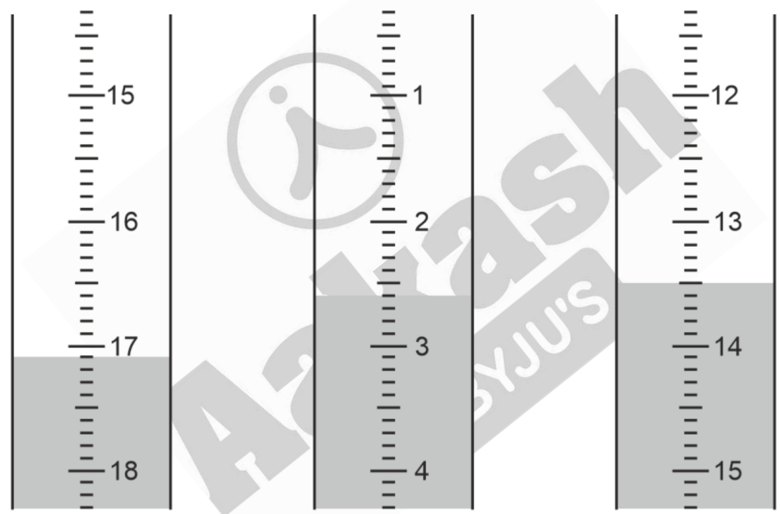
Also, complete loss of plasmid from bacterial cells eliminate all antibiotic resistance genes and thus bacterial cells will not grow on ampicillin containing medium.

(c)



29. Sumeet and Swapnil separately carried out experiments to find out the volume of dilute hydrochloric acid solutions required to react with a sample of 0.57 g of aluminium powder completely. **[13 Marks]**

Sumeet filled a burette with dilute hydrochloric acid up to the zero mark. He placed 0.57 g of aluminium powder into a conical flask and then slowly added the acid until the reaction was complete, indicated by no effervescence. The leftmost panel in the diagram below reveals his burette reading.



Swapnil repeated the experiment with 0.57 g of Aluminium powder from the same sample source, but with a different sample of dilute hydrochloric acid. The middle panel in the diagram above reveals his initial burette reading and the rightmost panel reveals his final burette reading.

(a) Write the balanced chemical equation for the reaction between aluminium and hydrochloric acid, stating the physical states of all chemicals.

(b) Use the information provided to complete the following table. Record the volumes to the nearest 0.1 cm^3

Burette reading in mL	Sumeet's Experiment	Swapnil's Experiment
Final burette reading		
Initial burette reading		
Volume of acid added		

(c) The concentration of the acid used by Sumeet in the experiment was 3.5 mol/dm^3. What was the concentration of the acid used by Swapnil for the experiment, if both titrations were done accurately?

(d) After completing the experiment and removing conical flask from tip of the burette, Swapnil observed his burette has started leaking, as he had not properly closed the stopper of the burette. He closed the stopper properly to stop leak and observes reading once again. It was approximately additional 11% of the volume consumed in reaction earlier. Leaked acid had fallen on the table. To keep table clean, neat and tidy he puts excess Sodium bi carbonate on it. Sumeet checked pH of resultant mixture by pH paper.

i. Write complete balanced chemical reaction between hydrochloric acid and sodium bicarbonate.

ii. What minimum quantity of sodium bicarbonate (in grams) is required to nullify the effect of spilled acid?

iii. Find the percent purity of aluminium sample.

(e) To check the process works good on other metals, both took the same amount of sample (0.57 g) of pure Zinc instead of Aluminium and carried out the titration process.

i. Write balanced chemical reaction, mentioning physical states, between Zinc powder and Hydrochloric acid.

ii. How many times Sumeet and Swapnil need to dilute their own acid solutions so as to get burette readings for the reaction with Zinc between 10 mL and 15 mL.

Sol. (a) $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$ **[1]**

(b)

Burette reading in mL	Sumeet's Experiment	Swapnil's Experiment
Final burette reading	17.1	13.5
Initial burette reading	0	2.6
Volume of acid added	17.1	10.9

[1+1]

(c)

For Sumeet	For Swapnil
M_1 = 3.5 mol/dm^3	M_2 = ?
V_1 = 17.1 cm^3	V_2 = 10.9 cm^3

Now, using formula

$M_1V_1 = M_2V_2$

$$\Rightarrow M_2 = \frac{M_1V_1}{V_2} = \frac{3.5 \times 17.1}{10.9}$$ **[1]**

= 5.49 mol/dm^3

= 5.5 mol/dm^3. **[1]**

(d) (i) $HCl(aq) + NaHCO_3(s) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$ **[1]**

(ii) Earlier used volume = 10.9 cm^3.

$$\Rightarrow \text{Volume spilled} = 10.9 \times \frac{11}{100} = 1.199\ cm^3.$$ **[½]**

$\Rightarrow$ Moles of HCl $= M \times V = \frac{5.5}{1000} \times 1.199$

$= 6.59 \times 10^{-3}$ moles

$\approx 6.6 \times 10^{-3}$ moles **[½]**

Molar mass of $NaHCO_3$ = 84 g/mol

1 mol of HCl $\longrightarrow$ 84 g of $NaHCO_3$

$\Rightarrow$ 6.6×10^{-3} moles of HCl $\longrightarrow \frac{84}{1} \times 6.6 \times 10^{-3}$ g

$= 554.4 \times 10^{-3}$ g

$= 0.55$ g **[1]**

(iii) In Swapnil's experiment,

Moles of HCl $= \frac{10.9 \times 5.49}{1000}$

$= 0.0598 \approx 0.06$ mole **[½]**

$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$

54 g of Al reacts with 6 moles of HCl

$\therefore$ 0.06 mole of HCl will react with $= \frac{54}{6} \times 0.06$

$= 0.54$ g of Al **[½]**

% Purity $= \frac{0.54}{0.57} \times 100$

$= 94.74\%$ **[1]**

(e) (i) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ **[1]**

(ii) Moles of Zn $= \frac{0.57}{65.38}$

$= 0.0087$ mol

$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

Moles of HCl required = 0.0087×2

$= 0.017$ mole

Considering the volume of HCl used is 10 mL

$0.017 = \frac{M \times 10}{1000}$

M = 1.7 M

Considering the volume of HCl used is 15 mL

$$0.017 = \frac{M \times 15}{1000}$$

M = 1.1 M

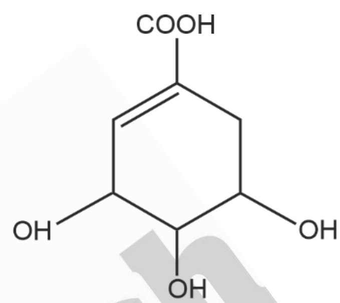
$\Rightarrow$ Molarity of Swapnil's solution = 5.5 M

So, Swapnil needs to dilute the solution by 4 times to obtain reading between 10 - 15 mL. **[1]**

$\Rightarrow$ Molarity of Sumeet's solution = 3.5 M

So, Sumeet needs to dilute the solution by 3 times to obtain reading between 10 - 15 mL. **[1]**

30. Shikimic acid is a natural product extracted from a spice called star anise, commonly used in India. It is a white solid with melting point 186°C and boiling point 401°C. It is also a raw material for synthesis of the antiviral drug Tamiflu. **[13 Marks]**



(a) What is the elemental composition of this molecule in terms of mass percentages?

(b) Shikimic acid (10.0 g) on esterification with ethanol in presence of acid gives compound A (8.5 g). When A was treated with aqueous sodium hydroxide, a new compound B was formed.

i. Give the structure of product A.

ii. How many C–H bonds are present in the molecule A?

iii. What happens to the pH value of the reaction mixture as shikimic acid converts to A, will it increase/decrease/remain the same?

iv. Practically in many reactions, complete conversion of reactants to products does not happen. The ratio of moles of actual yield versus moles of theoretical expected yield gives the percent yield. Calculate the yield (%) of the product A obtained, based on the data given above.

v. Which is more soluble in aqueous solution? Shikimic acid or A?

vi. Give the general chemical equation for the formation of B.

vii. Biryani is loved by many people in India. Star anise is a common flavouring agent for Biryani. Shyama added the whole spices including star anise with rice in water and half cooked it. Then she removed the whole spices from the half-cooked rice and layered the vessel with fried vegetables and again cooked the ingredients on a medium heat.

Tina made the same dish by first boiling rice in water (without star anise) to half cooked stage, added fried vegetable, and then recooked it. Then, she tempered the whole spices (including star anise) in oil, sauteed for a while and added it to the cooked biryani.

In whose Biryani, the rice grains would have higher amount of shikimic acid? What property of shikimic acid leads to this difference in amount in the two recipes?

Sol. (a) Shikimic acid molecule contains 7 atoms of carbon, 10 atoms of hydrogen and 5 atoms of oxygen. Molecular formula of shikimic acid = $C_7H_{10}O_5$

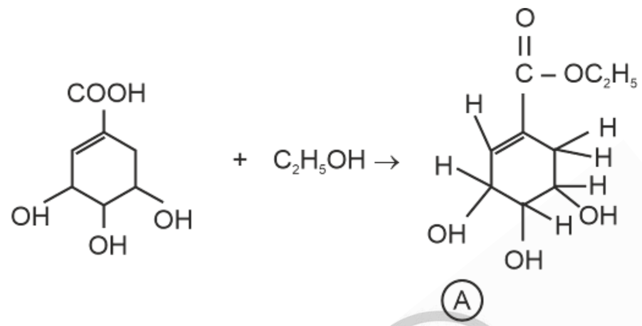
Molecular mass of $C_7H_{10}O_5$ = (12 × 7) + (1 × 10) + (16 × 5) = 174 u **[1]**

Percentage composition of C = $\frac{84}{174}\times 100 = 48.27\%$ **[1]**

Percentage composition of H = $\frac{10}{174}\times 100 = 5.75\%$ **[1]**

Percentage composition of O = $\frac{80}{174}\times 100 = 45.98\%$ **[1]**

(b) (i) **[1]**



(ii) No. of C–H bonds present in compound A = 11 **[1]**

(iii) Number of moles of shikimic acid $= \frac{10}{174} = 0.057$ mol

Molecular formula of ester = $C_9H_{14}O_5$

Molecular mass of ester = 202 u

Number of moles of ester formed $= \frac{8.5}{202} = 0.042$ mol

Since 0.042 mol of ester is formed, the acid is not completely consumed in the reaction but the concentration of the acid decreases in the final mixture

$$pH \propto \frac{1}{[H^+]}$$

Since the hydrogen ion concentration decreases, pH of solution will increase. **[1]**

(iv) Number of moles of shikimic acid = $\frac{10}{174} = 0.057$

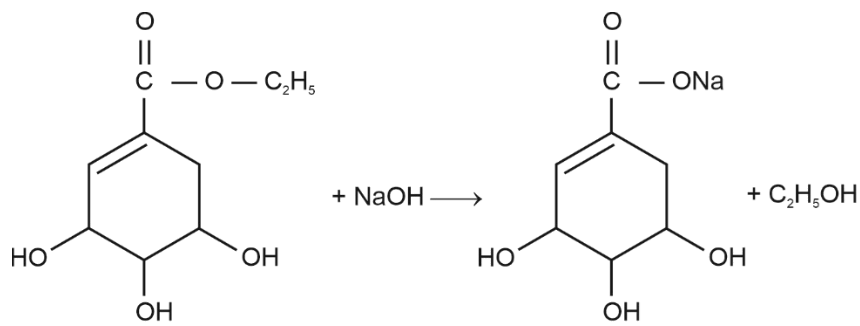
Number of moles of ester = 0.057

Weight of ester formed = 0.057 × 202

= 11.514 g **[1]**

% yield = $\frac{8.5}{11.514}\times 100 = 73.82\,\%$ **[1]**

(v) Shikimic acid is more soluble in water than ester due to larger extent of hydrogen bonding. **[1]**

(vi)  **[1]**

B

(vii) Shyama's biryani would have higher amount of shikimic acid. **[1]**

The property due to which there is a difference in amount of two recipes is "solubility". **[1]**

31. As a part of an experiment to study Tyndall effect, Aamir adds sugar to aqueous dispersion of gold nanoparticles of size 100 nm. Once the experiment is completed, he plans to recover gold nanoparticles and use them in another experiment. As he tries to separate gold nanoparticles and sugar, by mistake, he adds the mixture to a tube containing calcium carbonate. This results in a mixture containing gold nanoparticles, sugar, water, and calcium carbonate.

He separates the constituents in three steps by using set of apparatus available in the lab.

Instruments and materials available in the lab: Heater, sublimation set up, beaker, filter paper, funnel, centrifuge, centrifuge tubes, separating funnel, distillation set-up, fractional distillation set-up, and thermometer. Mention the separating methods in the correct sequence he used in order to obtain gold nanoparticles and sugar in their pure form with the least amount of loss. State which component is obtained at every step. **[4 Marks]**

Sol. Resultant mixture obtained by Aamir contains: Gold nanoparticles (100 nm), sugar, water and calcium carbonate.

Following steps are involved in order to separate the components of mixture:

(i) Filtration: Calcium carbonate being insoluble in water can be easily separated by using filter paper. On filtration, the residue contains calcium carbonate whereas the filtrate contains sugar, water and gold nanoparticles.

Component obtained – Calcium carbonate. **[1]**

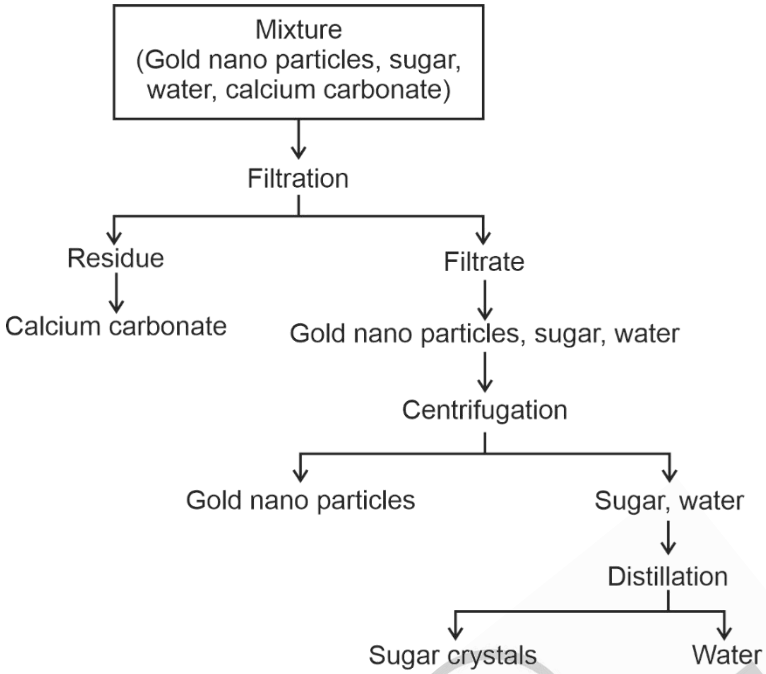
(ii) Centrifugation: Gold nanoparticles having size of 100 nm result in the formation of colloid. Therefore, it can be separated by using centrifuge and centrifuge tubes by the process centrifugation based on particle size.

Component obtained – Gold nanoparticles (100 nm) **[1]**

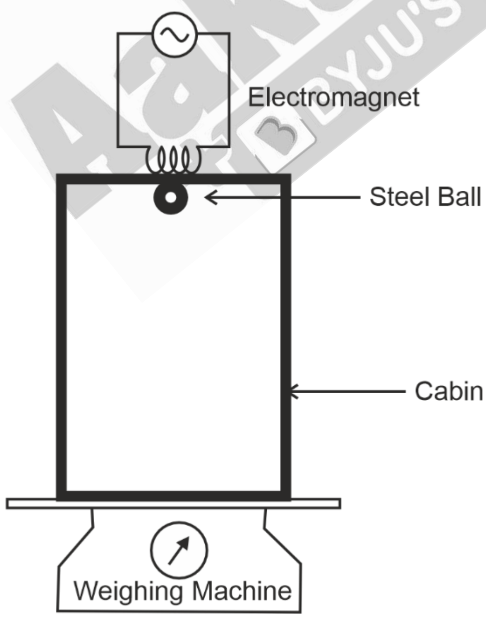
(iii) Distillation: Now the mixture is left with sugar and water. It can be separated by the process distillation.

The solution of sugar and water is boiled at 100°C. Since the boiling point of water is 100°C, it vapourise leaving behind the sugar in the flask.

Components obtained: Water and sugar **[1+1]**

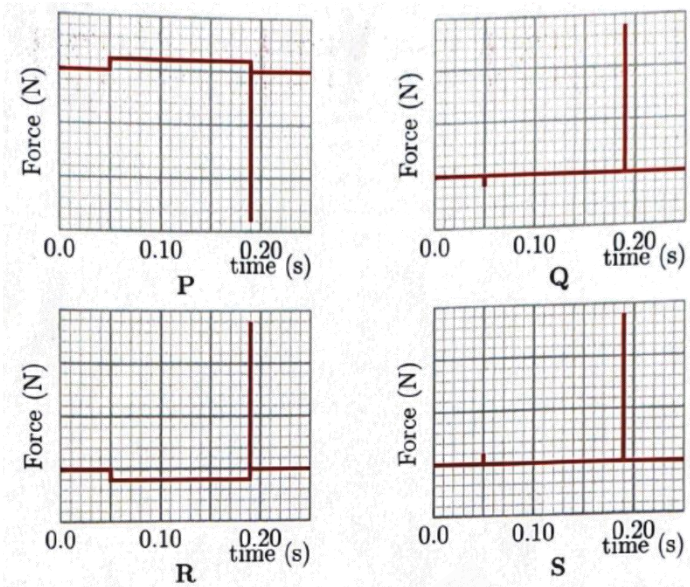


32. A steel ball of mass 100 g is attached to the ceiling of a cabin (of mass 4 kg) with an electromagnet of mass 0.5 kg resting on the upper side, as shown in the figure. At some instant, the electromagnet releases which allows the ball to fall and hit the floor of the cabin. Material of the floor is such that the ball comes to rest in a very short interval of time. For calculation purpose, treat the ball as a point mass. **[7 Marks]**



(a) For the following 4 graphs (Figures P, Q, R and S), the time interval of collision is too small to fit into the time scale on X-axis.

Which of these four graphs would best represent the time variation of the force felt by the weighing machine while this process takes place?



(b) Determine the height of the cabin using the data from the graph.

(c) Determine weighing machine reading in kilogram-weight during time of impact assuming that the colliding force is uniform for that time interval.

(d) Estimate the time interval for collision.

Sol. (a) R

(b) $\Delta t = 0.19 - 0.05$

$= 0.14$ s

$$h = \frac{1}{2}g(\Delta t)^2$$

$$= \frac{1}{2} \times 10 \times (0.14)^2$$

$= 0.098$ m

The height of cabin = 0.098 m

(c) 5 division = 46 N

1 division $= \frac{46}{5} = 9.2$ N

Weighing machine reading = 19 × 9.2

= 174.8 N

= 17.48 kg wt

(d) Impulsive force = 174.8 – 46

= 128.8 N

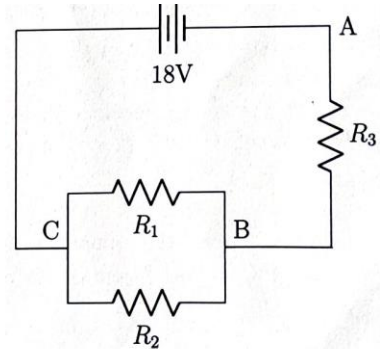
$v = \sqrt{2gh} = \sqrt{1.96}$ m/s

$Ft = mv - mu$

$$t = \frac{0 - \left(-100 \times 10^{-3} \times \sqrt{1.96}\right)}{128.8}$$

$\Rightarrow t = 0.001086$ s ≈ 1 ms

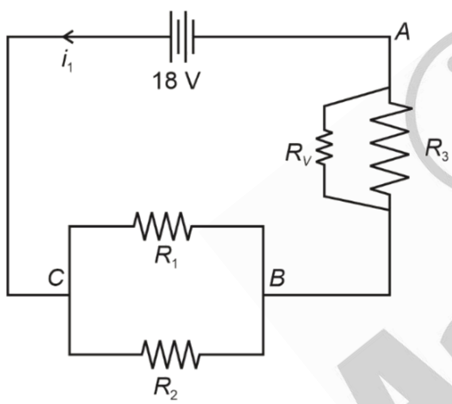
33. In a laboratory experiment, a student designs an electric circuit in which a battery of emf 18 V with negligible internal resistance is connected to a network of three resistors R_1, R_2 and R_3 as shown in figure below. $R_1 = R_2 = 100\ \Omega$ and $R_3 = 300\ \Omega$. **[11 Marks]**



She measures the potential difference across R_3 to be 14.4 V with the help of a non-ideal voltmeter. Now she disconnects the voltmeter and connects a non-ideal ammeter in this circuit to measure current flowing through R_2. This ammeter reads 20 mA.

She now connects the same voltmeter and ammeter simultaneously to measure potential difference across R_3 and current flowing through R_2 respectively. Determine the voltmeter and ammeter readings in this case.

Sol.

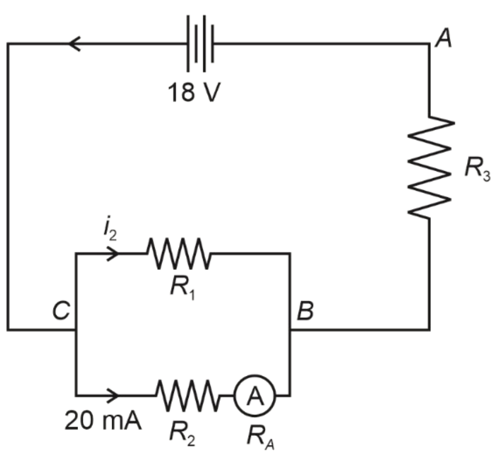


$$14.4 + 50i_1 = 18$$

$$\Rightarrow \quad i_1 = \frac{3.6}{50}\text{ A}$$

Again, $\frac{300R_V}{300 + R_V} \times i_1 = 14.4$

$$\Rightarrow \quad R_V = 600\ \Omega$$

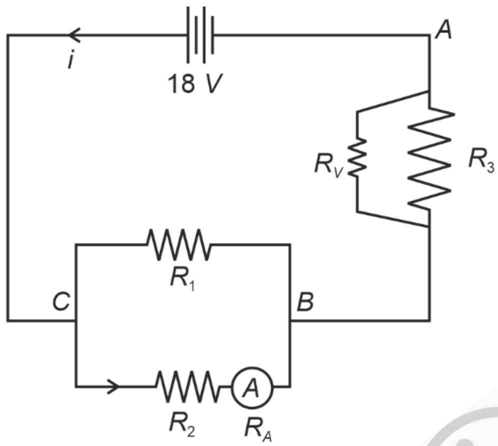


$$100i_2 + 300(i_2 + 20 \times 10^{-3}) = 18$$

$$\Rightarrow \quad i_2 = \frac{3}{100}\text{ A}$$

Again, $100i_2 = 20 \times 10^{-3}(100 + R_A)$

$$\Rightarrow \quad R_A = 50\ \Omega$$



$$R_{eq} = 260\ \Omega$$

$$i = \frac{18}{260}\text{ A}$$

$$= \frac{9}{130}\text{ A}$$

Voltmeter Reading (V_3) = $i \times 200 = \frac{9}{130} \times 200 = \frac{180}{13}$ V

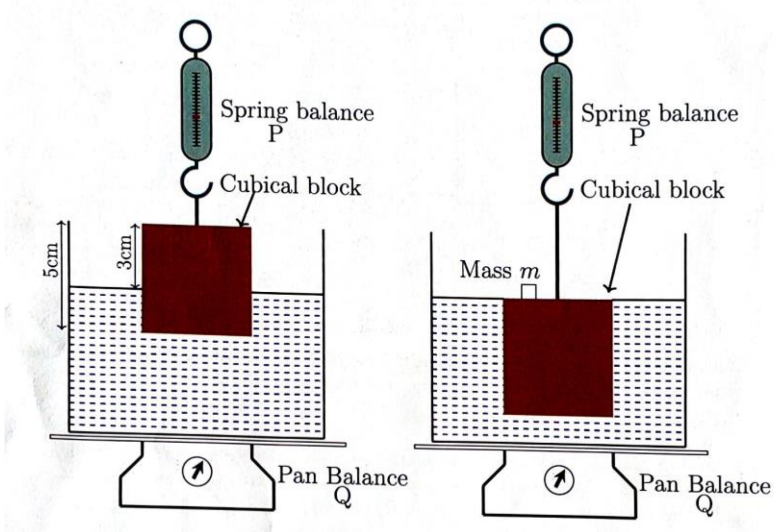
Ammeter Reading $(i_A) = \frac{\left(18 - \frac{180}{13}\right)}{150} = 27.7$ mA

34. A spring balance (P) reads 625 g when a cubical block of edge length 5 cm is suspended in air from it. Another pan balance (Q) reads 5.000 kg when a container filled with a liquid of density 1.2 g/cm^3 is put on its pan. These two preliminary readings are not shown as separate figures.

The spring balance, along with the cubical block suspended, is now arranged in such a way that the cubical block is partially submerged in the liquid inside the container. The height of the cube above the liquid is 3 cm. (left panel of the figure). Neglect the upthrust of air. **[7 Marks]**

(a) Compute the respective readings of balances P and Q as shown in the left panel of the figure.

(b) Assuming that spring of the spring balance extends linearly with applied force at a rate 50 N/m, calculate the maximum additional mass *m* that can be put on top of the block, such that only the upper mass remains above the liquid. What will be the respective readings of balance P and Q in this situation (right panel of the figure)?



Sol. (a) Volume of block under water

$= 5 \times 5 \times 2 = 50$ cc

Upthrust $= \rho_l \times V_l \times g$

$= 1.2 \times 50 \times g = 60$ gf

Reading of spring balance = 625 – 60 = 565 g

Reading of pan balance = 5 kg + 60 g

= 5.060 kg

(b) Liquid displaced $= 5 \times 5 \times 3 = 75$ cc

Upward thrust $= 75 \times 1.2 \times g = 90$ gf

Displacement of spring = 30 mm

Required force $= 50 \times 30 \times 10^{-3} = 1.5$ N = 150 gf

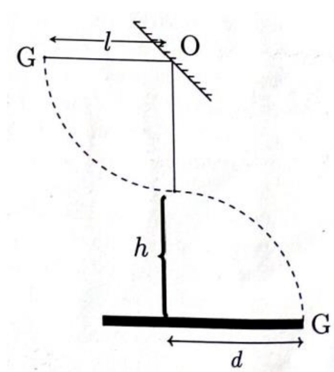
Mass = 150 + 90 = 240 g

Reading of spring balance = 565 + 150 = 715 g

Reading of pan balance $= 5.060 + 90 \times 10^{-3}$

= 5.150 kg

35. A gymnast (G) performing in a circus takes a swing with the help of a rod of length l hinged at point O. He starts the swing with the rod in the horizontal position and leaves the rod at the lowest position of the swing. There is a protecting net at depth h below the lowest point of the swing (see figure). Just for the sake of calculations, assume the gymnast to be a particle. **[5 Marks]**

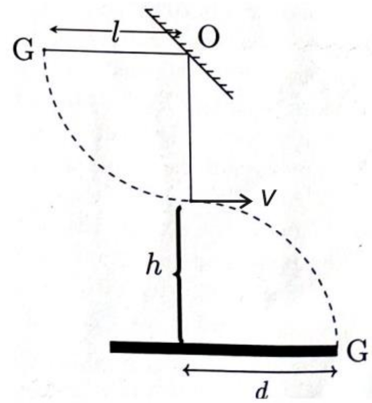


(a) Determine the horizontal distance d covered by the gymnast from the point of leaving the rod till he reaches the protecting net.

(b) Obtain the ratio of l and h so that the horizontal distance d covered by the gymnast from the point of release is maximum.

(c) The gymnast performs the same feat on an unknown planet almost like earth, except that its gravitational acceleration is half that of the earth. By what factor will d be affected?

Sol. (a) Let v be the speed of the gymnast at the lowest point.



$$-mgl + \frac{1}{2}mv^2 = 0$$

$$v = \sqrt{2gl}$$

Now, $d = vt$

$$= \sqrt{2gl} \times \sqrt{\frac{2h}{g}}$$

$$= 2\sqrt{hl}$$

(b) $d = 2\sqrt{hl}$

d will be maximum when $h \times l$ is maximum, which is possible when $h = l$

$$\Rightarrow \quad \frac{l}{h} = 1:1$$

(c) As $d = 2\sqrt{hl}$, which is independent of the value of acceleration due to gravity.

So, d will remain the same.

❑ ❑ ❑