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# CONTENTS

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# 1 CHAPTER

# Sexual Reproduction in Flowering Plants

✏️ **Topic-1:** *Pre-fertilisation: Structures and Events*

**1** *Multiple Choice Questions (1 Mark)*

**1.** Study the following diagram of Transverse Section of a young anther of an angiosperm: **[All India 2024, K]**
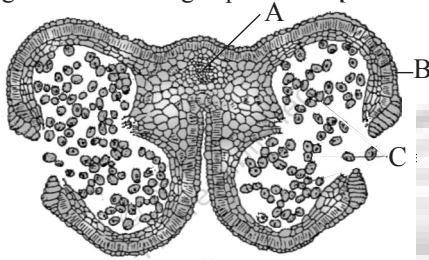


Select the option where parts 'A', 'B' and 'C' are correctly identified.
(a) A - Connective, B - Endothecium, C - Pollen grain
(b) A - Endothecium, B - Connective, C - Pollen grain
(c) A - Pollen grain, B - Connective, C - Endothecium
(d) A - Endothecium, B - Pollen grain, C - Connective

**2.** The wall layer of microsporangium which nourishes the pollen grain is: **[CBSE Sample Paper 2023-24, K]**
(a) epidermis (b) endothecium
(c) middle layers (d) tapetum

**3.** The aquatic plant having long and ribbon like pollen grains is : **[All India 2022, Term-I, K]**
(a) *Vallisneria* (b) *Hydrilla*
(c) *Eicchornia* (d) *Zostera*

**4.** To overcome incompatible pollinations so as to get desired hybrids, a plant breeder must have the knowledge of _____. **[All India 2022, Term-I, U]**
(a) pollen – nucellar interaction
(b) pollen – egg cell interaction
(c) pollen – pistil interaction
(d) pollen – embryo sac interaction

**5.** Pollen grains retain viability for months in plants belonging to different families given below :
**[All India 2022, Term-I, K]**
(i) Solanaceae (ii) Leguminosae
(iii) Gramineae (iv) Rosaceae
(v) Liliaceae
The correct option is :
(a) (i), (ii) and (v) (b) (i), (ii) and (iv)
(c) (ii), (iv) and (v) (d) (i), (iii) and (v)

**6.** In the tranverse section of a young anther shown below, identify the correct sequence of wall layers from outside to inside : **[All India 2022, Term-I, U]**
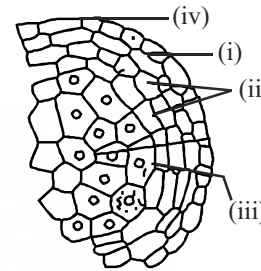


|     | (i) | (ii) | (iii) | (iv) |
|-----|-----|------|-------|------|
| (a) | Middle layers | Endothecium | Epidermis | Tapetum |
| (b) | Tapetum | Middle layers | Endothecium | Epidermis |
| (c) | Epidermis | Endothecium | Middle layers | Tapetum |
| (d) | Endothecium | Middle layers | Tapetum | Epidermis |

**7.** Floral reward/s provided by insect pollinated flowers to sustain animal visit is/are : **[All India 2022, Term-I, K]**
(a) nectar and fragrance
(b) nectar and pollen grains
(c) pollen grains and fragrance
(d) fragrance and bright colour

**8.** Which condition of gynoecium (pistil) is shown the figures (i) and (ii) ? **[All India 2022, Term-I, U]**
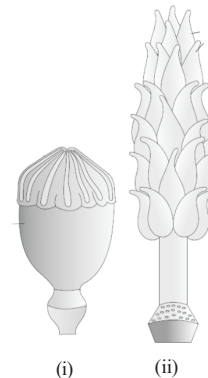


(a) (i) multicarpellary apocarpous, (ii) multicarpellary syncarpous
(b) (i) multicarpellary syncarpous, (ii) multicarpellary apocarpous
(c) (i) bicarpellary apocarpous, (ii) bicarpellary syncarpous
(d) (i) bicarpellary syncarpous, (ii) bicarpellary apocarpous

9.  Which of the following outbreeding devices are used by majority of flowering plants to prevent inbreeding depression ? **[All India 2022, Term-I, U]**
    (i)   Pollen release and stigma receptivity are not synchronised.
    (ii)  Different positions of anther and stigma.
    (iii) Production of different types of pollen grains.
    (iv)  Formation of unisexual flowers along with bisexual flowers.
    (a)  (i) and (ii)
    (b)  (ii), (iii) and (iv)
    (c)  (i), (iii) and (iv)
    (d)  (iii) and (iv)

10. Enclosed within the integuments of a typical anatropous ovule is a diploid mass of cellular tissue known as : **[All India 2022 Term-I, U]**
    (a)  Megaspore mother cell
    (b)  Nucellus
    (c)  Synergids
    (d)  Embryo sac

11. The structure of bilobed anther consists of **[CBSE Sample Paper 2021-22, K]**
    (a)  2 thecae, 2 sporangia
    (b)  4 thecae, 4 sporangia
    (c)  4 thecae, 2 sporangia
    (d)  2 thecae, 4 sporangia

12. In the figure of anatropous ovule given below, choose the correct option for the characteristic distribution of cells within the typical embryo sac. **[CBSE Sample Paper, 2021-22, K]**
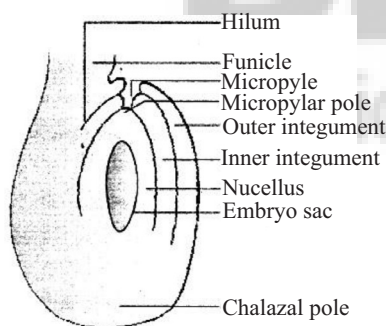


|     | Number of cells at chalazal end | Number of cells at micropylar end | Number of neclei left in central cell |
|-----|----|----|----|
| (a) | 3  | 2  | 3  |
| (b) | 3  | 3  | 2  |
| (c) | 2  | 3  | 3  |
| (d) | 2  | 2  | 4  |

13. Pollen grains are well preserved as fossils because of presence of **[CBSE Sample Paper, 2021-22, K]**
    (a)  sporopollenin
    (b)  cellulose
    (c)  lignocellulose
    (d)  pectocellulose

14. In the dioecious aquatic plant shown, identify the characteristics of the male flowers that reach the female flowers for pollination: **[CBSE Sample Paper, 2021-22, K]**
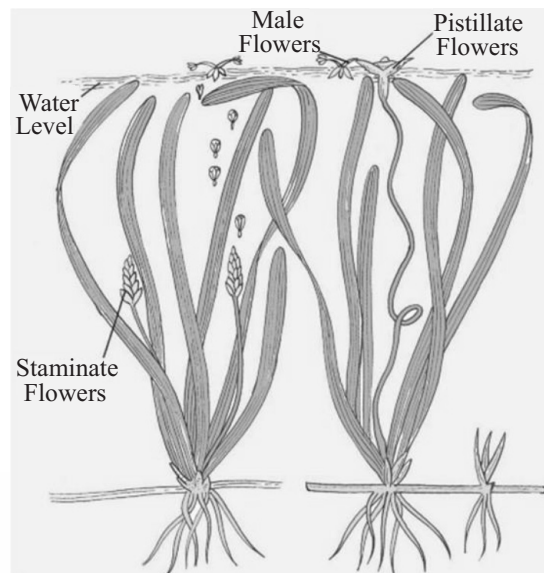


|     | Size of the flower | Colour of flower | Characteristic feature of pollengrain |
|-----|--------|-----------------|-----------------|
| (a) | small  | brightly coloured | Light wight and non-sticky |
| (b) | large  | colourless      | Large and sticky |
| (c) | small  | white           | small covered with mucilage |
| (d) | large  | colourless      | non sticky |

15. In a fertilized ovule, n, 2n and 3n conditions occur respectively in **[CBSE Sample Paper, 2021-22, K]**
    (a)  antipodal, zygote and endosperm
    (b)  zygote, nucellus and endosperm
    (c)  endosperm, nucellus and zygote.
    (d)  antipodals, synergids and integuments

16. A botanist studying Viola (common pansy) noticed that one of the two flower types withered and developed no further due to some unfavorable condition, but the other flower type on the same plant survived and it resulted in an assured seed set. Which of the following will be correct? **[CBSE Sample Paper, 2021-22, K]**
    (a)  The flower type which survived is Cleistogamous and it always exhibits autogamy
    (b)  The flower type which survived is Chasmogamous and it always exhibits geitonogamy.
    (c)  The flower type which survived is Cleistogamous and it exhibits both autogamy and geitonogamy.
    (d)  The flower type which survived is Chasmogamous and it never exhibits autogamy.

17. Self-pollination is fully ensured if
    (a) the flower is bisexual
    (b) the style is longer than the filament
    (c) the flower is cleistogamous
    (d) the time of pistil and anther maturity is different
    **[All India 2020, K]**

**4**    *Very Short Answer Questions (1 Mark)*

18. (a) Explain the process of the development of a male gametophyte in an angiosperm.
    **[All India 2023 Set-I, K]**
    (b) Why is it called a male gametophyte?
    **[All India 2023 Set-I, K]**

19. State the reason why pollen grains lose their viability when the tapetum in the anther is malfunctioning.
    **[Delhi 2019, U]**

**5**    *Short Answer Questions (2 or 3 Marks)*

20. Draw a well labelled diagram of sectional view of male gametophyte/microspore of an angiosperm and write the functions of any two parts labelled. (Any four labels).
    **[All India 2024, U]**

21. One of the major approaches of crop improvement programme is Artificial Hybridisation. Explain the steps involved in making sure that only the desired pollen grain pollinate the stigma of a bisexual flower by a plant breeder. **[Delhi 2023 Set-I, U]**

22. (i) Explain the monosporic development of embryo sac in the ovule of an angiosperm. 3
    (ii) Draw a diagram of the mature embryo sac of an angiospermic ovule and label any four parts in it. 2
    **[Delhi 2023 Set-I, U]**

23. Draw a schematic transverse section of a mature anther of an angiosperm. Label its epidermis, middle layers, tapetum, endothecium, sporogenous tissue and the connective.
    **[All India 2020, U]**

24. Explain three different modes of pollination that can occur in a chasmogamous flower.
    **[Delhi 2020, U]**

25. You are conducting artificial hybridization on papaya and potato. Which one of them would require the step of emasculation and why ? However for both you will use the process of bagging. Justify giving one reason.
    **[All India 2019, U]**

26. A mature embryo-sac in a flowering plant may possess 7-cells, but 8-nuclei. Explain with the help of diagram only. **[All India 2017, U]**

27. A pollen grain in angiosperm at the time of dehiscence from an anther could be 2-celled or 3-celled. Explain. How are the cells placed within the pollen grain when shed at a 2-celled stage? **[Delhi 2017, U]**

28. (a) Can a plant flowering in Mumbai be pollinated by pollen grains of the same species growing in New Delhi ? Provide explanations to your answer.

(b) Draw the diagram of a pistil where pollination has successfully occurred. Label the parts involved in reaching the male gametes to its desired destination.
**[Delhi 2017, U]**

29. Name the organic material exine of the pollen grain is made up of. How is this material advantageous to pollen grain? **[All India 2016, U]**

30. Make a list of any three out breeding devices that flowering plants have developed and explain how they help to encourage cross-pollination. **[All India 2014, U]**
**OR**
Why are angiosperm anthers called dithecous? Describe the structure of its microsporangium. **[All India 2014, U]**

31. Geitonogamous flowering plants are genetically autogamous but functionally crosspollinated. Justify.
**[Delhi 2013, U]**

32. State the reason why pollen grains lose their viability when the tapetum in the anther is malfunctioning.

**6**    *Long Answer Questions (5 Marks)*

33.



Observe the picture of *Commelina* plant bearing two types of flowers given above.
(i) Identify the two types of flowers labelled 'A' and 'B' in the picture.
(ii) Compare the two types of flowers with reference to:
    (1) Characteristic feature
    (2) modes of pollination
(iii) List any two 'out breeding devices' in flowering plants. Explain why do plants develop such devices.
**[All India 2024, A]**

34. (i) Describe the arrangement of nuclei and cells in a mature embryo sac of a typical angiosperm.
    **[All India 2023, Set-I, U]**
    (ii) Explain the devices the flowering plants have developed to prevent the following types of pollination: **[All India 2023, Set-I, U]**
    (1) Prevents both autogamy and geitonogamy
    (2) Prevents autogamy, but not geitonogamy

35. (a) Describe the process of megasporogenesis, in an angiosperm. **[Delhi 2020, U]**
    (b) Draw a diagram of mature embryo sac of angiosperm, label its any six parts. **[Delhi 2020, U]**

36. (a) Draw the embryo sac of a flowering plant and label the following: **[Delhi 2019, U]**
    (i) Central cell    (ii) Chalazal and    (iii) Synergids
    (b) Name the cell and explain the process it undergoes to develop into an embryo sac. **[Delhi 2019, U]**
    (c) Explain the development of endosperm in coconut.

37. Write down the difference between wind pollination and insect pollination. **[Delhi 2019, K]**

38. Describe any two devices in a flowering plant which prevent both autogamy and geitonogamy.
    **[All India 2018, U]**

39. Read the following statement and answer the questions that follow : **[All India 2017, U]**
    "A guava fruit has 200 viable seeds".
    (a) What are viable seeds?
    (b) Write the total number of :
        (i) Pollen grains
        (ii) Gametes in producing 200 viable guava seeds.
    (c) Prepare a flow-chart to depict the post-pollination events leading to viable-seed production in a flowering plant.

40. (a) As a senior biology student you have been asked to demonstrate to the students of secondary level in your school, the prodedure(s) that shall ensure crosspollination in a hermaphrodite flower. List the different steps that you would suggest and provide reasons for each one of them. **[All India 2016, U]**
    (b) Draw a diagram of a section of a megasporangium of an angiosperm and label funiculus, micropyle, embryosac and nucellus. **[All India 2016, U]**

41. Explain the post-pollination events leading to seed production in angiosperms. **[Delhi 2016, U]**

42. (a) Plan an experiment and prepare a flow chart of the steps that you would follow to ensure that the seeds are formed only from the desired sets of pollen grains. Name the type of experiment that you carried out. **[All India 2015, Ap]**
    (b) Write the importance of such experiments.
    **[All India 2015, Ap]**

43. List the different types of pollination depending upon the source of pollen grain.
    **[Delhi 2016, U]**

44. (a) Draw a L.S. of a pistil showing pollen tube entering the embryo-sac in an angiosperm and label any six parts other than stigma, style and ovary.
    **[All India 2013, U]**
    (b) Write the changes a fertilized ovule undergoes within the ovary in an angiosperm plant.
    **[All India 2013, U]**

✏️ **Topic-2:** **Double Fertilisation**

**1** *Multiple Choice Questions (1 Mark)*

1. In a fertilized ovule of an angiosperm, the cells in which n, 2n and 3n conditions respectively occur are:
   **[All India 2024, U]**
   (a) antipodal, zygote and endosperm
   (b) zygote, nucellus and endosperm
   (c) endosperm, nucellus and zygote
   (d) antipodals, synergids and integuments

2. Identify the correct labellings in the figure of a fertilised embryo sac of an angiosperm given below: **[Delhi 2024, K]**
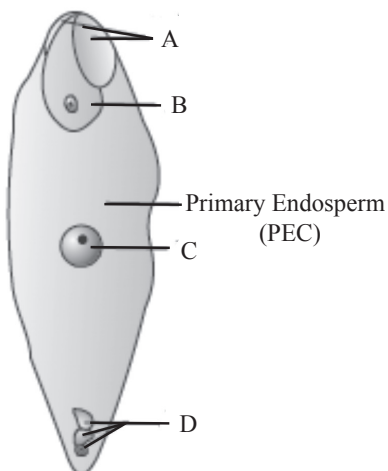


   (a) A-zygote, B-degenerating synergids, C-degenerating antipodals, D-PEN
   (b) A-degenerating synergids, B-zygote, C-PEN, D-degenerating antipodals
   (c) A-degenerating antipodals, B-PEN, C-degenerating synergids, D-zygote
   (d) A-degenerating synergids, B-zygote, A-degenerating antipodals, D-PEN

3. Choose the correct labellings for the parts X, Y and Z in the given figure of the stages in embryo development in a dicot:
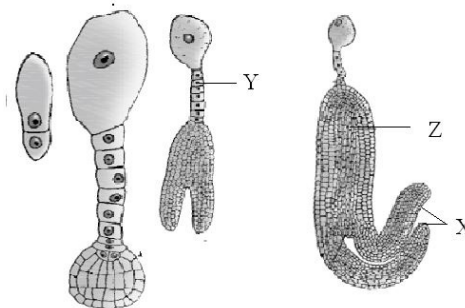


   (a) X is suspensor, Y is radicle and Z is cotyledon
   (b) X is radicle, Y is cotyledon and Z is suspensor
   (c) X is cotyledon, Y is suspensor and Z is radicle
   (d) X is zygote, Y is radicle and Z is cotyledon

   **[All India 2022, Term-I, U]**

**5** | *Short Answer Questions (2 or 3 Marks)*

**4.** If the cells in the leaves of a maize plant contain 10 chromosomes each, write the number of chromosomes in its endosperm and zygote. Name and explain the process by which an endosperm and a zygote are formed in maize. **[Delhi 2024, Ap]**

**5.** The diploid number of chromosomes in an angiospermic plant is 16. What will be the number of chromosomes in its endosperm and antipodal cells? **[Delhi 2019, U]**

**6.** Double fertilisation is reported in plants of both, castor and groundnut. However, the mature seeds of groundnut are non-albuminous and castor are albuminous. Explain the post fertilization events that are responsible for it. **[Delhi 2015, K]**

**6** | *Long Answer Questions (5 Marks)*

**7.** Explain the events upto double fertilization after the pollen tube enters one of the synergids in an ovule of an angiosperm. **[All India 2018, U]**

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## Topic-3: *Post-Fertilisation:Structures and Events*

**1** | *Multiple Choice Questions (1 Mark)*

**1.** Which of the following structures is well-developed in a mature seed of black pepper? **[All India 2023 Set-I, U]**
(a) Perisperm     (b) Thalamus
(c) Sepals        (d) Peduncle

**2.** Remnants of nucellus are persistent during seed development in: **[CBSE Sample Paper 2023-24, K]**
(a) pea           (b) groundnut
(c) wheat         (d) black pepper

**3.** In a typical dicotyledonous embryo, the portion of embryonal axis above the level of cotyledons is : **[All India 2022 Term-I, U]**
(a) Plumule       (b) Coleoptile
(c) Epicotyle     (d) Hypocotyle

**4.** Which of the following statements are true related to Seed X and Y? **[CBSE Sample Paper 2021-2022, U]**
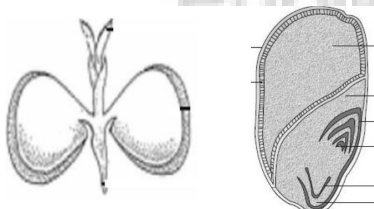


**Seed X**          **Seed Y**

(i) Seed X is dicot and endospermic or albuminous.
(ii) Seed X is dicot and non-endospermic or non-albuminous.
(iii) Seed Y is monocot and endospermic or albuminous.
(iv) Seed Y is monocot and non-endospermic or non-albuminous.

Choose the correct option with the respect to the nature of the seed
(a) (i), (iii)     (b) (ii), (iii)
(c) (i), (iv)      (d) (ii), (iv)

**5.** The thalamus contributes to the fruit formation in **[CBSE Sample Paper 2021-2022, K]**
(a) banana        (b) orange
(c) strawberry    (d) guava.

**6.** To produce 400 seeds, the number of meiotic divisions required will be **[CBSE Sample Paper 2021-2022, K]**
(a) 400           (b) 200
(c) 500           (d) 800

**5** | *Short Answer Questions (2 or 3 Marks)*

**7.** For a layman, both apple and banana are fruits. But a biology student categorises fruits as true fruits, false fruits and parthenocarpic fruits. Justify. **[All India 2020, U]**

**8.** Why do farmers find production of hybrid seeds costly?

**9.** Draw a diagram of LS of Maize grain and label its any six parts. **[Delhi 2019, U]**

**10.** Differentiate between Parthenocarpy and Parthenogenesis. Give one example of each. **[All India 2018, U]**

**11.** A single pea plant in your kitchen garden produces pods with viable seeds, but the individual papaya plant does not.Explain. **[All India 2016, K]**

**12.** Draw a labelled mature stage of a dicotyledonous embryo. **[All India 2014, U]**

**13.** Explain any three advantages the seeds offer to angiosperms. **[Delhi 2014, U]**

**14.** In angiosperms, zygote is diploid while primary endosperm cell is triploid. Explain. **[All India 2013, K]**

**6** | *Long Answer Questions (5 Marks)*

**15.** (i) With the help of labelled diagram **only**, show the different stages of embryo development in a dicot plant.
(ii) Endosperm development precedes embryo development. Justify. **[Delhi 2024, A]**

**16.** (a) When a seed of an orange is squeezed, many embryos, instead of one are observed. Explain how it is possible. **[Delhi 2017, U]**
(b) Are these embryos genetically similar or different ? Comment. **[Delhi 2017, U]**

📝 **Topic-4:** *Apomixis and Polyembryony*

**1** | *Multiple Choice Questions (1 Mark)*

1. Researchers the world over are trying to transfer apomictic genes to hybrid varieties as hybrid characters in the progeny : **[All India 2022 Term-I, U]**
   (a) do not segregate
   (b) segregate
   (c) develop genetic variations
   (d) will remain unexpressed

**2** | *Assertion Reason/Two Statement Type Questions (1 Mark)*

2. Consist of two statements–Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: **[CBSE Sample Paper 2022-23, U]**

   **Assertion:** Apomictic embryos are genetically identical to the parent plant.

   **Reason:** Apomixis is the production of seeds without fertilization.

   (a) Both A and R are true and R is the correct explanation of A.
   (b) Both A and R are true and R is not the correct explanation of A.
   (c) A is true but R is false.
   (d) A is False but R is true.

**4** | *Very Short Answer Questions (1 Mark)*

3. "Farmers prefer apomictic seeds to hybrid seeds." Justify giving two reasons. **[Delhi 2024, U]**

4. State two advantages of an apomictic seed to a farmer. **[Delhi 2020, K]**

**5** | *Short Answer Questions (2 or 3 Marks)*

5. State what is apomixis. Comment on its significance. How can it be commercially used? **[All India 2015, U]**

6. (a) Explain the different ways apomictic seeds can develop. Give an example of each. **[All India 2014, U]**
   (b) Mention one advantage of apomictic seeds to farmers. **[All India 2014, U]**

7. (a) Explain any two ways by which apomictic seed can develop.
   (b) List one advantage and one disadvantage of a apomictic crop.

**6** | *Long Answer Questions (5 Marks)*

8. (a) Explain any two ways by which apomictic seed can develop. **[All India 2019, U]**
   (b) List one advantage and one disadvantage of a apomictic crop. **[All India 2019, U]**
   (c) Why do farmers find production of hybrid seeds costly ? **[All India 2019, U]**

9. (a) Explain the different ways apomictic seeds can develop. Give an example of each. **[All India 2014, U]**
   (b) Mention one advantage of apomictic seeds to farmers. **[All India 2014, U]**
   (c) Draw a labelled mature stage of a dicotyledonous embryo. **[All India 2014, U]**
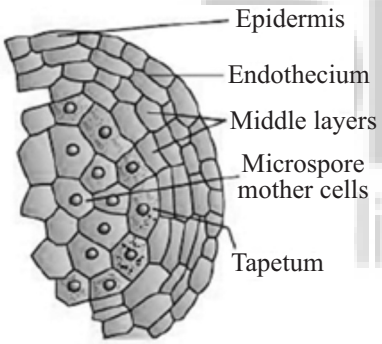
# ⚡ Hints & Solutions

**Topic-1:** *Pre-fertilisation: Structures and Events*

1.  **(a)** In the given figure,
    A – Connective, B - Endothecium, C - Pollen grains
2.  **(d)**                                                    **(1 Mark)**
3.  **(d)** *Zostera* is a submerged marine sea grass that releases long, ribbon-like pollen grains underwater. The pollen grains are carried passively by water and ultimately reach female flowers.          **(1 Mark)**
4.  **(c)** To overcome incompatible pollination so as to get a desirable hybrid a plant breeder must have the knowledge of pollen pistil interaction.     **(1 Mark)**

> 📝 **Note**
>
> *Pollination does not guarantee the transfer of right type of pollen C (comptabile pollen) of some species as the stigma.*

5.  **(b)** In some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability of pollen grains for months.          **(1 Mark)**
6.  **(d)**



Epidermis
Endothecium
Middle layers
Microspore mother cells
Tapetum

7.  **(b)** To sustain animal visits, the flower have to provide rewards to the animals. Nectar and pollen grains are usual floral rewards.          **(1 Mark)**
8.  **(b)** The gynoecium may consist more than one pistil is called multicarpellary. When there are more than one, the pistils may be fused together (syncarpous) or may be free (apocarpous).     **(1 Mark)**
9.  **(a)** Flowering plants continued self-pollination result in inbreeding depression. For this it developed many devices to discourage self-pollination and encourage cross-pollination.
    In some species, pollen release and stigma receptivity are not synchronised.
    In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. The third device to prevent inbreeding is self-incompatibility.          **(1 Mark)**

> 📝 **Note**
>
> *Majority of flowering plants prohermaphrodite flowers and pollen grain are likely to come in contact with stigma of same flower.*

10. **(b)** Enclosed within the integuments is a mass of cells called the nucellus. Cells of the nucellus have abundant reserve food materials. In the nucellus, the embryo sac or female gametophyte is present.     **(1 Mark)**

> 📝 **Note**
>
> *At the time of fertilization, the nucellus consist of a bulky tissue ventral to the embryo sac and a rather thin layer elsewhere.*

11. **(d)** The structure of bilobed anther consists of 2 theca which possess 4 sporangia.          **(1 Mark)**
12. **(b)** Chalazal end possess 3 antipodal cells, micropylar end possess 2 synergid cells and 1 egg cell. And central cell have 2 nuclei present in one cell.     **(1 Mark)**
13. **(a)** Pollen grains are well preserved as fossils because of presence of sporopollenin.          **(1 Mark)**
14. **(c)** small, white, small, covered with mucilage **(1 Mark)**
15. **(a)** antipodal, zygote and endosperm          **(1 Mark)**
16. **(a)** The flower type which survived is Cleistogamous and it will always exhibit autogamy     **(1 Mark)**
17. **(c)** The process of self-pollination is fully insured if the flower is cleistogamous. The clesitogamous flowers are the type of flower which does not open at all. In such flowers, the anther and stigma lie close to each other and when the anthers dehisce in the flower buds, and then the pollen grains come in contact with the stigma results in self-pollination.**(1 Mark)**
18. **(a)** In angiosperms, the pollen grain is the male gametophyte. Maturation of the male gametophyte or pollen grain includes two mitotic divisions. First divisions form vegetative and generative cell and in the second mitotic division the generative cell forms basically two male gametes and their release occurs from a mature anther. Therefore, it has two male gametes and one vegetative cell.     **(½ Marks)**
    **(b)** In angiosperms, microspores indicate the male gametophyte. Microspores divide mitotically, resulting in two unequal type of cells that are bigger vegetative cell and a small generative cell. The generative cell splits once again resulting in two male gametes or sperms. Microspore in angiosperms is also known as pollen grains.     **(½ Marks)**

> 📝 **Note**
>
> *For fertilization to occur in ongiosperms, pollen has to be transferred to stigma of a flower.*

**19.** Tapetum provides nourishment to the developing pollen grain. When the tapetum in anther is malfunctioning the pollen grain will not get enough nourishment and also loses its viability. **(1 Mark)**

📝 **Note**

*Cleistogamous flowers are autogamous flowers as there are no such chances of cross-pollination.*

**20.** **(1 Mark)**
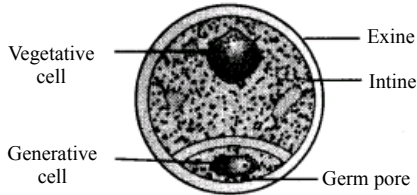


Function of Exine- It has a role in Protection as it can withstand high temperature and strong acids and alkali.
Function of Intine- It helps in maturation of pollen and germination of pollen tube. **(2 Marks)**

**21.** Artificial hybridisation is one of the major approaches of crop improvement programme. In such crossing experiments it is important to make sure that only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen). This is achieved by **emasculation and bagging techniques**. If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This step is referred to as emasculation. Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called bagging. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits allowed to develop. **(3 Marks)**

**22.** (i) In a majority of flowering plants, one of the megaspores is functional while the other three degenerate. Only the functional megaspore develops into the female gametophyte (embryo sac). This method of embryo sac formation from a single megaspore is termed monosporic development. The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles, forming the 2-nucleate embryo sac. Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac. It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation. After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac. Observe the distribution of cells inside the embryo sac. Six of the eight nuclei are surrounded by cell walls and organised into cells; the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell.
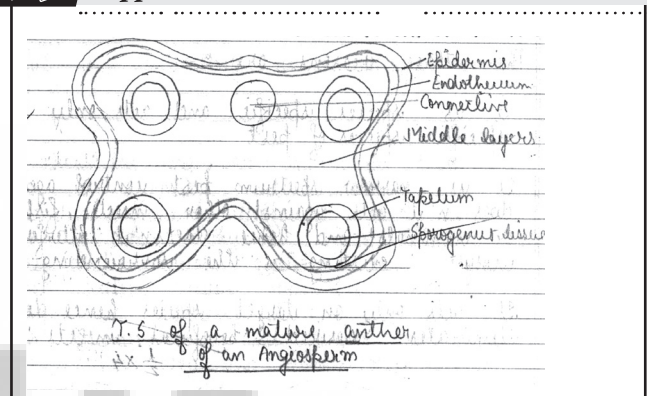
(ii) **(2 marks)**
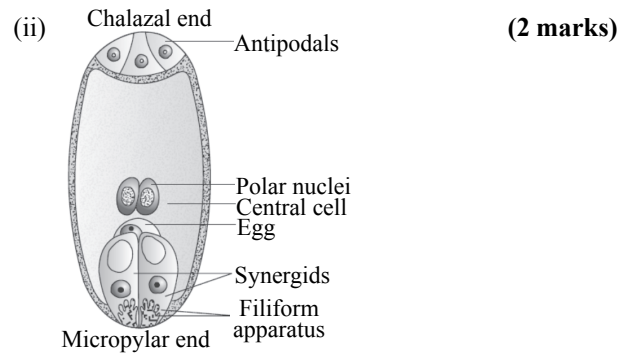


Diagrammatic representation of the mature embryo sac.
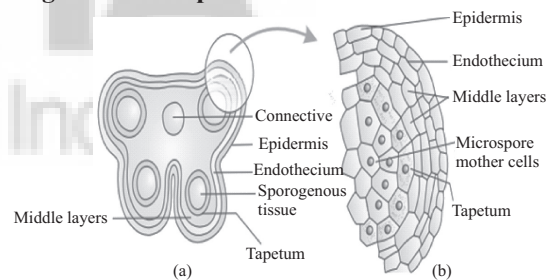
**23.**

🔬 **Topper's Answer**



**(3 Marks)**

**Diagrammatic representation of mature anther:**



A typical angiosperm anther is bilobed with each lobe having two theca such as they are dithecous. **(3 Marks)**

**24.** The three types of pollination that takes place in a chasmogamous flower are as follows:

(a) **Autogamy:** In this type, the process of pollination is achieved within the same flower. It involves the transfer of pollen grains from the anther to the stigma of the same flower. Chasmogamous flowers are type of flowers that are similar to the flowers of other species with exposed anthers and stigma.
In chasmogamous flowers, the anthers and stigma lie close to each other. When anther dehisces in the flower buds, the pollen grain comes in contact with the stigma to effect pollination. **(1 Mark)**

(b) **Geitonogamy:** It involves the transfer of pollen grains from the anther to the stigma of another flower of the same plant. It is functionally a type

of cross-pollination that involves pollinating agents. But genetically it is similar to autogamy so the pollen grains come from the same plant. **(1 Mark)**

(c) **Xenogamy:** It involves the transfer of pollen grains from anther to stigma of a different plant. This is the only type of pollination in which pollination brings genetically different types of pollen grains to the stigma. **(1 Mark)**

> **Note**
>
> *Pollination refers to the process of transfer of pollen grains (shed from the anther) to the stigma of a pistil.*

**25.** Potato require emasculation because it has bisexual flower whereas papaya would require only bagging for artificial hybridisation as papaya has unisexual flowers. After pollinating with the desired pollen grain it is required to bag the plant in order to prevent the plant from pollination by undesirable pollen grains. **(2 Marks)**

> **Note**
>
> *The process of removal of anthers from the flower bud before the dehiscence of anther by a pair of forceps is called Emasculation. The emasculated flower is covered with a bag of suitable size which is made up of butter paper in order to prevent from contamination of stigma with unwanted pollen and this process is called bagging.*

**26.** A mature embryo sac in a flowering plant possess 7 cells, but have 8 nuclei. This can be understood with the help of diagram given below:
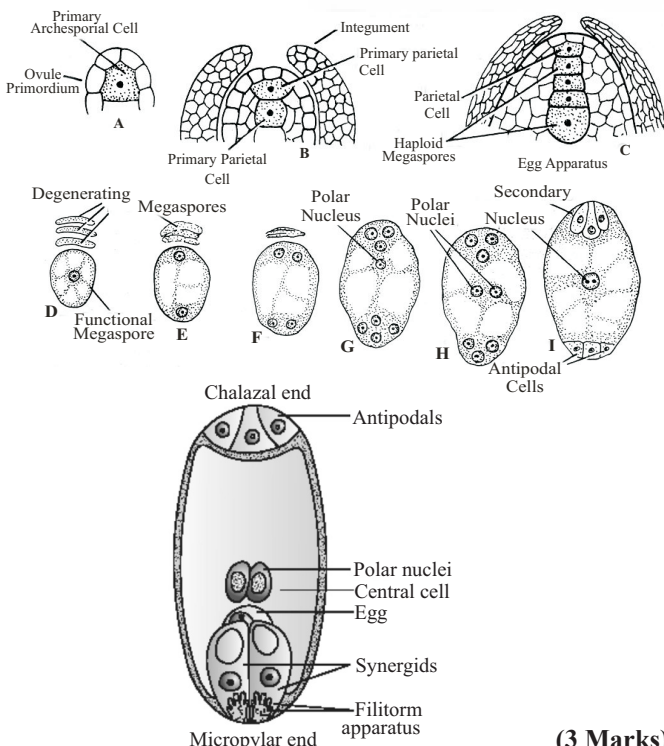


**Fig.:** Development of embryo sac
**(3 Marks)**

**27.** In many angiosperms, pollen grains are released in 2-celled stage while in other plant species, the generative cells are dividing into 2-male gametes and they will form 3-celled stage. When the pollen grain is shed at 2-celled stage then it has two unequal cells such as a bigger vegetative cell and smaller generative cell. **(2 Marks)**

**28.** (a) Yes, it can be only possible by means of artificial hybridisation in which a pollen grain of one flower is artificially introduced on the stigma of another flower. But it does not involve self-incompatibility of flowers.
   • In this, one flower is emasculated and bagged.
   • After some time, the bag is removed and then desired pollen grains are introduced on its stigma.

> **Note**
>
> *Emasculation refers to the removal of anthers from the floral bud before the anther dehiscence by using a pair of forceps. Whereas bagging refers to the covering of emasculated flower with a bag made of butter paper in order to prevent contamination of stigma with unwanted pollen.*

(b) **Diagrammatic representation of pistil:**
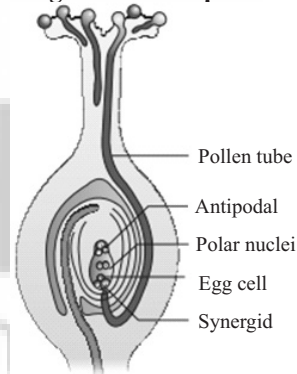


**(1 × ½ Marks)**

**29.** The hard outer layer of the pollen grain is called the exine which is made up of sporopollenin. Sporopollenin is one of the most resistant organic material as it tolerate high temperatures and strong acids as well as alkali. It cannot be degraded by enzymatic degradation. **(2 Marks)**

**30.** The outbreeding devices developed by plants are as follows:
   • Some species of plants, pollen release an receptivity of stigma are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.
   • Some species of plants, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. Both these devices prevent autogamy.
   • The third device helps to prevent inbreeding is self-incompatibility. It is genetic mechanism that prevents self-pollen (from the same flower or other flowers of the same flower) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil. **(3 Marks)**

**OR**

An angiosperm anther is bilobed with each lobe having two theca and because of this is called dithecous.

**Structure of microsporangium:**

A microsporangium is surrounded by four wall layers such as epidermis, endothecium, middle layer and tapetum. The outer three wall layers provide protection to the microsporangium and also help in dehiscence of anther to release the pollen. The innermost wall layer is the tapetum. It provide nourishment to the developing pollen grains. Cells of the tapetum possess dense cytoplasm and contain more than one nucleus. **(3 Marks)**

> **Note**
>
> *The outer hard layer called the exine is made up of **spocropollenin** which is one of the most resistant organic material. It can tolerate high temperature as well as all biochemical and enzymatic degeradation.*

**31.** Geitonogamy involves the transfer of pollen grains from the anther to the stigma of another flower of the same plant. Geitonogamy is functionally cross-pollination that involves pollinating agent but genetically is similar to autogamy since the pollen grains come from the same plant. **(2 Marks)**

> **Note**
>
> *Autogamy is a type of self-pollination in which pollination is achieved within the same flower. In this, transfer of pollen grains from the anther to the stigma of the same flower.*

**32.** Tapetum provides nourishment to the developing pollen grain. When the tapetum in anther is malfunctioning the pollen grain will not get enough nourishment and will lose its viability. **(2 Marks)**

**33.** (i) A- Chasmogamous flower

B- Cleistogamous flower **(1 Mark)**

(ii) (1) In A, the flower is open and have exposed anther and stigma whereas in B, the flower is closed where anther and stigma lies close to each other.

(2) In A, both geitonogamy and xenogamy can occur due to well-exposed stigma and anther but in B only autogamy will occur as flower does not open at all. **(2 Marks)**

(iii) Self-incompatibility- This is a genetic mechanism and prevents self-pollen (from the same flower or other flowers of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.

Production of unisexual flowers- If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy. In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female (dioecy). **(2 Marks)**

**34.** (i) In a typical embryo sac of an angiosperm there are seven cells- one central cell, two synergids, one egg cell, and three antipodals. The egg apparatus comprising a group of three cells (two synergids and one egg cell) is found at the micropylar end. Three antipodal cells are located at the chalazal end. Six of the eight nuclei are enclosed by cell walls, whereas, the remaining two nuclei (polar nuclei) are located in the central cell. Hence, a typical angiosperm embryo sac at maturity is 8-nucleate and 7-celled. **(2 × ½ Marks)**
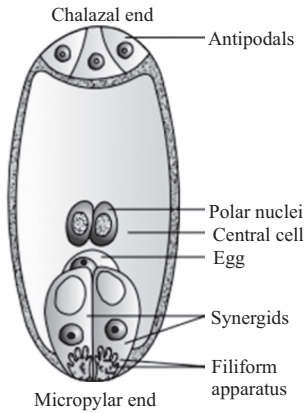
(ii) (1) Autogamy is a type of pollination is achieved within the same flower. Transfer of pollen grains from the anther to the stigma of the same flower. Geitonogamy involves the transfer of pollen grains from the anther to the stigma of another flower of the same plant. In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female (dioecy). This condition prevents both autogamy and geitonogamy.

(2) In some species, pollen release and stigma receptivity are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen. In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. Both these devices prevent autogamy but not geitonogamy. **(2 × ½ Marks)**

> **Note**
>
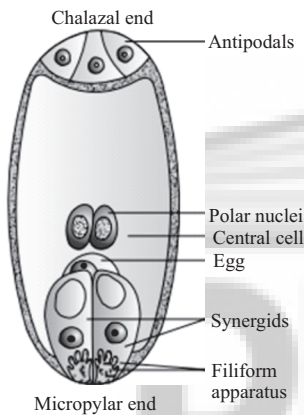> *Geitonogamy is a functionally cross pollination involving a pollinating agent.*

**35.** (a) The process of formation of megaspores from the megaspore mother cell is called megasporogenesis. The megaspore mother cell undergoes the process of meiosis and forms a four haploid tetrad megaspores. The chalazal megaspore remains functional whereas the other 3 will degenerate. So, the functional megaspore is the first cell of the female gametophyte. The cell enlarges and undergoes three free nuclear mitotic divisions.

So the first meiotic division produces two nucleate embryo sac and two nuclei shift to the two ends and again gets divide and forms four nucleate. In this way, eight nucleate structures is formed. One nucleus from each side moves to the middles and they are called polar nuclei. Then the remaining three nuclei form cells at the two ends, 3-celled egg apparatus at the micropylar end and three antipodal cells at the chalazal end. **(2 × ½ Marks)**

(b) **Diagrammatic Representation of mature embryo sac in angiosperm:**



Chalazal end — Antipodals — Polar nuclei — Central cell — Egg — Synergids — Filiform apparatus — Micropylar end

**(2 × ½ Marks)**

**36.** (a) **Diagrammatic representation of embryo sac:**



Chalazal end — Antipodals — Polar nuclei — Central cell — Egg — Synergids — Filiform apparatus — Micropylar end

**(c)**                 **(2 Marks)**

(b) The process of formation of megaspores from the megaspore mother cell is called megasporogenesis. The megaspore mother cell undergoes the process of meiosis and forms a four haploid tetrad megaspores. The chalazal megaspore remains functional whereas the other 3 will degenerate. So, the functional megaspore is the first cell of the female gametophyte. The cell enlarges and undergoes three free nuclear mitotic divisions.

So the first meiotic division produces two nucleate embryo sac and two nuclei shift to the two ends and again gets divide and forms four nucleate. In this way, eight nucleate structures is formed. One nucleus from each side moves to the middles and they are called polar nuclei. Then the remaining three nuclei form cells at the two ends, 3-celled egg apparatus at the micropylar end and three antipodal cells at the chalazal end. **(2 Marks)**

(c) The Primary Endosperm Nucleus (PEN) is triploid (3n) in nature that undergoes nuclear divisions and give rise to free nuclear endosperm. This free nuclear endosperm is a coconut water whereas its white kernel is the cellular endosperm that is formed when it undergoes cytokinesis. **(1 Mark)**

**37.**

**Topper's Answer**

| Wind Pollinated | Insect Pollinated |
|---|---|
| 1. It is an abiotic mode of pollination also called as anemophily. | 1. It is a biotic mode of pollination also called as entomophily. |
| 2. Pollen grains produced by these flowers are non sticky and light. | 2. Pollen grains produced by these flowers are sticky. |
| 3. These flowers are often white and colourless as well as odourless. | 3. These flowers are often and generally colourfull with odours to attract their pollinators. |
| 4. These flowers have exposed stamen and pistil with a single ovule. | 4. These flowers are of any type and may contain more |

| Wind pollinated | Insect pollinated |
|---|---|
| These are small | They are either large or grouped to form large clusters |
| Usually incospicuous due to dull colours. | The presence of bright colours in corolla, clayx or bracts to attract insects. |
| They are odourless and devoid of nectar. | Strongly odoured and usually possess nectar or edible pollen. |
| Pollens are produced in large numbers. | Fewer pollen grains are produced. |
| Examples *Urtica*, Maize, *Parthenium*. | Examples Rose, Snapdragon, Colotropis |

**38.** **Autogamy :** Transfer of pollen grains from anther to the stigma of same flower. It is a type of self-pollination.

**Geitonogamy :** Transfer of pollen grains from anther to the stigma of another flower of same plant. Two devices that prevent both autogamy and geitonogamy are :

**(i)** **Self - incompatibility :** This is a genetic mechanism & prevents self-pollen from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.

**(ii)** **Dioecious plants :** Male and female flowers are present on different plants, that is each plant is either male or female. **(2 × ½ Marks)**


(a)


(a)       (b)

**(2 Marks)**

**39.** **(a)** Those seeds that carry a living embryo and are capable of germinating into a seedling under appropriate conditions are termed as viable seeds. **(1 Mark)**

**(b)** **(i)** Number of pollen grams required to form 200 seeds will be 200 only as each pollen grain carries to generative cells or male gametes and only one of the two are involved in zygote formation.

**(ii)** In total 400 gamete cells are required for production of 200 viable zygotes leading to formation of 200 guava seeds. **(2 Marks)**

**(c)** **Flow chart depicting the post pollination events:**
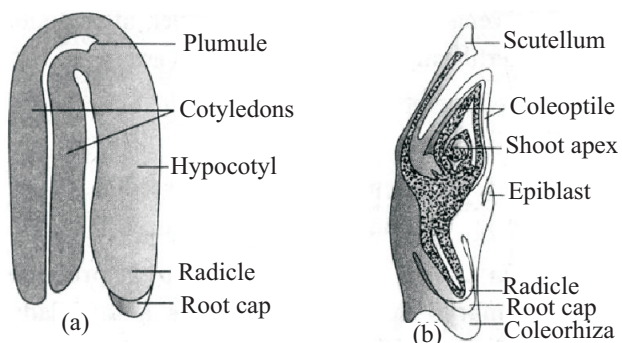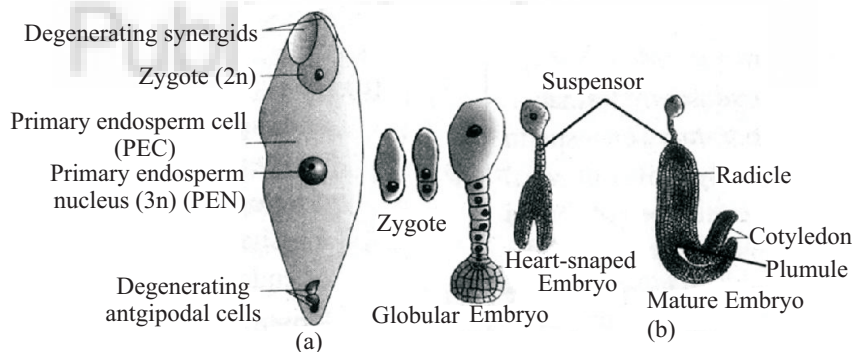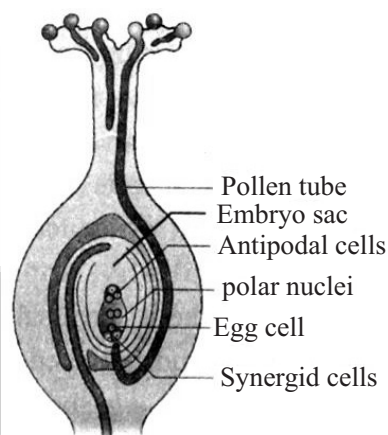


**40.** **(a)** The procedure used to ensure cross-pollination in hermaphrodite flower are as follows:

• **Emasculation:** If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces by using a pair of forceps is called emasculation.

• **Bagging:** Emasculated flower is covered with a bag of suitable size generally made up of butter paper to prevent contamination of its stigma with unwanted pollen and this process is called bagging.

When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma and the flowers are rebagged and the fruits allowed to develop.
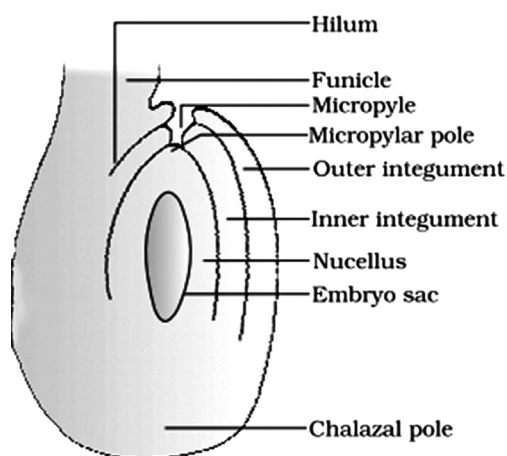
**(3 Marks)**

*The process of transfer of pollen grains to the stigma of a pistil is termed as **pollination.** The pollination can be divided into three types such as autogamy and geitonogamy are the type of self-pollination whereas xenogamy is a type of cross-pollination.*

(b) Diagrammatic representation of megasporangium of an angiosperm:



**(2 Marks)**

**41.** (a) Pollination is a defined as the process of transfer of pollen grains from anthers to stigma. It involves followings steps such as:
   • When the pollen grains fall on the stigma, pollen tube is formed and it enters one of the synergids and also releases two male gametes.
   • One of the male gametes moves towards the egg and fuse to form a zygote.
   • While the other male gamete fuses with polar nuclei and forms a primary endosperm nucleus. This process is termed as triple fusion.
   • The central cell becomes the primary endosperm cell after the process of triple endosperm. The primary endosperm nucleus forms endosperm whereas zygote is further developed into the embryo.
   • A seed refers to the fertilized ovules that are further inside a fruit.
   • The integuments of the ovules are hardened to form the seed coat whereas the micropyle facilitates the entry of oxygen and water into the seeds. **(5 Marks)**

**42.** (a) To obtain seeds formed only from the desired sets of pollen grains one can opt for artificial hybridisation. Following are the steps involved:

| A bisexual flower is taken. |
| :---: |
| ↓ |
| Anthers are removed from the flower bud before the anther dehisces (emasculation). |
| ↓ |
| Emasculated flower is covered with butter paper, to prevent contamination of its stigma with unwanted pollen |
| ↓ |
| When the bagged stigma attains receptivity, the desired set of mature pollen grains is dusted (pollination). |
| ↓ |
| Rebagging is done. |
| ↓ |
| Fruits are allowed to develop. |
| ↓ |
| Desired seeds are obtained. |

**(3 Marks)**

(b) Artificial hybridisation is important for the following reasons:
   • It helps to improve the crop yield.
   • It ensures that the crops produced have the desired characteristics.
   • It helps to yield commercially superior varieties.

**(2 Marks)**

**43.** There are three different types of pollinations such as:

(i) **Autogamy:** This type of pollination requires transfer of pollen grains from anther to stigma of same flower. In this, the anther and stigma lie close to each other so that self-pollination can occur. Some plants such as *Oxalis, Commeline* and *Viola* produces two types of flowers such as **Chasmogamous flowers:** Such flowers are similar to the flowers of other species with exposed anthers and stigma.
   **Cleistogamous flowers:** Such flowers do not open at all. The anthers and stigma lie close to each other.

(ii) **Geitonogamy:** In this type of pollination, the transfer of pollen grain from anther to the stigma of another flower of same plant. It involves cross-pollination through pollinating agents. But genetically it is similar to autogamy as the pollen grains come from the same plant.

(iii) **Xenogamy:** This type of pollination involves transfer of pollen grains from anther to stigma of a different plant. In this, pollination brings genetically different types of pollen grains to the stigma.   **(5 marks)**

*Plants uses one biotic agent such as animals and two abiotic agent such as wind and water for pollination.*

**44.** **(a)** **Diagrammatic representation of L.S of flower showing growth of a pollen tube:**



Pollen tube

Antipodal

Polar nuclei

Egg cell

Synergid
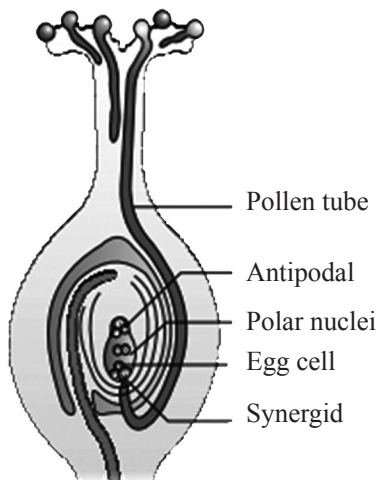
**(2 Marks)**

**(b)** When the unfertilized ovule passes through double fertilization and then fertilised ovule is formed which further develops into seed. In this process, the hilum and funiculus are present. Outer integument is developed into texta whereas inner integument is developed into tegman. The chalaza and micropyle are also present while nucellus is absent. In embryo sac, synergids and antipodal cell are degenerate. The central cell then develops into endosperm and egg is developed into the zygote and then into the embryo. **(3 Marks)**

> ✎ **Note**
>
> *Hilum is the region where the body of the ovule fuses with funicle thus, hilum represents the junction between ovule and funicle.*

**Topic-2:** **Double Fertilisation**

**1.** **(a)** n – antipodal cell, 2n – zygote, 3n – endosperm
**2.** **(b)**
**3.** **(c)**



Suspensor

Radicle

Cotyledon
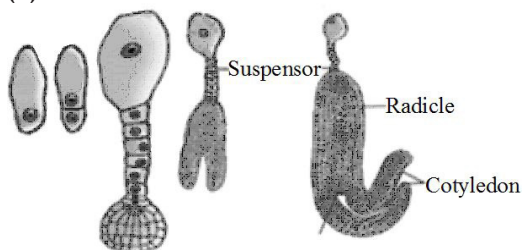
**(1 Mark)**

**4.** If plant leaves i.e., diploid structure contain 2n = 10 chromosome Then zygote will also contain 10 chromosome and endosperm which is a triploid structure will contain 3n = 15 chromosome. Zygote and endosperm are formed by the process called double fertilization. **(1 Mark)**

Double Fertilisation
- After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid.
- One of the male gametes moves towards the egg cell and fuses with its nucleus thus completing the syngamy.
- This results in the formation of a diploid cell, the zygote. The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a triploid primary endosperm nucleus (PEN).
- As this involves the fusion of three haploid nuclei it is termed triple fusion. Since two types of fusions, syngamy and triple fusion take place in an embryo sac the phenomenon is termed double fertilisation, an event unique to flowering plants.
- The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote develops into an embryo. **(2 Marks)**

**5.** The diploid number of chromosomes in an angiosperm plant (2n) = 16.
The haploid number (n) will be = 8
Endosperm of an angiosperm is triploid (3n), so the number of chromosome present in endosperm 3n = 8 × 3 = 24.
Whereas antipodal cells are haploid (n) in nature. So, the number of chromosome in antipodal cells will be = 8 **(2 Marks)**

**6.** The post fertilisation events that are responsible for the formation of non-albuminous mature seeds of groundnut and albuminous seeds of castor are as follows:
The primary endosperm nucleus divides repeatedly to give rise to free nuclei and this stage is called free nuclear endosperm. The cell wall is formed after the formation of cellular endosperm.
Hence, if the endosperm is consumed fully by the developing embryo before seed maturation results in the formation of non-albuminous seeds such as in groundnut. Whereas if the endosperm persists in the mature seed and can be used up during seed germination then is called as albuminous such as in castor. **(3 Marks)**

> ✎ **Note**
>
> *The process of double fertilisation involves the fusion of one gamete with nucleus of egg cell results in the formation of zygote whereas other male gamete move towards the two polar nuclei that is located in the central cell and fuses with polar nuclei to give rise to **primary endosperm nucleus (PEN)**. It is also called triple fusion as it involves the fusion of three haploid nuclei.*

**7.** The events seen after the pollen tube enters one of the synergids in an ovule are as follows :
**(i)** Pollen tube, after reaching the ovary, enters the ovule through the micropyle and thus enters one of the synergids through filiform apparatus.

**(ii)** After entering one of synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid.

**(iii)** One of the male gametes move towads the egg cell and fuses with its nucleus thus results in formation of zygote (diploid cell). This is Syngamy.

**(iv)** The other male gamete move towards the two polar nuclei located in the central cell and fuses to form triploid primary endosperm nucleus (PEN). This involves fusion of three haploid nuclei & hence termed as triple fusion.

**(v)** Two types of fusions, syngamy & triple fusion takes place in an embryosac and hence the phenomenon is termed as double fertilisation.

**(vi)** After fertilisation, PEN becomes the primary endosperm cell (PEC) & develops into endosperm while zygote develops into an embyo. **(2 × ½ Marks)**

---

*Topic-3:* **Post- Fertilisation: Structures and Events**

---

1. **(a)** Perisperm can be defined as the persistant part of nucellus that remain after the embryonic development. It persists in the mature seed of black pepper. **(1 Mark)**
2. **(d)** black pepper **(1 Mark)**
3. **(c)** The portion of embryonal axis above the level of cotyledons is the epicotyl, which terminates with the plumule or stem tip. **(1 Mark)**
4. **(b)** (ii), (iii) **(1 Mark)**
5. **(c)** strawberry **(1 Mark)**
6. **(c)** 500 **(1 Mark)**
7. Fruits that are matured ovaries of flowers are called true fruits and false fruits are develop only from the ovary. Fruits formed as a result of fertilisation, while some species of fruits that are develop without fertilisation and such fruits are called parthenocarpic fruits. Banana is a parthenocarpy and seedless fruit. **(3 Marks)**
8. Hybrid seeds are produced by cross-pollination of plants and in order to produce desirable hybrid character, plant breeders and scientists are trying thousands of combination to produce such hybrids. So hybrid seeds are produced every years and it requires a lots of scientific research for the production of such hybrid seeds. It is expensive and hence the cost of hybrid becomes too expensive for the farmers. **(2 Marks)**
9. **Diagrammatic Representation of L.S of Maize grain:**
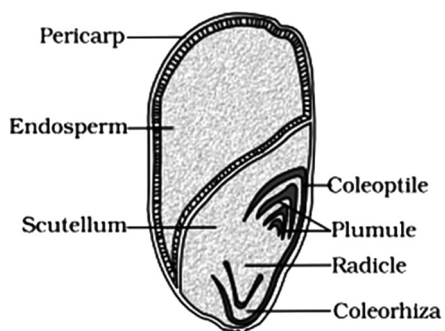


**(3 Marks)**

10. Parthenogenesis and parthenocarpy are two such processes that results in fruits and individuals from unfertilized ovules or eggs prior to fertilisation.

In most plants, flowers need to be pollinated and fertilized to produce fruits. However, some plants can produce fruits before fertilisation or without fertilisation.

Parthenocarpy is the process which produces fruits from unfertilised ovules in plants. Unfertilised ovules develop into fruits prior to fertilisation. These fruits do not contain seeds. E.g. banana and grapes.

Parthenogenesis is a type of reproduction commonly shown in organisms mainly by some invertebrates and lower plants. It can be described as a process in which unfertilised ovum develops into an individual (virgin birth) without fertilisation. Therefore, it can be considered as a method of asexual reproduction.

The key difference between parthenogenesis and parthenocarpy is, parthenogenesis is shown by animals and plants while parthenocarpy is shown only by plants. Parthenogenesis is seen in organism like rotifers, honeybees and even some lizards and birds (turkey). **(3 Marks)**

11. The pea plant is monoecious as the male and female gametes are found on the same plant. So, self pollination takes place in such plants results in the production of seeds. Whereas the papaya plant is dioecious as male and female gametes are found located on the different plants. As only single parent (papaya) is involved according to question so cross pollination will not take place so there will be no seed production. **(2 Marks)**

12. Diagrammatic Representation of mature stage of dicotyledonous embryo: **(1 Mark)**
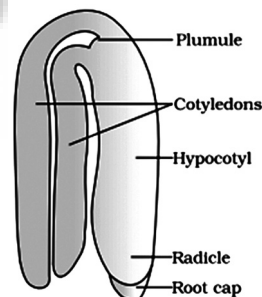


13. The three advantages that seeds offer to angiosperms are as follows:
   * The seeds of angiosperms provide protection to the embryo from harsh environmental conditions.
   * It provides nourishment and parental care to the developing embryo.
   * The dispersal of the seeds to far-off places prevents competition among the members of the same species and prevents their extinction. **(3 Marks)**
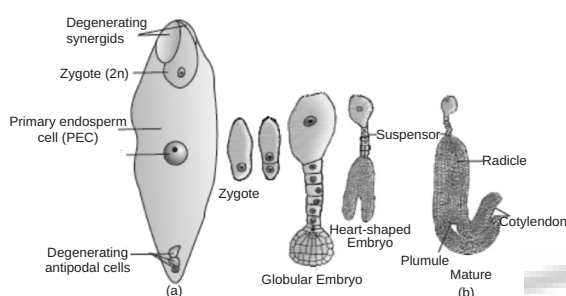
---

*Note*

*In angiosperms, there are two types of seeds albuminous and non-albuminous. Non-albuminous seeds have no residual endosperm as it is completely consumed during embryo development e.g. pea and groundnut whereas albuminous seeds retain a part of endosperm e.g. wheat, maize and castor.*

**14.** The fusion of one haploid male gamete with haploid female gamete (egg cells) results in the formation of a diploid zygote and this process is called sexual reproduction. Whereas endosperm is formed when other male gamete move towards the two polar nuclei which is located in the central cell and its fusion with the two polar nuclei results in the formation of triploid primary endosperm nucleus (PEN). This process is called triple fusion. The central cell after triple fusion becomes the **primary endosperm cell (PEC)** and develops into the **endosperm** whereas the zygote develops into an **embryo**. **(2 Marks)**

**15.** (i)



Degenerating synergids
Zygote (2n)
Primary endosperm cell (PEC)
Zygote
Degenerating antipodal cells
(a)
Globular Embryo
Heart-shaped Embryo
Suspensor
Radicle
Cotyledon
Plumule
Mature
(b)

**(3 Marks)**

(ii) The primary endosperm cell divides repeatedly and forms a triploid endosperm tissue. The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo. Thus, Endosperm development precedes embryo development. **(2 Marks)**

**16.** (a) The occurrence of more than one embryo in a seed in oranges is because of polyembryony. In orange, the nucellar cells, synergids and integument cells are developed into a number of embryos of different sizes. For Example: Citrus. **(2½ Marks)**

> **Note**
>
> *Sometimes the formation of more than one egg in an embryo sac can lead to polyembryony.*

(b) Parental characters are maintained in the embryos formed as a result of polyembryony and hence they are genetically similar. As, in this process there is no segregation of characters in the progeny. **(2½ Marks)**

**Topic-4:** *Apomixis and Polyembryony*

**1.** **(a)** Production of hybrid seeds is costly and hence the cost of hybrid seeds becomes too expensive for the farmers. If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year. **(1 Mark)**

**2.** **(a)** Both A and R are true and R is the correct explanation of A **(1 Mark)**

**3.** One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate

and do not maintain hybrid characters. Production of hybrid seeds is costly and hence the cost of hybrid seeds become too expensive for the farmers. If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year. **(2 Marks)**

**4.** Apomixis is a form of asexual reproduction that mimics sexual reproduction. As some species of plants such as *Asteraceae* and grasses have evolved special mechanism in order to produce seeds without fertilisation.

**Advantage of Apomixis:**
Apomixis reduces the cost of hybrid production and helps plant breeders to produce new varieties of seeds more quickly and more cheaply. **(2 Marks)**

**5.** **Apomixis:** It is a form of asexual reproduction that mimics sexual reproduction, and seeds are produced without fertilisation. It is called apomix is or agamospermy, *e.g.,* Grasses.

**Significance:** Diploid egg cell is formed without reduction division and develops into embryo without fertilisation, e.g., *Asteraceae* and Grasses.
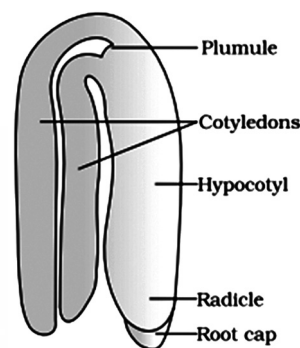
**Commercial applications of apomixis :**
**(i)** By apomixis, hybrid varieties of seeds can be produced, which will provide higher and better yield.
**(ii)** Apomixis prevents the loss of specific characteristics in the hybrid plants.
**(iii)** Apomixis is a cost-effective method of producing seeds. **(3 Marks)**

**6.** (a) There are two ways by which the apomitic seeds are produced:
**Agamospermy:** In this method, the seeds are produced from diploid cells without meiosis and fertilisation. For example: Apple.
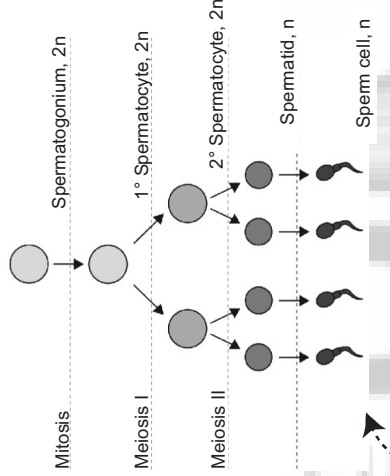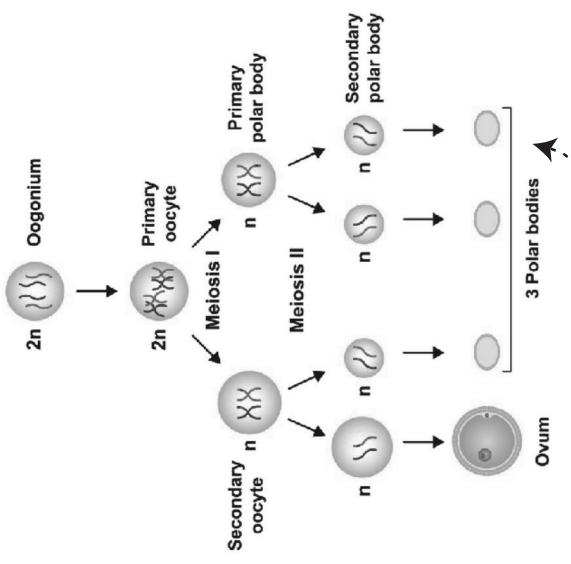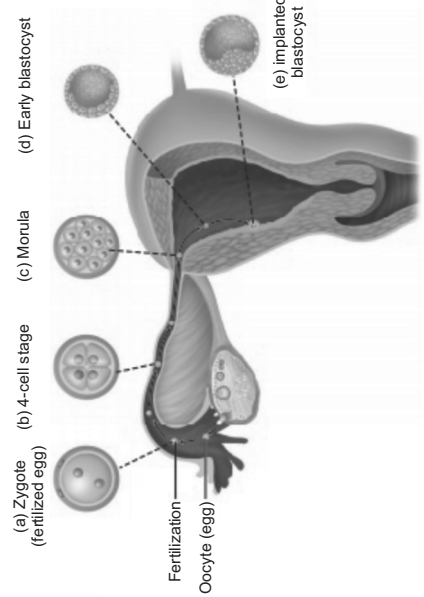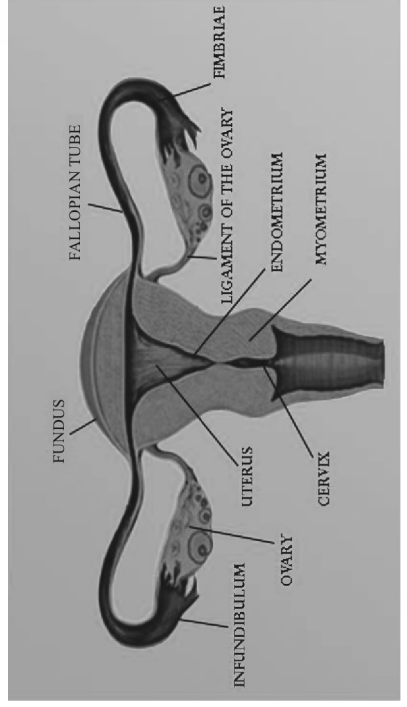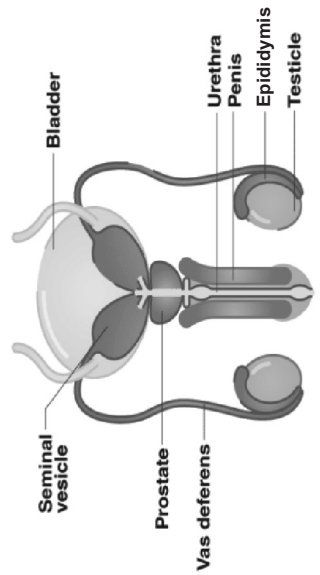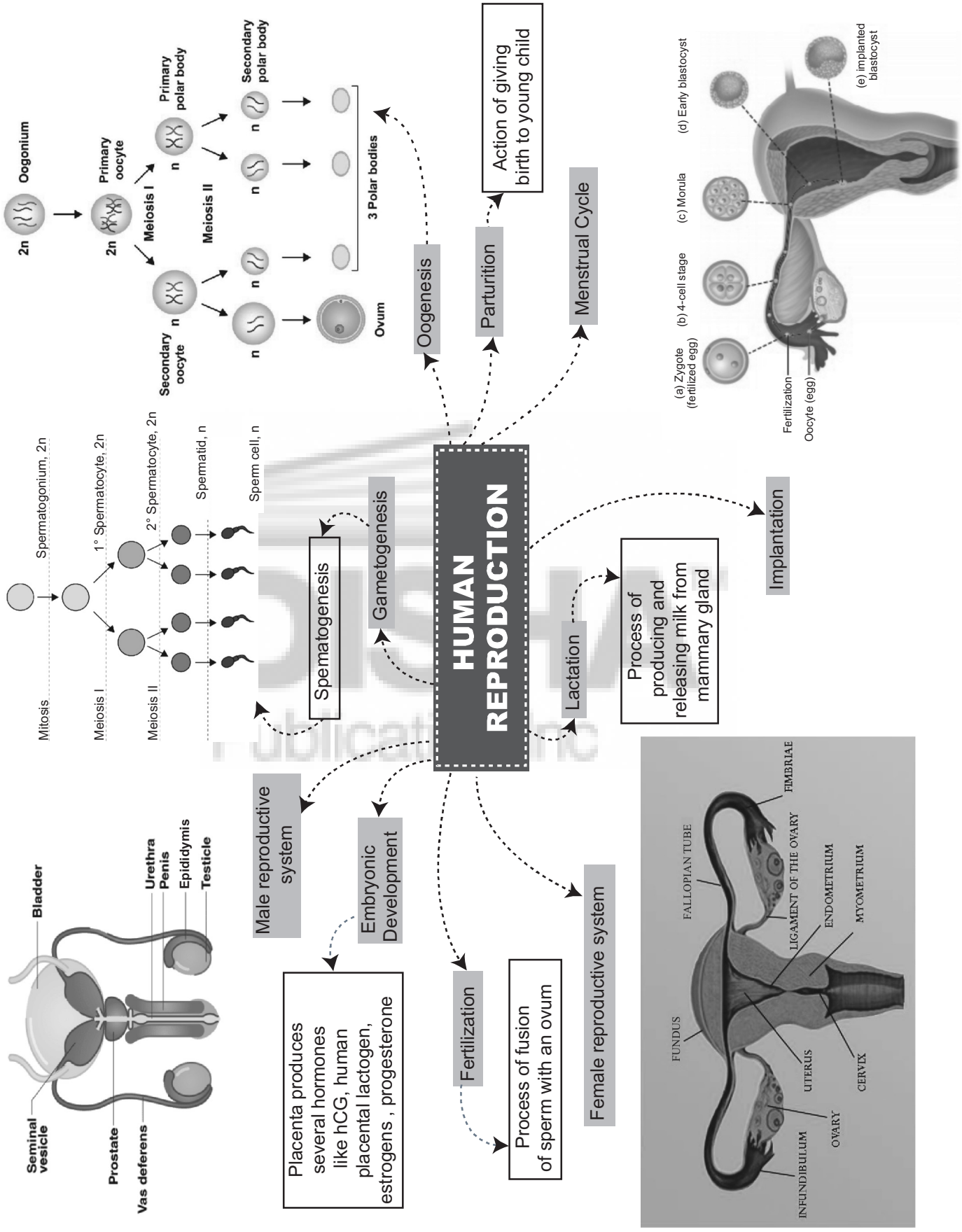**Adentive embryony:** In this method, the nucellus and integuments extends into the embryo sac and develops into embryo. It involves the formation of more than one embryo. For example: citrus fruit. **(3 Marks)**

(b) The main advantage of apomictic seeds is that there is no segregation of characters in the hybrid progeny. The apomictic seeds are cost effective and high yielding. **(1 Mark)**

**7.** (a) The different ways by which apomictic seeds are developed involved:
(i) Formation of diploid egg as embryo without undergoing reduction division or fertilization for example: *Asteraceae*.
(ii) In several citrus fruits and mango varieties, nuclear cells surrounding the embryo sac start dividing and project into the embryo sac. It gets further developed into the embryos. **(2 Marks)**

(b) **Advantages of apomictic crop:** Apomixis reduces the cost of the hybrid production so that new varieties of seeds are produced more quickly and at a cheaper rate.

**Disadvantages of apomictic crop:** Apomictic seeds reduce the genetic diversity because of a lack of variations. **(1 Mark)**

**8.** (a) The different ways by which apomictic seeds are developed involved:

(i) Formation of diploid egg as embryo without undergoing reduction division or fertilization for example: *Asteraceae.*

(ii) In several citrus fruits and mango varieties, nuclear cells surrounding the embryo sac start dividing and project into the embryo sac. It gets further developed into the embryos.

**(2 Marks)**

(b) **Advantages of apomictic crop:** Apomixis reduces the cost of the hybrid production so that new varieties of seeds are produced more quickly and at a cheaper rate.

**Disadvantages of apomictic crop:**

**Apomictic** seeds reduce the genetic diversity because of a lack of variations. **(1 Mark)**

(c) Hybrid seeds are produced by cross-pollination of plants and in order to produce desirable hybrid character, plant breeders and scientists are trying thousands of combination to produce such hybrids. So hybrid seeds are produced every years and it requires a lots of scientific research for the production of such hybrid seeds. It is expensive and hence the cost of hybrid becomes too expensive for the farmers. **(2 Marks)**

**9.** (a) There are two ways by which the apomitic seeds are produced:

**Agamospermy:** In this method, the seeds are produced from diploid cells without meiosis and fertilization. For example: Apple.

**Adentive embryony:** In this method, the nucellus and integuments extends into the embryo sac and develops into embryo. It involves the formation of more than one embryo. For example: citrus fruit. **(3 Marks)**

(b) The main advantage of apomictic seeds is that there is no segregation of characters in the hybrid progeny. The apomictic seeds are cost effective and high yielding. **(1 Mark)**

(c) **Diagrammatic Representation of mature stage of dicotyledonous embryo:** **(1 Mark)**

# CONCEPT MAP

## Oogenesis

2n — Oogonium

2n — Primary oocyte

**Meiosis I**

Secondary oocyte, n → Primary polar body, n

**Meiosis II**

Secondary oocyte → n → Ovum

n, n → Secondary polar body

3 Polar bodies

## Spermatogenesis

Mitosis — Spermatogonium, 2n

Meiosis I — 1° Spermatocyte, 2n

Meiosis II — 2° Spermatocyte, 2n

Spermatid, n

Sperm cell, n

## Male reproductive system

Bladder

Seminal vesicle

Prostate

Vas deferens

Urethra
Penis
Epididymis
Testicle

## Female reproductive system

FUNDUS
FALLOPIAN TUBE
FIMBRIAE
LIGAMENT OF THE OVARY
ENDOMETRIUM
MYOMETRIUM
OVARY
CERVIX
UTERUS
INFUNDIBULUM
OVARY

## HUMAN REPRODUCTION

- Gametogenesis
- Oogenesis
- Parturition — Action of giving birth to young child
- Menstrual Cycle
- Spermatogenesis
- Embryonic Development
- Fertilization — Process of fusion of sperm with an ovum
- Lactation — Process of producing and releasing milk from mammary gland
- Implantation

Placenta produces several hormones like hCG, human placental lactogen, estrogens, progesterone

## Embryonic Development

(a) Zygote (fertilized egg)
(b) 4-cell stage
(c) Morula
(d) Early blastocyst
(e) implanted blastocyst

Fertilization
Oocyte (egg)

# 27

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**3rd Level of Division : Skillwise Division**

Each Question in the topic has been further divided skillwise using following codes:

**K** Knowledge                 **U** Understanding

**Ap** Application                 **A** Analysis

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# CBSE Board Solved Paper

*Time Allowed : 3 Hours*             *Maximum Marks : 80*

**General Instructions:**

Read the following instructions very carefully and strictly follow them:

(i)   This Question Paper has **13** questions. **All** questions are compulsory.

(ii)  This question paper contains **THREE** Sections -

     **Section - A :** Reading Skills

     **Section - B :** Creative Writing Skills

     **Section - C :** Literature

(iii) Attempt all questions based on specific instructions for each part. Write the correct question number and part thereof in your answer sheet.

(iv)  Separate instructions are given with each question/part, wherever necessary.

(v)   Adhere to the prescribed word limit while answering the questions.

## SECTION - A : READING

**(22 Marks)**

1.   Read the passage given below :      **12 M**

(1)  What do we typically do when we find our children doing something we don't approve of? We become reactive parents. Often, we pepper our reactions with lectures. When it doesn't work and predictably so; we end up screaming and dole out a punishment. And our children react with anger, resentment or 'can't-be-bothered' attitude.

(2)  Buddhist Zen Master Thich Nhat Hanh put it beautifully when he described how each child has both negative seeds- of anger, despair, hatred, fear and violence- and wholesome seeds- of love, happiness, compassion and forgiveness. According to him, what will blossom depends on the seeds we nurture.

(3)  A parenting and educational approach that's gaining a large following internationally, called the Nurtured Heart Approach (NHA) by Howard Glasser, is very much in keeping with this Zen approach. The three main aspects of this approach are :

•   Refuse to energize negativity.

•   Relentlessly energize their positives.

•   Reset : Do not react negatively and stay calm when the child does something wrong.

Parents following this approach commit to not saying or doing anything that may fuel negativity in the child. But the parent has to make sure she/he does this very calmly, without any anger or resentment.

(4)  While on a mission to cut the negative, the parent looks for every opportunity to energize the positive in the child. This is done through persistently appreciating the goodness in the child in the smallest of ways : You were really generous about sharing your pizza with your sister; I appreciate the hard work you have put in your project; It takes courage to stand up to a bully. If you observe, the appreciation is not about saying "excellent", "amazing" or "good", which is really an empty praise and does not speak much to the child. Qualifying a praise, on the other hand, gives the child direction and she/he begins to understand what qualities, values and strengths are appreciated. These are also necessary ingredients of life skills and success.

(5)  This approach is not merely about noticing when the child is being good, it is about recognizing the child's worth at every step. It's about aligning his energy in believing that he has great qualities, which are being identified and validated by the parents at every step. He realizes that there is no point choosing negativity, as there are no pay-offs in it. So, start building your child's inner wealth - there is nothing to lose.

**Answer the following questions, based on the given passage :**

(i)  Complete the following sentence with an appropriate word:

"-we end up screaming and dole out punishment."

In the above sentence, the author criticizes the _____ approach of the parents.

(ii) Explain in about 40 words, when and how do parents become reactive. **2**

(iii) In the line 'what will bloom will depend on the seeds we nurture'- what seeds does the author refer to ? **1**

     (a) Seasonal seeds     (b) Societal news

     (c) Parental attitude    (d) Values and emotions

(iv) Explain in about 40 words why does NHA focus on reforming parents to reform children. **2**

(v) Share evidence from the text, in about 40 words, to support the view that parents appreciate the goodness of the child at every opportunity. **2**

(vi) In paragraph 5, in what way does 'This approach' differ from the earlier approach ? **1**

(vii) Select the option that can be classified as qualifying a praise as explained in the passage : **1**

     (a) You can be more helpful.

     (b) You demonstrated patience while teaching your junior.

     (c) Use your skill to be an excellent sportsman.

     (d) You have to be amazing in your work.

(viii) The phrase 'to cut the negative' in para 4 most nearly means: **1**

     (a) to reduce wasteful expenditure

     (b) to stop criticizing

     (c) to eliminate challenges

     (d) to humiliate someone

(ix) Read the five headlines (A) - (E) given below: **1**

     (A) New Age Parenting

     (B) Children - A Rebellious Generation

     (C) Channelizing Energy

     (D) Teacher - A Nation Builder

     (E) Skill Development - Careers Ahead

     Identify the option that displays the headlines that Does/Do not correspond with the occurrences in the text

     (a) (A) and (E)      (b) (C) and (E)

     (c) (B) only         (d) (A) and (C)

2. Read the passage given below : **10 M**

(1) We're all familiar with the usual reasons workers cite for wanting to stay away even after lockdowns have long ended: flexible schedules, not having to commute, and of course, increased productivity. However, productivity isn't the only reason people want to stay away from the office. We recently surveyed 1,000 remote workers to find out what's really keeping them tied to their work-from-home lives.

(2) The findings include : 72% want to be able to take a nap or exercise during the day. Nearly three out of four remote workers surveyed stated that the ability to take a nap or

workout during the workday was one of the reasons they wanted to stay home. Though these activities may very well increase worker productivity, there's no doubt that a nap on the kitchen couch would be frowned upon in the office.

(3) 73% want to be able to watch TV while they work. Three out of four respondents again say that being able to entertain themselves with TV, podcasts, music, or other media is one of the reasons they want to keep their work-from-home lifestyle.

(4) 62% cite concerns about their appearance. Well over half of respondents stated that they are concerned about their co-workers seeing them in-person again after such a long time apart. Whether it's weight loss or gain, not having the right clothes, or another concern about appearance, most would rather not have to worry about the way they look to their co-workers outside a Zoom call.

(5) When asked to choose the reason that most affects their desire to keep working from home, predictable answers like caring for children and lack of a commute were still the most common number one reasons. 14% of respondents stated that working remotely was so important to them, that they would not go back to work in-person even if their employers required it.

**Answer the following questions, based on the given passage:**

(i) '.....these activities will increase productivity'. By 'productivity' the author refers to **1**

     (a) products produced

     (b) efficiency of the employee

     (c) time spent by the employee

     (d) number of activities

(ii) What change in the work place would bring those people back to office who want amusement ? **1**

     (a) giving long breaks

     (b) free coffee and tea

     (c) building entertainment lounge

     (d) spacious conference hall

(iii) As per the survey, why do health conscious people prefer to work from home ? **1**

(iv) Complete the following sentence appropriately :

     The passage ends on a note that some people are resolved to _____. **1**

(v) Explain one inference that can be drawn from para 1 about the reason for people's preference to work from home. **1**

(vi) State whether the statement given below is True or False:

     The survey reveals that people deeply miss socializing in the work from home style. **1**

(vii) Explain in your own words how appearance is one of the factors for people's preference for work from home. **2**

(viii) As per the survey, what top priorities of people prevent them from going to office ? **2**

## SECTION - B

### CREATIVE WRITING SKILLS

**(18 Marks)**

(**Note:** All details presented in the questions are imaginary and created for assessment purpose)

3. Attempt **ANY ONE** of the two, in about **50** words :

(a) P.S. Public School, Aram Nagar has opened a gym for the benefit of students. As Sports Captain, draft a notice informing students about the facilities available in the gym, timings and other details. **4**

**OR**

(b) The RWA of Ganga Society, Pushp Nagar has planned to start free yoga classes for its residents. You are Sharmila Tiwari, the President of RWA. Draft a notice informing residents about the proposal, timing, venue and other details. **4**

4. Attempt **ANY ONE** of the two in about **50** words :

(a) You are Mr. Srikanth Sharma. You have recently built a new house in the hills of Uttarakhand. Draft a letter inviting your brother and his family to spend a few days with you in your new home. Include relevant details. **4**

**OR**

(b) You are Mr. Shyam Sundar, Professor of Psychology. You are invited by S.K.M. College, Mahboob Nagar to be the keynote speaker at its Annual Conclave on 'Student Health - The Emotional impact of Social Media'. Draft a reply letter expressing your inability to accept the invitation and also cite a reason for refusal. **4**

5. Attempt **ANY ONE** of the two in **120-150** words :

(a) You are Neeta/Neeraj of Rainbow Nagar, Shaktiganj a qualified basketball coach. You saw the advertisement given below and wish to apply for the position advertised.

> **R.J. Sports Academy**
> **Requires**
> **Basketball Coach**
> Qualification : Master's Degree in specific game with NIS diploma.
> Work Experience: Minimum 2 years in the relevant field.
> Skills : Patience, empathy, leadership qualities, attention to detail.
> Apply with complete bio-data to The Director, R.J. Sports Academy, 43, L.M. Square, Shaktiganj expressing your interest in the advertised post.

**5**

**OR**

(b) You are Mira/Mithun, parent of a class 12 student. You were recently invited among others by the school to attend a two-day workshop on 'Preparing youth for the Road ahead.'

Write a letter to the Editor, Daily News expressing your views on the need for such workshops to create awareness of skill development and future opportunities.

You may use the following cues along with your own ideas:

> • skill development
> • vocational education, apprenticeship and internship
> • entrepreneurship
> **OR**
> • skills for greater employment prospects and economic progress

**5**

6. Attempt ANY ONE of the two questions in **120-150** words:

(a) The rising obesity amongst youth today is a grave cause of concern. Addiction to technology, inactive life-style and eating sugary, and highly processed foods are among the leading causes.

Write an article for the school magazine, sharing the importance of a healthy lifestyle and nutritious diet. You may use the given cues along with your own ideas to compose this article. You are Shivani/Satish of Class XII-B.

> • Reasons for Obesity
> • Consequences - ill health
> • Suggestions
>   active lifestyle
>   regular exercise
>   change in eating habits
>   support and encouragement

**5**

**OR**

(b) As part of community outreach programme, a group of 40 students from your school identified a neighbourhood slum and took up the initiative to teach basic language and numerical skills, environmental cleanliness and personal hygiene awareness to the slum children. As Head of the team, write a report on the programme to be published in your school newsletter.

Use the cues given below, along with your own ideas to draft the report. You are Rahul/Radhika **5**

- date, venue, duration
- books distributed
- activities carried out
- feedback of people
- number of children who attended

**5**

## SECTION C: Literature

**(40 Marks)**

**(TEXT BOOK AND SUPPLEMENTARY READING TEXT)**

7. Attempt **ANY ONE** of the extracts given below and answer the questions that follow :                **6×1 = 6**

(a) The little old house was out with a little new shed in front at the edge of the road where the traffic sped.
A road side stand that too pathetically pled
It would not be fair to say for a dole of bread.
But for some of the money, the cash, whose flow supports
The flower of cities from sinking and withering faint.
(*A Roadside Stand*)

(i) Which of the following expressions has the same literary device as used in

"A roadside stand that too pathetically pled."

(a) All the world's a stage.

(b) I wandered lonely, as a cloud.

(c) The brutal wind bullied the tree.

(d) And life is too much like a pathless wood.

(ii) Select the option that aptly conveys the poet's point of view with reference to the above extract :

The roadside stand is put up with the purpose to

(a) display fruits          (b) to stop the traffic

(c) to do business       (d) to interact with city people

(iii) What do you infer about the people, who put up the roadside stand from the phrase 'would not be fair to say for a dole of bread'?

(iv) Complete the following sentence with reference to the extract. The word 'pathetically' reflects the _____ condition of the roadside stand.

(v) State whether the following statement is True or False :

By "Flower of Cities", the poet refers to the garden in cities.

(vi) Based on the rhyme scheme, evident in lines 1-4, which word would rhyme with line 2?

part, fled, seen

**OR**

(b) Aunt Jennifer's fingers fluttering through her wool

**6×1= 6**

Find even the ivory needle hard to pull.
The massive weight of Uncle's wedding band
sits heavily upon Aunt Jennifer's hand
when Aunt is dead, her terrified hands will lie
still ringed with ordeals she was mastered by,
The Tigers in the panel that she made
will go on prancing, proud and unafraid. (*Aunt Jennifer's Tigers*)

(i) 'Sits heavily upon Aunt Jennifer's hand.' Through the above expression the poet indicates:

(a) Aunt Jennifer is happily married.

(b) Aunt Jennifer loves the tigers in the panel.

(c) Aunt Jennifer's unhappy married life.

(d) Aunt Jennifer's rich and luxurious life.

(ii) Select the option that has the same literary device as used in 'still ringed with ordeals'.

(a) Leopards cannot hide in the jungle as they are spotted.

(b) Sun smiled happily on us.

(c) Her lovely voice was music to his ears.

(d) Life is like a box of chocolates.

(iii) Complete the following sentences with reference to the extract. The Tigers in the panel symbolize _____.

(iv) State whether the statement given below is True or False:

"Find even the ivory needle hard to pull." The above expression suggests that Aunt Jennifer is dying.

(v) Based on the rhyme scheme, evident in lines 1-2, which word would rhyme with line 1?

full, sand, bye

(vi) The use of the word 'fluttering fingers' in the extract suggests that the fingers of Aunt Jennifer are trembling. This creates an image of _____.

8. Attempt **ANY ONE** of the extracts given below and answer the questions that follow:

(a) I did not open my mouth to answer. Then the steps were quickened and the voices became excited. The sounds came nearer and nearer. Women and girls entered the room. I held my breath and watched them open closet doors and peep behind large trunks. Someone threw up the curtains, and the room was filled with sudden light. What caused them to stoop and look under the bed. I do not know. I remember being dragged out, though I resisted by kicking and scratching wildly. In spite of myself, I was carried downstairs and tied fast in a chair.

**4 × 1 = 4** (*Memories of Childhood*)

(i) Select the appropriate option:

_____ sounds came nearer and nearer _____

(a) describes the increase in volume.

(b) adds suspense and anxiety to readers

(c) reflects the thought of the speaker.

(d) is a factual narrative

(ii) Complete the following sentence :

'Inspite of myself' suggests that the speaker was _____.

(iii) What do you infer from the first line of the extract ?

(a) It was her first day in school.

(b) She did not want to get caught.

(c) She was unprepared for the lesson.

(d) She preferred to be by herself.

(iv) State whether the statement given below is True or False:

The speaker hoodwinked the people looking for her. _____.

**OR**

(b) Human civilisations have been around for a paltry 12,000 years-barely a few seconds on the geological clock. In that short amount of time, we've managed to create quite a rukus, etching our dominance over nature with our villages, towns, cities, mega cities. The rapid increase of human populations has left us battling with other species for limited resources, and the unmitigated burning of fossil fuels has now created a blanket of carbon dioxide around the world, which is slowly but surely increasing the average global temperature.

**4×1= 4 (***Journey to the End of the Earth***)**

(i) According to the view expressed by the author in the above extract, increase in global temperature is due to

(a) mega cities

(b) human people

(c) burning of fossil fuels

(d) limited resources

(ii) Complete the following sentence with reference to the extract:

Humans are criticised by the author for _____.

(iii) According to the author, the relation between human population and resources is _____.

(iv) 'In that short amount of time, we've managed to create ruckus'. By 'ruckus' the author refers to _____.

(a) movement (b) misunderstanding

(c) breach (d) commotion

9. Attempt **ANY ONE** of the extracts given below and answer the questions that follow :

(a) I heard M. Hamel say to me, "I won't scold you, little Franz: you must feel bad enough, see how it is ! Everyday we have said to ourselves. Bah! I've plenty of time I'll learn it tomorrow. And now you see where we've come out. Ah, that's the great trouble with Alsace; she puts of

learning till tomorrow. Now those fellows out there will have the right to say to you. 'How is it; you pretend to be Frenchmen, and yet you can neither speak nor write your own language?' But, you are not the worst, poor little Franz. We've all a great deal to reproach ourselves with".

**6 ×1=6 (***The Last Lesson***)**

(i) 'And now you see where we've come out.'

The tone of M. Hamel in the above line is that of :

(a) kindness (b) happiness

(c) regret (d) enthusiasm

(ii) 'We've all a great deal to reproach ourselves with.'

Select the option, which conveys the meaning of 'reproach' as reflected in the above line.

(a) The player received a reprimand for breach of rules.

(b) The students approached the management with a demand for new canteen.

(c) The clerk received a letter of appreciation for his innovative ideas.

(d) She could not find a way to broach the subject with her boss.

(iii) State whether the following statement is true or false with reference to the extract.

M. Hamel endorses the belief that there is plenty of time to learn their language.

(iv) Complete the sentence appropriately.

'You must feel bad enough.' Through these words' M. Hamel urges the people _____.

(v) Identify the line from the text that reinforces the theme of patriotism in the story.

(vi) She puts off learning till tomorrow. The phrase 'puts off' suggests _____.

**OR**

(b) They thought he would demand repayment in full of the money which they had illegally and deceitfully extorted from the sharecroppers. He asked only 50 percent. "There he seemed adamant", writes Reverend J.Z. Hodge, a British missionary in Champaran, who observed the entire episode at close range. "Thinking probably that he would not give way, the representatives of the planters offered to refund to the extent of 25 percent, and to his amazement Mr. Gandhi took him at his words thus breaking the deadlock."

**6 × 1 = 6 (***Indigo***)**

(i) Choose the correct option

'There he seemed adamant,' reflects Gandhi's trait of being

(a) arrogant (b) uncompromising

(c) argumentative (d) courageous

(ii) _____ deceitfully extorted from the sharecroppers.

The status of sharecroppers as inferred from the above line is

(a) law abiding citizens

(b) followers of Gandhi

(c) victims of exploitation

(d) contract labourers

(iii) Complete the following sentence :

Gandhi surprised them by _____.

(iv) The inference that can be drawn from the line "Mr. Gandhi took him at his word" is _____.

(v) 'Deadlock' in the last line means_____.

(vi) What do we infer about the attitude of planters towards sharecroppers ?

10. Answer **ANY FIVE** of the following six questions in **40-50** words each : **5 × 2 = 10**

(i) When I sense a flash of it in Mukesh, I am cheered. How is Mukesh's attitude of life different from that of his family and friends ? (*Lost Spring*)

(ii) "I was frightened, but not frightened out of my wits." Says Douglas. Which qualities of the speaker are highlighted in the above statement? (*Deep Water*)

(iii) 'See you soon Amma', How are these words contrary to the speaker's emotions? (*My Mother at Sixty-six*)

(iv) 'And such too is the grandeur of the dooms; we have imagined for the mighty dead.' Explain the inference you can draw from the phrase 'mighty dead'.

(*A Thing of Beauty*)

(v) What evidence from the text reveals that Rudyard Kipling did not walk the talk? (*The Interview*)

(vi) Soaf, you really should be sensible! What does Jansie's advice to her friend Sophie reveal about their friendship? (*Going Places*)

11. Answer **ANY TWO** of the following three questions, in **40-50** words each: **2 × 2 = 4**

(i) 'And for humans, the prognosis is not good;'

What is in store for humans, as per the above statement?

(*The Journey to the End of the Earth*)

(ii) 'My three hundred dollars bought less than two hundred in old style bills, but I didn't care.' What prompted Charlie to compromise on less value of money?

(*The Third Level*)

(iii) What was the servants' reaction to Sadao's decision of treating the American soldier? (*The Enemy*)

12. Answer **ANY ONE** of the following two questions in **120-150** words:

(a) Wars with gas, wars with fire,

Victory with no survivors.

Pablo Neruda in the above lines, highlights the futility of war. Gandhi also brought about the change in the plight of the Champaran sharecroppers through civil disobedience and not violence.

Write an article on the importance of peace and the right way to resolve issues. **5**

**OR**

(b) Imagine you are Mukund Padmanabhan from the Indian (The Interview) and you interviewed M. Hamel, after he finished delivering the last lesson. (*The Last Lesson*)

Write a paragraph on Hamel's views on individual responsibility and nationalism. **5**

13. Answer **ANY ONE** of the following two questions, in **120-150** words :

(a) Mr. Lamb : Oh, there's lot of things I've learned to do, and plenty of time for it. Years. I take it steady."

(*On the Face of it*)

Mr. Lamb, despite his handicap learnt to be independent and has proved where there is a will, there is a way. As a motivational speaker, write a speech to be delivered to school students, highlighting how one should develop resilience and determination to achieve one's goal citing references from this story.

You may begin like this.

To remain resilient during difficult times, will help one move forward in life. **5**

**OR**

(b) Until then the Maharaja had given his entire time and energy to tiger hunting. He had no time to spare for the crown prince. (*The Tiger King*)

In the present times, we see people following their profession and running after money and neglect their children. As a professional counsellor, you address working parents, stressing the need to spend quality time with children. Take material from the story 'The Tiger King' to re-inforce your points of view.

You may begin like this. **5**

Spending time with children will boost their confidence...

## Solutions

### SECTION - A

1. (I) The appropriate word to complete the sentence "we end up screaming and dole out punishment" is **criticize.**

The author criticizes the approach of the parents in the given sentence, highlighting the ineffectiveness of reactive parenting and punishment.

(II) Parents become reactive when they find their children doing something they don't approve of. This reaction often involves lectures, screaming, and punishment when the child's behavior doesn't change. The children, in turn, react with anger, resentment, or indifference.

(III) (d) Values and emotions

(IV) **Explanation of NHA's Focus on Reforming Parents to Reform Children**

The Nurtured Heart Approach (NHA) focuses on reforming parents to reform children because it believes that children's behavior is influenced by the seeds nurtured in them.

By encouraging parents to energize positivity and avoid fueling negativity, children are guided towards developing wholesome qualities like love, compassion, and forgiveness.

This approach aims to create a nurturing environment where children feel valued and recognized for their positive attributes, leading them to choose positivity over negativity in their actions.

(V) **Evidence of Appreciating Child's Goodness**

The text mentions that parents following the Nurtured Heart Approach commit to persistently appreciating the goodness in the child in the smallest of ways, such as acknowledging acts of generosity, hard work, and courage.

By energizing the positives in the child through consistent appreciation, parents align the child's energy in believing in their great qualities, thus recognizing the child's worth at every step.

(VI) The approach in paragraph 5 focuses on recognizing the child's worth at every step and aligning their energy towards believing in their great qualities, which are consistently validated by the parents.

This differs from the earlier approach by emphasizing building the child's inner wealth and guiding them to understand that there are no payoffs in choosing negativity.

(VII) (b) You demonstrated patience while teaching your junior.

(VIII) (b) to stop criticizing

(IX) (d) (A) and (C)

2. (I) (b) efficiency of the employee

(II) (c) building entertainment lounge

(III) Health conscious individuals prefer working from home for various reasons according to the survey findings:

72% of respondents want to be able to take a nap or exercise during the day, which contributes to their overall well-being and health.

62% of remote workers are concerned about their appearance, including weight management, clothing choices, and other appearance-related factors, which can be more easily managed while working from home.

(IV) continue working from home

(V) Workers prefer to work from home not only for flexible schedules and increased productivity but also for reasons like being able to take a nap or exercise during the day.

This indicates that the ability to have personal time and comfort while working remotely is a significant factor influencing their preference to stay away from the office.

(VI) The statement given is False.

(VII) Appearance is a significant factor for people's preference for working from home because many workers are concerned about how they look to their co-workers after a long period of remote work.

Over 60% of respondents expressed worries about their appearance, including weight changes or not having suitable clothes, making them prefer the comfort of their home environment where they don't have to face these concerns in person.

(VIII) 72% of respondents want to be able to take a nap or exercise during the day, which is a key factor in their desire to work from home.

73% of remote workers prioritize being able to watch TV while they work, showing that entertainment plays a significant role in their decision to stay away from the office.

62% of respondents express concerns about their appearance, indicating that worries about how they look to their co-workers are a major factor in their preference for remote work.

## SECTION - B

3.  (A)

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**P.S. Public School, Aram Nagar**
**NOTICE**
**Date: May 31, 2024**
**Opening of School Gym**

We are excited to announce the opening of our school gym for your benefit. The gym is equipped with state-of-the-art facilities including cardio machines, weights, and a designated area for workouts. Timings are from 7:00 AM to 6:00 PM. Join us to stay fit and healthy!

Rahul Sharma

Sports Captain

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**OR**

(B)

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**Ganga Society, Pushp Nagar Residents' Welfare Association (RWA)**
**NOTICE**
**Date: May 31, 2024**
**Commencement of Free Yoga Classes**

We are delighted to announce the initiation of free yoga classes for the residents of Ganga Society. These classes aim to promote physical and mental well-being among our community members. Sessions will be held every weekday from 7:00 AM to 8:00 AM in the society clubhouse. Please join us in this endeavor for a healthier lifestyle.

[Signature]

Sharmila Tiwari

President, Ganga Society RWA

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4.  (A)

Mr. Srikanth Sharma

Hillside Retreat, Uttarakhand

May 28, 2024

Dear Brother,

I hope this letter finds you well. I have recently built a beautiful house in the serene hills of Uttarakhand. I would love for you and your family to spend a few days here and enjoy the tranquillity. Looking forward to your visit!

Warm regards,
Srikanth

**OR**

(B)  36, Ganga Village

110089

31 May 2024

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The Principal

S.K.M. College

Mahboob Nagar

Subject: Regretful Decline of Invitation

Dear Sir/Madam,

I am honored to receive your invitation to be the keynote speaker at the Annual Conclave on 'Student Health - The Emotional Impact of Social Media'. However, due to prior commitments, I regretfully decline the invitation. My schedule is currently occupied with ongoing research commitments and academic responsibilities. I appreciate the opportunity and extend my best wishes for a successful event.

Thank you for considering me.

Sincerely,

Shyam Sundar

Professor of Psychology

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5.  (A)

Neeta/Neeraj

Rainbow Nagar, Shaktiganj

31 May 2024

The Director

R.J. Sports Academy

43, L.M. Square

Shaktiganj

Subject: Application for the Position of Basketball Coach

Dear Sir/Madam,

I am writing to express my keen interest in the position of Basketball Coach advertised by R.J. Sports Academy. With a Master's Degree in basketball along with an NIS diploma, and over three years of experience for coaching basketball teams at both school and club levels, I believe I possess the necessary qualifications and skills to contribute effectively to your esteemed academy.

My coaching approach is characterized by patience, empathy, and strong leadership qualities, allowing me to connect with players on a personal level while fostering a culture of teamwork and discipline. My attention to detail ensures that training sessions are meticulously planned and executed to enhance players' skills and performance.

I am excited about the opportunity to be a part of R.J. Sports Academy and contribute to the development of young basketball talents. Please find enclosed my bio-data for your consideration.

I look forward to the possibility of discussing how I can contribute to the success of your academy.

Sincerely,

Neeta/Neeraj

**OR**

(B)
36, Bihar Kunj
New Delhi-110089

31 May 2024

The Editor
The Hindu
36, Hindu Nagar
New Delhi-110065

Subject: Importance of Workshops for Youth Skill Development

Dear Editor,

I am writing to express my appreciation for the recent initiative taken by schools to organize workshops aimed at preparing youth for the road ahead. As a parent of a class 12 student, I strongly believe that such workshops play a crucial role in creating awareness about skill development and future opportunities.

In today's rapidly changing world, traditional academic knowledge alone is not sufficient to ensure success. Therefore, workshops focusing on skill development, vocational education, apprenticeship, and entrepreneurship are essential. These workshops provide students with practical knowledge and hands-on experience, equipping them with the skills necessary to thrive in the professional world.

Moreover, emphasizing skills for greater employment prospects and economic progress is vital for the overall development of our youth. By instilling a sense of entrepreneurship and encouraging innovative thinking, we can empower our youth to become job creators rather than job seekers.

I commend schools for taking proactive steps to organize such workshops and urge them to continue investing in initiatives that promote youth skill development and future readiness.

Sincerely,
Mira/Mithun

6.    (A)
Title: Combating Obesity: Embracing a Healthy Lifestyle
In the contemporary era, the escalating rates of obesity among youth have emerged as a pressing concern. The proliferation of technology, coupled with sedentary lifestyles and unhealthy dietary habits, has contributed significantly to this alarming trend. As Shivani/Satish of Class XII B, I feel compelled to address this issue and advocate for the adoption of a healthy lifestyle and nutritious diet among my peers.

The root causes of obesity are multifaceted. Excessive screen time, whether it be on smartphones, computers, or televisions, has led to a significant decrease in physical activity levels among youth. Concurrently, the widespread availability and consumption of sugary, highly processed foods has further exacerbated the problem, resulting in adverse health outcomes such as diabetes, heart disease, and hypertension.

However, all hope is not lost. By making conscious choices and embracing a healthier lifestyle, we can combat obesity and its detrimental effects. Firstly, incorporating regular exercise into our daily routine is imperative. Engaging in physical activities such as sports, jogging, or even brisk walking can significantly enhance our overall fitness levels and promote weight management.

Moreover, a fundamental shift in eating habits is essential. Instead of indulging in processed snacks and sugary beverages, we should prioritize the consumption of whole, nutritious foods such as fruits, vegetables, lean proteins, and whole grains. Adopting a balanced diet rich in vitamins, minerals, and antioxidants not only aids in weight control but also fosters optimal health and well-being.

Additionally, fostering a supportive environment that encourages healthy choices is paramount. Schools can play a pivotal role in promoting physical activity through sports programs, gym classes, and extracurricular activities. Likewise, parents and educators should serve as role models by advocating for nutritious eating habits.

In conclusion, the battle against obesity necessitates a collective effort and a commitment to prioritizing our health and well-being. By embracing an active lifestyle, incorporating regular exercise, and making informed dietary choices, we can safeguard ourselves against the perils of obesity and pave the way for a healthier future.
Shivani/Satish
Class XII B

**OR**

(B)
Empowering Communities: School Students' Outreach Program

As part of our school's commitment to community service, a group of 40 students, led by Rahul/Radhika, embarked on a meaningful outreach programme aimed at uplifting the children in a nearby slum area. Here's a report on the successful initiative:

Date, Venue, Duration:

The programme took place on May 15, 2024, at the slum area located near our school. It spanned over two days, from 10:00 AM to 4:00 PM each day.

Books Distributed:

To support the educational aspect of the programme, we distributed basic reading and arithmetic books to the children, providing them with essential learning resources.

Activities Carried Out:

The programme encompassed various activities designed to impart valuable skills and knowledge to the slum children. We conducted interactive sessions on basic language and numerical skills, engaging the children in fun learning exercises and games. Additionally, we organized sessions on environmental cleanliness and personal hygiene awareness, emphasizing the importance of maintaining a clean and healthy living environment.

Feedback of People:

The response from the community was overwhelmingly positive. The residents expressed gratitude towards our students for their efforts in contributing to the welfare of their children. They commended the initiative and expressed hope for its continuation in the future.

Number of Children Who Attended:

Approximately 50 children from the slum area actively participated in the programme, displaying eagerness to learn and improve their skills.

The outreach programme proved to be a rewarding experience for both the students and the community. It not only provided valuable education and awareness but also fostered a sense of empathy and social responsibility among our students. We look forward to organizing similar initiatives in the future, continuing our commitment to serving and empowering communities.

Rahul/Radhika

Head of the Team

## SECTION - C

7. (A) (i)  The literary device used in "A roadside stand that too pathetically pled" is personification, as the roadside stand is described as pleading, which is a human characteristic.

(ii)  Option (c) to do business aptly conveys the poet's point of view. The purpose of the roadside stand is to conduct business, not merely to display fruits or to stop traffic.

(iii)  The phrase "would not be fair to say for a dole of bread" suggests that the people who put up the roadside stand are not begging for charity but are trying to earn a living through their business.

(iv)  The word 'pathetically' reflects the desperate condition of the roadside stand.

(v)  False. By "Flower of Cities," the poet refers to the vibrant and essential aspects of urban life, not necessarily a literal garden.

(vi)  Based on the rhyme scheme evident in lines 1-4, the word "fled" would rhyme with line 2.

### OR

(B) (i)  Option (c) The expression "sits heavily upon Aunt Jennifer's hand" indicates Aunt Jennifer's unhappy married life.

(ii)  Option (c) "Her lovely voice was music to his ears" has the same literary device as used in "till ringed with ordeals", which is a metaphor.

(iii)  The Tigers in the panel symbolize Aunt Jennifer's inner strength, resilience, and desire for freedom.

(iv)  False. The expression "Find even the ivory needle hard to pull" suggests the physical and emotional burden Aunt Jennifer carries, not necessarily her impending death.

(v)  Based on the rhyme scheme evident in lines 1-2, the word "sand" would rhyme with line 1.

(vi)  The use of the phrase "fluttering fingers" suggests that Aunt Jennifer's fingers are trembling, creating an image of her anxiety or fear.

8. (A) (i)  Option (b) "adds suspense and anxiety to readers" is the appropriate choice. The phrase "sounds came nearer and nearer" creates tension and anticipation, adding suspense and anxiety to the readers.

(ii)  "Inspite of myself" suggests that the speaker was acting against her own will or desires.

(iii)  The inference from the first line of the extract is that the speaker did not want to get caught. This is evident from her reluctance to open her mouth to answer and her subsequent resistance to being dragged out.

(iv)  False. The speaker did not hoodwink the people looking for her; rather, she was eventually found and dragged out, despite her resistance.

### OR

(B) (i)  According to the view expressed by the author in the above extract, the increase in global temperature is due to (c) burning of fossil fuels.

(ii)  Humans are criticized by the author for their detrimental impact on the environment and the rapid consumption of resources.

(iii)  According to the author, the relation between human population and resources is strained or in conflict, as the rapid increase in human populations has left us battling with other species for limited resources.

(iv)  By 'ruckus', the author refers to (d) commotion, indicating the chaos and disruption caused by human civilization's rapid expansion and its impact on the environment.

9. (A) (i)  The tone of M. Hamel in the line "And now you see where we've come out" is one of (c) regret.

(ii)  Option (a) "The player received a reprimand for breach of rules" conveys the meaning of 'reproach' as reflected in the line "We've all a great deal to reproach ourselves with."

(iii)  False. M. Hamel does not endorse the belief that there is plenty of time to learn their language. Instead, he highlights the consequences of procrastination.

(iv)  "You must feel bad enough." Through these words, M. Hamel urges the people to recognize and acknowledge their feelings of regret or remorse for not having taken their language lessons seriously.

(v)  The line "you pretend to be Frenchmen, and yet you can neither speak nor write your own language" reinforces the theme of patriotism in the story by emphasizing the importance of preserving and honoring one's national identity and heritage.

(vi) The phrase 'puts off' suggests procrastination or delaying tasks until a later time.

**OR**

(B) (i) The correct option is (b) uncompromising. Gandhi's trait of being adamant reflects his uncompromising stance.

(ii) The status of sharecroppers as inferred from the line "They thought he would demand repayment in full of the money which they had illegally and deceitfully extorted from the sharecroppers" is (c) victims of exploitation.

(iii) Gandhi surprised them by accepting the offer of refunding only 25 percent, breaking the deadlock.

(iv) The inference that can be drawn from the line "Mr. Gandhi took him at his words" is that Gandhi was willing to accept the offer made by the representatives of the planters, demonstrating his willingness to negotiate and resolve the situation.

(v) "Deadlock" in the last line means a situation where no progress can be made, typically because opposing sides are unwilling to compromise.

(vi) The attitude of planters towards sharecroppers appears exploitative and unjust, as they had illegally and deceitfully extorted money from them.

10. (I) Mukesh's attitude towards life differs from that of his family and friends as he dares to dream and aspire for a better future. While his family and friends seem resigned to their circumstances, Mukesh shows a spark of ambition and determination.

Unlike his family who are caught in a cycle of poverty and acceptance, Mukesh expresses a desire to become a motor mechanic and is willing to walk a long way to achieve his goal.

His dream of becoming a motor mechanic and learning to drive a car sets him apart from his family and friends who seem to have accepted their fate without daring to envision a different life.

(II) Qualities that were highlighted through the statement are:

Courage: The speaker shows courage by facing fear without losing control of their senses.

Resilience: Despite being frightened, the speaker maintains composure and does not panic.

Control: The speaker demonstrates the ability to manage fear without being overwhelmed.

(III) The words "See you soon, Amma" are contrary to the speaker's emotions because despite feeling a deep ache and childhood fear, the speaker chooses to express a positive and hopeful sentiment towards their mother. The words signify a sense of denial or suppression of the true emotions the speaker is experiencing at that moment.

(IV) Inference from 'mighty dead' in 'and such too is the grandeur of the dooms; we have imagined for the mighty dead.' (A Thing of Beauty)

The phrase 'mighty dead' suggests that even in death, great and influential individuals continue to hold power and significance in the minds of people. It implies that the grandeur associated with the 'mighty dead' stems from the lasting impact they have left behind, inspiring admiration and reverence.

(V) Rudyard Kipling condemned interviews as immoral and likened them to a crime, yet he himself had previously conducted an interview with Mark Twain.

Kipling's strong stance against interviews as a violation of personal integrity contradicts his own actions of engaging in such interviews, showcasing his hypocrisy.

Despite Kipling's vocal disapproval of interviews, his past behavior of conducting one himself with Mark Twain reveals his inconsistency and lack of adherence to his own principles.

(VI) Jansie's advice to Sophie to be sensible reveals a sense of concern and practicality in their friendship. It shows that Jansie is more grounded and realistic compared to Sophie's dreams of having a boutique. This advice highlights the differences in their personalities and aspirations, indicating a balance in their friendship where one is more dreamy and the other more practical.

11. (I) Humans face an uncertain future due to their short existence on the geological timescale. The rapid human impact on the environment, including climate change and resource depletion, raises concerns about the sustainability of human civilization.

Antarctica's pristine nature and ancient ice cores provide crucial insights into Earth's past, present, and future. Studying Antarctica is essential for understanding the planet's geological history and potential future scenarios.

(II) Charley didn't mind that his three hundred dollars bought less than two hundred in old-style bills because he was focused on the value of the old money in terms of purchasing power. The lower exchange rate didn't deter him due to the significantly lower cost of living in 1894.

The difference in the amount he received didn't bother Charlie as he was more concerned about the practical benefits of using old-style currency, such as the cheaper prices of goods like eggs at thirteen cents a dozen in 1894. This made the exchange worthwhile for him despite the premium he had to pay.

(III) The servants grew more watchful and their courtesy remained, but their eyes turned cold towards Sadao and his wife.

They were hired to serve, yet they were uneasy with the decision to treat the American soldier, showing their disapproval subtly.

The old gardener and the cook expressed their contrasting opinions on Sadao's actions, reflecting the divided views among the household staff.

12. (A) The Importance of Peace and Non-Violent Conflict Resolution

In today's world filled with conflicts and wars, it is crucial to emphasize the importance of peace. Wars only bring destruction and suffering, leaving no survivors as highlighted by Pablo Neruda. Gandhi's approach in Champaran shows that change can be brought about through civil disobedience rather than violence.

Peaceful Resolution of Issues

Peace should be the ultimate goal in resolving conflicts. Through dialogue, understanding, and empathy, issues can be addressed without resorting to violence. Gandhi's method of non-violence in Champaran serves as a powerful example of how change can be achieved through peaceful means.

The Power of Civil Disobedience

Civil disobedience, as demonstrated by Gandhi, is a potent tool in fighting against injustice. It shows that standing up for what is right can bring about positive change without resorting to aggression. Peaceful resistance can lead to long-lasting solutions and a more harmonious society.

**OR**

(B) M. Hamel's Views on Individual Responsibility and Nationalism

M. Hamel emphasized the importance of individual responsibility by highlighting how procrastination leads to missed opportunities for learning. He expressed regret over not instilling a sense of urgency in his students to prioritize their education.

Regarding nationalism, M. Hamel stressed the significance of language as a key to cultural identity and freedom. He underscored the power of language in preserving a nation's heritage and resisting external oppression.

Concluding Hamel's Interview

In conclusion, M. Hamel's reflections on individual responsibility and nationalism serve as poignant reminders of the impact of education on personal growth and cultural preservation. His dedication to imparting knowledge until the last moment exemplifies his unwavering commitment to his students and his country.

13. (A) Speech on Resilience and Determination

Introduction:

Resilience and determination are key qualities that pave the way for success in life. Mr. Lamb, despite his physical challenges, exemplifies the power of perseverance and a positive mindset.

Body:

Mr. Lamb's journey teaches us that obstacles are not roadblocks but stepping stones to growth. His ability to adapt and learn new skills over time showcases the importance of patience and consistency.

By embracing challenges with a steady approach, one can conquer any adversity and emerge stronger.

Conclusion: In conclusion, let us remember Mr. Lamb's inspiring story as a testament to the fact that with resilience and determination, one can overcome any hurdle and achieve their goals. Let's strive to face life's challenges head-on, knowing that every setback is an opportunity for growth and success.

**OR**

(B) Spending Quality Time with Children

Spending time with children will boost their confidence and strengthen the parent-child bond.

In "The Tiger King," the Maharaja neglected his crown prince due to his obsession with tiger hunting, highlighting the consequences of not prioritizing family.

Quality time with children can enhance their emotional well-being and overall development.

Engaging in activities together fosters communication, trust, and a sense of security in children.

Parents should balance work commitments with dedicated time for their children to nurture a healthy parent-child relationship.

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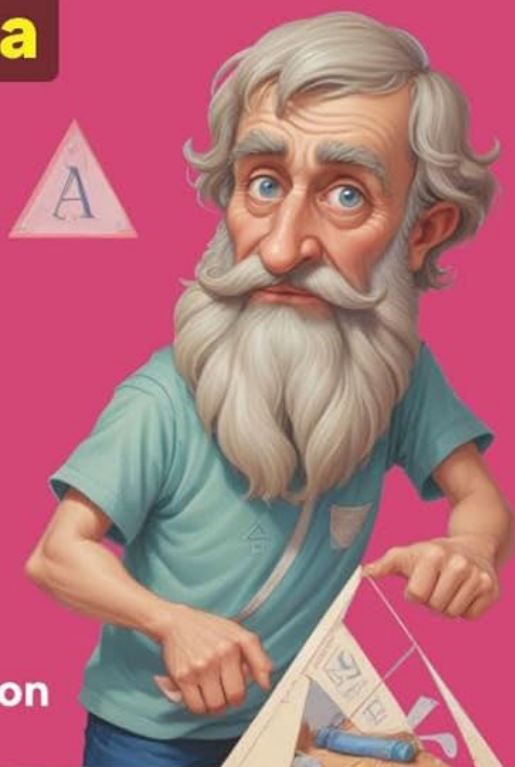
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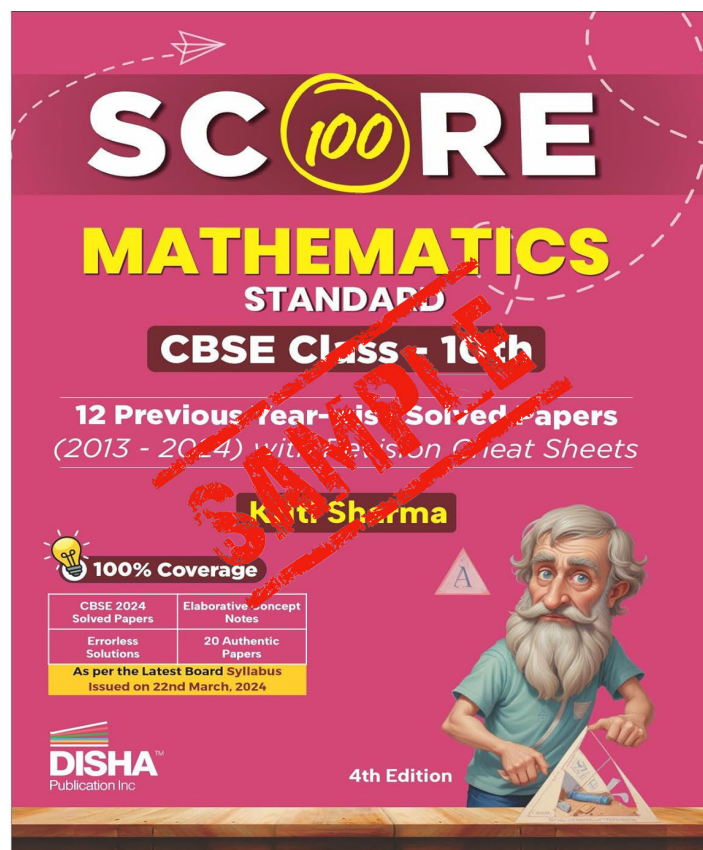


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### 3rd Level of Division : Skillwise Division

Each Question in the topic has been further divided skillwise using following codes:

**K** Knowledge    **U** Understanding    **Ap** Application    **A** Analysis

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# 1 CHAPTER

# Relations and Functions

---

**1** *Multiple Choice Questions (1 Mark)*

**1.** Let R be a relation in the set N given by

R = {(a, b) : a = b – 2, > 6}.

Then **[CBSE Sample Paper 2021-22, Term-I,**

**All India 2023, Set-II, K]**

(a) (8, 7) ∈ R

(b) (6, 8) ∈ R

(c) (3, 8) ∈ R

(d) (2, 4) ∈ R

**2.** Let A = {3, 5}. Then number of reflexive relations on A is **[Delhi 2023, K]**

(a) 2        (b) 4

(c) 0        (d) 8

**3.** Let set X = {1, 2, 3} and a relation R is defined in X as : R = {(1, 3), (2, 2), (3, 2)}, then minimum ordered pairs which should be added in relation R to make it reflexive and symmetric are **[All India 2022, Term-I, U]**

(a) {(1,1), (2, 3), (1, 2)}

(b) {(3, 3), (3, 1), (1, 2)}

(c) {(1, 1), (3, 3), (3, 1), (2, 3)}

(d) {(1, 1), (3, 3), (3, 1), (1, 2)}

**4.** If $R = \{(x, y): x, y \in Z, x^2 + y^2 \le 4\}$ is a relation in set $Z$, then domain of $R$ is **[All India 2022, Term-I, U]**

(a) {0, 1, 2}        (b) {–2, –1, 0, 1, 2}

(c) {0, –1, –2}        (d) {–1, 0, 1}

**5.** A relation R in set A = {1,2,3} is defined as R = {(1, 1), (1, 2), (2, 2), (3, 3)}. Which of the following ordered pair in R shall be removed to make it an equivalence relation in A?

**[CBSE Sample Paper 2021-22, Term-I, K]**

(a) (1, 1)        (b) (1, 2)

(c) (2, 2)        (d) (3, 3)

**6.** Let the relation R in the set A = {x ∈ Z : 0 ≤ x ≤ 12}, given by R = {(a, b) : |a – b| is a multiple of 4}. Then [1], the equivalence class containing 1, is:

**[CBSE Sample Paper 2021-22, Term-I, U]**

(a) {1, 5, 9}

(b) {0, 1, 2, 5}

(c) φ

(d) A

**7.** The relation R in the set {1, 2, 3} given by R = {(1, 2), (2, 1), (1, 1)} is **[Delhi 2020, K]**

(a) symmetric and transitive, but not reflexive

(b) reflexive and symmetric, but not transitive

(c) symmetric, but neither reflexive nor transitive

(d) an equivalence relation

**2** *Fill in the Blanks (1 Mark)*

**8.** A relation R in a set A is called _____, if $(a_1, a_2) \in$ R implies $(a_2, a_1) \in$ R, for all $a_1, a_2 \in$ A.

**[All India 2020, Set-I, A]**

**3** *Assertion Reason/ Two Statement Type Questions (1 Mark)*

9. **Assertion (A) :** The relation R = {(x, y) : (x + y) is a prime number and x, y ∈N} is not a reflexive relation.

**Reason (R) :** The number '2n' is composite for all natural numbers n. **[All India 2024, K]**

(a) Both Assertion (A) and Reason (R) are true and the Reason (R) is the correct explanation of Assertion (A).

(b) Both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false, but Reason (R) is true.

**4** *Very Short Answer Question (1 Mark)*

10. If R = {(x, y) : x + 2y = 8} is a relation on N, write the range of R. **[All India 2014, K]**

**6** *Long Answer Questions (4 or 5 or 6 Marks)*

11. Check whether the relation S in the set of real numbers R defined by S = {(a, b) : where $a - b + \sqrt{2}$ is an irrational number} is reflexive, symmetric or transitive. **[All India 2024, K]**

12. A relation R is defined on N × N (where N is the set of natural numbers) as (a, b) R (c, d) ⇔ a − c = b − d
Show that R is an equivalence relation. **[Delhi 2024, A]**

13. Let ℕ be the set of all natural numbers and R be a relation on ℕ×ℕ defined by (a, b) R (c, d) ⇔ ad = bc for all (a, b), (c, d) ∈ ℕ×ℕ. Show that R is an equivalence relation on ℕ×ℕ. Also, find the equivalence class of (2, 6), i.e., [(2, 6)].

**[CBSE Sample Paper 2022, 23, 2023-24, K]**

14. If N denotes the set of all natural numbers and R is the relation on N × N defined by (a,b,) R (c,d), if ad(b+c) = bc(a + d). Show that R is an equivalence relation.

**[Delhi, 2015, All India 2023, Set-I, K]**

15. Given a non-empty set X, define the relation R in P(X) as follows:

For A, B ∈ P(X), (A, B) ∈ R iff A ⊂ B. Prove that R is reflexive, transitive and not symmetric.

**[CBSE Sample Paper 2022-23, K]**

16. Let N be the set of natural numbers and R be the relation on N × N defined by (a, b) R (c, d) if ad = bc for all a, b, c, d ∈ N. Show that R is an equivalence relation.

**[All India 2020, Set-I, Ap]**

17. Check whether the relation R in the set N of natural numbers given by R = {(a, b) : a is divisor of b} is reflexive, symmetric or transitive. Also determine whether R is an equivalence relation. **[Delhi 2020, K]**

18. Let A = {1, 2, 3, ... , 9} and R be the relation in A × A defined by (a, b) R (c, d) if a + d = b + c for (a, b), (c, d) in A × A. Prove that R is an equivalence relation. Also obtain the equivalence class [(2, 5)]. **[Delhi 2014, K]**

19. Show that the relation R on ℝ defined as R = {(a, b) : a ≤ b}, is reflexive, and transitive but not symmetric.

**[Delhi 2019, Set-I, K]**

20. Show that the relation S on the set A = {x ∈ Z : 0 ≤ x ≤ 12} given by S = {(a, b) : a, b ∈ Z, |a − b| is divisible by 3} is an equivalence relation. **[All India 2019, K]**

## Topic-2: *Types of Functions*

**1** *Multiple Choice Questions (1 Mark)*

**1.** Let $f : \to [-5, \infty)$ be defined as $f(x) = 9x^2 + 6x - 5$, $R^+$ is the set of all non-negative real numbers. Then, f is:

**[Delhi 2024, Ap]**

(a) one-one

(b) onto

(c) bijective

(d) neither one-one more onto

**2.** If $f(x) = |\cos x|$, then $f\left(\dfrac{3\pi}{4}\right)$ is

**[All India 2023, Set-II, K]**

(a) 1

(b) $-1$

(c) $\dfrac{-1}{\sqrt{2}}$

(d) $\dfrac{-1}{\sqrt{2}}$

**3.** Let $X = \{x^2 : x \in N\}$ and the function $f : N \to X$ is defined by $f(x) = x^2$, $x \in N$. Then this function is

**[All India 2022, Term-I, A]**

(a) injective only

(b) not bijective

(c) surjective only

(d) bijective

**4.** A function $f : R \to R$ defined by $f(x) = 2 + x^2$ is

**[All India 2022, Term-I, A]**

(a) not one-one

(b) one-one

(c) not onto

(d) neither one-one nor onto

**5.** The function $f : R \to R$ defined as $f(x) = x^3$ is:

**[CBSE Sample Paper 2021-22, Term-I, K]**

(a) One-one but not onto

(b) Not one-one but onto

(c) Neither one-one nor onto

(d) One-one and onto

**6.** Let A = {1, 2, 3}, B = {4, 5, 6, 7} and let $f$ = {(1, 4), (2, 5), (3, 6)} be a function from A to B. Based on the given information, $f$ is best defined as:

**[CBSE Sample Paper 2021-22, Term-I, K]**

(a) Surjective function    (b) Injective function

(c) Bijective function     (d) Function

**7.** The function $f : R \to [-1, 1]$ defined by $f(x) = \cos x$ is

**[Delhi 2020, K]**

(a) both one-one and onto

(b) not one-one, but onto

(c) one-one, but not onto

(d) neither one-one, nor onto

**3** *Assertion Reason/ Two Statement Type Questions (1 Mark)*

**8.** **Assertion (A):** The relation $f : \{1, 2, 3, 4\} \to \{x, y, z, p\}$ defined by $f = \{(1, x), (2, y), (3, z)\}$ is a bijective function.

**Reason (R):** The function $f : \{1, 2, 3\} \to \{x, y, z, p\}$ such that $f = \{(1, x), (2, y), (3, z)\}$ is one-one.

**[CBSE Sample Paper 2023-24, A]**

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).

(b) Both (A) and (R) are true but (R) is not the correct explanation of (A).

(c) (A) is true but (R) is false.

(d) (A) is false but (R) is true.

**5** *Short Answer Question (2 or 3 Marks)*

**9.** Prove that the function $f$ is surjective, where $f : \mathbf{N} \to \mathbf{N}$

such that $f(n) = \begin{cases} \dfrac{n+1}{2}, & \text{if } n \text{ is odd} \\ \dfrac{n}{2}, & \text{if } n \text{ is even} \end{cases}$

**[CBSE Sample Paper 2022-23, A]**

| **6** | *Long Answer Questions (4 or 5 or 6 Marks)* |

**10.** Let A = R − {5} and B = R − {1}. Consider the function f : A → B, defined by f(x) = $\dfrac{x-3}{x-5}$. Show that f is one - one and onto. **[All India 2024, Ap]**

**11.** Show that a function f : R → defined by f(x) = $\dfrac{2x}{1+x^2}$ is neither one-one nor onto. Further, find set A so that the given function f : R → A becomes an onto function. **[Delhi 2024, K]**

**12.** Show that the function $f : \mathbb{R} \to \{x \in \mathbb{R} : -1 < x < 1\}$ defined by $f(x) = \dfrac{x}{1+|x|}, x \in \mathbb{R}$ is one-one and onto function. **[CBSE Sample Paper 2023-24 Ap]**

**13.** Let f : R − $\left\{-\dfrac{4}{3}\right\}$ → R be a function defined as f(x) = $\dfrac{4x}{3x+4}$. Show that f is one -one function. Also, check whether f is an onto function or not. **[All India 2023, Set-I, K]**

**14.** A function f : [−4, 4] → [0, 4] is given by f(x) = $\sqrt{16-x^2}$. Show that f is an onto function but not a one-one function. Further, find all possible values of 'a' for which f(a) = $\sqrt{7}$. **[All India 2023, Set-III, A]**

**15.** Prove that the function $f : N \to N$, defined by $f(x) = x^2 + x + 1$ is one-one but not onto. Find inverse of $f : N \to S$, where S is range of $f$. **[Delhi 2019, Set-I, K]**

**16.** Let A = R − {2} and B = R − {l}. If f : A → B is a function defined by $f(x) = \dfrac{x-1}{x-2}$, show that f is one-one and onto. Hence, find $f^{-1}$. **[All India 2019, K]**

| **7** | *Case Based Questions (4 Marks)* |

**17.** An organization conducted bike race under two different categories – Boys and Girls. There were 28 participants in all. Among all of them, finally three from category 1 and two from category 2 were selected for the final race. Ravi forms two sets B and G with these participants for his college project.

Let B = {$b_1, b_2, b_3$} and G = {$g_1, g_2$}, where B represents the set of Boys selected and G the set of Girls selected for the final race. **[Delhi 2023, Ap]**
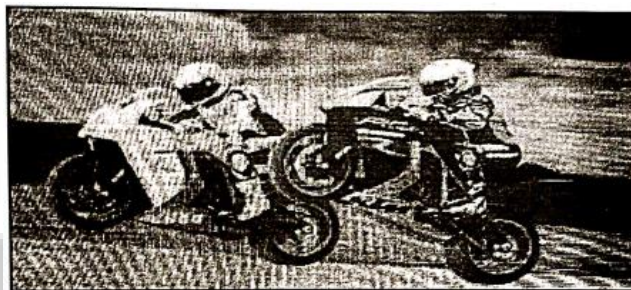


Based on the above information, answer the following question:

(I) How many relations are possible from B to G?

(II) Among all the possible relations from B to G, how many functions can be formed from B to G?

(III) Let R: B → B be defined by R = {(x, y) : x and y are students of the same sex}. Check if R is an equivalence relation.

**OR**

A function f : B → G be defined by f = {($b_1, g_1$), ($b_2, g_2$), ($b_3, g_1$)}.

Check if is bijective. Justify your answer.

# Solutions

## Topic-1: Types of Relations

1. **(b)** given, R= {(a,b) ; a = b - 2, b > 6}
   where a, b ∈ N
   option (a) will not be the answer. because,
   Here a = 8, b = 7
   and 8 ≠ 7 - 2
   option (b) will be the answer because,
   Here 6 = 8 - 2
   option (c) will not be the answer because,
   Here 3 ≠ 8 - 2
   also, option (d) will not be the answer because,
   Here a = 2, b = 4 and a = b - 2 follows
   but b < 6 **(1 Mark)**

2. **(b)** Given set $A = \{3,5\} \Rightarrow n(A) = 2$
   Now number of reflexive relation on A
   $= 2^{(n^2-n)} = 2^{(2^2-2)} = 2^{(4-2)} = 2^2 = 4$ **(1 Mark)**

3. **(c)** Given that set $X = \{1, 2, 3\}$
   $R$ is reflexive since (1, 1), (2, 2) and (3, 3) lie in $R$.
   Also,
   $R$ is symmetric if
   $(1, 3) \in X \Rightarrow (3, 1) \in X \Rightarrow (3, 2) \in X \Rightarrow (2, 3) \in X$
   Therefore
   $R = \{(1, 1), (2, 2), (3, 3), (1, 3), (3, 1), (3, 2), (2, 3)\}$
   **(1 Mark)**

4. **(b)** We have $R = \{(x, y): x, y \in Z, x^2 + y^2 \le 4\}$
   When $x = 0$
   $x^2 + y^2 \le 4 \Rightarrow y^2 \le 4 \Rightarrow y = 0, \pm 1, \pm 2$
   When $x = \pm 1$
   $x^2 + y^2 \le 4 \Rightarrow 1 + y^2 \le 4 \Rightarrow y^2 \le 3 \Rightarrow y = 0, \pm 1$
   When $x = \pm 2$
   $x^2 + y^2 \le 4 \Rightarrow 4 + y^2 \le 4 \Rightarrow y^2 \le 0 \Rightarrow y = 0$
   Therefore, $R = \{(0, 0), (0, -1), (0, 1), (0, -2), (0, 2),$
   $(-1, 0), (1, 0), (1, 1), (1, -1), (-1, 1), (-1, -1), (2, 0),$
   $(-2, 0)\}$
   Hence,
   Domain of $R = \{x : (x, y) \in R\}$
   $= \{0, -1, 1, -2, 2\}$ **(1 Mark)**

5. **(b)** (1, 2) **(1 Mark)**
6. **(a)** {1, 5, 9} **(1 Mark)**
7. **(a)** Let set A = {1, 2, 3}
   R = {(1, 2) (2, 1) (1, 1)}
   (i) Relation R is reflexive if
   $a \in$ A
   $(a, a) \in$ R
   But here (2, 2) and (3, 3) is missing.
   So, R is not reflexive.

(ii) A relation R is symmetric if $(a, b) \in$ R
   then $(b, a) \in$ R
   Here R has (1, 2) and (2, 1)
   Therefore, R is symmetric.
(iii) A relation R is said to be transitive if
   $(a, b) \in$ R and $(b, c) \in$ R then $(a, c) \in$ R
   $(1, 2) \in$ R, $(2, 1) \in$ R
   Also $(1, 1) \in$ R
   Therefore, relation R is transitive. **(1 Mark)**

8. [Symmetric] **(1 Mark)**

9. **(c)** $(a, a) \in$ R implies a + a is a prime number
   But a + a = 2a is not always a prime number.
   Hence, R is not reflexive.
   Let n = 1
   2n = 2 which is a prime number.
   2n is not composite for all natural numbers n. **(1 Mark)**

10. $R = \{(x, y) : x + 2y = 8\}$
    $x = 1, \ y = \dfrac{7}{2} \notin N, \ x = 5, \ y = \dfrac{3}{2} \notin N$
    $x = 2, \ y = 3 \in N, \ x = 6, \ y = 1 \in N$
    $x = 3, \ y = \dfrac{5}{2} \notin N, \ x = 7, \ y = \dfrac{1}{2} \notin N$
    $x = 4, y = 2, \in N, x = 8, \ y = 0 \notin N$
    $\therefore$ Range $(R) = \{1, 2, 3\}$ **(1 Mark)**

11. Consider $2\sqrt{2} \ R \sqrt{2}$ as $2\sqrt{2} - \sqrt{2} + \sqrt{2} = 2\sqrt{2}$
    (irrational)
    $\sqrt{2} R 3\sqrt{2}$ as $\sqrt{2} - 3\sqrt{2} + \sqrt{2} = -\sqrt{2}$ (irrational)
    But $2\sqrt{2} \ \cancel{R} \ 3\sqrt{2}$
    $2\sqrt{2} - 3\sqrt{2} + \sqrt{2} = 0$ (rational number)
    Hence, R is not transitive. **(2 Marks)**
    $(a, a) \in$ R as $a - a + \sqrt{2} = \sqrt{2}$
    which is irrational number $\forall$ a $\in$ R.
    Hence, R is reflexive. **(1 Mark)**
    Consider $(2\sqrt{2}, \sqrt{2})$
    $2\sqrt{2} - \sqrt{2} + \sqrt{2} = 2\sqrt{2}$ (irrational number)
    $(\sqrt{2}, 2\sqrt{2}) \notin R$
    as $\sqrt{2} - 2\sqrt{2} + \sqrt{2} = 0$ (not irrational)
    Hence, R is not symmetric. **(2 Marks)**

**12.** Reflexive

(a, b) R (a, b) $\Rightarrow$ a – a = b – b = 0

Which is true for all (a, b) $\in$ N × N.   **(1 Mark)**

Symmetric

(a, b)R(c, d) $\Rightarrow$ a – c = b – d $\Rightarrow$ c – a = d – b

$\Rightarrow$  (c, d) R (a, b) $\forall$ (a, b) $\in$ N × N and (c, d) $\in$ N × N

Hence R is symmetric.   **(2 Marks)**

Transitive

Let (a, b) R (c, d) and (c, d) R (e, f)

$\Rightarrow$  a – c = b – d ...(i)

$\Rightarrow$  c – e = d – f ...(ii)

Adding (i) & (ii)

a – e = b – f $\Rightarrow$ (a, b) R (e, f)

Hence R is transitive.

R is an equivalence Relation.   **(2 Marks)**

**13.** Let (a, b) be an arbitrary element of $\mathbb{N} \times \mathbb{N}$. Then,

(a, b) $\in \mathbb{N} \times \mathbb{N}$ and $a, b \in \mathbb{N}$

We have, ab = ba;

(As $a, b \in \mathbb{N}$ and multiplication is commutative on $\mathbb{N}$)

$\Rightarrow$  (a, b) R (a, b), according to the definition of the relation R on N × N.

Thus (a, b) R (a, b), $\forall (a, b) \in \mathbb{N} \times \mathbb{N}$.

So, R is reflexive relation on $\mathbb{N} \times \mathbb{N}$.   **(1 Mark)**

Let (a, b), (c, d) be arbitrary elements of $\mathbb{N} \times \mathbb{N}$ such that (a, b) R (c, d).

Then, (a, b) R (c, d) $\Rightarrow$ ad = bc $\Rightarrow$ bc = ad;

(changing LHS and RHS)

$\Rightarrow$ cb = da; (As a, b, c, d $\in \mathbb{N}$ and multiplication is commutative on $\mathbb{N}$)

$\Rightarrow$ (c, d) R (a, b); according to the definition of the relation R on $\mathbb{N} \times \mathbb{N}$

Thus (a, b) R (c, d) $\Rightarrow$ (c, d) R (a, b)

So, R is symmetric relation on $\mathbb{N} \times \mathbb{N}$.   **(1 Mark)**

Let (a, b), (c, d), (e, f) be arbitrary elements of $\mathbb{N} \times \mathbb{N}$ such that (a, b) R(c, d) and (c, d) R (e, f).

Then $\begin{matrix} (a,b)R(c,d) \Rightarrow ad = bc \\ (c,d)R(e,f) \Rightarrow cf = de \end{matrix} \Bigg\}$

$\Rightarrow$  (ad) (cf) = (bc) (de) $\Rightarrow$ af = be

$\Rightarrow$  (a, b) R(e, f); (according to the definition of the relation R on $\mathbb{N} \times \mathbb{N}$)

Thus (a, b) R (c, d) and (c, d) R (e, f) $\Rightarrow$ (a, b) R (e, f)

So, R is transitive relation on $\mathbb{N} \times \mathbb{N}$.   **(1 Mark)**

As the relation R is reflexive, symmetric and transitive so, it is equivalence relation on $\mathbb{N} \times \mathbb{N}$.

[(2, 6)] = {(x, y) $\in \mathbb{N} \times \mathbb{N}$ (x, y) R (2, 6)}   **(½ Mark)**

$= \left\{ (x, y) \in \mathbb{N} \times \mathbb{N} : 3x = y \right\}$   **(½ Mark)**

$= \left\{ (x, 3x) : x \in \mathbb{N} \right\} = \left\{ (1,3), (2,6), (3,9), ..... \right\}$  **(1 Mark)**

**14. (a)** Let R be defined on N × N

**Reflexivity:** Sum and product of natural numbers obeys commutative property

(a, b) R (c, d) $\Leftrightarrow$ ad (b + c) = bc(a + d)

Hence, R is reflexive.   **(1½ Marks)**

Symmetry: Let (a, b) R(c, d)

$\Rightarrow$  ad(b + c) = bc(a + d)

$\Rightarrow$  da(c + b) = cb(d + a)

$\Rightarrow$  (c, d) = R(a, b)   **(1½ Marks)**

So, R is symmetric.

**Transitivity:** Let (a, b), (c, d), (e, f) $\in$ N × N

(a, b) R(c, d) and (c, d) R (e, f)

ad(b +c) = bc(a + d) and cf(d + e) = de (c + f)

$\Rightarrow \dfrac{ab}{a-b} = \dfrac{cd}{c-d}, \dfrac{cd}{c-d} = \dfrac{ef}{e-f}$

$\Rightarrow \dfrac{ab}{a-b} = \dfrac{ef}{e-f} \Rightarrow$ (a, b) R(e, f)

Hence, R is transitive.   **(2 Marks)**

**15.** Let $A \in P(X)$. Then $A \subset A$

$\Rightarrow (A, A) \in R$

Hence, R is reflexive.   **(1 Mark)**

Let $A, B, C \in P(X)$ such that

$(A, B), (B, C) \in R$

$\Rightarrow A \subset B, B \subset C$

$\Rightarrow A \subset C$

$\Rightarrow (A, C) \in R$

Hence, R is transitive.   **(2 Marks)**

$\phi, X \in P(X)$ such that $\phi \subset X$. Hence, $(\phi, X) \in R$. But, $X \in \phi$, which implies that $(X, \phi) \notin R$.

Thus, R is not symmetric.   **(2 Marks)**

**16.**

$R : N \times N$

$(a,b)R(c,d)$ iff $ad = bc$.

$\quad\quad\quad a,b,c,d \in N$.

for reflexive

let $(a,b) \in$  $a, b \in N$

$\quad (a,b)R(a,b)$

$\quad\quad as \quad ab = ba$

$\therefore$ for all $a,b \in N$  $(a,b)\in R$ $(a,b)R(a,b)$

$\quad\quad \therefore$ The relation is reflexive.

For symmetric

$\quad let \quad a,b,c,d \in N$

$\quad\quad such \ that \quad (a,b)R(c,d)$

$\quad\quad\quad\quad \Rightarrow \quad ad = bc$

$\quad\quad\quad\quad \Rightarrow \quad cb = da$

$\quad\quad\quad\quad \Rightarrow \quad (c,d)R(a,b)$

$\quad\quad \therefore$ for all $(a,b)R(c,d)$ & $(c,d)R(a,b)$ $\forall \ a,b,c,d \in N$

∴ The relation is symmetric

For transitive

let $a, b, c, d, e, f \in N$

such that $(a, b) R (c, d)$ and $(c, d) R (e, f)$

$\Rightarrow ad = bc$      $\Rightarrow cf = de$

        (i)          $\Rightarrow c = \dfrac{de}{f}$   (ii)

from equations (i) and (ii)

$$ad = \dfrac{bde}{f}$$

$$\Rightarrow af = be$$

$$\cancel{\Rightarrow af = eb}$$

∴    $(a, b) R (e, f)$

∴ For all $(a, b) R (c, d)$ and $(c, d) R (e, f)$

$$\Rightarrow (a, b) R (e, f)$$

$$\forall a, b, c, d, e, f \in N$$

∴ The relation is transitive

As the relation is reflexive, symmetric and

transitive, it is an equivalence relation.

<u>Hence Proved</u>

**17.** R = {(*a*, *b*) : *a* is divisor of *b*}
  (i) Reflexive:
    Since every natural number divisor of itself
    ∴ $\forall a \in R \Rightarrow (a, a) \in R$
    ∴ R is reflexive. **(1 Mark)**
  (ii) Symmetric
    Let (2, 4) ∈ R      (2 is divisor of 4)
    but (4, 2) ∉ R      (4 is not divisor of 2)
    ∴ R is not symmetric. **(1 Mark)**

  (iii) Transitive
    Let $(a, b) \in R$, $(b, c) \in R \ \Box \ a, b, c \in N$
    $\Rightarrow$ Let $b = ma \ c = bn = n(ma)$
    $= mna$
    $\Rightarrow a$ is divisor of $c$
    $\Rightarrow (a, c) \in R$
    ∴ R is transitive.
    R is reflexive, transitive but not symmetric.
    Therefore, R is not equivalence. **(2 Marks)**

**18.** Here $A = [1, 2, 3, ... 9]$ and $R$ is *a* relation on $A \times A$ defined by
$(a, b) R (c, d) \Leftrightarrow a + d = b + c \; \forall \, a, b, c, d \in A$

(i) Let $(a, b) \in A \times A$
$a + b = b + a$
$(a, b) R (a, b), \; \forall \, (a, b) \in A \times A$
$\Rightarrow R$ is reflexive on $A$        **(1 Mark)**

(ii) Let $(a, b) R (c, d)$
$a + d = b + c$
$b + c = d + a$
$(c, d) R (a, b), \; \forall \, (a, b), (c, d) \in A \times A$
$\Rightarrow R$ is symmetric on $A$        **(1 Mark)**

(iii) Let $(a, b) R (c, d)$ and $(c, d) R (e, f), \; \forall \, (a, b), (c, d)$ and $(e, f) \in A \times A$

$a + d = b + c$ and $c + f = d + e$
On adding
$(a + d) + (c + f) = (b + c) + (d + e)$
$\Rightarrow a + f = b + e$
$(a, b) R (e, f)$
$\Rightarrow R$ is transitive on $A$.
Hence $R$ is an equivalence relation on $A$   **(1 Mark)**
Also equivalence class $[(2, 5)]$
$= [(a, b) \in A \times A \, | \, (2, 5) R (a, b)]$
$= [(a, b) \in A \times A \, | \, 2 + b = 5 + a]$
$= [(a, b) \in A \times A \, | \, b = a + 3]$
$= [(a, a + 3) \, | \, a \in A \,|$
$= \{(1, 4), (2, 5), (3, 6), (4, 7), (5, 8), (6, 9)\}$
                                     **(1 Mark)**

**19.**

**Topper's Answer**

$R = \{(a, b) : a \leq b\}$

REFLEXIVE :

Every element $a \in R$ is equal to itself
$\Rightarrow a = a$
$\Rightarrow a \leq a$ is true
$\therefore (a, a) \in R$ for all $a \in R$    where $\mathbb{R} = $ set of Real nos
The relation is REFLEXIVE    $R = $ Relation.

TRANSITVE :

For all $(a, b) \in R$ and $(b, c) \in R$
$a \leq b$ and $b \leq c$    where , $a, b, c \in \mathbb{R}$
$\Rightarrow a \leq c$
$\Rightarrow (a, c) \in R$
$\therefore$ The ~~set is tr~~ relation is TRANSITVE
$\therefore$ for $(a, b), (b, c) \in R$ , ~~(a, c) $\in$ R~~ $(a, c) \in R$

SYMMETRIC : For relation to be symmetric,
 for all $(a, b) \in R$, $(b, a)$ should also exist in R

$a \leq b \neq a \leq b$
$\qquad\qquad b \not\leq a \rightarrow$ This relation is true only $a = b = 1$.

For eg: $\frac{1}{2} \leq 1 \Rightarrow \left(\frac{1}{2}, 1\right) \in R$

but $1 \not\leq \frac{1}{2} \therefore \left(1, \frac{1}{2}\right) \notin R$

$\therefore$ Relation is NOT SYMMETRIC

**20.** Given set A = { 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12}.

and S = {(a, b) : a, b ∈ Z, |a – b| is divisible by 3}.

(i) For all a ∈ A, (a, a) ∈ S ($\because$ a – a = 0 is divisible by 3).

$\therefore$ S is reflexive on A. **(1 Mark)**

(ii) For all a, b ∈ A,

If (a, b) ∈ S, i.e, | a – b| is divisible by 3.

$\Rightarrow$ |b – a| is also divisible by 3.

$\therefore$ S is symmetric on A. **(1 Mark)**

(iii) For all a, b, c ∈ A.

Let (a, b) ∈ S and (b, c) ∈ S.

i.e; |a – b| is divisible by 3 and |b – c| is divisible by 3.

and let (a – b) = ± 3q, (b – c) = ± 3p.

Adding we get :

$a - c = \pm 3(p + q) = \pm 3m$ (say)

$\Rightarrow |a - c| = 3m$ (divisible by 3).

$\therefore$ S is transitive in A.

Hence, S is an equivalence relation on A.

A relation is equivalence when it is reflexive, symmetric and transitive. **(2 Marks)**

## Topic-2: Types of Functions

**1.** **(c)** To show function is one-one, let $f(x_1) = f(x_2)$ where $x_1, x_2 \in (0, \infty)$

$$\Rightarrow \quad 9x_1^2 + 6x_1 - 5 = 9x_2^2 + 6x_2 - 5$$

$$\Rightarrow \quad 9(x_1^2 - x_2^2) + 6(x_1 - x_2) = 0$$

$$\Rightarrow \quad (x_1 - x_2)[9(x_1 + x_2) + 6] = 0$$

$$\Rightarrow \quad x_1 = x_2 \ [\because 9(x_1 + x_2) + 6 > 0]$$

Hence function $f(x)$ is one-one

Given, $f(x) = 9x^2 + 6x - 5 = (3x + 1)^2 - 6$

$$\Rightarrow \quad y = (3x + 1)^2 - 6 \Rightarrow x = \frac{\sqrt{y + 6} - 1}{3}$$

Clearly, $\forall y \in [-5, \infty)$, There exist pre-image $x \in [0, \infty)$.

Hence $f(x)$ is onto. Therefore we can say that $f(x)$ is bijective. **(1 Mark)**

**2.** **(d)** we have to find $f(3\pi/4) = ?$

and we have given, $f(x) = |\cos x|$     ...(1)

putting $x = 3\pi/4$, we will get,

$$\Rightarrow f\left(\frac{3\pi}{4}\right) = \left|\cos\frac{3\pi}{4}\right|$$

$$= |\cos\left(\pi - \pi/4\right)|$$

$$= |-\cos\left(\pi/4\right)|$$

$$= \left|-\frac{1}{\sqrt{2}}\right|$$

$$= \frac{1}{\sqrt{2}}$$

Hence, option (d) is correct. **(1 Mark)**

**3.** **(d)** Let $f(x_1) = f(x_2)$

$$\Rightarrow \quad x_1^2 = x_2^2$$

$$\Rightarrow \quad x_1 = x_2 \qquad\qquad [\because x \in N]$$

$\therefore \quad f(x)$ is injective

$\because \quad f : N \rightarrow X$

Angle range of

$f(x) = x^2, x \in N$ is $X$

$\therefore$    Range = codomain

So, it is surjective also

Hence, it is bijective. **(1 Mark)**

**4.** **(d)** Let $f(x_1) = f(x_2)$

$$\Rightarrow \quad 2 + x_1^2 = 2 + x_2^2$$

$$\Rightarrow \quad x_1 = \pm x_2$$

$\therefore \quad f(x)$ is not one-one

$\because \quad x^2 \geq 0 \Rightarrow 2 + x^2 \geq 2$

$$\Rightarrow \quad f(x) \geq 2$$

$\therefore$    Range $= [2, \infty) \neq$ codomain

So, $f(x)$ is not onto. **(1 Mark)**

**5.** **(d)**

Let $f(x_1) = f(x_2) \forall x_1 x_2 \in R$   | Let $f(x) = x^3 = y$

$\Rightarrow x_1^3 = x_2^3$               | $\Rightarrow x = y^{\frac{1}{3}}, \forall y \in R$

$\Rightarrow x_1 = x_2$                | every image $y \in R$ has a

So, $f(x)$ is one-one     | unique pre image in $R$

                              | $\Rightarrow f$ is onto

$\therefore \quad f$ is one-one and onto **(1 Mark)**

**6.** **(b)** As every per-image $x \in A$ has a unique image $y \in B$ but range $= \{4, 5, 6\} \neq B$.

$\Rightarrow \quad f$ is injective function **(1 Mark)**

**7.** **(b)** $f(x) = \cos x$

$f : R \rightarrow [-1, 1]$

if $x_1 = \dfrac{\pi}{2}$

$$f(x_1) = f\left(\frac{\pi}{2}\right) = \cos\frac{\pi}{2} = 0$$

if $x_2 = -\dfrac{\pi}{2}$

$$f(x_2) = f\left(\frac{-\pi}{2}\right) = \cos\left(\frac{-\pi}{2}\right) = \cos\frac{\pi}{2} = 0$$

$$[\because \cos(-\theta) = \cos\theta]$$

$$f(x_1) = f(x_2)$$

But $x_1 \neq x_2$

So, $f(x)$ is not one-one

Also range of cos $x$ is [−1, 1]

∴ Range = Co-domain

So, it is onto. **(1 Mark)**

8. **(d) Assertion is false.** As element 4 has no image under f, so relation f is not a function.

**Reason is true.** The given function f : {1, 2, 3} → {x, y, z, p} is one-one, as for each a ∈ {1, 2, 3}, there is different image in {x, y, z, p} under f. **(1 Mark)**

9. Let $y \in N$(codomain). Then $\exists\, 2y \in N$(domain) such that

$f(2y) = \dfrac{2y}{2} = y$ . Hence, $f$ is surjective. **(1 Mark)**

1, 2 ∈ N (domain) such that F(1) = 1 = F(2)

Hence, f is not injective. **(1 Mark)**

10. Let f($x_1$) = f($x_2$)

$\dfrac{x_1 - 3}{x_1 - 5} = \dfrac{x_2 - 3}{x_2 - 5}$

$x_1 x_2 - 5x_1 - 3x_2 + 15 = x_1 x_2 - 3x_1 - 5x_2 + 15$

$2x_1 = 2x_2 \Rightarrow x_1 = x_2$

$f(x_1) = f(x_2) \Rightarrow x_1 = x_2$. Hence f(x) is one one.

**(2½ Marks)**

Let $y = \dfrac{x - 3}{x - 5}$

$xy - 5y = x - 3$

$x(y - 1) = 5y - 3 \Rightarrow x = \dfrac{5y - 3}{y - 1}$

x is defined ∀y∈R−{1}

Range of f = R − {1}

Range = codomain

⟹ f is onto **(2½ Marks)**

11. Let $f(x) = \dfrac{1}{2} = \dfrac{2x}{1 + x^2}$

$1 + x^2 = 4x \Rightarrow x^2 - 4x + 1 = 0$

$\Rightarrow \quad x = \dfrac{4 \pm \sqrt{16 - 4}}{2} - \dfrac{4 \pm 2\sqrt{3}}{2}$

$= 2 \pm \sqrt{3}$

For $f(x) = \dfrac{1}{2}$ there are two values of x belonging to domain. Hence f is not one one. **(2 Marks)**

$y = \dfrac{2x}{1 + x^2}$

$y + yx^2 = 2x \Rightarrow yx^2 - 2x + y = 0$

For x to be real

$4 - 4y^2 \geq 0$

$y^2 \leq 1 \Rightarrow y \in [-1, 1]$ **(2 Marks)**

Range of f is [−1, 1]. For f(x) = 2 ∈ R there is no preimage.

f is not onto.

For f to be onto A should be [−1, 1] **(1 Mark)**

12. We have $f(x) = \begin{cases} \dfrac{x}{1 + x}, & \text{if } x \geq 0 \\[2mm] \dfrac{x}{1 - x}, & \text{if } x < 0 \end{cases}$

Now, we consider the following cases

**Case 1:** When x ≥ 0, we have $f(x) = \dfrac{x}{1 + x}$

**Injectivity:** Let $x, y \in \mathbb{R}^+ \cup \{0\}$ such that f(x) = f(y), then

$\Rightarrow \dfrac{x}{1 + x} = \dfrac{y}{1 + y} \Rightarrow x + xy = y + xy \Rightarrow x = y$ **(1 Mark)**

So, f is injective function. **(1 Mark)**

**Surjectivity:** When x ≥ 0, we have

$f(x) = \dfrac{x}{1 + x} \geq 0$ and $f(x) = 1 - \dfrac{1}{1 + x} < 1$, as $x \geq 0$

Let $y \in [0, 1)$, thus for each $y \in [0, 1)$ there exists

$x = \dfrac{y}{1 - y} \geq 0$ such that $f(x) = \dfrac{\dfrac{y}{1 - y}}{1 + \dfrac{y}{1 - y}} = y.$ **(1 Mark)**

So, f is onto function on [0, ∞) to [0, 1).

**Case 2:** When $x < 0$, we have $f(x) = \dfrac{x}{1-x}$

**Injectivity:** Let $x, y \in \mathbb{R}^-$ i.e, $x, y < 0$, such that $f(x) = f(y)$, then

$\Rightarrow \dfrac{x}{1-x} = \dfrac{y}{1-y} \Rightarrow x - xy = y - xy \Rightarrow x = y$

So, f is injective function.

**Surjectivity :** $x < 0$, we have $f(x) = \dfrac{x}{1-x} < 0$ also,

$f(x) = \dfrac{x}{1-x} = -1 + \dfrac{1}{1-x} > -1$ **(1 Mark)**

$-1 < f(x) < 0$.

Let $y \in (-1, 0)$ be an arbitrary real number and there exists

$x = \dfrac{y}{1+y} < 0$ such that,

$f(x) = f\left(\dfrac{y}{1+y}\right) = \dfrac{\dfrac{y}{1+y}}{1 - \dfrac{y}{1+y}} = y.$

So, for $y \in (-1, 0)$, there exists $x = \dfrac{y}{1+y} < 0$ such that

$f(x) = y.$ **(1 Mark)**

Hence, f is onto function on $(-\infty, 0)$ to $(-1, 0)$.

**Case 3:**

**(Injectivity):** Let $x > 0$ & $y < 0$ such that

$f(x) = f(y) \Rightarrow \dfrac{x}{1+x} = \dfrac{y}{1-y}$

$\Rightarrow x - xy = y + xy \Rightarrow x - y = 2xy$, here LHS > 0 but RHS < 0, which is inadmissible.

Hence, $f(x) \neq f(y)$ when $x \neq y$.

Hence f is one-one and onto function. **(1 Mark)**

**13. (b)** Given, $f(x) = \dfrac{4x}{3x+4} \Rightarrow f(x) = f(y)$

$\Rightarrow \dfrac{4x}{3x+4} = \dfrac{4y}{3y+4} \Rightarrow 12xy + 16x = 12xy + 16y$

$\Rightarrow 16x = 16y \Rightarrow x = y$

$\therefore$ f is one-one $\Rightarrow f(x) = \dfrac{4x}{3x+4}$ **(2½ Marks)**

$\Rightarrow 4x = 3xy + 4y \Rightarrow x = \dfrac{4y}{4-3y}$

So $y \in R - \left\{\dfrac{4}{3}\right\}$

So, every element in $R - \left\{\dfrac{4}{3}\right\}$ has pre-image in $R - \left\{-\dfrac{4}{3}\right\}$

Hence, f is onto. **(2½ Marks)**

**14.** A function $f: [-4, 4] \to [0, 4]$ is given by $f(x) = \sqrt{16 - x^2}$

f (x) is not one-one:-

Let if possible f (x) is one-one and let $x_1, x_2 \in [-4, 4]$ such that $f(x_1) = f(x_2)$

$\Rightarrow \sqrt{16 - x_1^2} = \sqrt{16 - x_2^2}$

$\Rightarrow 16 - x_1^2 = 16 - x_2^2$

$\Rightarrow x_1 = \pm x_2$

Hence f (x) is not one-one. **(2 Marks)**

f (x) is into :-

We know that,

$0 \le x^2, \le \infty$

$\Rightarrow -\infty \le -x^2 \le 0$

$\Rightarrow -\infty \le 16 - x^2 \le 16$

$\Rightarrow 0 \le \sqrt{16 - x^2} \le 4$

$\Rightarrow 0 \le f(x) \le 4$

Therefore range = [0, 4] = codomain

$\therefore$ f(x) is onto 　　　　　　　　　　　　　　　**(2 Marks)**

given f (a) = $\sqrt{7}$

$\Rightarrow \sqrt{16 - a^2} = \sqrt{7}$

$\Rightarrow 16 - a^2 = 7 \Rightarrow a^2 = 9$

$\Rightarrow \boxed{a = \pm 3}$ 　　　　　　　　　　　**(1 Mark)**

**15.** Given function if

$f(x) = x^2 + x + 1, f : N \to N$

Let $f(x_1) = f(x_2)$ when $x_1, x_2 \in$ N.

$x^2_1 + x_1 + 1 = x^2_2 + x_2 + 1$

$x^2_1 - x^2_2 = x_2 - x_1$ 　　　$[\because (a^2 - b^2) = (a - b)(a + b)]$

$(x_1 - x_2)(x_1 + x_2) + (x_1 - x_2) = 0$

$(x_1 - x_2)(x_1 + x_2 + 1) = 0$

$x_1 - x_2 = 0 \Rightarrow x_1 = x_2$

$\because x_1 + x_2 \ne -1$ (Sum of natural number is not negative)

So, $f(x_2) = f(x_1)$ only for $x_1 = x_2$

$\therefore f(x)$ is one-one function 　　　　　　**(1 Mark)**

$f(x) = x^2 + x + 1$

$f(x) = x^2 + x + 1 + \left(\dfrac{1}{2}\right)^2 - \left(\dfrac{1}{2}\right)^2 = \left(x + \dfrac{1}{2}\right)^2 + 1 - \dfrac{1}{4}$

$= \left(x + \dfrac{1}{2}\right)^2 + \dfrac{3}{4}$

$\left(x + \dfrac{1}{2}\right)^2$ is always positive

$\therefore f(x)$ is increasing function

If $x = 1, f(1) = 3$

$x = 2, f(2) = 7$

Range of $f(x)$ [3, 7, ...]

But $f(x)$ does not have 1, 2

$\therefore f(x)$ is an into function, not onto function. **(1 Mark)**

Let $f^{-1}$ denote inverse of $f$

$fof^{-1}(x) = x$ for all $x \in$ Range $(f)$

$f(f^{-1}(x)) = x$ for all $x \in$ Range $(f)$

$\Rightarrow [f^{-1}(x)]^2 + f^{-1}(x) + 1 = x$ for all $x \in$ Range $(f)$

$\Rightarrow [f^{-1}(x)]^2 + f^{-1}(x) + (1 - x) = 0$

$f^{-1}(x) = \dfrac{-1 \pm \sqrt{1 - 4(1)(1 - x)}}{2}$ 　$\left[\begin{array}{l}\because \text{ for } ax^2 + bx + c = 0 \\ x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}\end{array}\right]$

$f^{-1}(x) = \dfrac{-1 \pm \sqrt{4x - 3}}{2}$ 　　　　　**(2 Marks)**

**16.** Let $x_1, x_2$ be any two elements of set A, such that

$f(x_1) = f(x_2)$

$\Rightarrow \dfrac{x_1 - 1}{x_1 - 2} = \dfrac{x_2 - 1}{x_2 - 2} \Rightarrow x_1 x_2 - 2x_1 - x_2 + 2$

$= x_1 x_2 - x_1 - 2x_2 + 2$

$\Rightarrow -2x_1 + x_1 = -2x_2 + x_2 \Rightarrow x_1 = x_2$

Thus, f is one-one, for all $x_1, x_2 \in$ A. 　　**(1 Mark)**

Let y be an arbitrary element of B, then f(x) = y

$\Rightarrow \dfrac{x - 1}{x - 2} = y, x \ne 2 \Rightarrow x = \dfrac{1 - 2y}{1 - y}$

Clearly, $x = \dfrac{1 - 2y}{1 - y}$ is a real number for all $y \ne 1$.

$\Rightarrow$ Corresponding to each $y \in B$, there exists

$\dfrac{1 - 2y}{1 - y} \in$ A, such that $f\left(\dfrac{1 - 2y}{1 - y}\right) = y$ 　**(2 Marks)**

Thus, f is onto $\Rightarrow$ f is invertible.

$x = \dfrac{1 - 2y}{1 - y} \Rightarrow f^{-1}(y) = \dfrac{1 - 2y}{1 - y}$

Hence, $f^{-1}(x) = \dfrac{1 - 2x}{1 - x}$ for all $x \in R - \{1\}$ **(1 Mark)**

**17.**

$$P(H_1/E) = \frac{\frac{3 \times 1}{5}}{\frac{3}{5} \times 1 + \frac{2}{5} \times \frac{1}{3}} = \frac{3}{3 + \frac{2}{3}}$$

$$= \frac{3}{\frac{9+2}{3}}$$

$$P(H_1/E) = \frac{9}{11}$$

ans $\frac{9}{11}$

Section - E

T.) Total possible relations from $B$ to $G$ = $2^{3 \times 2}$ = $2^6$ = 64

Total functions from $B$ to $G$ = $2^3$ = 8

III → 2nd option

$$f = \{(b_1, g_1), (b_2, g_2), (b_3, g_1)\}$$

It is not bijective as

$f(b_1) = g_1$  &  $f(b_3) = g_1$

As  $f(b_1) = f(b_3)$
though  $b_1 \neq b_3$
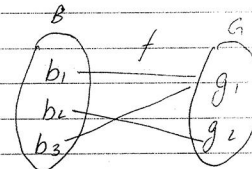
∴ It is not one one as for $b_1$ & $b_3$ are related
to same element $g_1$
As it is not one one, hence it is not bijective

**OR**

$f : B \rightarrow G$

$f = \{(b_1, g_1), (b_2, g_2), (b_3, g_1)\}$

Since $f(b_1) = g_1$ and $f(b_3) = g_1$

So f is not one-one.

Range of f = $\{g_1, g_2\}$ = G = codomain

So f is onto function

Hensce f is not bijective.                                                    **(2 Marks)**

**INVERSE TRIGONOMETRIC FUNCTIONS**

**Identities**

(i) $\tan^{-1} x \pm \tan^{-1} y = \tan^{-1}\left(\dfrac{x \pm y}{1 \mp xy}\right)$

(ii) $\sin^{-1} x \pm \sin^{-1} y = \sin^{-1}\left\{x\sqrt{1-y^2} \pm y\sqrt{1-x^2}\right\}$

(iii) $\cos^{-1} x \pm \cos^{-1} y = \cos^{-1}\left\{xy \mp \sqrt{1-x^2}\sqrt{1-y^2}\right\}$

(iv) $\sin^{-1} x + \cos^{-1} x = \dfrac{\pi}{2}$, (v) $\tan^{-1} x + \cot^{-1} x = \dfrac{\pi}{2}$

(vi) $\sec^{-1} x + \cosec^{-1} x = \dfrac{\pi}{2}$

(vii) $2\tan^{-1} x = \tan^{-1}\left(\dfrac{2x}{1-x^2}\right) = \sin^{-1}\left(\dfrac{2x}{1+x^2}\right) = \cos^{-1}\left(\dfrac{1-x^2}{1+x^2}\right)$

$y = \tan(\tan^{-1}x)$

$y = \cos(\cos^{-1}x)$
$y = \sin(\sin^{-1}x)$

$y = \tan^{-1}(\tan x)$

$y = \sin^{-1}(\sin x)$

$y = \cos^{-1}(\cos x)$

**y = sin⁻¹x**
$x \in [-1, 1]$
$y \in \left[-\dfrac{\pi}{2}, \dfrac{\pi}{2}\right]$

$f(x) = \sin^{-1}(x)$

**y = cos⁻¹x**
$x \in [-1, 1]$
$y \in [0, \pi]$

$f(x) = \cos^{-1}(x)$

**y = cosec⁻¹x**
$x \in R - (-1, 1)$
$y \in \left[-\dfrac{\pi}{2}, \dfrac{\pi}{2}\right] - \{0\}$

$f(x) = \cosec^{-1}(x)$

**y = sec⁻¹x**
$x \in R - (-1, 1)$
$y \in [0, \pi] - \left\{\dfrac{\pi}{2}\right\}$

$f(x) = \sec^{-1}(x)$

**y = tan⁻¹x**
$x \in (-\infty, \infty)$
$y \in \left(-\dfrac{\pi}{2}, \dfrac{\pi}{2}\right)$

$f(x) = \tan^{-1}(x)$

**y = cot⁻¹x**
$x \in (-\infty, \infty)$
$y \in (0, \pi)$

$f(x) = \cot^{-1}(x)$
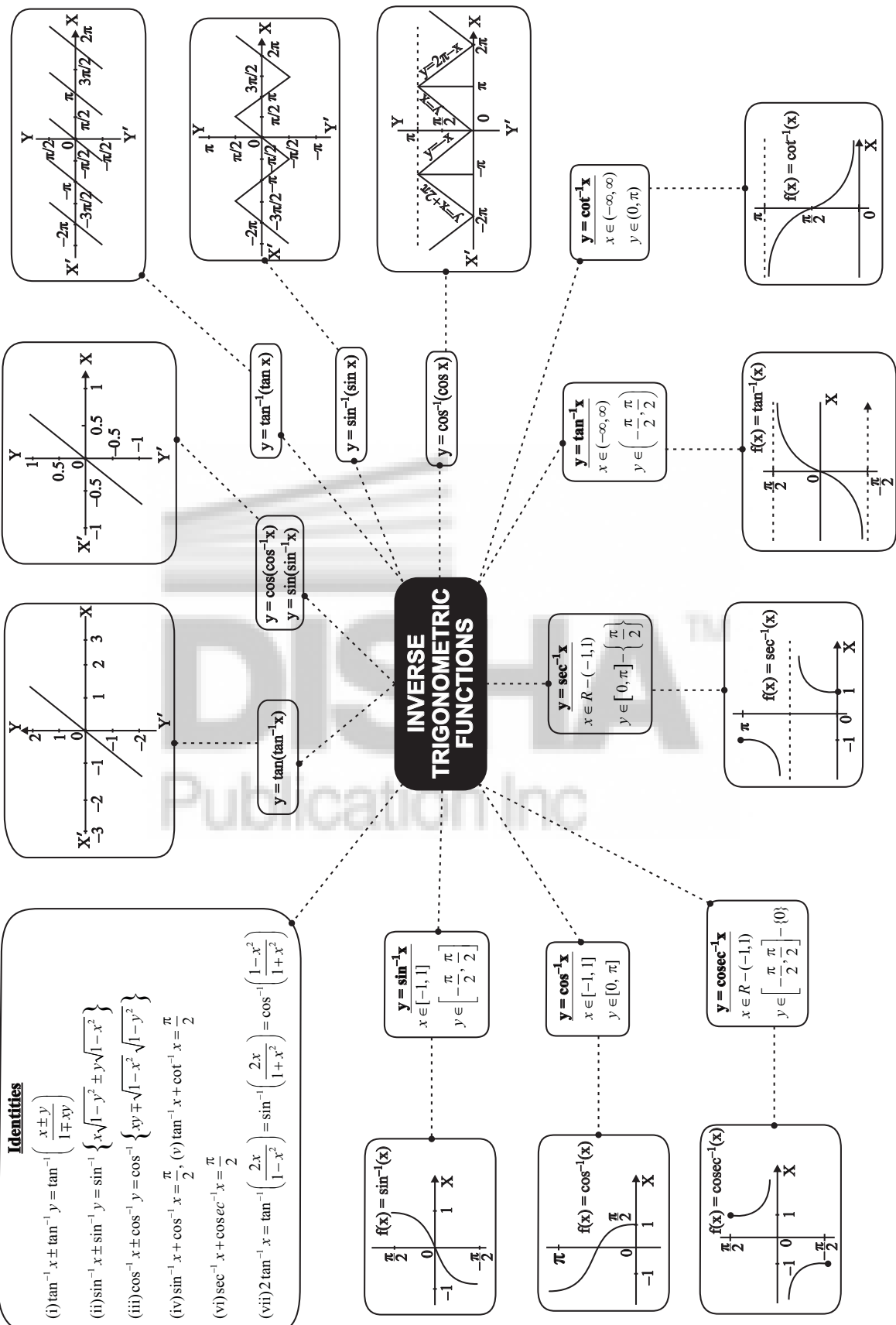
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**3rd Level of Division : Skillwise Division**

Each Question in the topic has been further divided skillwise using following codes:

K Knowledge    U Understanding    Ap Application    A Analysis

# 1 CHAPTER

# Electric Charges and Fields

---

**1**     *Multiple Choice Questions (1 Mark)*

**1.** A steady current of 8 mA flows through a wire. The number of electrons passing through a cross-section of the wire in 10 s is     **[All India 2023, Ap]**

(a) $4.0 \times 10^{16}$
(b) $5.0 \times 10^{17}$
(c) $1.6 \times 10^{16}$
(d) $1.0 \times 10^{17}$

**2.** A negatively charged object X is repelled by another charged object Y. However an object Z is attracted to object Y. Which of the following is the most possible for the object Z ?     **[All India 2022, Term-I, K]**

(a) positively charged only
(b) negatively charged only
(c) neutral or positively charged
(d) neutral or negatively charged

**3.** In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges +3e, +5e and –3e respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres ? **[All India 2022, Term-I, U]**

(a) +5e, –4e, +5e
(b) +6e, +6e, –7e
(c) –4e, +3.5e, +5.5e
(d) +5e, –8e, +7e

**4.** An object has charge of 1 C and gains $5.0 \times 10^{18}$ electrons. The net charge on the object becomes –

**[All India 2022, Term-I, Ap]**

(a) –0.80 C
(b) +0.80 C
(c) +1.80 C
(d) +0.20 C

**4**     *Very Short Answer Questions (1 Mark)*

**5.** Does the charge given to a metallic sphere depend on whether it is hollow or solid? Give reason for your answer. **[Delhi 2017, U]**

---

**1**     *Multiple Choice Questions (1 Mark)*

**1.** An infinite long straight wire having a charge density $\lambda$ is kept along y′y axis in x - y plane. The Coulomb force on a point charge q at a point P(x, 0) will be **[Delhi 2024, A]**

(a) attractive and $\dfrac{q\lambda}{2\pi\varepsilon_0 x}$
(b) repulsive and $\dfrac{q\lambda}{2\pi\varepsilon_0 x}$
(c) attractive and $\dfrac{q\lambda}{\pi\varepsilon_0 x}$
(d) repulsive and $\dfrac{q\lambda}{\pi\varepsilon_0 x}$

2. According to Coulomb's law, which is the correct relation for the following figure? **[CBSE Sample 2022-23, U]**

$q_1$ $\overrightarrow{F_{12}}$ $\overrightarrow{F_{21}}$ $q_2$
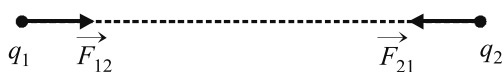
(a) $q_1\,q_2 > 0$
(b) $q_1\,q_2 < 0$
(c) $q_1\,q_2 = 0$
(d) $1 > q_1 / q_2 > 0$

3. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$ respectively. The point on x axis at which net electric field is zero due to these charges is-

**[All India 2021-22, Term-I, Ap]**

(a) 8L
(b) 4L
(c) 2L
(d) L

4. Two point charges placed in a medium of dielectric constant 5 are at a distance r between them, experience an electrostatic force 'F'. The electrostatic force between them in vacuum at the same distance r will be-

**[All India 2021-22, Term-I, Ap]**

(a) 5F
(b) F
(c) F/2
(d) F/5

5. A small object with charge q and weight mg is attached to one end of a string of length 'L' attached to a stationary support. The system is placed in a uniform horizontal electric field 'E', as shown in the accompanying figure. In the presence of the field, the string makes a constant angle $\theta$ with the vertical. The sign and magnitude of q-

**[All India 2021-22, Term-I, A]**
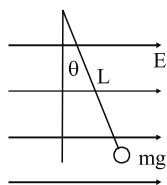
(a) positive with magnitude mg/E

(b) positive with magnitude (mg/E) tan$\theta$

(c) negative with magnitude mg/E tan$\theta$

(d) positive with magnitude E tan$\theta$/mg

6. The magnitude of electric field due to a point charge 2q, at distance r is E. Then the magnitude of electric field due to a uniformly charged thin spherical shell of radius R with total charge q at a distance $\frac{r}{2}$ (r >> R) will be
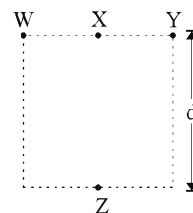
**[All India 2022, Term-I, Ap]**

(a) $\frac{E}{4}$
(b) 0
(c) 2E
(d) 4E

7. Three charges q, $-q$ and $q_0$ are placed as shown in figure. The magnitude of the net force on the charge $q_0$ at point O is $\left[ k = \dfrac{1}{(4\pi\varepsilon_0)} \right]$ **[All India 2022, Term-I, A]**
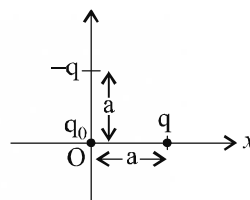
(a) 0
(b) $\dfrac{2kqq_0}{a^2}$
(c) $\dfrac{\sqrt{2}kqq_0}{a^2}$
(d) $\dfrac{1}{\sqrt{2}}\dfrac{kqq_0}{a^2}$

8. Four objects W, X, Y and Z each with charge $+q$ are hold fixed at four points of a square of side d as shown in the figure. Objects X and Z are on the midpoints of the sides of the square. The electrostatic force exerted by object W on object X is F. Then the magnitude of the force exerted by object W on Z is. **[All India 2022, Term-I, U]**
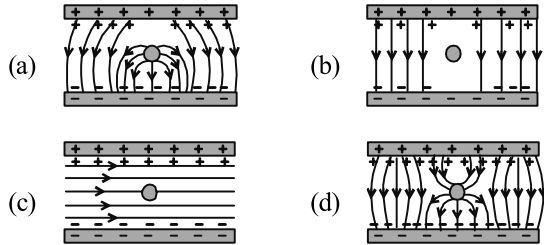
(a) $\dfrac{F}{7}$
(b) $\dfrac{F}{5}$
(c) $\dfrac{F}{3}$
(d) $\dfrac{F}{2}$

**9.** Which of the diagrams correctly represents the electric field between two charged plates if a neutral conductor is placed in between the plates ?

**[All India 2022, Term-I, Ap]**

(a)          (b)

(c)          (d)

---
**2** | *Fill in the Blanks* | *(1 Mark)*
---

**10.** The physical quantity having SI unit $NC^{-1} m$ is _____.

**[Delhi 2020, K]**

---
**3** | *Assertion Reason/Two Statement Type Questions (1 Mark)*
---

**11.** **Assertion (A) :** A negative charge in an electric field moves along the direction of the electric field.

**Reason (R) :** On a negative charge a force acts in the direction of the electric field.

**[All India 2022, Term-I, K]**

Select the most appropriate answer from the options given :

(a) Both (A) & (R) are true and (R) is the correct explanation of (A)

(b) Both (A) & (R) are true and (R) is not the correct explanation of (A)

(c) (A) is true but (R) is false

(d) (A) is false and (R) is also false

---
**4** | *Very Short Answer Questions (1 Mark)*
---

**12.** Draw the pattern of electric field lines, when a point charge –Q is kept near an uncharged conducting plate.

**[Delhi 2019, U]**

---
**5** | *Short Answer Questions (2 or 3 Marks)*
---

**13.** (a) Four points charges of 1 µC, –2 µC, 1 µC and –2 µC are placed at the corners A, B, C and D respectively, of a square of side 30 cm. Find the net force acting on a charge of 4µC placed at the centre of the square.

**[All India 2024, Ap]**

**OR**

(b) Three point charges, 1 pC each are kept at the vertices of an equilateral triangle of side 10 cm. Find the net electric field at the centroid of triangle.

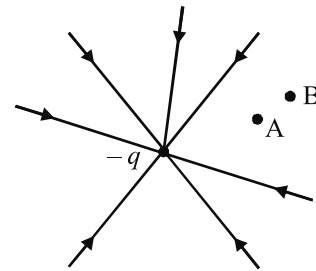**[All India 2024, Ap]**

**14.** Two identical point charges, q each, are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

**[All India 2019, U]**

**15.** The field lines of a negative point charge are as shown in the figure. Does the kinetic energy of a small negative charge increase or decrease in going from B to A?

**[All India 2015, A]**



**16.** Two equal balls with equal positive charge 'q' coulombs are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two? **[All India 2014, Ap]**

**17.** Two charged conducting spheres of radii a and b are connected to each other by a wire. Find the ratio of the electric fields at their surfaces.

**[Set-II, All India 2023, Ap]**

**18.** Two point charges of + 1 µC and + 4 µC are kept 30 cm apart. How far from the + 1 µC charge on the line joining the two charges, will the net electric field be zero ?
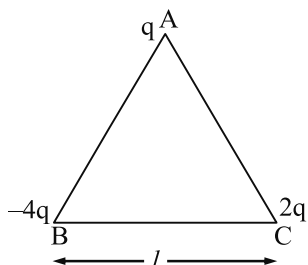
**[All India 2020, Ap]**

**19.** Four point charges Q, q, Q and q are placed at the corners of a square of side '*a*' as shown in the figure.
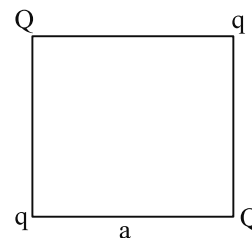


Find the resultant electric force on a charge Q.

**[All India 2018, Ap]**

**20.** Three point charges q, –4q and 2q are placed at the vertices of an equilateral triangle ABC of side '$\ell$' as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q.



[All India 2018, **Ap**]

**21.** A charge is distributed uniformly over a ring of radius '$a$'. Obtain an expression for electric intensity $E$ at a point on the axis of ring. Hence show that for points at large distances from ring, it behaves like a point charge.

[Delhi 2016, **Ap**]

---

> *Topic-3:* **Electric Flux, Electric Dipole, Dipole in a Uniform External Field and Continuous Charge Distribution**

**1** _Multiple Choice Questions (1 Mark)_

**1.** An electric dipole placed in an electric field of intensity $2 \times 10^5$ N/C at an angle of 30° experiences a torque equal to 4 Nm. The charge on the dipole of dipole length 2 cm is

[CBSE Sample 2023-24, **Ap**]

(a)  7 μC
(b)  8 mC
(c)  2 mC
(d)  5 mC

**2.** A charge Q is placed at the centre of a cube. The electric flux through one if its face is          [Delhi 2023, **Ap**]

(a)  $\dfrac{Q}{\varepsilon_0}$

(b)  $\dfrac{Q}{6\varepsilon_0}$

(c)  $\dfrac{Q}{8\varepsilon_0}$

(d)  $\dfrac{Q}{3\varepsilon_0}$

**3.** An electric dipole of moment p is placed parallel to the uniform electric field. The amount of work done in rotating the dipole by 90° is-          [All India 2021-22, Term-I, **Ap**]

(a)  2pE
(b)  pE
(c)  pE/2
(d)  Zero

**4.** A cylinder of radius r and length l is placed in an uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by-

[All India 2021-22, Term-I, **A**]

(a)  zero
(b)  $\pi r^2$
(c)  $E\pi r^2$
(d)  $2 E\pi r^2$

**5.** Consider an uncharged conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then,     [All India 2021-22, Term-I, **A**]

(a)  negative and uniformly distributed over the surface of sphere

(b)  positive and uniformly distributed over the surface of sphere

(c)  negative and appears at a point the surface of sphere closest to point charge.

(d)  Zero

**6.** A square sheet of side 'a' is lying parallel to XY plane at $z = a$. The electric field in the region is $\vec{E} = cz^2\hat{k}$. The electric flux through the sheet is     [All India 2021-22, Term-I, **Ap**]

(a)  $a^4 c$

(b)  $\dfrac{1}{3} a^3 c$

(c)  $\dfrac{1}{3} a^4 c$

(d)  0

**7.** If the net electric flux through a closed surface is zero, then we can infer          [All India 2020, **Ap**]

(a)  no net charge is enclosed by the surface.

(b)  uniform electric field exists within the surface.

(c)  electric potential varies from point to point inside the surface.

(d)  charge is present inside the surface.

**8.**  An electric dipole consisting of charges $+q$ and $-q$ separated by a distance $L$ is in stable equilibrium in a uniform electric field . The electrostatic potential energy of the dipole is                    **[All India 2020, K]**

(a)  $qLE$                    (b)  zero

(c)  $-qLE$                   (d)  $-2\,qEL$

---

**2**　　　　*Fill in the Blanks*　　　　*(1 Mark)*

---

**9.**  A point charge is placed at the centre of a hollow conducting sphere of internal radius '$r$' and outer radius '$2r$'. The ratio of the surface charge density of the inner surface to that of the outer surface will be _____ .

**[Delhi 2020, Ap]**

---

**4**　　*Very Short Answer Questions (1 Mark)*

---

**10.**  A charge 'q' is moved from a point A above a dipole of dipole moment 'p' to a point B below the dipole in equatorial plane without acceleration. Find the work done in the process.                    **[All India 2016, Ap]**
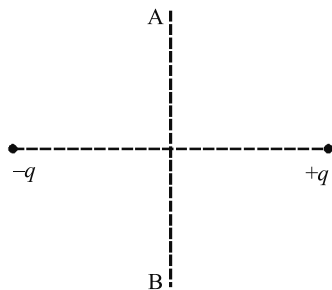


**11.**  How does the electric flux due to a point charge enclosed by a spherical surface get affected when its radius is increased ?                    **[Delhi 2016, K]**

**12.**  What is the electric flux through a cube of side 1 cm which encloses an electric dipole?                    **[Delhi 2015, Ap]**

---

**5**　　*Short Answer Questions (2 or 3 Marks)*

---

**13.**  (a)  Define the term 'electric flux' and write its dimensions.                    **[All India 2024, K]**

(b)  A plane surface, in shape of a square of side 1 cm is placed in an electric field $\vec{E} = \left(100\,\dfrac{N}{C}\right)\hat{i}$ such that the unit vector normal to the surface is given by $\hat{n} = 0.8\hat{i} + 0.6\hat{k}$. Find the electric flux through the surface.                    **[All India 2024, Ap]**

**14.**  An electric dipole of dipole moment $(\vec{p})$ is kept in a uniform electric field $\vec{E}$. Show graphically the variation of torque acting on the dipole ($\tau$) with its orientation ($\theta$) in the field. Find the orientation in which torque is (i) zero and (ii) maximum.                    **[Set-II, Delhi 2023, U]**

**15.**  Derive the expression for the torque acting on an electric dipole, when it is held in a uniform electric field. Identify the orientation of the dipole in the electric field, in which it attains a stable equilibrium.                    **[Delhi 2020, U]**

**16.**  Two small identical electric dipoles AB and CD, each of dipole moment $\vec{p}$ are kept at an angle of 120° to each other in an external electric field $\vec{E}$ pointing along the x-axis as shown in the figure. Find the
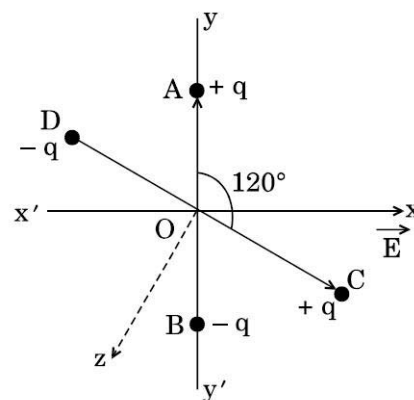


(a)  dipole moment of the arrangement, and                    **[All India 2020, U]**

(b)  magnitude and direction of the net torque acting on it.                    **[All India 2020, U]**

**17.** Derive an expression for the electric field at any point on the equatorial line of an electric dipole.

[**Delhi 2019, Ⓤ**]

**18.** Define electric dipole moment. Is it a scalar or a vector? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.

[**All India 2013, Ⓤ**]

**19.** Given a uniform electric field $\overrightarrow{E} = 2 \times 10^3\, \hat{i}$ N/C, find the flux of this field through a square of side 20 cm, whose plane is parallel to the $y$–$z$ plane. What would be the flux through the same square, if the plane makes an angle of 30° with the $x$-axis ? [**Delhi 2014, Ⓐⓟ**]

**20.** A hollow cyindrical box of length 1 m and area of cross-section 25 cm$^2$ is placd in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50\, x\hat{i}$ , where E is in NC$^{-1}$ and x is in metres. Find : [**Delhi 2013, Ⓐ**]

(i) Net flux through the cylinder
(ii) Charge enclosed by the cylinder
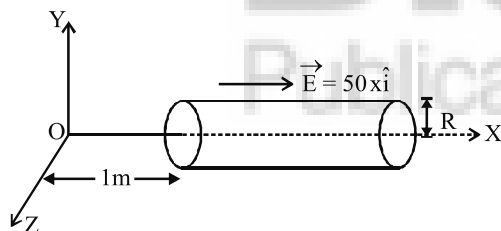


**21.** A thin metallic spherical shell of radius R carries a charge $Q$ on its surface. A point charge $\dfrac{Q}{2}$ is placed at its centre $C$ and an other charge $+2Q$ is placed outside the shell at a distance $x$ from the centre as shown in figure. Find (i) the force on the charge at the centre of shell and at the point $A$ and (ii) the electric flux through the shell.

[**Delhi 2015, Ⓐⓟ**]
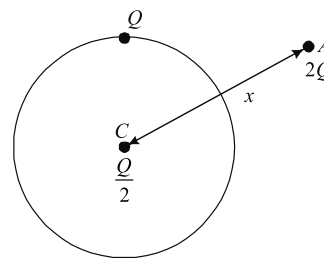
**22.** (i) Derive the expression for electric field at a point on the equatorial line of an electric dipole.

[**Delhi 2017, Ⓤ**]

(ii) Depict the orientation of the dipole in (i) stable, (ii) unstable equilibrium in a uniform electric field.

[**Delhi 2017, Ⓚ**]

**23.** (a) "The outward electric flux due to charge + Q is independent of the shape and size of the surface which encloses it." Give two reasons to justify this statement. [**All India 2015, Ⓚ**]

(b) Two identical circular loops '1' and '2' of radius $R$ each have linear charge densities $-\lambda$ and $+\lambda$ C/m respectively. The loops are placed coaxially with their centres $R\sqrt{3}$ distance apart. Find the magnitude and direction of the net electric field at the centre of loop '1'. [**All India 2015, Ⓐ**]

**24.** (a) Deduce the expression for the torque acting on a dipole of dipole moment $\vec{p}$ in the presence of a uniform electric field $\vec{E}$ . [**All India 2014, Ⓤ**]

(b) Consider two hollow concentric spheres, S$_1$ and S$_2$, enclosing charges 2Q and 4Q respectively as shown in the figure. (i) Find out the ratio of the electric flux through them. (ii) How will the electric flux through the sphere S$_1$ change if a medium of dielectric constant '$\varepsilon_r$' is introduced in the space inside S$_1$ in place of air? Deduce the necessary expression.

[**All India 2014, Ⓤ**]
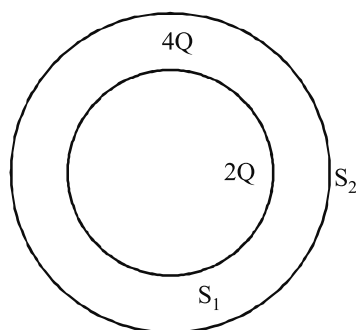
**25.** An electric dipole of dipole moment $\vec{p}$ consists of point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field $\vec{E}$ due to the dipole at a distance $x$ from the centre of the dipole on its axis line in terms of the dipole moment $\vec{p}$. Hence show that in the limit $x \gg a$, $\vec{E} \rightarrow 2\vec{p}/(4\pi\varepsilon_0 x^3)$.

**[Delhi 2015, U]**

**26.** (a) Derive an expression for the electric field E due to a dipole of length '2a' at a point distant r from the centre of the dipole on the axial line. **[All India 2017, U]**

(b) Draw a graph of E versus r for r >> a.

**[All India 2017, U]**

(c) If this dipole were kept in a uniform external electric field $E_0$, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases. **[All India 2017, U]**

---

📝 **Topic-4:** **Gauss's Law and its Applications**

---

**1** | **Multiple Choice Questions (1 Mark)**

**1.** Two parallel large thin metal sheets have equal surface densities $26.4 \times 10^{-12}$ C/m² of opposite signs. The electric field between these sheets is- **[All India 2021-22, Term-I, Ap]**

(a) 1.5 N/C  (b) $1.5 \times 10^{-16}$ N/C

(c) $3 \times 10^{-10}$ N/C  (d) 3 N/C

**2.** Which statement is true for Gauss law-

**[All India 2021-22, Term-I, K]**

(a) All the charges whether inside or outside the gaussian surface contribute to the electric flux.

(b) Electric flux depends upon the geometry of the gaussian surface.

(c) Gauss theorem can be applied to non-uniform electric field.

(d) The electric field over the gaussian surface remains continuous and uniform at every point.

**3.** The electric flux through a closed Gaussian surface depends upon **[Delhi 2020, K]**

(a) Net charge enclosed and permittivity of the medium

(b) Net charge enclosed, permittivity of the medium and the size of the Gaussian surface

(c) Net charge enclosed only

(d) Permittivity of the medium only

**5** | **Short Answer Questions (2 or 3 Marks)**

**4.** Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for r $\leq$ R and r $\geq$ R. **[All India 2020, K + U]**

**5.** State Gauss's law on electrostatics and derive an expression for the electric field due to a long straight thin uniformly charged wire (linear charge density $\lambda$) at a point lying at a distance r from the wire. **[Delhi 2020, U]**

**6.** Two long charged plane sheets of charge densities $\sigma$ and $-2\sigma$ C/m² are arranged vertically with a separation of d between them. Deduce the expressions for the electric field at points (i) to the left of first sheet, (ii) to the right of second sheet and (iii) between two sheets.

**[All India 2019, Ap]**

**7.** A spherical conducting shell of inner radius $r_1$ and outer radius $r_2$ has charge $Q$.

   (a) A charge q is placed at the centre of the shell. Find out the surface charge density on the inner and outer surfaces of the shell. **[All India 2020, Ap]**

   (b) Is the electric field inside a cavity (with no charge) zero; independent of fact whether the shell is spherical or not? Explain. **[All India 2019, U]**

**8.** (a) Use Gauss's law to derive the expression for the electric field (E) due to a straight uniformly charged infinite line of charge density $\rho$ C/m. **[All India 2018, U]**

   (b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge. **[All India 2018, U]**

**9.** Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density $\sigma$. **[All India 2017, U]**

**10.** Use Gauss's law to find the electric field due to a uniformly charged infinite plane sheet. What is the direction of field for positive and negative charge densities ? **[All India 2016, U]**

**11.** Given the electric field in the region $\vec{E} = 2x\hat{i}$, find the net electric flux through the cube and the charge enclosed by it. **[Delhi 2015, A]**



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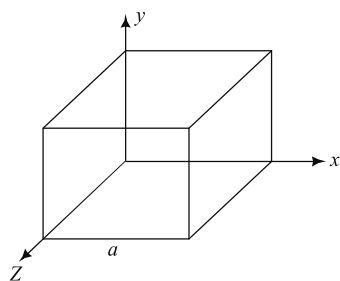
**6** | *Long Answer Questions (5 Marks)*

**12.** (i) A thin spherical shell of radius R has a uniform surface charge density $\sigma$. Using Gauss' law, deduce an expression for electric field (i) outside and (ii) inside the shell. **[All India 2024, U]**

   (ii) Two long straight thin wires AB and CD have linear charge densities $10\,\mu$C/m and $-20\,\mu$C/m, respectively. They are kept parallel to each other at a distance 1 m. Find magnitude and direction of the net electric field at a point midway between them.

**[All India 2024, Ap]**

**13.** (i) Using Gauss's law, show that the electric field $\vec{E}$ at a point due to a uniformly charged infinite plane sheet is given by $\vec{E} = \dfrac{\sigma}{2\varepsilon_0}\hat{n}$ where symbols have their usual meanings. **[Delhi 2024, U]**
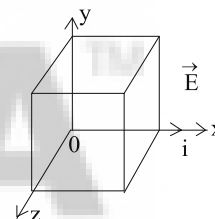
   (ii) Electric field $\vec{E}$ in a region is given by $\vec{E} = \left(5x^2 + 2\right)\hat{i}$ where E is in N/C and x is in meters.

   A cube of side 10 cm is placed in the region as shown in figure.



   Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube.

**[Delhi 2024, A]**

**14.** (i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density $\lambda$. **[All India 2023, U]**

   (ii) An infinitely long positively charge straight wire has a linear charge density $\lambda$. An electron is revolving in a circle with a constant speed $v$ such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density $\lambda$ on the wire. **[All India 2023, U]**

   (iii) Draw a graph of kinetic energy as a function of linear charge density $\lambda$. **[All India 2023, U]**

**15.** (a) Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution $\sigma$ and radius $R$ at a point lying at a distance $x$ from the centre of shell, such that

(i) $0 < x < R$, and (ii) $x > R$.    **[All India 2020, U]**

(b) An electric field is uniform and acts along $+x$ direction in the region of positive $x$. It is also uniform with the same magnitude but act in $-x$ direction in the region of negative $x$. The value of the field is $E = 200$ N/C for $x > 0$ and $E = -200$ N/C for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the $x$-axis so that one flat face is at $x = +10$ cm and the other is at $x = -10$ cm. Find:

(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder.

**[All India 2020, U]**

**16.** (a) Define electric flux. Is it a scalar or a vector quantity? A point charge $q$ is at a distance of $d/2$ directly above the centre of a square of side $d$, as shown in the figure. Use Gauss's law to obtain the expression for the electric flux through the square.    **[All India 2018, U]**
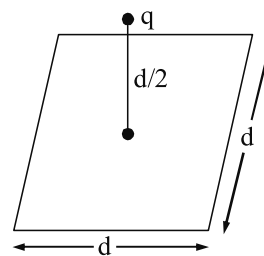


(b) If the point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected.

**[All India 2018, Ap]**

**17.** Using Gauss' law deduce the expression for the electric field due to a uniformly charged spherical conducting shell of radius R at a point (i) outside and (ii) inside the shell. Plot a graph showing variation of electric field as a function of r > R and r < R. (r being the distance from the centre of the shell).    **[All India 2013, U]**

# Solutions

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**Topic-1:** *Electric Charge, Conductors & Insulators and Basic Properties of Electric Charge*

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**1.** **(b)** We have
$q = It \Rightarrow q = 8 \times 10^{-3} \times 10 = 0.08\,C = 8 \times 10^{-2}\,C$
So, no. of electrons $= 6.25 \times 10^{18} \times 8 \times 10^{-2}$
$= 50.00 \times 10^{16} = 5 \times 10^{17}$
**(1 Mark)**

> **Note**
>
> *1 Coulomb charge means charge on $6.25 \times 10^{18}$ electrons.*

**2.** **(c)** As charged object Y repels negatively charged X so Y must be negatively charged object. And Z is attracted to Y so Z is neutral or positively charged. **(1 Mark)**

**3.** **(b)** Net charge of three spheres with charges +3e, +5e, –3e
$= +5e$.

Also net charge of +6e, +6e, –7e = +5e
So possible values for the final charge on the spheres are
+6e, +6e, –7e **(1 Mark)**

**4.** **(d)** The net charge on the object $= 1C - ne$ [$\because Q = ne$]
$= 1C - 5 \times 10^{18} \times 1.6 \times 10^{-19}\,C = +0.20\,C$ **(1 Mark)**

**5.** No, the charge given to a metallic sphere does not depend on whether it is hollow or solid because whatever charge is given to metallic sphere it will reside on its surface.
**(½ + ½ = 1 Mark)**

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**Topic-2:** *Coulomb's Law, Forces between Multiple Charges, Electric Field and Electric Field Lines*

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**1.** **(b)** The electric field at point P is $E = \dfrac{\lambda}{2\pi\varepsilon_0 x}$
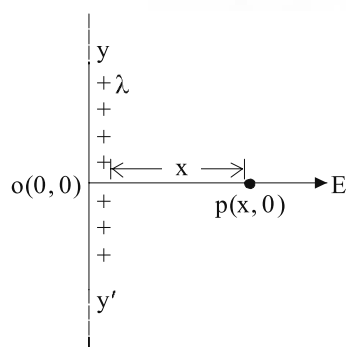


$\therefore$ The force on point charge q at point P is

$F = qE = \dfrac{q\lambda}{2\pi\varepsilon_0 x}$ (repulsive) **[1 Mark]**

**2.** **(b)** $q_1 q_2 < 0$ **(1 Mark)**

**3.** **(c)** Let P is the observation point at a distance r from –2q and at (L+r) from +8q.
Given now, net EFI at P = 0

$\therefore \vec{E}_1$ = EFI (Electric Field Intensity) at P due to +8q

$\vec{E}_2$ = EFI (Electric Field Intensity) at P due to – 2q

$\left| \vec{E_1} \right| = \left| \vec{E_2} \right|$

$\therefore \dfrac{k(8q)}{(L+r)^2} = \dfrac{k(2q)}{r^2}$

$\therefore \dfrac{4}{(L+r)^2} = \dfrac{1}{(r)^2}$

$4r^2 = (L+r)^2 \Rightarrow 2r = L+r$
$r = L$
$\therefore$ P is at $x = L + L = 2L$ from origin **(1 Mark)**

**4.** **(a)** $\underset{r}{\overline{Q_1 \qquad\qquad Q_2}}$ $K = 5$

$$F = \frac{1}{4\pi\varepsilon_0 k}\frac{Q_1 Q_2}{r^2}$$

$\underset{}{\overline{Q_1 \qquad\qquad Q_2}}$ force in the charges in the air is

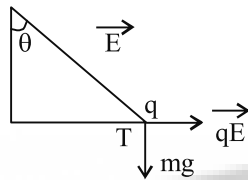$$F' = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

$= K F = 5 F$ **(1 Mark)**

**5.** **(b)** $F_e = mg\tan\theta$

$qE = mg\tan\theta$

$$q = \left(\frac{mg}{E}\right)\tan\theta$$



$$\tan\theta = \frac{F_e}{mg}$$

**(1 Mark)**

**6.** **(c)** Electric field due to point charge $\dfrac{K2q}{r^2} = E$

So electric field due to shell outside $\dfrac{Kq}{\left(\dfrac{r}{2}\right)^2} = 2\left(\dfrac{K2q}{r^2}\right) = 2E$

**(1 Mark)**

**7.** **(c)** Forces due to q is $F_q$ and that due to $-q$ $F_{-q}$ are as shown.

Net force $= \sqrt{F_q^2 + F_{-q}^2}$



$= \sqrt{F^2 + F^2}$ (As $F_{-q} = F_q$)

$= \sqrt{2}F = \dfrac{\sqrt{2}Kqq_0}{a^2}$ $\left(\because F = \dfrac{Kqq_0}{r^2}\right)$ **(1 Mark)**
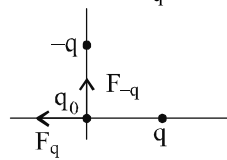
**8.** **(b)** $F = \dfrac{Kq^2}{(d/2)^2} = \dfrac{4Kq^2}{d^2}$



Let W exerts $F'$ force on Z
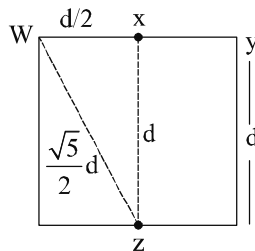
$\therefore F' = \dfrac{Kq^2}{\left(\dfrac{\sqrt{5}d}{2}\right)^2} = \left(\dfrac{4}{5}\right)\dfrac{Kq^2}{d^2} = \dfrac{F}{5}$

**(1 Mark)**

**9.** **(d)** Negative charge will appear on the surface of neutral conductor near positive plate and positive charge on surface of conductor near negative plate. Field lines start from positive plate end at –ve charge of ball and start from +ve charge on conductor to –ve plate. **(1 Mark)**
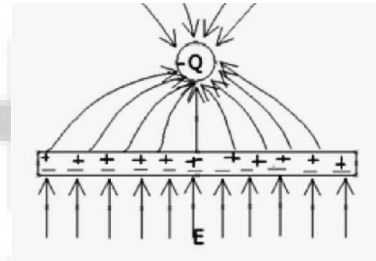
**10.** Voltage/potential difference.

$NmC^{-1} \Rightarrow J/C \Rightarrow V$ **(1 Mark)**

**11.** **(d)** –ve charge moves in the opposite direction to the electric field, as it experiences force in the direction opposite to electric field. **(1 Mark)**

**12.** The pattern of electric field lines, when a point charge –Q is kept near an uncharged conducting plate is given below:
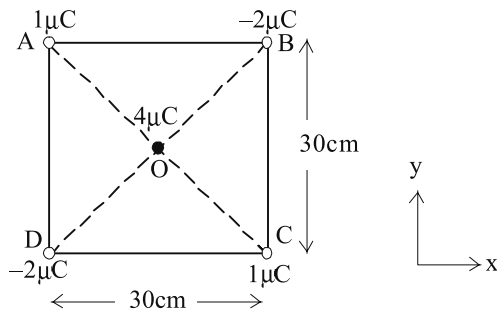


**(1 Mark)**

As we can see from figure, due to charge –Q, +q charge will be induced on the top surface of conducting plate and –q charge on the bottom surface of conducting plate. Therefore, Electric lines of forces should fall normally (90°) away from the conducting plate.

> **Note**
>
> *Electric lines of force do not pass through a conductor. Hence, the interior of the conductor is free from the influence of the electric field. Also, electric lines of force start from positive charges and end at negative charges.*

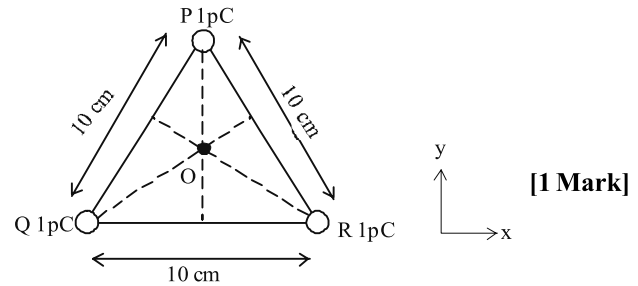**13.** **(a)** Net force acting on charge 4 µC is given by;

**[1 Mark]**

**(b)** Net Electric field at point 'O' (centroid of the triangle) is given by;

$$\vec{F}_{net} = \vec{F}_{OA} + \vec{F}_{OB} + \vec{F}_{OC} + \vec{F}_{OD} =$$

$$\frac{K(1\mu C)(4\mu C)}{(15 cm)^2}(\hat{i} - \hat{j}) + \frac{K(-2\mu C)(4\mu C)}{(15 cm)^2}(\hat{i} + \hat{j})$$

$$+ \frac{K(1\mu C)(4\mu C)}{(15 cm)^2}(-\hat{i} - \hat{j}) + \frac{K(-2\mu C)(4\mu C)}{(15 cm)^2}(-\hat{i} - \hat{j})$$

$$\Rightarrow \quad \vec{F}_{net} = 0 \qquad \qquad \textbf{[1 Mark]}$$

$$F_{net} = \vec{E}_{OP} + \vec{E}_{OQ} + \vec{E}_{OR}$$

$$= \frac{K.(1pC)}{(OP)^2}(-\hat{j}) + \frac{K(1pC)}{(OQ)}\left(+\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right) + \frac{K(1pC)}{(OR)^2}\left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right)$$

where, $OP = OQ = OR = 5\sqrt{3}$ cm

Hence, $\vec{E}_{net} = 0$ **[1 Mark]**

**14.**

> **Topper's Answer**

So, $F_q = 0 \Rightarrow (2-x)^2 = x^2$ OR $x = 1m$
(condition of equilibrium)

Now for any of the $q$ to be at equilibrium it is necessary for $Q$ to be negative to counteract for any repulsion faced by it due to the other positive charge $q$.

So, $F_q$ ($q$ placed at $A$)

$$F_q = \frac{1}{4\pi\varepsilon_0} \frac{q^2}{(2)^2} - \frac{1}{4\pi\varepsilon_0} \frac{qQ}{(1)^2}$$

For equilibrium, $F_q = 0$

$$OR \quad \frac{q^2}{4} = \frac{qQ}{1}$$

$$OR \quad |Q| = \frac{q}{4}$$

Hence, for the entire system to be in equilibrium, $Q$ should be placed in between the two charges (at a distance of 1m from either of them) and its value should be $-\frac{q}{4}$.

---

**15.** Since we know that a negative charge always experiences a force in the direction opposite to that of the electric field present, the negative charge will experience the force away from the centre. This will cause its motion to retard while moving from B to A. Hence, its kinetic energy will decrease in going from B to A. **(1 Mark)**

> *Note*
>
> *Alternate solution.*
>
> *Due to force of repulsion between two negative charge, the kinectic energy will decrease as the small negative charge tries to move towards the charge –q.*

**16.** Electric field lines due to any of the charge will not be able to pass through plastic because it is an insulation of electricity. And in the absence of an external electric field both the charges will not experience any force due to each other. **(1 Mark)**

**17.**
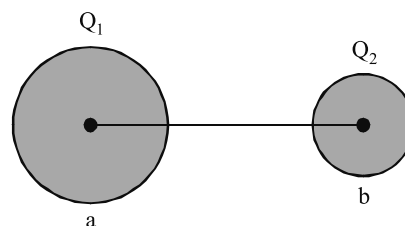


Let $Q_1$ and $Q_2$ be the charge on two sphere when they are connected by the wire.

As two sphere are connected by wire, they will have same potential.

So, $\dfrac{KQ_1}{a} = \dfrac{KQ_2}{b} \Rightarrow \dfrac{Q_1}{Q_2} = \dfrac{a}{b}$ **(1 Mark)**

Let $E_1$ and $E_2$ be the electric field at surface of 'a' and 'b'.

Then, $E_1 = \dfrac{KQ_1}{a^2}$ and $E_2 = \dfrac{KQ_2}{b^2}$ **(1 Mark)**

So, $\dfrac{E_1}{E_2} = \dfrac{Q_1}{Q_2} \cdot \dfrac{b^2}{a^2} = \dfrac{a}{b} \cdot \dfrac{b^2}{a^2} = \dfrac{b}{a}$ **(1 Mark)**

**18.**

*Topper's Answer*

**19.** Force on charge, $Q$ due to other charges is shown in the figure
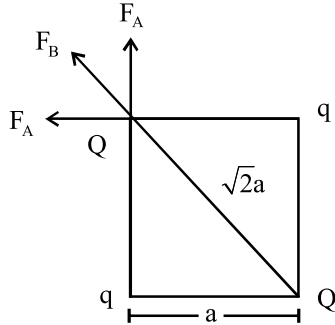


**(½ Mark)**

Here, $F_A$ is force acting on Q due to $q$

$F_B$ is force acting on Q due to Q

Using Coulomb's law

$$F_A = K\frac{Qq}{a^2} \text{ and } F_B = K\frac{Q^2}{a^2} \left[ \text{here, } K = \frac{1}{4\pi \in_\circ} \right]$$
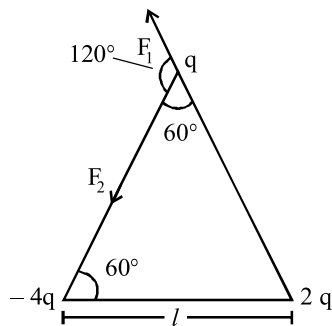
**(½ Mark)**

Net force is equal to resultant of two perpendicular forces $F_A$ (acting in different direction) + force $F_B$

$$F_{net} = \sqrt{2}\, F_A + F_B \Rightarrow F_{net} = k\left[ \sqrt{2}\frac{Qq}{a^2} + \frac{Q^2}{2a^2} \right] \quad \textbf{(1 Mark)}$$

**20.** The forces on the charge $q$ due to other charges are shown in the figure



The resultant electric force acting on the charge $q$ is the resultant of forces $F_1$ and $F_2$

Using Coulomb's law,

$$|F_1| = k\frac{2qq}{l^2} = k\frac{2q^2}{l^2} \text{ and}$$

$$|F_2| = k\frac{4qq}{l^2} = k\frac{4q^2}{l^2}$$

Now, resulant force

$$F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos\theta}$$

$$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos120°}$$

**(1 Mark)**

Resultant force

$$F = \sqrt{F_1^2 + F_2 - 2F_1F_2} \quad \left[ \because \cos120° = -\frac{1}{2} \right]$$

$$F = \sqrt{F_1^2 + F_2^2 - F_1F_2}$$

Since $F_2 = 2F_1$

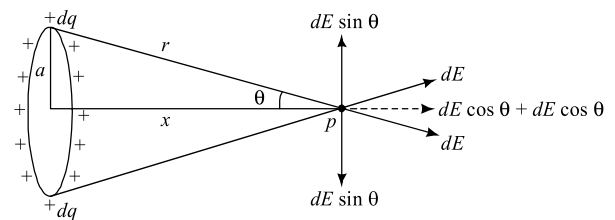$$\therefore \quad F = \sqrt{(F_1)^2 + (2F_1)^2 - 2F_1^2}$$

$$F = \sqrt{5F_1^2 - 2F_1^2}$$

$$F = F_1\sqrt{3}$$

$$F = \frac{K2q^2}{l^2} \times \sqrt{3} \quad \textbf{(1 Mark)}$$

**21.**

Suppose that the ring is placed with its plane perpendicular to the *x*-axis as shown in figure.

Electric field $d\vec{E}$ due to charge element $dq$ at point $p$, r distance from ring is

$$d\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{dq}{\pi^2}$$

Let $\lambda$ = linear charge density

$\therefore$ $\qquad\qquad \lambda = \dfrac{dq}{dl}$

where $dl$ = line element on ring

so $\qquad\qquad d\vec{E} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{\lambda dl}{r^2}$ **(1 Mark)**

As show in figure, the field $d\vec{E}$ has two components, the axial component $dE\cos\theta$ and the perpendicular component $dE\sin\theta$.

Since perpendicular components of any two diametrically opposite element are equal and opposite, they will cancel out in pairs. Only the axial components will add up to produce the resultant field $\vec{E}$ at point *P*, which is given by,

$$E = \int_0^{2\pi a} dE \cos\theta$$

$$E = \int_0^{2\pi a} \frac{1}{4\pi\varepsilon_0} \frac{\lambda dl}{r^2} \times \frac{x}{r} \quad (\because \cos\theta = \frac{x}{r})$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{r^3} \int_0^{2\pi a} dl$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{r^3} [l]_0^{2\pi a}$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{r^3} (2\pi a)$$

Now $\lambda = \dfrac{\text{Total charge } Q}{\text{Perimeter of ring} = 2\pi a}$

Also $r^2 = x^2 + a^2$ (from pythagorous thm.)

$\therefore$ $r^3 = (x^2 + a^2)^{3/2}$

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

$$E = \frac{1}{4\pi\varepsilon_0} \frac{Qx}{(x^2 + a^2)^{3/2}}$$ **(1 Mark)**

At large distance $x \gg a$,

$\therefore$ $\qquad\qquad x^2 + a^2 \approx x^2$

So, $E$ will become

$$E = \frac{1}{4\pi\varepsilon_0} \frac{Qx}{(x^2)^{3/2}}$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{Q}{x^2}$$

which is electric field due to a point charge. **(1 Mark)**
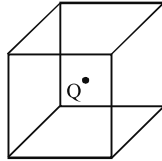
**Topic-3:** *Electric Flux, Electric Dipole, Dipole in a Uniform External Field and Continuous Charge Distribution*

**1.** **(c)** $q = \tau / [(2a) E \sin\theta] = \dfrac{4}{2 \times 10^{-2} \times 2 \times 10^5 \sin 30°}$

$= 2 \times 10^{-3} \, C = 2 \, mC$ **(1 Mark)**

**2.** **(b)** Total flux through cube is $\dfrac{Q}{\varepsilon_0}$



So, flux through one face is $\dfrac{\frac{Q}{\varepsilon_0}}{6}$ i.e. $\dfrac{Q}{6\varepsilon_0}$

**(1 Mark)**

**3.** **(b)** $W = pE (\cos\theta_1 - \cos\theta_2)$

$\theta_1 = 0°$

$\theta_2 = 90°$

$W = pE (\cos 0° - \cos 90°)$

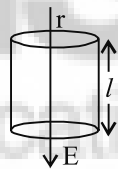$= pE (1 - 0) = pE$ **(1 Mark)**

**4.** **(a)** Since –ve electric flux

$= + $ ve flux electric flux enclosed
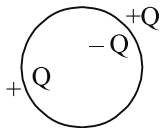
with a cylinder here



∴ Total Electric

Flux $= 0$. **(1 Mark)**

**5.** **(d)** Equal and opposite charges appear on the nearby conductor due to induction, but still net charge on the conductor is zero.



**(1 Mark)**

**6.** **(a)** Electric flux = Electric field × area

$= EA = cz^2\hat{k}.a^2\hat{k}$

$= ca^2\hat{k}.a^2\hat{k} = ca^4$ **(1 Mark)**

**7.** **(a)** According to Gauss's theorem

$\phi = \dfrac{\Sigma q_{in}}{\varepsilon_0}$

So, electric flux through a closed surface is zero if $\Sigma q_{in} = 0$ i.e. electric flux is zero if not net charge is enclosed by surface.

**(1 Mark)**

**Note**

*Electric field in is complete electric field. It may be partly due to charge within the surface and partly due to charge outside the surface. If there is no charge enclosed in the Gaussian surface, then = 0. The electric field due to a charge outside the Gaussian surface contributes zero net flux through the surface because as many lines due to that charge enter the surface as leave it.*

**8.** **(c)** Potential energy of a dipole in external field $U$ is given as

$U = -\vec{P} \cdot \vec{E}$

For stable equilibrium $\theta = 0°$

So, $U = -p \, E \cos 0° = -pE$

∴ $U = -qLE$ **(1 Mark)**

**9.** Charge $-q$ will be induced on the inner surface and $+q$ on the outer surface.

∴$\sigma_1 = \dfrac{-q}{4\pi r^2}$ $\sigma_2 = \dfrac{q}{4\pi(2r)^2} = \dfrac{\sigma_1}{\sigma_2} = \dfrac{4}{1}$ **(1 Mark)**

**10.** The net force on the charge is directed parallel to the dipole and hence perpendicular to its motion along AB.

∴ Work done $= 0$ **(1 Mark)**

**11.** According to Gauss's law, electric flux through a gaussian surface is

$\phi = \dfrac{q_{nc}}{\varepsilon_0}$ ...(i)

where $q = $ charge enclosed by gaussian surface.

As we see from, eqn (i) the flux is independent of radius of spherical gaussian surface. So, electric flux would remain unchanged, when the radius of spherical gaussian surface is increased. **(1 Mark)**

12. From gauss's law, electric flux

$$\phi = \frac{q}{\varepsilon_0} \qquad \textbf{(½ Mark)}$$

where $q$ = total charge enclosed in gaussian surface.

Here, total charge is zero (as electric dipole consists of two equal and opposite charge) within the cube. So, since $q = 0$, flux $\phi$ through cube is also zero. **(½ Mark)**

> *Note*
>
> *In Gauss law, which states that $\phi = \dfrac{q}{\varepsilon_0}$*
>
> *Electric flux, $\phi$ is due to all charges, outside or inside gaussian surface. But the term q, on the right side of Gauss's law, however represents only the charge inside gaussian surface.*

13. **(a)** Electric flux is defined as the number of electric field lines crossing per unit area.
Dimension of electric flux is $[ML^3 T^{-3}I^{-1}]$
**[1½ Marks]**

**(b)** $\vec{E} = 100 \dfrac{N}{C}\hat{i}, \vec{S} = 1cm^2 (0.8\hat{i} + 0.6\hat{k})$
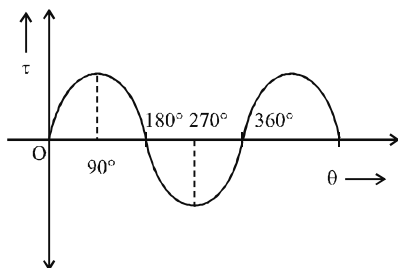
electric flux is given by;

$$\phi_E = \vec{E}.\vec{S} = \left(100\frac{N}{C}\hat{i}\right).[1cm^2 (0.8\hat{i} + 0.6\hat{k})]$$

$$\Rightarrow \quad \phi_E = 80\,N\,cm^2\,C^{-1} \qquad \textbf{[1½ Marks]}$$

14. We know that torque acting on a dipole placed in uniform electric field is given as

$$\tau = PE\sin\theta$$

So, graph between '$\tau$' and 'E' will look like as shown below



**(1 Mark)**

(i) For $\tau = 0 \Rightarrow PE\sin\theta = 0 \Rightarrow \sin\theta = 0 \Rightarrow \theta = 0°$ or $180°$

So, when dipole moment is parallel or anti-parallel to electric field, net torque on it is zero. **(½ Mark)**

(ii) For maximum torque

$$\frac{d\tau}{d\theta} = 0 \quad \Rightarrow \frac{d}{d\theta}(PE\sin\theta) = 0 \Rightarrow \cos\theta = 0$$

$$\Rightarrow \theta = 90° \text{ or } 270° \qquad \textbf{(½ Mark)}$$

15. Torque on a dipole in a uniform electric field:

Consider an electric dipole consisting of charges $+q$ and $-q$ and of length $2a$ placed in a uniform electric field making an angle $\theta$ with it. It has a dipole moment of magnitude $= q \times 2a$ **(½ Mark)**

Since force exerted on charge $+q$ and $-q$ by field is equal and opposite $(qE)$, therefore the net translating force on a dipole in a uniform electric field is zero. **(½ Mark)**
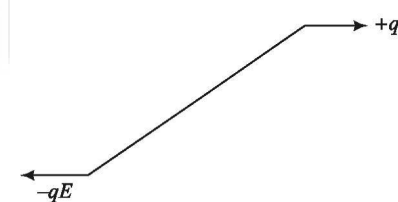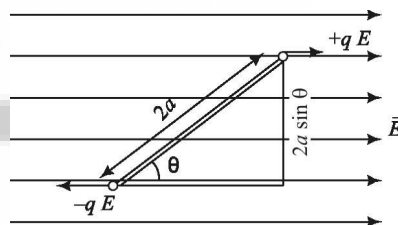


But two equal and opposite forces act at different points of the dipole. They form a couple which exerts a torque.

Torque $\tau$ = Force $\times \perp$ ar distance $b/w$ two force

$$\tau = qE \times 2a\sin\theta$$

$$\tau = pE\sin\theta$$

$$\therefore \qquad \tau = \vec{P} \times \vec{E} \qquad \textbf{(½ Mark)}$$

Stable equilibrium $\rightarrow \theta = 0°$ *i.e.* dipole is parallel to external electric field. **(½ Mark)**

**16.**

(a) Dipole moment of dipole
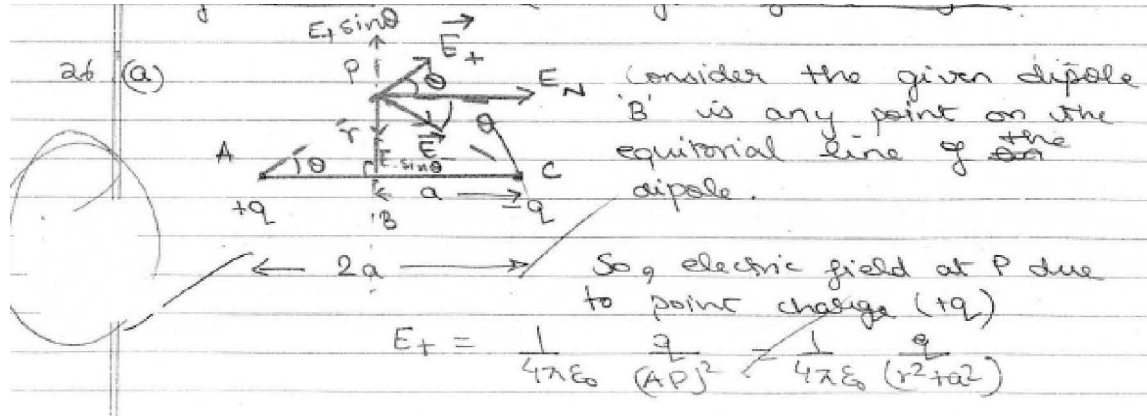
$AB = \vec{p} = p\,\hat{j}$

Dipole moment of dipole

$CD = \vec{p} = p\cos 30\,\hat{i} - p\cos 60\,\hat{j}$

$= p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j}$

∴ net dipole moment $(\vec{P}) = p\,\hat{j} + \left(p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j}\right)$

$= p\frac{\sqrt{3}}{2}\hat{i} + \frac{p}{2}\hat{j}$

∴ $|\vec{P}| = \sqrt{\frac{p^2 3}{4} + \frac{p^2}{4}} = \sqrt{p^2} = p$

∴ magnitude of dipole moment $= p$.

$\tan\theta = \frac{\frac{p}{2}}{p\frac{\sqrt{3}}{2}} = \frac{1}{\sqrt{3}}$ ∴ angle made by it with +ve x-axis $= 30°$ (Ans!)



(b) Torque acting on a dipole of dipole moment $\vec{p}$ in electric field $\vec{E}$

$= \vec{p} \times \vec{E}$

For AB, dipole moment $= p\,\hat{j}$

field $= E\,\hat{i}$

∴ Torque, $\vec{\tau}_{AB} = (p\,\hat{j} \times E\,\hat{i}) = pE(-\hat{k})$

For CD, dipole moment $= \left(p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j}\right)$

field $= E\,\hat{i}$

Torque, $\vec{\tau}_{CD} = \left(p\frac{\sqrt{3}}{2}\hat{i} - \frac{p}{2}\hat{j}\right) \times E\,\hat{i}$

$= pE\frac{\sqrt{3}}{2} \times 0 - \frac{p}{2}E\cdot(-\hat{k}) = \frac{pE}{2}\hat{k}$

net Torque $(\vec{\tau}) = \vec{\tau}_{AB} + \vec{\tau}_{CD} = -pE\,\hat{k} + \frac{pE}{2}\hat{k} = \frac{pE}{2}(-\hat{k})$

∴ magnitude $= \frac{pE}{2}$

direction = into the plane of paper $(-\hat{k})$

**17.**

26 (a) Consider the given dipole 'B' is any point on the equitorial line of the dipole.



So, electric field at P due to point charge (+q)

$$E_+ = \frac{1}{4\pi\varepsilon_0} \frac{q}{(AP)^2} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2+a^2)}$$

And electric field at P due to negative charge (-q)

$$E_- = \frac{1}{4\pi\varepsilon_0} \frac{q}{BP^2} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2+a^2)}$$

Clearly $|\vec{E_+}| = |\vec{E_-}|$ —— ①

and vertical components of $E_+$ and $E_-$ will mutually cancel out. (as $E_+\sin\theta = E_-\sin\theta$)

∴ net electric field is only along the horizontal as shown.

So, net electric field, $E_N = E_+\cos\theta + E_-\cos\theta$

$$E_N = 2E_+\cos\theta \quad (\text{from ①})$$

Now in right △ABP

$$\cos\theta = \frac{AB}{AP} = \frac{a}{\sqrt{r^2+a^2}}$$

So, $E_N = 2 \frac{1}{4\pi\varepsilon_0} \frac{q}{(r^2+a^2)} \frac{a}{(r^2+a^2)^{1/2}}$

OR $E_N = \frac{1}{4\pi\varepsilon_0} \frac{(2qa)}{(r^2+a^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0} \frac{p}{(r^2+a^2)^{3/2}}$

and vectorially,

$$\vec{E_N} = \frac{-1}{4\pi\varepsilon_0} \frac{\vec{p}}{(r^2+a^2)^{3/2}}$$

$\vec{p}$ is the dipole moment of the given dipole and $\hat{n}$ is from right to left. ($p=2qa$)

The negative sign indicates that $\vec{E_N}$ is opposite to $\vec{p}$ as shown.

for $r >> a$

$$\vec{E_N} = \frac{-1}{4\pi\varepsilon_0} \frac{\vec{p}}{r^3} \quad (\text{ignoring the } a \text{ sum})$$

**18.** Electric dipole moment is defined as the product of either charge of the dipole and the distance between them.

*i.e.*, $\vec{p} = q \times \overline{2l}$, where $\overline{2l}$ is the vector distance from the –ve to +ve charge **(½ + ½ + 2 = 3 Marks)**

It is a vector quantity.

**Expression** for the electric field of a dipole at a point on the equatorial plane of the dipole :

Let there be a point P (on the equatorial plane of the dipole) at a distance r from the centre of a dipole formed by two charges –q and +q and having dipole moments $\vec{p} = 2\,\vec{ql}$. We have to find the electric field intensity at point P.
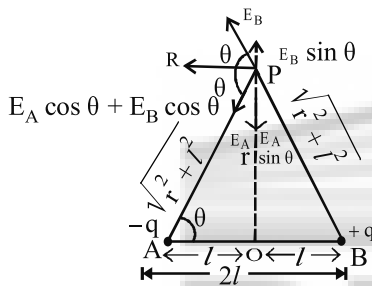


The electric field intensity at point P due to +q (at B)

$$E_A = \frac{1}{4\pi \in_0} \cdot \frac{q}{\left(r^2 + l^2\right)} \text{ along BP}$$

and electric field intensity at P due to –q charge (at A)

$$E_B = \frac{1}{4\pi \in_0} \cdot \frac{q}{\left(r^2 + l^2\right)} \text{ along PA}$$

Clearly, $E_A = E_B$ in magnitude.

$E_A$ and $E_B$ can be resolved into two rectangular components.

Components of $E_A$

(i) $E_A \cos\theta$ along PX

(ii) $E_A \sin\theta$ along PY

Components of $E_B$

(i) $E_B \cos\theta$ along PX

(ii) $E_B \sin\theta$ along YP

Vertical components being equal and opposite cancel each other.

Therefore, net electric field intensity along PX

$$E = E_A \cos\theta + E_A \cos\theta \qquad (\because E_A = E_B)$$
$$= 2E_A \cos\theta \text{ along PX}$$

$$= 2 \cdot \frac{1}{4\pi \in_0} \cdot \frac{q}{\left(r^2 + l^2\right)} \cdot \frac{1}{\sqrt{r^2 + l^2}}$$

or, $E = \frac{1}{4\pi \in_0} \cdot \frac{p}{\left(r^2 + l^2\right)^{3/2}}$ along PX $(\because p = q \times 2l)$

If $l << r$ so that it can be neglected, then

$$E = \frac{1}{4\pi \in_0} \cdot \frac{p}{r^3} \text{ along PX}$$

$$\therefore \quad E \propto \frac{1}{r^3}$$

**19.** When the plane is parallel to the *y-z* plane:

$$\phi = \vec{E} \cdot \vec{A} \qquad \textbf{(1 + 1 = 2 Marks)}$$

Here: $\vec{E} = 2 \times 10^3 \hat{i}$ N/C

$$\vec{A} = (20 \text{ cm})^2 \hat{i} = 4 \times 10^{-2} \hat{i} \text{ m}^2$$

$\therefore \qquad \phi = (2 \times 10^3 \hat{i}) \cdot (4 \times 10^{-2} \hat{i})$

$\Rightarrow \qquad \phi = 80$ weber

When the plane makes a 30° angle with the *x*-axis, the area vector makes a 60° angle with the *x*-axis.

$$\phi = \vec{E} \cdot \vec{A}$$

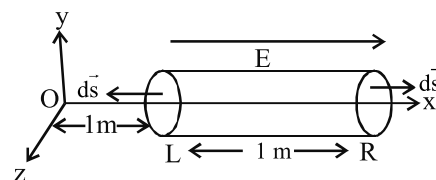$\Rightarrow \qquad \phi = EA \cos\theta$

$\Rightarrow \qquad \phi = (2 \times 10^3)(4 \times 10^{-2}) \cos 60°$

$\Rightarrow \qquad \phi = 80/2$

$\Rightarrow \qquad \phi = 40$ weber

**20.** (i) From question, it is clear that the electric field $\vec{E} = 50\, x\hat{i}$ is directed along the x-axis. Hence, there is no electric flux through the curved surface.



**(½ Mark)**

Electric field on the left face of the cylinder,

$$E = 50\,\hat{i} \qquad (\because x = 1\,m)$$

∴ Electric flux through this face
angle between E and $ds$ is 180°

So, $\phi_1 = \oint \vec{E}.\overrightarrow{ds} = -E \times A$

$(\because \cos 180 = -1)$

$$= 50 \times 25 \times 10^{-4}\,m^2$$

$(\because A = 25\,cm^2)$

$$= -0.125\,NC^{-1}\,m^2$$

Electric flux through the other face **(½ Mark)**
angle between E and ds is 0°.

So, $\phi_2 = E \times A \quad \left(\because E = 50\,\hat{i}, x = 2\,m\right)\cos 0 = 1$

$$= 100 \times 25 \times 10^{-4}$$
$$= 0.25\,NC^{-1}\,m^2$$

Net flux through the cylinder $= \phi_1 + \phi_2$ **(1 Mark)**
$$= 0.25 - 0.125\,NC^{-1}m^2$$
$$= 0.125\,NC^{-1}\,m^2$$

(ii) Let q be the charge enclosed by the cylinder.
According to Gauss's theorem

$$\phi = \frac{q}{\in_0} \qquad \therefore \quad q = \phi \in_0$$

$$= 0.125 \times 8.854 \times 10^{-12}\,C \qquad \textbf{(1 Mark)}$$
$$= 1.11 \times 10^{-12}\,C$$

**21.** (i) Electric field inside the conductor (here shell) is always
zero.

∴ Force on charge $\dfrac{Q}{2}$ at the centre is zero.

Force on charge $2Q$ at $A$ due to charges $\dfrac{Q}{2}$ and $Q$ will be

$$F = \frac{1}{4\pi\varepsilon_0}\frac{\left(Q + \dfrac{Q}{2}\right) \times 2Q}{x^2}$$

$$F = \frac{1}{4\pi\varepsilon_0 x^2} \times \frac{3Q}{2} \times 2Q$$

$$\therefore \quad F = \frac{3Q^2}{4\pi\varepsilon_0 x^2} \qquad \textbf{(1 Mark)}$$

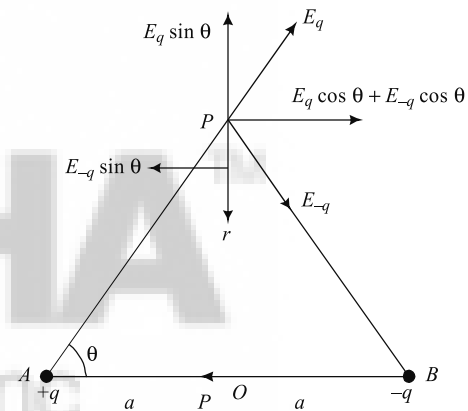(ii) Electric flux through the shell can be calculated using
Gauss law which is

$$\phi = \frac{q}{\varepsilon_0}$$

where $q$ = total charge enclosed by shell.

Total charge enclosed by shell is $\dfrac{Q}{2}$

$$\therefore \qquad \phi = \frac{Q/2}{\varepsilon_0} = \frac{Q}{2\varepsilon_0}. \qquad \textbf{(1 Mark)}$$

**22.** (i)



**(½ Mark)**

Let '$P$' be equitorial point where electric field has to be
calculated.

$$E_q = \frac{q}{4\pi\varepsilon_0 AP^2}$$

$$E_{-q} = \frac{q}{4\pi\varepsilon_0 PB^2}$$

From $\Delta PAO$ and $\Delta PBO$
$$AP^2 = r^2 + a^2$$
and $\quad BP^2 = r^2 + a^2$

$$\therefore \quad E_q = E_{-q} = \frac{q}{4\pi\varepsilon_0(r^2 + a^2)} \qquad \textbf{(1 Mark)}$$

From the figure, we see that at $P$ the vertical component of $E_q$ and $E_{-q}$ are equal and opposite, hence cancel each other. Where as horizontal component are in same direction, therefore they add up.

So, net electric field due to dipole at point $P$ is,

$$\vec{E} = -[E_q \cos\theta + E_{-q}\cos\theta]\,\hat{P}$$

Negative sign show that electric field is in opposite direction of $\vec{P}$ (dipole moment)

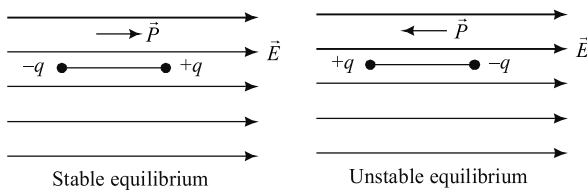$$\cos\theta = \frac{a}{\sqrt{r^2 + a^2}}$$

$$\vec{E} = \frac{-2q}{4\pi\varepsilon_0(r^2 + a^2)} \times \frac{a}{\sqrt{r^2 + a^2}}\hat{P}$$

$$\vec{E} = \frac{-2qd}{4\pi\varepsilon_0(r^2 + a^2)3/2}\hat{P}$$

Since $|\vec{P}| = q \times 2a$

$$\therefore \quad \vec{E} = \frac{P}{4\pi\varepsilon_0(r^2 + a^2)3/2}\hat{P} \qquad \textbf{(½ Mark)}$$

(ii) For stable equilibrium, angle between dipole moment $\vec{P}$ and electric field $\vec{E}$ is 0° and for unstable equilibrium, it is 180°.



Stable equilibrium        Unstable equilibrium

**23.** (a) The outward electric flux due to charge +Q is independent of the shape and size of the surface, which encloses it because:

(i) Number of electric field lines coming out from a closed surface enclosing the charge depends on the charge enclosed by the surface.

(ii) Number of electric field lines coming out from a closed surface enclosing the charge is independent of the position of the charge inside the closed surface.      **(2 Marks)**

(b) Magnitude of electric field at any point on the axis of a uniformly charged loop is given by,

$$E = \frac{\lambda}{2\in_0} \frac{rR}{(r^2 + R^2)^{\frac{3}{2}}} \qquad \text{...(i)} \ \textbf{(1 Mark)}$$
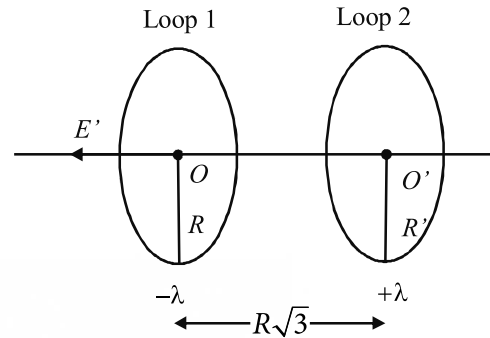


Electric field at the centre of loop 1 due to charge present on it is zero. [From (i), when $r = 0$]

Hence, electric field at the centre of the loop 1 due to charge present on the loop 2 is,

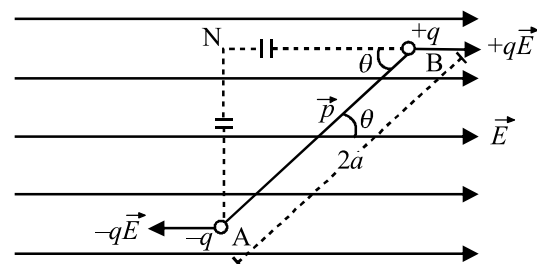$$E = \frac{+\lambda}{2\in_0} \frac{(R\sqrt{3})R}{[(R\sqrt{3})^2 + R^2]^{3/2}}$$

$$= \frac{\lambda}{2\varepsilon_0} \frac{R^2\sqrt{3}}{8R^3}$$

$$\Rightarrow \qquad E = \frac{\sqrt{3}}{16\in_0}\frac{\lambda}{R} \qquad \textbf{(1½ Marks)}$$

The direction of this net field is from loop 2 to loop 1 as shown.      **(½ Mark)**

                                             **(1 Mark)**

**24.** (a) Dipole in a Uniform External Field

Consider an electric dipole consisting of charges $-q$ and $+q$ and of length $2a$ placed in a uniform electric field $\vec{E}$ making an angle $\theta$ with electric field.

Force on charge $-q$ at $A = q\vec{E}$ (opposite to $\vec{E}$)

Force on charge $+q$ at $B = q\vec{E}$ (along $\vec{E}$)

When electric dipole is placed under the action of two equal and opposite parallel forces, it gives rise a torque on the dipole.

$$\tau = \text{Force} \times \text{Perpendicular}$$
$$\text{distance between the two forces}$$
$$\tau = qE\,(AN) = qE\,(2a\sin\theta)$$
$$\tau = q(2a)\,E\sin\theta$$
$$\tau = pE\sin\theta \quad \{\because p = q\,(2a)\} \qquad \textbf{(2 Marks)}$$
$$\therefore \qquad \vec{\tau} = \vec{P} \times \vec{E}$$

**Note**

$\tau = \vec{P} \times \vec{E}$

$\tau = PE\sin\theta$

*at $\theta = 0°$ and $180°$, torque on dipole will be zero.*

$\therefore$ *At $\theta = 0°$, dipole is in stable equilibrium.*

*At $\theta = 180°$, dipole is in unstable equilibrium.*

(b) (i) Charge enclosed by sphere
$$S_1 = 2Q$$
By Gauss law, electric flux through
sphere $S_1$ is $\phi_1 = 2Q/\varepsilon_0$
Charge enclosed by sphere
$$S_2 = 2Q + 4Q = 6Q$$
$\therefore \qquad \phi_2 = 6Q/\varepsilon_0$ **(1½ Marks)**
The ratio of the electric flux is
$$\phi_1/\phi_2 = 2Q/\varepsilon_0 \div 6Q/\varepsilon_0 = 2/6 = 1/3$$
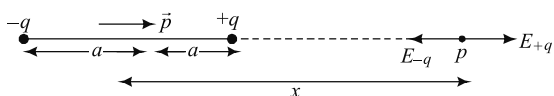(ii) For sphere $S_1$, the electric flux is
$$\phi' = 2Q/\varepsilon_r$$
$\therefore \qquad \phi'/\phi_1 = \varepsilon_0/\varepsilon_r \Rightarrow \phi' = \phi_1 \cdot \varepsilon_0/\varepsilon_r$
$\because \qquad \varepsilon_r > \varepsilon_0$
$\therefore \qquad \phi' < \phi_1$

Therefore, the electric flux through the sphere $S_1$ decreases with the introduction of the dielectric inside it. **(1½ Marks)**

**25.** Let P be the point where electric field due to dipole has to be evaluated.



Here, $\vec{P}$ = dipole moment = $q \times 2a$ **(½ Mark)**

$2a$ = distance between two charges of dipole

$x$ = distance from the centre of dipole to point $p$.

Electric field due to $+q$ at $p$ is

$$\vec{E}_{+q} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(x-a)^2} - (\hat{p}) \qquad \textbf{(½ Mark)}$$

Electric field due to $-q$ at $p$ is

$$\vec{E}_{-q} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(x+a)^2}(-\hat{p}) \qquad \textbf{(½ Mark)}$$

Total electric field at point $p$, $E$ will be

$$\vec{E} = \vec{E}_q + \vec{E}_{-q}$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\left[\frac{1}{(x-a)^2} - \frac{1}{(x+a)^2}\right]\hat{p}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{(x+a)^2 - (x-a)^2}{(x^2-a^2)^2}\right]\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0} \times \frac{4ax}{(x^2-a^2)^2}\hat{p} \qquad \textbf{(½ Mark)}$$

$$\vec{E} = \frac{2 \times 2aq \times x}{4\pi\varepsilon_0(x^2-a^2)^2}\hat{p}$$

$$\vec{E} = \frac{2px}{4\pi\varepsilon_0(x^2-a^2)^2}\hat{p} \qquad \textbf{(½ Mark)}$$

For $x \gg a$

$$x^2 - a^2 \approx x^2$$

$$\therefore \qquad \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2px}{(x^2)^2}\hat{p}$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{x^3}\hat{p}\,N/C^{-1} \qquad \textbf{(½ Mark)}$$
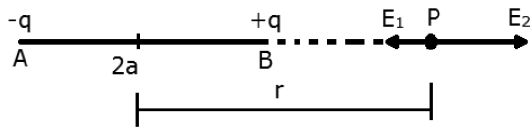
**26.** (a) Consider an electric dipole consisting of two point charges $+q$ and $-q$ separated by a small distance $2a$.

Electric field intensity at point P due to charge $-q$

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{AP^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

It is along PA.                                    **(½ Mark)**



Electric field intensity at point P due to charge +q

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{BP^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}$$

It is along BP.                                    **(½ Mark)**

Hence, the resultant field $E = E_2 - E_1$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]$$
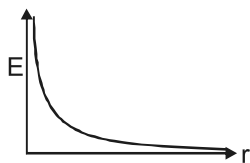
$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{4ar}{(r^2-a^2)}\right] \quad \textbf{(½ Mark)}$$

$$E = \frac{q}{4\pi\varepsilon_0}\frac{2a \times 2r}{(r^2-a^2)^2}$$

Now, the dipole moment is $q \times 2a = p$

$\therefore \qquad E = \dfrac{p}{4\pi\varepsilon_0}\dfrac{2r}{(r^2-a^2)^2} \qquad$ **(1 Mark)**
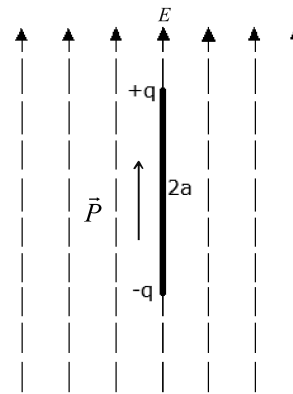
(b)  Graph of E versus r for r >> a



$\because \qquad E = \dfrac{p}{4\pi\varepsilon_0}\dfrac{2r}{r^4} = \dfrac{2p}{4\pi\varepsilon_0 r^3}$

$\therefore \qquad E \propto \dfrac{1}{r^3} \qquad$ **(1 Mark)**

(c)  Diagram representing the position of the dipole in stable equilibrium:
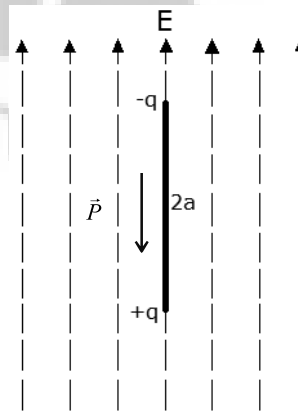


                                                   **(½ Mark)**

In this case, torque acting on the dipole,

$\tau = pE \sin\theta = pE \sin 0$

Diagram representing the position of the dipole in unstable equilibrium:



                                                   **(½ Mark)**

In this case, torque acting on the dipole,

$\tau = pE \sin\theta = pE \sin 180$                 **(½ Mark)**
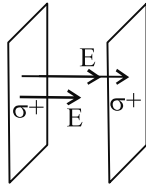
**Topic-4:** **Gauss's Law and its Applications**

**1.** **(d)** Surface Charge density, $\sigma = 26.4 \times 10^{-12} \dfrac{C}{m^2}$

$$E = \dfrac{\sigma}{2\varepsilon_0} + \dfrac{\sigma}{2\varepsilon_0}$$

$$= \dfrac{2\sigma}{2\varepsilon_0} + \dfrac{\sigma}{\varepsilon_0}$$



$$= \dfrac{26.4 \times 10^{-12}}{8.85 \times 10^{-12}} \dfrac{N}{C} = 3 \dfrac{N}{C}$$ **(1 Mark)**

**2.** **(d)** All other statements except (d) are in correct. The electric field over the Gaussian surface remains continuous and uniform at every point. **(1 Mark)**

**3.** **(d)** **(1 Mark)**

**4.**



🎖 **Topper's Answer**



25

25 (a) Let, a charge $q$ is situated in a region. Electric field due to $q$ at a radial distance $r = \dfrac{kq\hat{r}}{r^2} = \dfrac{q}{4\pi\varepsilon_0 r^2}$

Now, consider a uniformly charged spherical shell of radius $R$, containing charge $q$.

Let, we take a spherical Gaussian surface of radius $r > R$ & centring at centre of shell, say O.

∴, from symmetry of the figure,
① magnitude of $\vec{E}$ of throughout the Gaussian surface is constant
② The angle between $\vec{E}$ and area vector $\vec{S}$ is constant. Always, $\vec{E} \parallel \vec{S}$

So, using Gauss' law for a sphere of radius $r$,

$$\oint \vec{E} \cdot d\vec{S} = \dfrac{Q_{in}}{\varepsilon_0}$$

$$\oint E \, ds = \dfrac{q}{\varepsilon_0} \quad [\because \vec{E} \cdot d\vec{S} = E \, ds \cos 0° = E \, ds]$$

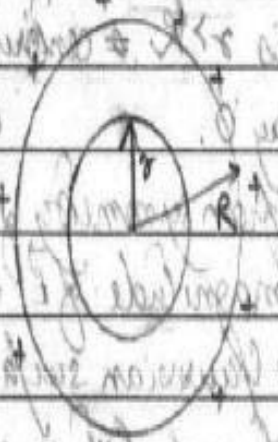$$\Rightarrow E \cdot 4\pi r^2 = \dfrac{q}{\varepsilon_0} \Rightarrow \boxed{E = \dfrac{q}{4\pi\varepsilon_0 r^2}}$$

∴, field due to a distance $r = \dfrac{q}{4\pi\varepsilon_0 r^2}$.

∴ The field at distance $r$ is equal to the field as if whole charge $q$ is placed at the centre.

Now again, taking Gaussian surface of radius $r<R$, inside the shell,

$$\oint \vec{E} \cdot d\vec{s} = \frac{q_{in}}{\epsilon_0}$$

∵ whole charge of shell is at the surface, ∴ $q_{in} = 0$.

$$\Rightarrow \oint \vec{E} \cdot d\vec{s} = 0$$

$$\Rightarrow E \cdot 4\pi r^2 = 0$$

$$\Rightarrow \boxed{\vec{E} = 0}$$

graph:-



$\vec{r} = R$

$\vec{r}$
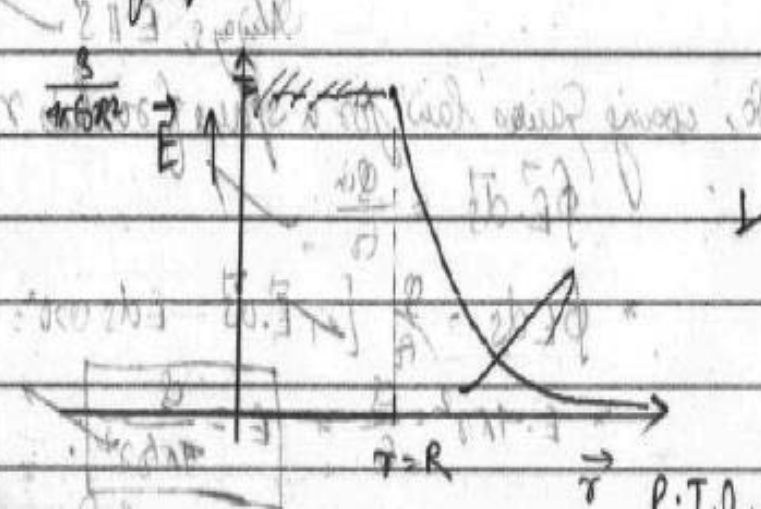
P.T.O.

**5.** Gauss's law: Gauss's law states that the total flux through a closed surface is $\frac{1}{\varepsilon_o}$ times the net charge enclosed by the closed surface. **(1 Mark)**
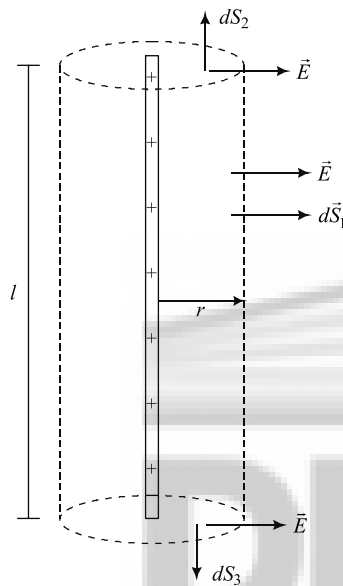
$$\phi_E = \oint_s \vec{E}.d\vec{s} = \frac{q}{\varepsilon_o}$$
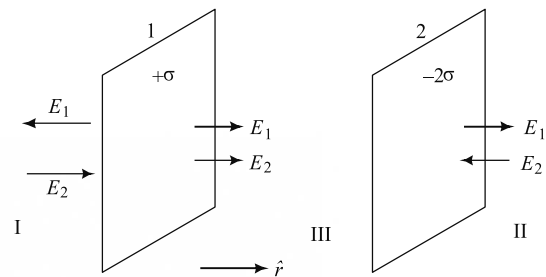
$$\phi_E = \frac{q}{\varepsilon_o}$$

$$\Rightarrow \frac{\lambda l}{\varepsilon_o} = E \times 2\pi r l$$

$$E = \frac{\lambda}{2\pi\varepsilon_o r} \qquad \text{(1 Mark)}$$

*Electric field due to long straight charged wire*
Consider a thin long straight wire having a uniform linear charge density $\lambda$. By symmetry, the field of the line charge is directed radially outward and its magnitude is same at all points equidistant from the line charge. **(1 Mark)**

Flux $\phi_E = \int \vec{E}.d\vec{S}$

$$= \int \vec{E} \cdot d\vec{S}_1 + \int \vec{E} \cdot d\vec{S}_2 + \int \vec{E} \cdot d\vec{S}_3$$

$$\phi_E =$$

$$\int E ds_1 \cos\theta^\circ + \int E ds_2 \cos 90^\circ + \int E ds_3 \cos 90^\circ$$

**(½ Mark)**

$$\phi_E = \int E ds_1 + 0 + 0$$

$$= E \times \text{area of curved surface}$$

$$\phi_E = E \times 2\pi r l \qquad \text{(½ Mark)}$$

Charge enclosed by gaussian surface, $q = \lambda l$

**6.**



**(1 + 1 + 1 = 3 Marks)**

Electric field due to charge plane sheet is

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{r}$$

(i) Electric field to the left of first sheet

$$\vec{E}_I = \vec{E}_1 + \vec{E}_2$$

$$= \frac{-\sigma}{2\varepsilon_0}\hat{r} + \frac{2\sigma}{2\varepsilon_0}\hat{r}$$

$$\vec{E}_I = \frac{\sigma}{2\varepsilon_0}\hat{r}$$

(ii) Electric field to the right of second sheet

$$\vec{E}_{II} = \vec{E}_1 + \vec{E}_2$$

$$\vec{E}_{II} = \frac{\sigma}{2\varepsilon_0}\hat{r} - \frac{(2\sigma)}{2\varepsilon_0}\hat{r}$$

$$\vec{E}_{II} = \frac{-\sigma}{2\varepsilon_0}\hat{r}$$

(iii) Electric field between the sheets

$$\vec{E}_{III} = \vec{E}_1 + \vec{E}_2$$

$$\vec{E}_{III} = \frac{\sigma}{2\varepsilon_0}\hat{r} + \frac{(2\sigma)}{2\varepsilon_0}\hat{r} = \frac{3\sigma}{2\varepsilon_0}\hat{r}$$
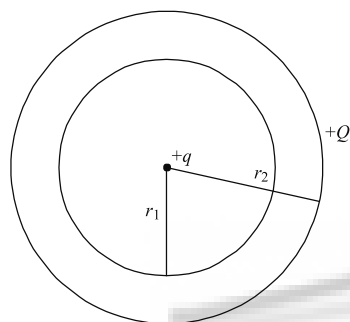


**7.** (a) Surface charge density $\sigma$ is

$$\sigma = \frac{q}{A}$$

where $q$ = total charge

$A$ = surface area

Surface charge density on inner surface of shell $\sigma_1$ is

$$\sigma_1 = \frac{q}{4\pi\varepsilon_0 r_1^2} \qquad [\because A = 4\pi r^2 \text{ for sphere}]$$

Surface charge density on outer surface of shell $\sigma_2$ is

**(1½ Marks)**

$$\sigma_2 = \frac{Q+q}{4\pi r_2^2}$$

(b) Gauss law states that

$$\phi_E = \frac{q}{\varepsilon_0}$$

where $\phi_E$ = electric flux through gaussian surface

$q$ = total charge enclosed in gaussian surface.

Consider a gaussian surface inside the cavity. It is given the cavity does not have any charge in it.

So, $q = 0$ inside gaussian surface.

$$\therefore \qquad \phi_E = 0$$

Since flux is zero, therefore electric field inside cavity with no charge is zero. This does not depend on shape and size of sheet as long as charge inside cavity is zero. **(1½ Marks)**

**8.** (a) Electric field due to an infinitely long straight wire : Consider an infinitely long line charge having linear charge density $\lambda$. To determine its electric field at distance $r$, consider a cylindrical Gaussian surface of radius r and length l coaxial with the charge. By symmetry, the electric field $E$ has same magnitude at each point of the curved surface $S_1$ and is directed radially outward.
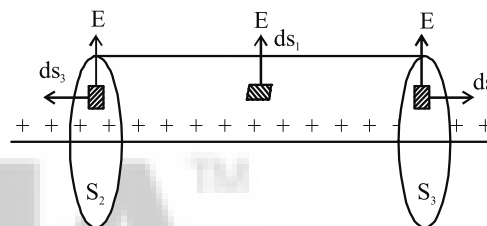


Total flux through the cylindrical surface,

$$\oint \vec{E}\cdot\overrightarrow{ds} = \oint_{S_1} \vec{E}\cdot\overrightarrow{ds_1} + \oint_{S_2} \vec{E}\cdot\overrightarrow{ds_2} + \oint_{S_3} \vec{E}\cdot\overrightarrow{ds_3}$$

$$= \oint_{S_1} Eds_1 \cdot \cos 0° + \oint_{S_2} Eds_2 \cdot \cos 90° + \oint_{S_3} Eds_3 \cdot \cos 90°$$

$$= E\int ds_1 = E \times 2\pi rl$$

**(1 Mark)**

As $l$ is the charge per unit length and $l$ is the length of the wire, so charge enclosed, $q = \lambda l$

By Gauss's theorem,

$$\oint_S \vec{E}\cdot\overrightarrow{ds} = \frac{q}{\varepsilon_0} \quad \text{or,} \quad E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$
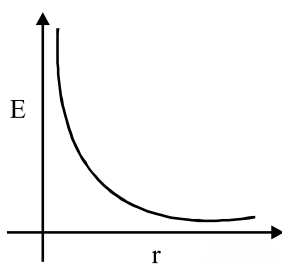
This is the required expression. **(1 Mark)**

(b) From above equation, we can observe, $E \propto \dfrac{1}{r}$

The graph showing the variation of $E$ with perpendicular distance '$r$' from the line of charge



**(1 Mark)**

9. Consider a thin infinite plane uniformly charged sheet having a surface charge density $\sigma$.

To find electric field due to the plane sheet of charge at any point P distant r from it, choose a cylinder of area of cross-section A through the point P as the Gaussian surface.

The flux due to the electric field of the plane sheet of charge passes only through the two circular caps of the cylinder.

Let surface charge density $= \sigma$

According to Gauss's law

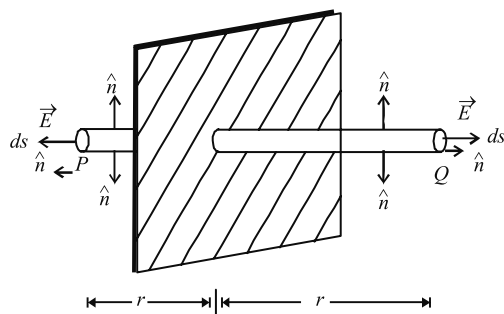$$\oint \vec{E} . \vec{dS} = q_{in} / \varepsilon_0$$ **(1 Mark)**
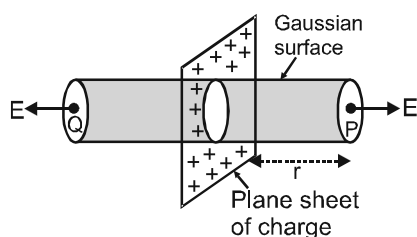


**(1 Mark)**

$$\underset{\substack{\text{I circular} \\ \text{surface}}}{\int} E\, ds \cos\theta + \underset{\substack{\text{II circular} \\ \text{surface}}}{\int} E\, ds \cos\theta +$$

$$\underset{\substack{\text{cylindrical} \\ \text{surface}}}{\int} E\, ds \cos\theta = \dfrac{\sigma A}{\varepsilon_0}$$ **(1 Mark)**

or, $EA + EA + 0 = \dfrac{\sigma A}{2\varepsilon_0}$ or $E = \dfrac{\sigma}{2\varepsilon_0}$ **(1 Mark)**

10. Electric fields due to a uniformly charged infinite plane sheet: Suppose a thin non-conducting infinite sheet of uniform surface, charge density $\sigma$. **(1 Mark)**



**(1 Mark)**

Electric field intensity $\vec{E}$ on either side of the sheet must be perpendicular to the plane of sheet having same magnitude at all points from sheets.

Let P be any point at a distance r from the sheet. Let the small area element $\vec{ds} = ds\hat{n}$.

$\vec{E}$ and $\hat{n}$ are parallel on the two cylinderical edges $P$ and $Q$, which contributes electric flux.

$\therefore$ Electric flux over the edges $P$ and $Q$ of the cylinder is $2\phi$

$$\Rightarrow \quad 2\oint \vec{E} \cdot \vec{ds} = \dfrac{q}{\in_0} \quad \Rightarrow \quad 2E\pi\, r^2 = \dfrac{q}{\in_0}$$

$$E = \dfrac{q}{2\pi \in_0 r^2}$$ **(1 Mark)**

Charge density, $\sigma = \dfrac{q}{s} \Rightarrow q = \pi\, r^2\, \sigma$

[Where $S$ – area of circle]

$$E = \dfrac{\pi r^2 \sigma}{2\pi \in_0 r^2}$$

$$E = \dfrac{\sigma}{2 \in_0}, \text{ Vectorically } \vec{E} = \dfrac{\sigma}{2 \in_0} \hat{n}$$

where $\hat{n}$ is a unit vector normal to the plane and going away from it.

When σ > 0, E is directed away from both sides. Hence electric field intensity is independent of $r$.

The direction of an electric field for positive charge density is in outward direction and perpendicular to the plane infinite sheet. And for the negative charge density the direction of the field is in inward direction and perpendicular to the sheet. **(1 Mark)**

11. Electric flux $\phi$ is

$$\phi = \oint \vec{E} \cdot d\vec{s}$$

where $\vec{E}$ is electric field

$d\vec{s}$ is area element.

Given, Electric field $\vec{E} = 2x\,\hat{i}$

The faces perpendicular to $\vec{E}$ will not contribute in total flux as angle between $\vec{E}$ and $d\vec{s}$ will be 90°.

**(½ Mark)**

The faces parallel to $\vec{E}$ will contribute to the flux.

$$\phi = \phi_I + \phi_{II}$$

$$\vec{E}_I = 2 \times 0 \times \hat{i} = 0$$

$$\vec{E}_{II} = 2 \times a \times \hat{i} = 2a\,\hat{i}$$

$$\therefore \qquad \phi = \oint \vec{E}_I \cdot d\vec{s} + \oint \vec{E}_{II} \cdot d\vec{s}$$

$$= 0 + 2a\hat{i}.a^2\hat{i}$$

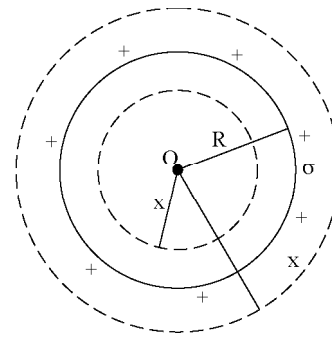$$\phi = 2a^3 \; Nm^2C^{-1} \qquad \textbf{(½ Mark)}$$

The net charge enclosed by cube can be found out by Gauss law, which is

$$\phi = \frac{q}{\varepsilon_0} \qquad\qquad \textbf{(½ Mark)}$$

$$\therefore \qquad q = \phi\varepsilon_0 \qquad\qquad \textbf{(½ Mark)}$$

$$q = 2a^3\varepsilon_0 \; C \qquad\qquad \textbf{(½ Mark)}$$

12. **(i)**



$0 < x < R$

As $x$ lies inside the shell, the charge enclosed by the gaussian surface is zero

$q = 0$

Flux through the Gaussian surface

$\phi = E \times 4\pi x^2$

Applying Gauss's theorem,

$$\phi = \frac{q}{\varepsilon_0}$$

$E \times 4\pi x^2 = 0$

$\therefore \quad E = 0$

$x > R$

The total charge $q$ inside the gaussian surface is the charge on the shell of radius $R$ and area $4\pi R^2$.

$\therefore \quad q = 4\pi R^2\sigma$

Flux through gaussian surface
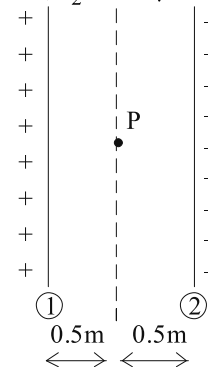
$$\phi = E \times 4\pi x^2$$

Applying gauss theorem,

$$\phi = \frac{q}{\varepsilon_0}$$

$$E \times 4\pi x^2 = \frac{4\pi R^2 \sigma}{\varepsilon_0}$$

$$E = \frac{\sigma R^2}{\varepsilon_0 x^2} \qquad\qquad \textbf{[2 Marks]}$$

(ii) $\lambda_1 = 10\,\mu c/m$, $\lambda_2 = -20\,\mu c/m$



**[1 Marks]**

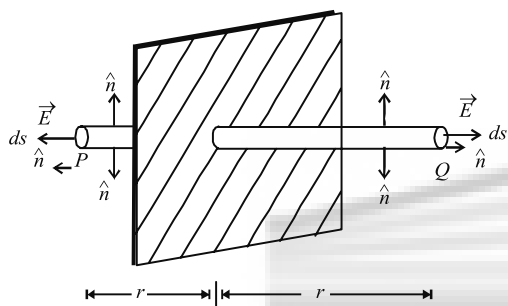Electric field due to linear charge distribution is given by.

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$      **[1 Mark]**

So, Electric field at point P is,

$$E_{net} = \frac{10 \times 10^{-6}}{2 \times 3.14 \times 8.85 \times 10^{-12} \times 0.5}$$

$$+ \frac{(-20) \times 10^{-6}}{2 \times 3.14 \times 8.85 \times 10^{-12} \times 0.5}$$

$E_{net} = 35.95 \times 10^{-4}$ N/C      **[2 Marks]**

**13. (b)** (i) Electric fields due to a uniformly charged infinite plane sheet: Suppose a thin non-conducting infinite sheet of uniform surface, charge density σ.     **[3 Marks]**



Electric field intensity $\vec{E}$ on either side of the sheet must be perpendicular to the plane of sheet having same magnitude at all points from sheets.

Let P be any point at a distance r from the sheet. Let the small area element $\vec{ds} = ds\hat{n}$.

$\vec{E}$ and $\hat{n}$ are parallel on the two cylinderical edges $P$ and $Q$, which contributes electric flux.

∴ Electric flux over the edges $P$ and $Q$ of the cylinder is 2ϕ

$$\Rightarrow \quad 2\oint \vec{E}\cdot \vec{ds} = \frac{q}{\in_0} \quad \Rightarrow \quad 2E\pi\, r^2 = \frac{q}{\in_0}$$

$$E = \frac{q}{2\pi \in_0 r^2}$$

Charge density, $\sigma = \dfrac{q}{s} \Rightarrow q = \pi\, r^2\, \sigma$

[Where $S$ – area of circle]

$$E = \frac{\pi r^2 \sigma}{2\pi \in_0 r^2}$$

$$E = \frac{\sigma}{2 \in_0}, \text{Vectorically} \quad \vec{E} = \frac{\sigma}{2 \in_0}\hat{n}$$

where $\hat{n}$ is a unit vector normal to the plane and going away from it.

When σ > 0, E is directed away from both sides. Hence electric field intensity is independent of $r$.

The direction of an electric field for positive charge density is in outward direction and perpendicular to the plane infinite sheet. And for the negative charge density the direction of the field is in inward direction and perpendicular to the sheet.

(ii)   $\vec{E} = \left(5x^2 + 2\right)\hat{i}$

(1)   The net electric flux through the cube is

$\phi = \phi_1 + \phi_2$

$= -(5 \times 0 + 2)\,\hat{i}\,.\,(100 \times 10^{-4})\,\hat{i} + (5 \times 100 \times 10^{-4} + 2)\,\hat{i}\,.$

$(100 \times 10^{-4})\,\hat{i}$

$= -200 \times 10^{-4} + 5 \times 10^4 \times 10^{-8} + 200 \times 10^{-4}$

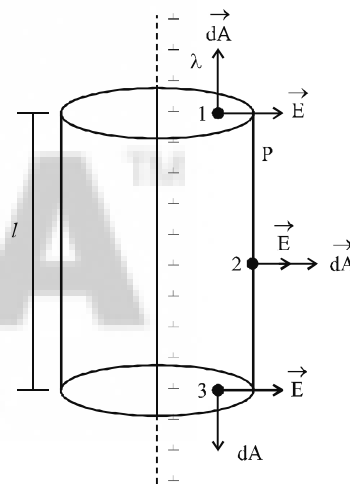$= 5 \times 10^{-4}\ \text{Nm}^2\,\text{C}^{-1}$

(2)   By Gauss' theorem,

$$\phi = \frac{q_{in}}{\varepsilon_o} \Rightarrow q_{in} = \phi\varepsilon_o$$

$= 5 \times 10^{-4} \times 8.85 \times 10^{-12}$

$= 44.\,25 \times 10^{-14}\ \text{C}$      **[2 Marks]**

**14.** (i)   Let us take an infinitely long positively charged straight wire having linear charge density 'λ' as shown in figure below.



               **(1 Mark)**

Suppose we have to determine electric field at 'P'. For this we will draw a gaussian surface as shown in fig.

Net flux through gaussian surface is

$$\phi = \oint \vec{E}\,.\,\vec{dA}$$

$$\Rightarrow \quad \phi = \int_1 \vec{E}\,.\,\overset{0}{\vec{dA}} + \int_2 \vec{E}\,.\,\vec{dA} + \int_3 \vec{E}\,.\,\overset{0}{\vec{dA}}$$

               **(½ Mark)**

[∵ For surface 1 and 3, $\vec{E} \perp \vec{A}$ ]

$\Rightarrow \quad \phi = \int\limits_{2} \overrightarrow{E}.\overrightarrow{dA} \Rightarrow \phi = \int E.dA$

$\Rightarrow \quad \phi = E \times \int dA$

$\Rightarrow \quad \phi = E \times 2\pi r l$ **(½ Mark)**

By Gauss law, $\phi = \dfrac{q_{in}}{\in_0}$ **(½ Mark)**

$\Rightarrow \quad E \times 2\pi r l = \dfrac{\lambda l}{\in_0}$

$\Rightarrow E = \dfrac{\lambda}{2\pi \in_0 r}$ and direction is away from wire

**(½ Mark)**

(ii) Here, the necessary centripetal force is provided by electrostatic attraction
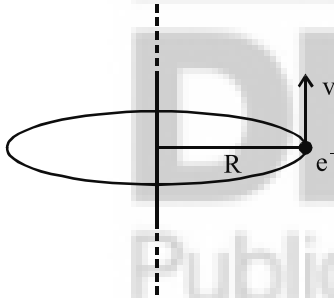
So, $\dfrac{mv^2}{R} = qE$ **(½ Mark)**

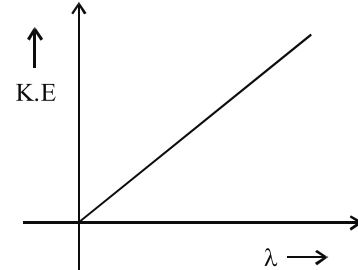$\Rightarrow \quad \dfrac{mv^2}{R} = \dfrac{e\lambda}{2\pi \in_0 R}$

$\Rightarrow \quad mv^2 = \dfrac{e\lambda}{2\pi \in_0} \Rightarrow \dfrac{1}{2}mv^2 = \dfrac{e\lambda}{4\pi \in_0}$

$\Rightarrow \quad K.E = \dfrac{e\lambda}{4\pi \in_0}$ **(½ Mark)**

(iii) As $K.E = \dfrac{e\lambda}{4\pi \in_0}$

$\Rightarrow \quad K.E \propto \lambda$

So, graph will be straight line passing through origin as shown below



**(1 Mark)**

**15.** (a)
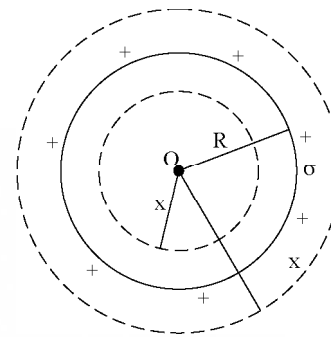


(i) $0 < x < R$

As $x$ lies inside the shell, the charge enclosed by the gaussian surface is zero

$q = 0$

Flux through the Gaussian surface

$\phi = E \times 4\pi x^2$ **(½ Mark)**

Applying Gauss's theorem,

$\phi = \dfrac{q}{\varepsilon_0}$

$E \times 4\pi x^2 = 0$

$\therefore \quad E = 0$ **(½ Mark)**

(ii) $x > R$

The total charge $q$ inside the gaussian surface is the charge on the shell of radius $R$ and area $4\pi R^2$.

$\therefore \quad q = 4\pi R^2 \sigma$ **(½ Mark)**

Flux through gaussian surface

$\phi = E \times 4\pi x^2$

Applying gauss theorem,

$\phi = \dfrac{q}{\varepsilon_0}$

$E \times 4\pi x^2 = \dfrac{4\pi R^2 \sigma}{\varepsilon_0}$

$$E = \frac{\sigma R^2}{\varepsilon_0 x^2}$$  **(½ Mark)**

(b)



**(½ Mark)**

(i) Outward flux through left face is

$$\phi = \vec{E}.\Delta\vec{S}$$

$$= +200 \times \pi (0.05)^2 (-\hat{i}).(-\hat{i})$$

$$= +1.57 \ Nm^2 C^{-1}.$$  **(½ Mark)**

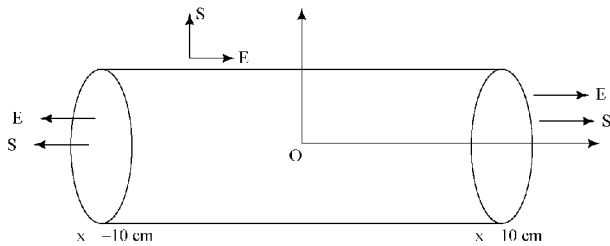Outward flux through right face

$$\phi = \vec{E}.\Delta\vec{S}$$

$$= 200 \times \pi (0.05)^2$$

$$\phi = +1.57 \ Nm^2 C^{-1}$$  **(½ Mark)**

Flux through the curved surface of the cylinder

$$\phi = E\Delta S \cos 90° = 0$$  **(½ Mark)**

∴ Net outward flux through the cylinder

$$\phi = 1.57 + 1.57$$

$$= 3.14 \ Nm^2 C^{-1}$$  **(½ Mark)**

(ii) The net charge inside the cylinder

$$q = \varepsilon_0 \phi_E$$

$$= 8.854 \times 10^{-12} \times 3.14$$

$$q = 2.78 \times 10^{-11} \ C$$  **(½ Mark)**

**16.** (a) Electric flux is defined as the number of electric filed lines crossing the per unit area. It is a scalar quantity.

**(1 Mark)**

When cube is of side $d$ and point charge $q$ is at the center of the cube then the total electric flux due to this charge will pass evenly through the six faces of the cube. So, the electric flux through one face will be equal to 1/6 of the total electric flux due to this charge.

Flux through 6 faces $= \dfrac{q}{\in_0}$  **(1 Mark)**

∴ Flux through 1 face, $= \dfrac{q}{6 \in_0}$  **(1 Mark)**

(b) If we moved point charge d from centre and square side changes to 2$d$, still the point charge can be imagined at the center of a cube of side 2$d$. Again the flux through one face of the cube will be 1/6 of the total electric flux due to the charge $q$.

Hence, the electric flux through the square will not change and it will remain the same *i.e.*, $q/6 \in_0$.

**(2 Marks)**

**17. Expression** for the electric field due to a uniformly charged conducting shell :

Let there be a spherical conducting shell whose radius is R.

Let σ be the uniform surface charge density.

(i) We have to find electric field intensity at a point P *i.e.*, outside the shell. Imagine a sphere of radius r with its centre at O to serve as Gaussian surface.

Electric field intensity at P, $\vec{E}$ and area element $\vec{ds}$ are mutually perpendicular at every point on the Gaussian surface.  **(2 Marks)**
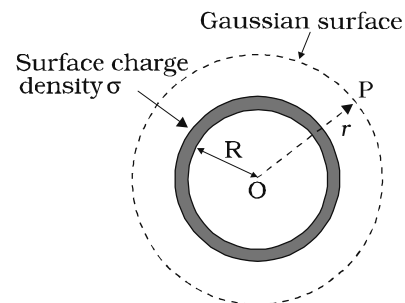


Fig. (a) $r > R,$

∴ $\displaystyle\oint_S \vec{E}.\vec{ds} = E\int_S ds = E \times S$

or, $\phi = E \times 4\pi r^2$ ..... (i)

According to Gauss's theorem

$$\phi = \frac{Q}{\in_0}$$

$\therefore \quad \vec{E} \cdot \vec{ds} = \frac{1}{\in_0} \cdot Q = \frac{1}{\in_0} \cdot \sigma \times 4\pi R^2$ ....(ii)

$\therefore \quad E \times 4\pi r^2 = \frac{\sigma}{\in_0} \cdot 4\pi R^2$

or, $\quad E = \frac{q}{4\pi \in_0 r^2} \cdot R^2$ \qquad (for r > R)

where q is the total charge on the shell.

(ii) When the point P lies inside the shell : In this case, the spherical Gaussian surface lies inside the cell. Since the charge lies outside the surfaces the Gaussian surface enclose no charge. **(2 Marks)**



Surface charge density σ — Gaussian surface
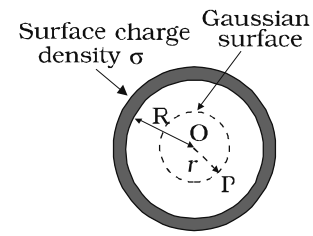
$\therefore \quad \oint \vec{E} \cdot \vec{ds} = E \oint S = E \times 4\pi r^2 = \frac{q}{\in_0}$

(from Gauss's law)

or, $\quad E \times 4\pi r^2 = 0$ \qquad $(\because q = 0)$

$\therefore \quad E = 0$ \qquad (for r < R)

**Graph** showing variation of the electric field E with distance r from the centre : **(1 Mark)**

## ELECTROSTATIC POTENTIAL AND CAPACITANCE

**Relation between electric potential and field,**
$$E = -\frac{dV}{dr}$$



Equipotentials

- On axial line
$$V = \frac{P}{4\pi\varepsilon_0 r^2}$$
- On equatorial line $V = 0$
- At general point,
$$Vg = \frac{kp\cos\theta}{r^2}$$

At a point outside the spherical shell
$$\frac{1}{4\pi \in_0}\frac{q}{r}(r > R)$$

At a point on the surface or inside the spherical shell
$$V = \frac{1}{4\pi \in_0}\frac{q}{R}(r \leq R)$$

**Electrostatic potential due to a system of charges**
$$V = V_1 + V_2 + V_3 \cdots + V_n$$
$$V = k\sum_{i=1}^{n}\frac{q_i}{r_i}$$



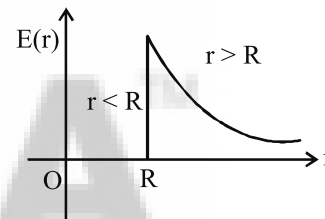**Electric potential due to a dipole**

Electric potential due to a charged conducting spherical shell
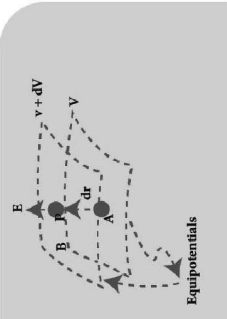
**Electrostatic potential**
$$(V_0) = \frac{\text{work done } w_\infty}{\text{charge } (q_0)}$$
Positive potential due to +(ve) charge and negative potential due to –(ve) charge

**Electrostatic Potential Energy**
The electrostatic potential energy of a system of point charges is defined as the work done in assembling this system of charges from an infinite distance apart to a certain distance
$$U_{12} = \frac{kq_1q_2}{r_{12}} = q_1V_2$$

**Electrostatic potential due to a point charge**
$$V = k\frac{q}{r}$$

**Capacitance**
$$\text{Capacitance }(C) = \frac{\text{Charge }(Q)}{\text{Potential }(V)}$$

**Equipotential surface**
Imaginary surface joining the points of same potential in an electric field



Equipotential surface for a uniform electric field

Equipotential surface for a dipole

Equipotential surface due to single charge q

Equipotential surface for two identical positive charge

**Capacitance of a parallel plate capacitor**
$$C = \frac{KA\varepsilon_0}{d}\quad K = \text{dielectric constant}$$



The parallel plate capacitor
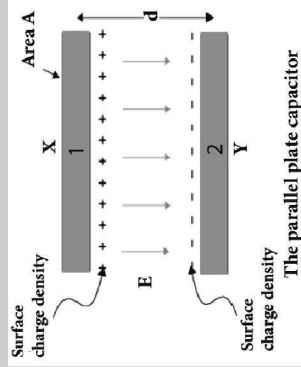
- If a dielectric slab is partially filled between the plates
$$\Rightarrow C' = \frac{\varepsilon_0 A}{d - t + \dfrac{t}{K}}$$
- When a metallic slab is inserted between the plates
$$C' = \frac{\varepsilon_0 A}{(d - t)}$$

**Series combination of capacitors**
Equivalent capacitance
$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

**Combination of capacitors**

**Parallel combination of capacitors**
Equivalent capacitance
$$C_P = C_1 + C_2 + \cdots C_n$$

**Energy stored in a capacitor**
$$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV$$

# 27

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Class

# 12

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# CONTENTS

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# CHAPTER 1

# Solutions

## 1 Multiple Choice Questions

**1.** Which of the following is an example of a solid solution?

[CBSE Sample 2021-22, K]

(a) sea water      (b) sugar solution

(c) smoke      (d) 22 carat gold

## 2 Assertion Reason/Two Statement Type Questions

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).

(b) Both (A) and (R) are true, but (R) is not the correct explanation of (A).

(c) (A) is true, but (R) is false.

(d) (A) is false, but (R) is true.

**2.** **Assertion (A):** Molarity of a solution changes with temperature.

**Reason (R):** Molarity is a colligative property.

[All India 2021-22, Term-I, K]

## 1 Multiple Choice Questions

**1.** Solubility of gas in liquid decreases with increase in

[All India 2023, Set-I, K]

(a) Pressure

(b) Temperature

(c) Volume

(d) Number of solute molecules

**2.** An unknown gas 'X' is dissolved in water at 2.5 bar pressure and has mole fraction 0.04 in solution. The mole fraction of 'X' gas when the pressure of gas is doubled at the same temperature is

[All India 2022, Term-I, Ap]

(a) 0.08      (b) 0.04

(c) 0.02      (d) 0.92

**3.** Solubility of gases in liquids decreases with rise in temperature because dissolution is an:

[CBSE 2021-22, Term-I, K]

(a) endothermic and reversible process

(b) exothermic and reversible process

(c) endothermic and irreversible process

(d) exothermic and irreversible process

## 2 Assertion Reason/Two Statement Type Questions

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).

(b) Both (A) and (R) are true, but (R) is not the correct explanation of (A).

(c) (A) is true, but (R) is false.

(d) (A) is false, but (R) is true.

**4.** **Assertion (A) :** Aquatic species are more comfortable in cold waters rather than in warm waters.

**Reason (R) :** Different gases have different $K_H$ values at the same temperature      [CBSE Sample 2020-21, U]

| 5 | *Short Answer Questions (2 or 3 Marks)* |
|---|---|

5. Answer the following questions:

[CBSE Sample 2022-23, **U**]

(a) State Henry's law and explain why are the tanks used by scuba divers filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen)?

(b) Assume that argon exerts a partial pressure of 6 bar. Calculate the solubility of argon gas in water. (Given Henry's law constant for argon dissolved in water, $K_H = 40$ kbar)

---

| Topic-3: | *Vapour Pressure of Liquid Solutions, Ideal and Non-ideal Solutions* |
|---|---|

| 1 | *Multiple Choice Questions* |
|---|---|

1. An azeotropic mixture of two liquids will have a boiling point lower than either of the two liquids when it

[All India 2023 Set-II, **U**]

(a) shows a negative deviation from Raoult's law

(b) forms an ideal solution

(c) shows a positive deviation from Raoult's law

(d) is saturated

2. 1 mole of liquid A and 2 moles of liquid B make a solution having a total vapour pressure 40 torr. The vapour pressure of pure A and pure B are 45 torr and 30 torr respectively. The above solution.

[Delhi 2023 Set-I, **Ap**]

(a) is an ideal solution

(b) shows positive deviation

(c) shows negative deviation

(d) is a maximum boiling azeotrope.

3. Which one of the following pairs will form an ideal solution? [All India 2022, Term-I, **K**]

(a) Chloroform and acetone

(b) Ethanol and acetone

(c) *n*-hexane and *n*-heptane

(d) Phenol and aniline

4. Which of the following formula represents Raoult's law for a solution containing non-volatile solute ?

[All India 2022, Term-I, **K**]

(a) $p_{solute} = p°_{solute} \cdot x_{solute}$

(b) $p = K_H \cdot X$

(c) $p_{total} = p_{solvent}$

(d) $p_{solvent} = p°_{solvent} \cdot x_{solvent}$

5. An azeotropic solution of two liquids has a boiling point lower than either of the two when it

[All India 2022, Term-I, **K**]

(a) shows a positive deviation from Raoult's law.

(b) shows a negative deviation from Raoult's law.

(c) shows no deviation from Raoult's law.

(d) is saturated.

6. On mixing 20 mL of acetone with 30 mL of chloroform, the total volume of the solution is

[All India 2022, Term-I, **U**]

(a) < 50 mL         (b) = 50 mL

(c) > 50 mL         (d) = 10 mL

7. Identify the law which is stated as:

"For any solution, the partial vapour pressure of each volatile component in the solution is directly proportional to its mole fraction."

[All India 2021-22, Term-I, **K**]

(a) Henry's law

(b) Raoult's law

(c) Dalton's law

(d) Gay-Lussac's Law

8. When 1 mole of benzene is mixed with 1 mole of toluene The vapour will contain: (Given : vapour of benzene = 12.8kPa and vapour pressure of toluene = 3.85 kPa).

[CBSE Sample 2020-21, **U**]

(a) equal amount of benzene and toluene as it forms an ideal solution

(b) unequal amount of benzene and toluene as it forms a non ideal solution

(c) higher percentage of benzene

(d) higher percentage of toluene

**2**  *Assertion Reason/Two Statement Type Questions*

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:
(a)  Both (A) and (R) are true and (R) is the correct explanation of (A).
(b)  Both (A) and (R) are true, but (R) is not the correct explanation of (A).
(c)  (A) is true, but (R) is false.
(d)  (A) is false, but (R) is true.

**9.**  **Assertion (A) :** The enthalpy of mixing $\Delta_{mix} H$ is equal to zero for an ideal solution.
    **Reason (R) :** For an ideal solution the interaction between solute and solvent molecules is stronger than the interactions between solute-solute or solvent-solvent molecules.  **[All India 2023, Set-I, K]**

**10.**  **Assertion (A) :** Nitric acid and water form maximum boiling azeotrope.  **[CBSE Sample 2020-21, U]**
    **Reason (R) :** Azeotropes are binary mixtures having the same composition in liquid and vapour phase.

**4**  *Very Short Answer Questions (1 Mark)*

**11.**  The vapour pressure of pure liquid X and pure liquid Y at 25 °C are 120 mm Hg and 160 mm Hg respectively. If equal moles of X and Y are mixed to form an ideal solution, calculate the vapour pressure of the solution.  **[All India 2023, Set-I, Ap]**

**5**  *Short Answer Questions (2 or 3 Marks)*

**12.**  What is Henry's Law? Give one application of it.  **[All India 2023, K]**

**13.**  State Raoult's law for a solution containing volatile components. What is the similarity between Raoult's law and Henry's law?  **[Delhi 2020, K]**

**14.**  Give reasons for the following:  **[All India 2019, U]**
    (a)  Aquatic species are more comfortable in cold water than warm water.  **[All India 2019, U]**
    (b)  At higher altitudes, people suffer from anoxia resulting in inability to think.
    **[All India 2019, U]**

**15.**  What type of azeotropic mixture will be formed by a solution of acetone and chloroform? Justify on the basis of strength of intermolecular interactions that develop in the solution.  **[All India 2019, U]**

**16.**  State Raoult's law for a solution containing volatile components. Write two characteristics of the solution which obeys Raoult's law at all concentrations.
    **[Delhi 2019, K]**

**17.**  Write two differences between an ideal solution and a non-ideal solution.  **[All India 2019, Set-II]**

**18.**  (i)  Gas (A) is more soluble in water than gas (B) at the same temperature. Which one of the two gases will have the higher value of $K_H$ (Henry's constant) and why ?  **All India 2016, K**
    (ii)  In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes ?
    **[All India 2016, K]**

**19.**  What is meant by positive deviations from Raoult's law ? Give an example. What is the sign of $\Delta_{mix}H$ for positive deviation ?  **[Delhi 2015, K]**

**20.**  Define azeotropes. What type of azeotrope is formed by positive deviation from Raoult's law ? Give an example.
    **[Delhi 2015]**

**21.**  Define an ideal solution and write one of its characteristics.
    **[Delhi 2014, K]**

---

**Topic-4:**  *Colligative Properties and Determination of Molar Mass, Abnormal Molar Masses*

**1**  *Multiple Choice Questions*

**1.**  Isotonic solutions have the same  **[Delhi 2024, K]**
    (a)  density  (b)  refractive index
    (c)  osmotic pressure  (d)  volume

**2.**  Van't Hoff factor for $Na_2SO_4.10H_2O$ solution, assuming complete ionization is  **[Delhi 2024, Ap]**
    (a)  1  (b)  3
    (c)  13  (d)  2

**3.**  Which of the following aqueous solution will have highest boiling point?  **[Delhi 2023, Set-I, U]**
    (a)  1.0 M KCl  (b)  1.0 M $K_2SO_4$
    (c)  2.0 M KCl  (d)  2.0 M $K_2SO_4$

**4.**  If molality of a dilute solution is doubled, the value of the molal elevation constant ($K_b$) will be
    **[Delhi 2023 Set-I, U]**
    (a)  halved  (b)  doubled
    (c)  tripled  (d)  unchanged

**5.** Out of the following 1.0 M aqueous solutions, which one will show largest freezing point depression?

**[Delhi 2023 Set-III, U]**

(a) NaCl      (b) $Na_2SO_4$

(c) $C_6H_{12}O_6$      (d) $Al_2(SO_4)_3$

**6.** Elevation of boiling point is inversely proportional to

**[All India 2022, Term-I, K]**

(a) molal elevation constant ($K_b$)

(b) molality ($m$)

(c) molar mass of solute ($M$)

(d) weight of solute ($W$)

**7.** The boiling point of a 0.2 m solution of a non-electrolyte in water is ($K_b$ for water = 0.52 K kg mol$^{-1}$)

**[All India 2022, Term-I, Ap]**

(a) 100 °C      (b) 100.52 °C

(c) 100.104 °C      (d) 100.26 °C

**8.** In the following diagram point, 'X' represents

**[All India 2022, Term-I, U]**
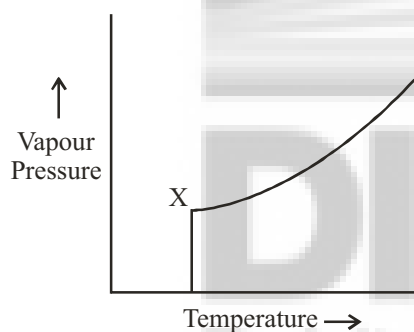
(a) Boiling point of solution

(b) Freezing point of solvent

(c) Boiling point of solvent

(d) Freezing point of solution

**9.** In which of the following cases blood cells will shrink:

**[CBSE Sample 2021-22, U]**

(a) when placed in water containing more than 0.9% (mass/volume) NaCl solution.

(b) when placed in water containing less than 0.9% (mass /volume) NaCl solution.

(c) when placed in water containing 0.9% (mass/volume) NaCl solution.

(d) when placed in distilled water.

**10.** How much ethyl alcohol must be added to 1 litre of water so that the solution will freeze at –14°C?

($K_f$ for water = 1.86°C/mol)

**[CBSE Sample 2021-22, Ap]**

(a) 7.5 mol      (b) 8.5 mol

(c) 9.5 mol      (d) 10.5 mol

**11.** Water retention or puffiness due to high salt intake occurs due to: **[CBSE Sample 2021-22, K]**

(a) diffusion

(b) vapour pressure difference

(c) osmosis

(d) reverse osmosis

**2** *Assertion Reason/Two Statement Type Questions*

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).

(b) Both (A) and (R) are true, but (R) is not the correct explanation of (A).

(c) (A) is true, but (R) is false.

(d) (A) is false, but (R) is true.

**12.** **Assertion (A):** Elevation in boiling point is a colligative property. **[All India 2023 Set-II, U]**

**Reason (R):** The lowering of vapour pressure of solution causes elevation in boiling point.

**13.** **Assertion (A):** A raw mango placed in a saline solution loses water and shrivel into pickle.

**Reason (R):** Through the process of reverse osmosis, raw mango shrivel into pickle.

**[All India 2022, Term-I, K]**

**14.** **Assertion (A):** Cryoscopic constant depends on nature of solvent. **[CBSE Sample 2021-22, U]**

**Reason (R):** Cryoscopic constant is a universal constant.

**15.** **Assertion (A):** Elevation in boiling point is a colligative property. **[Delhi 2020, Set-I]**

**Reason (R):** Elevation in boiling point is directly proportional to molarity.

**16.** **Assertion (A):** 0.1 M solution of KCl has greater osmotic pressure than 0.1 M solution of glucose at same temperature.

**Reason (R):** In solution, KCl dissociates to produce more number of particles. **[Delhi 2020, U]**

**4** *Very Short Answer Questions (1 Mark)*

**17.** Identify which liquid will have a higher vapour pressure at 90°C if the boiling points of two liquids A and B are 140°C and 180°, respectively. **[All India 2020, U]**

**18.** What are isotonic solutions? **[Delhi 2014, K]**

**5** **Short Answer Questions (2 or 3 Marks)**

**19.** 18 g of a non-volatile solute is dissolved in 200 g of $H_2O$ freezes at 272.07 K. Calculate the molecular mass of solute ($K_f$ for water = 1.86 K kg mol$^{-1}$)

**[All India 2024, Ap]**

**20.** A 5% solution of $Na_2SO_4.10H_2O$ (MW = 322) is isotonic with 2% solution of non– electrolytic, non volatile substance X. Find out the molecular weight of X. **[CBSE Sample 2023-24, U]**

**21.** When 19.5 g of F – $CH_2$ – COOH (Molar mass = 78g mol$^{-1}$). is dissolved in 500 g of water, the depression in freezing point is observed to be FC. Calculate the degree of dissociation of F – $CH_2$ – COOH.

[Given : $K_f$ for water = 1.86 K kg mol$^{-1}$]

**[All India 2023, Set-I, Ap]**

**22.** For a 5% solution of urea (Molar mass = 60 g/mol), calculate the osmotic pressure at 300 K. [R = 0.0821 L atm K$^{-1}$ mol$^{-1}$] **[All India 2020, U]**

**23.** Visha took two aqueous solutions – one containing 7.5 g of urea (Molar mass = 60 g/mol) and the other containing 42.75 g of substance Z in 100 g water, respectively. It was observed that both the solutions froze at the same temperature. Calculate the molar mass of Z.

**[All India 2020, U]**

**24.** Calculate the mass of ascorbic acid (Molar mass = 176 g mol$^{-1}$) to be dissolved in 75 g of acetic acid, to lower its freezing point by 1.5°C. ($k_f$ = 3.9 K kg mol$^{-1}$)

**[All India 2020, Ap]**

**25.** A 0.01 m aqueous solution of $AlCl_3$ freezes at –0.068 °C. Calculate the percentage of dissociation.

[Given: $K_f$ for water = 1.86 K kg mol$^{-1}$]

**[Delhi 2020, Ap]**

**26.** At 300 K, 30 g of glucose present in a litre of its solution has an osmotic pressure of 4·98 bar. If the osmotic pressure of a glucose solution is 1·52 bar, at the same temperature what would be its concentration?

**[All India 2019, Ap]**

**27.** A 4% solution(w/w) of sucrose (M = 342 g mol$^{-1}$) in water has a freezing point of 271.15 K. Calculate the freezing point of 5% glucose (M = 180 g mol$^{-1}$) in water. (Given: Freezing point of pure water = 273.15 K)

**[Delhi 2019, Ap]**

**28.** Calculate the freezing point of a solution containing 60 g glucose (Molar mass = 180 g mol$^{-1}$) in 250 g of water.

($k_f$ of water = 1.86 K kg mol$^{-1}$) **[All India 2018, Ap]**

**29.** Given reasons for the following : **[All India 2018, U]**

(a) Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers.

**[All India 2018, U]**

(b) Aquatic animals are more comfortable in cold water than in warm water. **[All India 2018, U]**

(c) Elevation of boiling point of 1 M KCl solution is nearly double than of 1 M sugar solution.

**[All India 2018, U]**

**30.** Define the following terms : **[Delhi 2017, K]**

(i) Colligative properties

(ii) Molality (m)

**31.** A 10% solution (by mass) of sucrose in water has freezing point of 269.15 K. Calculate the freezing point of 10% glucose in water, if freezing point of pure water is 273.15 K. **[Delhi 2017, Ap]**

Given : (Molar mass of sucrose = 342 g mol$^{-1}$) (Molar mass of glucose = 180 g mol$^{-1}$)

**32.** Calculate the boiling point of solution when 4g of $MgSO_4$ (M = 120 g mol$^{-1}$) was dissolved in 100 g of water, assuming $MgSO_4$ undergoes complete ionization.

($K_b$ for water = 0.52 K kg mol$^{-1}$) **[All India 2016, Ap]**

**33.** Why does a solution containing non-volatile solute have higher boiling point than the pure solvent?

Why is elevation of boiling point a colligative property?

**[All India 2015, K]**

**34.** Calculate the freezing point of the solution when 31 g of ethylene glycol ($C_2H_6O_2$) is dissolved in 500 g of water ($K_f$ for water = 1.86 K kg mol$^{-1}$)

**[All India 2015, Ap]**

**35.** 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute (associated or dissociated).

(Given : Molar mass of benzoic acid = 122 g mol$^{-1}$, $K_f$ for benzene = 4.9 K kg mol$^{-1}$) **[Delhi 2015, Ap]**

**36.** Calculate the mass of compound (molar mass = 256 g mol$^{-1}$) to be dissolved in 75 g of benzene to lower its freezing point by 0.48 K ($K_f$ = 5.12 K kg mol$^{-1}$).

**[Delhi 2014, Ap]**

**37.** 18 g of glucose, $C_6H_{12}O_6$ (Molar Mass = 180 g mol$^{-1}$) is dissolved in 1 kg of water in a sauce pan. At what temperature will this solution boil?

($K_b$ for water = 0.52 K kg mol$^{-1}$, boiling point of pure water = 373.15 K) **[Delhi 2013, Ap]**

**38.** Determine the osmotic pressure of solution prepared by dissolving $2.5 \times 10^{-2}$ g of $K_2SO_4$ in 2 L of water at 25°C, assuming that it is completely dissociated.
($R = 0.0821$ L atm $K^{-1}$ mol$^{-1}$, Molar mass of $K_2SO_4 = 174$ g mol$^{-1}$).      **[Delhi 2013, Ap]**

┌─── **6** ─────────── *Long Answer Questions* ─────┐

**39.** (a) (i) Define reverse osmosis.
    (ii) Why are aquatic species more comfortable in cold water in comparison to warm water?
    (iii) A solution containing 2 g of glucose (M = 180 g mol$^{-1}$) in 100 g of water is prepared at 303 K. If the vapour pressure of pure water at 303 K is 32.8 mm Hg, what would be the vapour pressure of the solution?     **[All India 2024, Ap]**

**OR**

(b) (i) Predict whether Van't Hoff factor will be less or greater than one, when Ethanoic acid is dissolved in benzene.     **[All India 2024, Ap]**
    (ii) Define ideal solution.
    (iii) Calculate the mass of $CaCl_2$ (molar mass = 111 g mol$^{-1}$) to be dissolved in 500 g of water to lower its freezing point by 2K, assuming that $CaCl_2$ undergoes complete dissociation.
    ($K_f$ for water = 1.86 K kg mol$^{-1}$)

**40.** (a) (i) Ishan's automobile radiator is filled with 1.0 kg of water. How many grams of ethylene glycol (Molar mass = 62 g mol$^{-1}$) must Ishan add to get the freezing point of the solution lowered to $-2.8$ °C. $K_f$ for water is 1.86 K kg. mol$^{-1}$.
    (ii) What type of deviation from Raoult's law is shown by ethanol and acetone mixture? Give reason.     **[Delhi 2024, Ap]**

**OR**

(b) (i) Boiling point of water at 750 mm Hg pressure is 99.68 °C. How much sucrose (Molar mass = 342 g mol$^{-1}$) is to be added to 500 g of water such that it boils at 100 °C? ($K_b$ for water = 0.52 K kg mol$^{-1}$).     **[Delhi 2024, Ap]**
    (ii) State Henry's law and write its any one application.

**41.** (a) What is the effect of temperature on the solubility of glucose in water?    **[CBSE Sample 2023-24, K]**
(b) Ibrahim collected a 10mL each of fresh water and ocean water. He observed that one sample labeled "P" froze at 0°C while the other "Q" at –1.3°C. Ibrahim forgot which of the two, "P" or "Q" was ocean water. Help him identify which container contains ocean water, giving rationalization for your answer.
     **[CBSE Sample 2023-24, Ap]**

(c) Calculate Van't Hoff factor for an aqueous solution of $K_3[Fe(CN)_6]$ if the degree of dissociation ($\alpha$) is 0.852. What will be boiling point of this solution if its concentration is 1 molal? ($K_b = 0.52$ K kg/mol)
     **[CBSE Sample 2023-24, Ap]**

**42.** (a) What type of deviation from Rault's Law is expected when phenol and aniline are mixed with each other? What change in the net volume of the mixture is expected? Graphically represent the deviation.
     **[CBSE Sample 2023-24, K]**

(b) The vapour pressure of pure water at a certain temperature is 23.80 mm Hg. If 1 mole of a non–volatile non–electrolytic solute is dissolved in 100g water, Calculate the resultant vapour pressure of the solution.    **[CBSE Sample 2023-24, Ap]**

**43.** (i) Why is boiling point of 1M NaCl solution more than that of 1M glucose solution?
     **[Delhi 2023, Set-I, Ap]**

(ii) A non-volatile solute 'X' (molar mass = 50 g mol$^{-1}$) when dissolved in 78g of benzene reduced its vapour pressure to 90%. Calculate the mass of X dissolved in the solution.    **[Delhi 2023, Set-I, Ap]**

(iii) Calculate the boiling point elevation for a solution prepared by adding 10g of $MgCl_2$ to 200g of water assuming $MgCl_2$ is completely dissociated.
($K_b$ for Water = 0.512 K kg mol$^{-1}$. Molar mass $MgCl_2$ = 95g mol$^{-1}$)    **[Delhi 2023, Set-I, Ap]**

**44.** (i) Why is the value of Van't Hoff factor for ethanoic acid in benzene close to 0.5?
     **[Delhi 2023, Set-I, Ap]**

(ii) Determine the osmotic pressure of a solution prepared by dissolving $2.32 \times 10^{-2}$g of $K_2SO_4$ in 2L of solution at 25 °C, assuming that $K_2SO_4$ is completely dissociated.
($R = 0.082$ L atm $K^{-1}$ mol$^{-1}$, Molar mass $K_2SO_4 = 174$g mol$^{-1}$)    **[Delhi 2023, Set-I, Ap]**

(iii) When 25.6g of Sulphur was dissolved in 1000g of benzene, the freezing point lowered by 0.512 K. Calculate the formula of Sulphur ($S_x$).
($K_f$ for benzene = 5.12 K kg mol$^{-1}$. Atomic mass of Sulphur = 32g mol$^{-1}$)    **[Delhi 2023, Set-I, Ap]**

**45.** (a) A 10% solution (by mass) of sucrose in water has a freezing point of 269.15K. Calculate the freezing point of 10% glucose in water if the freezing point of pure water is 273.15K    **[All India 2017, Ap]**

Given:

(Molar mass of sucrose = 342 g mol$^{-1}$)

(Molar mass of glucose =180 g mol$^{-1}$)

(b) Define the following terms:   **[All India 2017, K]**

(i) Molality (m)

(ii) Abnormal molar mass

**46.** (a) 30 g of urea (M = 60 g mol$^{-1}$) is dissolved in 846 g of water. Calculate the vapour pressure of water for this solutions if vapour pressure of pure water at 298 K is 23.8 mm Hg.

**[All India 2017, Ap]**

(b) Write two difference between ideal solutions and non-ideal solutions.   **[All India 2017, K]**

**47.** (a) Calculate the freezing point of solution when 1.9 g of MgCl$_2$ (M = 95 g mol$^{-1}$) was dissolved in 50 g of water, assuming MgCl$_2$ undergoes complete ionization. (K$_f$ for water = 1.86 K kg mol$^{-1}$)

**[Delhi 2016, Ap]**

(b) (i) Out of 1 M glucose and 2 M glucose, which one has a higher boiling point and why ?

**[Delhi 2016, U]**

(ii) What happens when the external pressure applied becomes more than the osmotic pressure of solution ?   **[Delhi 2016, U]**

**48.** (a) When 2.56 g of sulphur was dissolved in 100 g of CS$_2$, the freezing point lowered by 0.383 K. Calculate the formula of sulphur (S$_x$).

(K$_f$ for CS$_2$ = 3.83 K kg mol$^{-1}$, Atomic mass of Sulphur = 32 g mol$^{-1}$]   **[Delhi 2016, Ap]**

(b) Blood cells are isotonic with 0.9% sodium chloride solution. What happens if we place blood cells in a solution containing   **[Delhi 2016, U]**

(i) 1.2% sodium chloride solution ?

(ii) 0.4% sodium chloride solution ?

**49.** (a) Define the following terms :   **[All India 2014, K]**

(i) Molarity

(ii) Molal elevation constant (K$_b$)

(b) A solution containing 15 g urea (molar mass = 60 g mol$^{-1}$) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g mol$^{-1}$) in water. Calculate the mass of glucose present in one litre of its solution.   **[All India 2014, Ap]**

**50.** (a) What type of deviation is shown by a mixture of ethanol and acetone? Give reason.

**[All India 2014, K]**

(b) A solution of glucose (molar mass = 180 g mol$^{-1}$) in water is labelled as 10% (by mass). What would be the molality and molarity of the solution?

(Density of solution = 1.2 g mL$^{-1}$)

**[All India 2014, Ap]**

**51.** (a) State Raoult's law for a solution containing volatile components. How does Raoult's law become a special case of Henry's law?   **[All India 2013, Ap]**

(b) 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. Find the molar mass of the solute. (K$_f$ for benzene = 5.12 K kg mol$^{-1}$)   **[All India 2013, Ap]**

**52.** (a) Define the following terms :   **[All India 2013, Ap]**

(i) Ideal solution

(ii) Azeotrope

(iii) Osmotic pressure

(b) A solution of glucose (C$_6$H$_{12}$O$_6$) in water is labelled as 10% by weight. What would be the molality of the solution?   **[All India 2013, Ap]**

(Molar mass of glucose = 180 g mol$^{-1}$)

**7**   *Case Based Questions*

**53.** Henna is investigating the melting point of different salt solutions. She makes a salt solution using 10 mL of water with a known mass of NaCl salt. She puts the salt solution into a freezer and leaves it to freeze. She takes the frozen salt solution out of the freezer and measures the temperature when the frozen salt solution melts. She repeats each experiment.   **[CBSE Sample 2022-23, A]**

| S.No. | Mass of the salt Used in g | Melting point in °C | |
|---|---|---|---|
| | | Readings Set 1 | Reading Set 2 |
| 1 | 0.3 | −1.9 | −1.9 |
| 2 | 0.4 | −2.5 | −2.6 |
| 3 | 0.5 | −3.0 | −5.5 |
| 4 | 0.6 | −3.8 | −3.8 |
| 5 | 0.8 | −5.1 | −5.0 |
| 6 | 1.0 | −6.4 | −6.3 |

**Assuming the melting point of pure water as 0°C, answer the following questions:**

(a) One temperature in the second set of results does not fit the pattern. Which temperature is that? Justify your answer.

(b) Why did Henna collect two sets of results?

(c) In place of NaCl, if Henna had used glucose, what would have been the melting point of the solution with 0.6 g glucose in it?

What is the predicted melting point if 1.2 g of salt is added to 10 mL of water? Justify your answer.

# Solutions

1. **(d)** 22 carat gold (it is an alloy so solid in solid solution)
   **(1 Mark)**

2. **(c)** Molarity of a solution changes with temperature. Molarity is not a colligative property. **(1 Mark)**

1. **(b)** Temperature;
   The solubility of gas in the decreases with increase in temperature as the kinetic energy of the gas increases. Which is increases the escaping tendency from liquid. **(1 Mark)**

2. **(a)** We know that;
   $$\frac{P_1}{P_2} = \frac{\chi_1}{\chi_2}$$
   Here;
   $P_1$ = initial pressure; $P_2$ = final pressure; $\chi$ = mole fraction
   $$\frac{2.5}{5} = \frac{0.04}{\chi_2}$$
   $\chi_2 = 0.08$ **(1 Mark)**

3. **(b)** Exothermic and reversible process (according to Le-Chatlier principle solubility of gases in liquids decreases with rise in temperature) **(1 Mark)**

4. **(b)** Aquatic species are more comfortable in cold water because solubility of oxygen in water is more in cold water than in warm water. **(1 Mark)**

5. **(a)** Henry's law: the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution. **(1 Mark)**
   The pressure underwater is high, so the solubility of gases in blood increases. When the diver comes to surface the pressure decreases so does the solubility causing bubbles of nitrogen in blood, to avoid this situation and maintain the same partial pressure of nitrogen underwater too, the dilution is done. **(1 Mark)**

   **(b)** $p = K_H x$
   mole fraction of argon in water $x = p/k = 6/40 \times 10^3$
   $= 1.5 \times 10^{-4}$ **(1 Mark)**

1. **(c)** When a solution shows positive deviation from Raoult's law, the intermolecular attractive forces between the solute-solvent molecules are weaker than those between the solute-solute and solvent-solvent molecules. This will increase the vapour pressure and results in positive deviation. Hence, the azeotropic mixture of the two liquids will have a boiling point lower than either of the two liquids.
   **(1 Mark)**

2. **(b)** Total vapour pressure, $P_{Total} = P_A + P_B$
   $$P_{Total} = X_A P_A^° + X_B P_B^°$$
   $$= \left(\frac{1}{3} \times 45\right) + \left(\frac{2}{3} \times 30\right)$$
   $= 15 + 20$
   $= 35$ torr
   Since, the actual vapour pressure of solution is 40 torr which is greater than the calculated value. It means the solution shows positive deviation from the ideal solution. **(1 Mark)**

3. **(c)** n-heptane and n-hexane obeys Raoult's law at all temperature and concentration. Hence; they will form an ideal solution. **(1 Mark)**

4. **(d)** Formula of Raoult's law for a non-volatile solute is:
   $$P_{solvent} = P_{solvent}^° \cdot \chi_{solvent}$$
   **(1 Mark)**

5. **(a)** Azeotropes are of two types:
   (i) The solution which shows large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition.
   (ii) The solution which shows large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition. **(1 Mark)**

6. **(a)** The mixture of acetone and chloroform show negative deviation due to which the total volume of the solution will be less than 50. **(1 Mark)**

7. **(b)** Raoult's law. **(1 Mark)**

8. **(c)** The vapour will contain higher percentage of benzene. **(1 Mark)**

9. **(c)** For ideal solution, $\Delta_{mix} H = 0$
   Solute – Solvent interaction = Solute – solute or Solvent – solvent interaction **(1 Mark)**

10. **(b)** Nitric acid and water solution show large negative deviation from Raoult's law. **(1 Mark)**

**11.** $p_x^0 = 120$ mm Hg, $p_y^0 = 166$ mm Hg at 25°C
Equal moles of X and Y.

$\therefore \quad \chi_x$ = mole fraction of X = $\dfrac{1}{2}$

$\chi_y$ = mole fraction of Y = $\dfrac{1}{2}$     **(½ Mark)**

$p_{Total} = p_x + p_y$     **(½ Mark)**
$\qquad = \chi_x\, p_x^0 + \chi_y\, p_y^0$

$\qquad = \left(\dfrac{1}{2}\times 120 + \dfrac{1}{2}\times 160\right)$ mm Hg     **(½ Mark)**

$\qquad = 140$ mm Hg     **(½ Mark)**

The vapour pressure of the solution = 140 mm Hg.

**12.**

**Topper's Answer**

Henry's Law states that the solubility of a gas in a liquid is directly proportional to its partial pressure over the liquid surface.
Mathematically, $P = K_H \chi$
where P: partial pressure of the gas
$\chi$: mole fraction of the gas in the solution
$K_H$: Henry's law constant

One application of Henry's law is seen in carbonated drinks. The cans are sealed under high pressure, and as soon as a can is opened, the pressure drops. This leads to $CO_2$ escaping from the drink, which we see as fizz.

**13.**

**Topper's Answer**

Ans 21: Raoult's law state that in a solution of volatile components, the partial pressure of each volatile component is directly proportional to their partial pressures mole fraction in the solution.

Let 2 volatile components be A and B
then, $p_A \propto x_A$ and $p_B \propto x_B$
$\Rightarrow p_A = p_A^0\, x_A$     $\Rightarrow p_B = p^0{}_B\, x_B$
$p_A^0, p^0{}_B$: proportionality constants.

On the other hand, Henry law states that partial pressure of a (volatile) gas in a liquid is directly proportional to its mole fraction.
$p \propto x \Rightarrow p = K_H\, x$
$K_H$ = Henry's constant

By comparing the two equations, we see they are very similar and it seems as the Raolts law is special case of Henry's law in which $K_H = p^0$

**Raoult's law:** For a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction in solution, $P \propto x$ ; $P = x\,P°$.

by Henry's law,

$P = x.K_H$

Here, P is the partial pressure of gas, $x$ is mole fraction of it in the solution and $K_H$ is the Henry's law constant.

In both Henry's law and Raoult's law, partial pressure of volatile component is directly proportional to mole fraction of it in the solution. **(1 + 1 = 2 Marks)**

14. (a) Solubility of gases in liquid is inversely proportional to temperature. As temperature increases, solubility of dissolved gases in water decreases. Hence, aquatic species find difficult to breath in warm water due to decreased availability of oxygen. **(1 Mark)**

    (b) Henry's Law states that the solubility of a gas in a liquid at a given temperature is directly proportional to the partial pressure of the gas.
    At higher altitude, partial pressure of oxygen is less than that at ground level, so low $O_2$ in blood causes

17.

climbers to become weak and makes them unable to think clearly. **(1 Mark)**

15. Maximum boiling azeotropes mixture will be formed by mixing of acetone and chloroform. In these solutions, the A—B interactions are stronger than the A—A and B—B molecular interactions present in the two liquids forming the solution. Hydrogen bonding will decrease the escaping tendency of the molecules.
    **(1 + 1 = 2 Marks)**

16. According to Raoult's law for a solution containing volatile components.

    "The partial vapour pressure of each component of the solution is directly proportional to it's mole fraction present in solution"

    The characteristics of the solution which obeys Raoult's law at all concentrations are as follows:

    (i) In a binary solution of components, A and B, the enthalpy of mixing $\Delta H_{mix} = 0$, i.e., in prepration of an ideal solution no thermal change is observed.

    (ii) In an ideal solution, the volume of mixing $\Delta V_{mix} = 0$, i.e., the final volume of the solution is equal to the sum of volumes of components being mixed.
    **(1 + 1 = 2 Marks)**

**Topper's Answer**

**18.** (i) According to Henry's law, the solubility of a gas is inversely related to the Henry's constant ($K_H$) for that gas. Hence, gas (B), being less soluble, would have a higher $K_H$ value than gas(A). **(1 Mark)**

> ✏️ **Note**
>
> *Henry's law only works if the molecules are at equilibrium. It does not work for gases at high pressure and if there is a chemical reaction between the solute and solvent.*

(ii) The non-ideal solution which shows large negative deviation from Raoult's law form maximum boiling azeotrop at a specific composition. Example, nitric acid and water. **(1 Mark)**

**19. Positive Deviation:** When the experimently determined vapour pressures of a binary liquid-liquid solution having different compositions are greater than calculated values of vapour pressure using Raoult's law, this is known as positive deviation.

In positive deviation the interaction between A-B is weaker than A-A and B-B. Where A and B are the two constituents liquid of binary solution. **(2 Marks)**

> ✏️ **Note**
>
> *In positive deviation the interaction between A – B is weaker than A – A and B – B while in negative deviation the interaction between A – A and B – B is weaker than A – B. Where A and B are the two constituents liquids of binary solution.*

**20.** Azeotropes are the binary mixtures of solution that have the same composition in liquid and vapour phases and that have constant boiling points.

A minimum boiling azeotrope is formed by solutions showing a large positive deviation from Raoult's law at a specific composition.

**Example:** An ethanol – water mixture containing approximately 95% ethanol by volume. **(2 Marks)**

**21.** The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions. For an ideal solution, the A-B interactions are nearly same as the A-A and B-B interactions. Where A and B are the two components of the solution. **(2 Marks)**

> ✏️ **Topic-4:** *Colligative Properties and Determination of Molar Mass, Abnormal Molar Masses*

**1. (c)** Isotonic solutions have equal osmotic pressure due to which there is no net flow of solvent / water across them. **(1 Mark)**

**2. (b)** $Na_2SO_4 \cdot 10H_2O$ dissociates into $2Na^+$, $SO_4^{2-}$ and $10H_2O$. The water of crystallization is not counted in the Van't Hoff factor as it is the solvent.
Thus, i = 2 + 1 = 3. **(1 Mark)**

**3. (d)** All the given species are strong electrolytes so they dissociate completely in the aqueous solution.

The species that gives the highest number of particles upon dissociation will have the highest boiling point.

1.0 M KCl = 1 mole $K^+$ ions + 1 mole $Cl^-$ ions.

2.0 M KCl = 2 moles $K^+$ ions + 2 mole $Cl^-$ ions.

1.0 M $K_2SO_4$ = 1 × 2 = 2 moles $K^+$ ions + 1 mole $SO_4^{2-}$ ions.

2.0 M $K_2SO_4$ = 2 × 2 = 4 moles $K^+$ ions + 2 moles $SO_4^{2-}$ ions.

Therefore, 2.0 M $K_2SO_4$ will give the highest number of particles and therefore its boiling point will be highest.

Therefore, option **(d)** is correct. **(1 Mark)**

**4. (d)** Since, the value of molal elevation constant ($K_b$) is constant for a particular solvent. Hence, it will remain unchanged when molality of the solution is doubled. **(1 Mark)**

**5. (d)** Freezing point depression is given by,

$\Delta T_f = i \times K_f \times m$

$\Rightarrow \quad \Delta T_f \, \alpha \, i$ (Van't Hoff factor)

NaCl dissociates to give 2 ions. $Na_2SO_4$ dissociates to give 3 ions. $C_6H_{12}O_6$ dissociates to give no ions. $Al_2(SO_4)_3$ dissociates to give 5 ions.

Hence, $Al_2(SO_4)_3$ will exhibit largest freezing point depression due to highest value of Van't Hoff factor (i = 5). **(1 Mark)**

**6. (c)** The formula of elevation in boiling point is:

$\Delta T_b = K_b \times m$

$\Delta T_b = \dfrac{K_b \times W_A}{M_B \times W_B (Kg)}$

∴ Elevation in boiling point is inversely proportional to molar mass of solute ($M_B$).

**(1 Mark)**

**7. (c)** $\Delta T_b = K_b \times m$
$\qquad = 0.52 \times 0.2$
$\Delta T_b = 0.104$
$\quad T_b = T_b^\circ + \Delta T_b$
$\qquad = 100 + 0.104$
$\qquad = 100.104°C$ **(1 Mark)**

**8. (b)** The point 'X' represents the freezing point of solvent. The freezing point of a substance may be defined as the temperature at which the vapour pressure of the substance in its liquid phase is equal to the vapour pressure in the solid phase. **(1 Mark)**

**9.** **(a)** When placed in water containing more than 0.9% (mass/volume) NaCl solution because fluid inside blood cells is isotonic with 0.9% NaCl solution.

**(1 Mark)**

**10.** **(a)** 7.5 mol

$$\Delta T_f = K_f m$$

$$\Delta T_f = K_f \frac{n_2 \times 1000}{w_1}$$

$$14 = 1.86 \times \frac{n_2 \times 1000}{1000}$$

$$n_2 = 7.5 \text{ mol}$$ **(1 Mark)**

**11.** **(c)** Osmosis **(1 Mark)**

**12.** **(a)** Elevation in boiling point depends on the number of solute molecules rather than their nature. So, it is a colligative property.

$$\Delta T_b = K_b, \text{ molality}$$

When a non–volatile solute is added to a solvent, the vapour pressure of the resulting solution is lower than that of pure solvent. Thus, a greater amount of heat must be supplied to the solution for it to boil.

This increase in the boiling point of the solution is the elevation of boiling point. **(1 Mark)**

**13.** **(c)** A is true but R is false. When raw mango is placed in a saline solution to prepare pickle the mango looses water due to osmosis and get shrivel. This event does not occur due to reverse osmosis.

**(1 Mark)**

> **Note**
>
> *In reverse osmosis the direction of osmosis is reversed by making pressure larger than the osmotic pressure and is applied to the solution side. In this, pure solvent flows outside of the conc. solution through a semipermeable membrane.*

**14.** **(c)** Cryoscopic constant depends on nature of solvent.

Cryoscopic constant is not a universal constant.

Cryoscopic constant varies with type of solvent.

**15.** ⭐ *Topper's Answer*

Ans19: A✓ RX ◯ Ans : C . A correct , R wrong

**(c)** Elevation in boiling point is directly proportional to molality. **(1 Mark)**

**16.** **(a)** KCl is an electrolyte, thus in solution it produces more number of particles than glucose. Hence, solution of KCl has greater osmotic pressure than glucose. **(1 Mark)**

**17.** Liquid A has higher vapour pressure. **(1 Mark)**

**18.** Two solutions having same osmotic pressure at a given temperature are called isotonic solutions. **(1 Mark)**

**19.** $M_2 = \dfrac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$ **(1 Mark)**

$$= \frac{1.86 \times 18 \times 1000}{(273.15 - 272.07) \times 200} = 155 \text{ g mol}^{-1}.$$ **(1 Mark)**

**20.** $\pi_1 = \pi_2$ **(½ Mark)**

$$iC_1RT = C_2RT$$ **(½ Mark)**

$$\frac{3 \times 5}{322} = \frac{2}{M}$$ **(½ Mark)**

$$M = \frac{2 \times 322}{3 \times 5}$$ **(½ Mark)**

$$M = 42.9 \text{ g}$$

**21.** 19.5 g of $F - CH_2 - COOH$ : $n_1 = \dfrac{19.5}{78} = 0.25$ mol

**(½ Mark)**

Molality of solution (m) $= \dfrac{0.25}{0.5} = 0.5$ (m)

Depression of freezing point due to dissociation $= 1°$

$\therefore \quad \Delta T_f = i \, mK_f$

$\therefore \quad i = \dfrac{1}{0.5 \times 1.86} = 1.075$ **(½ Mark)**
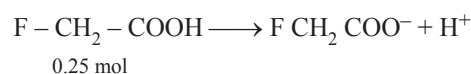
$$F - CH_2 - COOH \longrightarrow F\,CH_2\,COO^- + H^+$$
$$0.25 \text{ mol}$$
$$0.25(1-x) \text{ mol} \qquad 0.25x \text{ mol} \qquad 0.25x \text{ mol}$$

[Suppose x is the degree of dissociation]

$\therefore$ Total no. of particles

$= 0.25(1 - x) + 0.25x + 0.25x$ **(½ Mark)**

$= 0.25 + 0.25x$

$$i = \frac{\text{Total no. of moles of particles after dissociation}}{\text{Total no. of moles of particles before dissociation}}$$ **(½ Mark)**

$\therefore \quad i = \dfrac{0.25(1 + x)}{0.25} = 1.075$ **(½ Mark)**

or $\quad 1 + x = 1.075$

or $\quad x = 1.075 - 1 = 0.075$

$\therefore$ Degree of dissociation of $F - CH_2 - COOH = 0.075$.

**(½ Mark)**

**22.** 5% urea solution means. 5g urea is present in 100 mL of solution.

Molarity of solution

$$C = \frac{5g}{60 \text{ g/mol}} \times \frac{1000}{100L}$$

$$C = \frac{10}{12} \text{mol/L}$$ **(1 Mark)**

Osmotic pressure, $\pi = CRT$

$$\pi = \frac{10}{12} \times 0.0821 \times 300$$

$$= 20.525 \text{ atm}$$ **(1 Mark)**

**23.** It is given that the depression in freezing points of the two given aqueous solution are same.

$$(\Delta T_f)_{\text{urea}} = (\Delta T_f)_z$$ **(½ Mark)**

$$m_{\text{urea}} \times (k_f)_{\text{water}} = m_z \times (k_f)_{\text{water}}$$

$$\Rightarrow \quad \frac{\dfrac{7.5}{60}}{\dfrac{100}{1000}} = \frac{\dfrac{42.75}{M_z}}{\dfrac{100}{1000}}$$ **(½ Mark)**

$$\Rightarrow \quad M_z = 342 \text{ g/mol}$$ **(1 Mark)**

**24.** Let '*w*' be the required mass of ascorbic acid.

Molality of ascorbic and

$$m = \frac{(w/176)}{(75/1000)} \quad \Rightarrow \quad m = \frac{w}{176} \times \frac{1000}{75}$$ **(½ Mark)**

$(k_f)_{\text{acetic}} = 3.9 \text{ K kg mol}^{-1}$ **(1 Mark)**

$\Delta T_f = 1.5 \text{ °C} \quad \Rightarrow \quad \Delta T_f = 1.5 \text{ K}$

$\Delta T_f = m.k_f$ **(½ Mark)**

$$\Rightarrow \quad 1.5 = \frac{w}{176} \times \frac{1000}{75} \times 3.9$$

$\Rightarrow \quad w = 5.08 \text{ g} \approx 5\text{g}$ **(1 Mark)**

**25.**

$m = 0.01$; $\Delta T_f = 0.068\text{°C}$; $k_f = 1.86 \text{ K kg mol}^{-1}$

If *i* is the van't Hoff factor for the aqueous solution of $AlCl_3$, then

$\Delta T_f = i.K_f.m$ **(½ Mark)**

$$\Rightarrow \quad i = \frac{\Delta T_f}{K_f.m}$$

$$= \frac{0.068}{1.86 \times 0.01}$$ **(½ Mark)**

$$= 3.66$$ **(½ Mark)**

$$AlCl_3 \longrightarrow Al^{3+} + 3Cl^-$$ **(½Mark)**

initial      1      0      0

at equilibrium    $1 - x$    $x$    $3x$
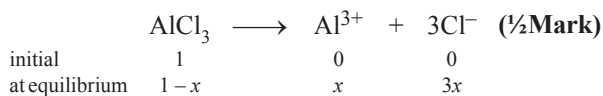
$$i = \frac{(1-x) + x + 3x}{1}$$ **(½ Mark)**

$$\Rightarrow \quad 3.66 = 1 + 3x \quad \Rightarrow \quad x = 0.89$$

$x$ is degree of dissociation.

$\therefore$ Percentage of dissociation = 89%. **(½ Mark)**

**Note**

$$i = \frac{Total\ number\ of\ moles\ after\ dissociation/association}{Total\ number\ of\ moles\ before\ dissociation/association}$$

**26.** Osmotic pressure,

$$\pi = CRT$$

$$\pi_1 = C_1 RT$$ **(1 Mark)**

$$4.98 = \frac{30/180}{1} RT \qquad \text{... (i)}$$

$$1.52 = C_2 RT \qquad \text{... (ii)}$$

Divide equation (i) by (ii)

$$\frac{4.98}{1.52} = \frac{1}{6 \times C_2} \Rightarrow C_2 = 0.0508 \text{ mol L}^{-1} \quad \textbf{(1 Mark)}$$

**Note**

*The measurement of osmotic pressure can be used to determine molecular weight of compounds and is also used in the desalination and purification of sea water, which involves the process of reverse osmosis.*

**27.**

**Topper's Answer**

14. Concentration of solution = 4% (w/w) [sucrose]

Considering 100g of solution

Mass of Sucrose = 4g ($m_S$)

Mass of water = 100 – 4 = 96g ($m_w$)

Molar mass of Sucrose, $M_S$ = 342 g mol$^{-1}$

Moles of Sucrose molecules

$$n_S = \frac{m_S}{M_S} = \frac{4}{342} \text{ mol} = \frac{2}{171} \text{ mol}$$

Molality of Solution = $\dfrac{n_S}{m_w (\text{in kg})}$

$$m = \frac{2 (1000)}{171 (96)} \text{ mol kg}^{-1}$$

$$m = \frac{2000}{171 \times 96} \text{ mol kg}^{-1}$$

Freezing point of solution = 271.15 K

Depression in freezing point = (273.15 – 271.15) K

= 2K = $\Delta T_f$

Now, $\Delta T_f = K_f \, m$

where $K_f$ = molal depression constant of water.

Substituting values,

$$2 = \frac{K_f \times 2000}{171 \times 96}$$

OR $\quad K_f = \frac{2 \times 171 \times 96}{2000} = \frac{171 \times 96}{1000} \; K \, kg \, mol^{-1}$    ⊕

Now, given 5% glucose solution.

Considering 100 g of solution.

Mass of glucose $= 5g = m_g$    [Mass of water $= 95g$]

Molar mass of glucose $= 180 \, g \, mol^{-1} = M_g$

moles of glucose, $n_g = \dfrac{m_g}{M_g} = \dfrac{5}{180} \, mol = \dfrac{1}{36} \, mol$

Molality of solution $= \dfrac{n_g}{mass\ of\ water\ (in\ kg)}$

$$m = \frac{1}{36(95)} \, 1000 \; mol \, kg^{-1} = \frac{1000 \, mol}{36 \times 95 \, kg^{-1}}$$

Using $\Delta T_f = K_f \, m$

$$\Delta T_f = \frac{171 \times 96}{1000} \times \frac{1000}{36 \times 95} \quad (from \; ① )$$

$$\Delta T_f = \frac{171 \times 96}{36 \times 95} \; K = 4.8 \, K$$

So, actual freezing point $= 273.15 K - 4.8 K$

$$= 2\overset{6}{7}\overset{12}{3}.15$$
$$\quad\ \ 4.80$$
$$\overline{\quad 268.35}$$

$$= 268.35 \, K$$

Hence, the freezing point of 5% glucose solution in water is $268.35 \, K$.

We know, $\Delta T_f = k_f m$

or $\quad \Delta T_f = \dfrac{k_f \times w_{sucrose} \times 1000}{E_{sucrose} w_{water}}$ $\qquad$ ...(i)

**(1 Mark)**

$\Delta T_f = 273.15 - 271.15 = 2$ K

put the value in (i) for 4% solution of sucrose in water

$2 = \dfrac{k_f \times 4 \times 1000}{342 \times 100} \Rightarrow k_f = 17.1$ K kg mol$^{-1}$

For 5% solution of glucose

$\Delta T_f = \dfrac{k_f \times w_{glucose} \times 1000}{M_{glucose} \times w_{water}}$ $\qquad$ **(1 Mark)**

$= \dfrac{17.1 \times 5 \times 1000}{180 \times 100} = 4.75$ K

$T_f = 273.15 - 4.75 = 268.4$ K $\qquad$ **(1 Mark)**

**28.** Given : Mass of glucose ($C_6H_{12}O_6$), $w_2 = 60$ g

Mass of water, $w_1 = 250$ g

Molecular mass of (glucose) ($M_2$) = 180 g mol$^{-1}$

$k_f = 1.86$ K kg mol$^{-1}$

Freezing point of solution, $T_f = ?$

We know,

$\Delta T_f = i k_f m$

for glucose, $i = 1$

$\therefore \quad \Delta T_f = k_f m$

$= k_f \times \dfrac{w_2}{M_2} \times \dfrac{1000}{w_1}$ $\qquad$ **(1 Mark)**

$\Delta T_f = 1.86 \times \dfrac{60}{180} \times \dfrac{1000}{250} = 2.48$ K

Now,

$\Delta T_f = T_f^0 - T_f$

$2.48 = 0\ °C - T_f$

$\therefore \quad T_f = -2.48\ °C$

$= 270.67$ K $\qquad$ **(1 Mark)**

**29.** (a) Osmotic pressure method is preferred for the determination of molar masses of macromolecules. This is because it is done around room temperature and molarity of solution is used instead of molality. as compared to other colligative properties, its magnitude is large even for very dilute solutions. this method is preferred for biomolecules as they are not stable at higher temperatures and polymers have poor solubility. $\qquad$ **(1 Mark)**

(b) Aquatic animals are more comfortable in cold water than in warm water. This is because as temperature increase, solubility of gases in water decreases (from Le-chatelier's principle). Thus, in warm water the amount of oxygen available decreases. As a result, aquatic animals are more comfortable in cold water. $\qquad$ **(1 Mark)**

(c) Elevation of boiling point for 1M KCl solution is nearly double than that of 1 M sugar solution. This is because elevation of boiling point depends on the value of '$i$'. KCl being a strong electrolyte completely dissociates in water to give K$^+$ and Cl$^-$ ions. Thus, $i = 2$ for KCl. On the other hand, sugar does not dissociate/associate in water so $i = 1$ for sugar solution. Hence $\Delta T_b$ (kCl) = $2\Delta T_b$ (sugar)

**(1 Mark)**

**30.** (i) Properties which depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are called colligative properties. $\qquad$ **(1 Mark)**

(ii) Molality (m): The number of gram molecule or moles of solute dissolved in 1 kg of solvent represents the molality of solution.

$\text{Molality} = \dfrac{\text{Number of gram molecule of solute (mol)}}{\text{Mass of solvent (in kg)}}$

**(1 Mark)**

**31.** Freezing point of surcose ($T_f$) = 269.15 K

Freezing point of water ($T°_f$) = 273.15 K

Molar mass of surcose = 342 g mol$^{-1}$

$\Delta T_f = 273.15 - 269.15 = 4$ K

Molar mass of glucose = 180 g mol$^{-1}$

Freezing point of glucose = ?

For sucrose $m = \dfrac{\text{moles of solute}}{W (in\ \text{kg})}$ $\qquad$ **(1 Mark)**

$= \dfrac{w \times 1000}{M_{sucose} \times W} = \dfrac{10 \times 1000}{90 \times 342}$

$\Delta T_f = K_f \times m$

$4 = K_f \times \dfrac{10 \times 1000}{90 \times 342}$

$K_f = 12.30$ K kg mol$^{-1}$

For glucose $\Delta T_f = K_f \times m$ $\qquad$ **(1 Mark)**

$\Delta T_f = 12.30 \times \dfrac{10 \times 1000}{90 \times 180}$

$\Delta T_f = 7.7$ K

Freezing point of glucose = $T_f = 273.15 - 7.7 = 265.45$ K

**(1 Mark)**

**32.** $K_b = 0.52$ K kg mol$^{-1}$

Mass of solute, $MgSO_4 = 4$g

Mass of solvent, water $= 100$ g

So, Molality of the solution, $m = \dfrac{4}{120} \times \dfrac{1000}{100}$

$\qquad m = 0.33$ mol/kg   **(1 Mark)**

Also, $MgSO_4$ undergoes complete ionisation, thereby yielding 2 moles of consituent ions for every mole of $MgSO_4$.

$\therefore \quad i = 2$   **(½ Mark)**

Now, elevation in boiling point is given as

$\Delta T_b = iK_b m$   **(½ Mark)**

$\qquad = 2 \times 0.52 \times 0.33$

$\qquad = 0.34$ K

$\qquad \because \Delta T_b = T_b - T_b^\circ$

$\qquad 0.34 = T_b - 373.15\text{K}$

$T_b \quad = 373.15 + 0.34$

$\qquad = 373.49$ K   **(1 Mark)**

Therefore, the new boiling point of the solution is 373.49 K.

**33.** Boiling point is the temperature at which vapour pressure of the substance becomes equal to atmospheric pressure. As the vapour pressure of the solution containing non-volatile solute is lower than that of the pure solvent and vapour pressure increases with increase in temperature. Hence, the solution has to be heated more to make its vapour pressure equal to the atmospheric pressure so that it starts boiling.

Elevation of boiling point is a colligative property because, it depends upon the number of particles of solute dissolved in solution.   **(1 + 1 = 2 Marks)**

**34.** $W_2 = 31$g, $W_1 = 500$ g, $K_f = 1.86$ K kg mol$^{-1}$

$M_2 (C_2H_6O_2) = 24 + 6 + 32 = 62$ g mol$^{-1}$

$\Delta T_f = \dfrac{1000 K_f \times W_2}{W_1 \times M_2}$   **(1 Mark)**

$\qquad = \dfrac{1000 \times 1.86 \times 31}{500 \times 62} = 1.86$ K   **(1 Mark)**

Freezing point of pure water $= 273.15$ K

$\therefore$ Freezing point of solution $= T_f^\circ - \Delta T_f$

$\qquad = 273.15 - 1.86$ K

$\qquad = 271.29$ K   **(1 Mark)**

**35.** $\Delta T_f = K_f \times$ molality

Molality $= \dfrac{3.9 \times 1000}{122 \times 49} = 0.612$ m   **(½ Mark)**

Now, $\Delta T_f = 4.9 \times 0.612 = 2.99$ K   **(1 Mark)**

$i = \dfrac{\text{observed } \Delta T_f}{\text{calculated } \Delta T_f}$   **(½ Mark)**

$\Delta T_f$ observed $= 1.62$ K (given)

$\therefore \quad i = \dfrac{1.62}{2.99} = 0.54$

As $i < 1$, benzoic acid is an associated solute.   **(1 Mark)**

**36.** **Given :** $\Delta T_f = 0.48$ K

$M_2 = 256$ g mol$^{-1}$

$w_1 = 75$ g

$K_f = 5.12$ K kg mol$^{-1}$

**To find :** $w_2 = ?$

Solution $\Delta T_f = K_f m$   **(½ Mark)**

$\Delta T_f = K_f \times \dfrac{w_2}{M_2} \times \dfrac{1000}{w_1}$

$\Rightarrow \quad w_2 = \dfrac{\Delta T_f \times M_2 \times w_1}{K_f \times 1000}$   **(½ Mark)**

$\qquad = \dfrac{0.48 \times 256 \times 75}{5.12 \times 1000}$

$\Rightarrow \quad w_2 = 1.8$ g   **(1 Mark)**

**37.** $W_2 = 18$ g

$M_2 = 180$ g mol$^{-1}$

$W_1 = 1$ kg $= 1000$ g

$K_b = 0.52$ K kg mol$^{-1}$

$\Delta T_b = K_b \times \dfrac{W_2}{M_2} \times \dfrac{1000}{W_1}$   **(½ Mark)**

$\qquad = 0.52 \times \dfrac{18}{180} \times \dfrac{1000}{1000} = \dfrac{0.52}{10}$   **(½ Mark)**

$\qquad = 0.052$ K

Now, $\Delta T_b = T_s - T^\circ$   **(½ Mark)**

$\qquad 0.052 = T_s - 373.15$

$\therefore \quad T_s = 373.15 + 0.052 = 373.202$ K

$\therefore \quad$ Boiling point of solution $= 373.202$ K.   **(½ Mark)**

**38.** $\pi = iCRT = i\dfrac{W}{M} \times \dfrac{R \times T}{V}$   **(½ Mark)**

For $K_2SO_4 \rightleftharpoons 2K^+ + SO_4^{2-}$   **(½ Mark)**

$i = 3$

$\dfrac{3 \times 2.5 \times 10^{-2} (\text{gram}) \times 0.0821 \text{ L atm K}^{-1}\text{mol}^{-1} \times 298\text{K}}{174(\text{g mol}^{-1}) \times 2 \text{ L}}$

   **(1 Mark)**

$= 5.27 \times 10^{-3}$ atm   **(1 Mark)**

**39.** (i) When the externally applied pressure on the impure water side becomes greater than the osmotic pressure, water flows into the pure form side against the natural osmotic flow and this is called reverse osmosis. **(1 Mark)**

(ii) In cold water, there is a greater concentration of oxygen for breathing due to higher solubility of gases at lower temperature.

Thus, aquatic species are more comfortable in cold water. **(1 Mark)**

(iii) Moles of $H_2O$ :

$n_{H_2O} = \dfrac{100 \text{ g}}{18 \text{ g mol}^{-1}} = 5.56 \text{ mol}$ **(½ Mark)**

$n_{C_6H_{12}O_6} = \dfrac{2 \text{ g}}{180 \text{ g mol}^{-1}} = 0.0111 \text{ mol}$ **(½ Mark)**

$\Rightarrow$ Total moles = 5.56 + 0.0111 = 5.571 mol

$\Rightarrow$ Mole fraction of water $x_{H_2O} = \dfrac{5.56}{5.571} = 0.998$ **(1 Mark)**

Using Raoult's Law :

$P_{solution}$ (non-volatile solute) = $P^o_{H_2O} \times x_{H_2O}$
= 32.8 × 0.998
= 32.73 mm Hg **(1 Mark)**

**OR**

(b) (i) Ethanoic acid in benzene would undergo association or dimerization due to which the number of particles would be haved and thus i ≅ 0.5. **(1 Mark)**

📝 *Note*

*Acetic acid undergoes association in benzene but dissociates in water.*

(ii) An ideal solution is a solution that follows Raoult's law over an appreciable range of concentrations. **(1 Mark)**

(iii) $\Delta T_f = iK_f m = iK_f \left[\dfrac{W_2 \times 1000}{M_2 \times W_1}\right]$ **(1 Mark)**

$\Rightarrow W_2 = \dfrac{\Delta T_f M_2 W_1}{1000 \times i \times K_f} = \dfrac{2 \times 111 \times 500}{1000 \times 3 \times 1.86}$

= 19.89 g **(1 + 1 = 2 Marks)**

**40.** (a) (i) $\Delta T_f = K_f \left[\dfrac{W_2 \times 1000}{M_2 \times W_1}\right]$ **(1 Mark)**

$2.8K = 1.86 \left[\dfrac{W_2 \times 1000}{62 \times 1000}\right]$

= 0.03 × $W_2$ **(1 Mark)**

$\Rightarrow W_2$ = 93.34 g **(1 Mark)**

(ii) A mixture of ethanol and Acetone show positive deviation from Roult's law. **(1 Mark)**

This is so because addition of acetone breaks some hydrogen bonds and thus more ethanol molecule are evaporated. **(1 Mark)**

**OR**

(b) (i) $\Delta T_b = T_b' - T_b = 100 - 99.63 = 0.37° C$
= 0.37 K **(1 Mark)**

Molality = $\dfrac{W_2 \times 1000}{M_2 \times W_1} = \dfrac{W_2 \times 1000}{342 \times 500}$

$= \dfrac{W_2}{171}$ **(1 Mark)**

Now, $\Delta T_b = K_b \times$ molality

$\Rightarrow 0.37 = 0.52 \times \dfrac{W_2}{171} \Rightarrow W_2 = 121.67 \text{ g}$ **(1 Mark)**

(ii) According to Henry's law the solubility of gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of the liquid or solution. **(1 Mark)**

**Application :**

To increase the solubility of $CO_2$ in soft drinks and soda water, the bottle is sealed under high pressure. **(1 Mark)**

**41.** (a) Addition of glucose to water is an endothermic reaction. According to Le Chat elier's principle, on increase in temperature, solubility will increase. **(1 Mark)**

(b) Q is ocean water, due to the presence of salts it freezes at lower temperature (depression in freezing point) **(1 Mark)**

(c) $K_3[Fe(CN)_6]$ gives 4 ions in aqueous solution **(½ Mark)**

i = 1 + (n − 1) α **(½ Mark)**

i = 1 + (4 − 1) × 0.0.852

i = 3.556 **(½ Mark)**

$\Delta T_b = iK_b m = 3.556 \times 0.52 \times 1 = 1.85$ **(1 Mark)**

$T_b$ = 101.85°C **(½ Mark)**

**42.** (a) Negative Deviation is expected when phenol and aniline are mixed with each other. The net volume of the mixture will decrease, ΔV < 0 due to stronger intermolecular interactions. **(1 Mark)**
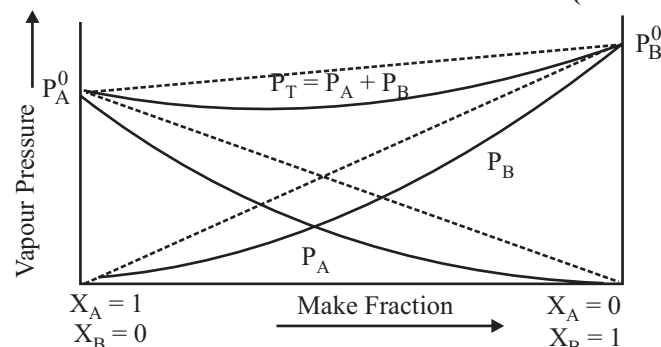


**P-X Diagram for Solutions Showing Negative Deviation from Raoult-Law**

**(1 Mark)**

(b) Relative lowering of vapour pressure = $(P° – P)/P°$
= $x_2$ **(½ Mark)**

$x_2 = n_2/n_1$

$n_2 = 0.1$

$n_1 = 100/18$

$x_2 = 0.1/5.55 + 0.1 = 0.1/5.65 = 0.018$ **(½ Mark)**

$P° = 23.8$ mm Hg

Relative lowering of vapour pressure = $(23.80 – P)/23.80$

= 0.018 **(½ Mark)**

$23.80 – P = 0.428$ **(½ Mark)**

$P = 23.80 – 0.428 = 23.37$ mm Hg **(1 Mark)**

**43.** (i) The boiling point of 1 M NaCl solution more than that of 1 M glucose solution because NaCl is an ionic compound that dissociates into ions $Na^+$ and $Cl^-$ in aqueous solutions while glucose does not.

Boiling point is a colligative property that increases with an increase in the number of particles. **(1 Mark)**

(ii) The vapour pressure is reduced to 90% when certain mass of 'X' is dissolved in 78 g of benzene.

If $P°_{benzene} = 1$ atm,

$P°_{Benzene} – P_{Benzene} = 0.1$ atm **(½ Mark)**

$M_{Benzene} = 78.11$ g/mol $\approx 78$ g/mol

$M_X = 50$ g/mol, $W_{Benzene} = 78$ g

$\Rightarrow x_X = \dfrac{\dfrac{W_X}{M_X}}{\dfrac{W_X}{M_X} + \dfrac{W_{Benzene}}{M_{Benzene}}} = 0.2$ **(½ Mark)**

$= \dfrac{\dfrac{W_X}{50}}{\dfrac{W_X}{50} + 1} = 0.2$

$= \dfrac{W_X}{W_X + 50} = 0.2$ **(½ Mark)**

$\Rightarrow 0.2W_X + 10 = W_X$

$\Rightarrow W_X – 0.2W_X = 10$

$\Rightarrow 0.8W_X = 10$

$\Rightarrow W_X = \dfrac{10}{0.8} = 12.5$ g **(½ Mark)**

(iii) $\Delta T_b = iK_b m$

$= iK_b \left[ \dfrac{1000 \times W_2}{M_2 \times W_1} \right]$ **(1 Mark)**

i for $MgCl_2 = 3 \times 0.512 \times \left[ \dfrac{1000 \times 10}{95 \times 200} \right]$

= **0.808 K** **(1 Mark)**

**44.** (i) The value of Van't Hoff factor for ethanoic acid in benzene is determined by its association in benzene. It forms a dimer in benzene so:

$i = \dfrac{\text{no. of particles present}}{\text{Theoretical no. of particles}} = \dfrac{1}{2} = \textbf{0.5}$ **(1 Mark)**

(ii) Osmotic pressure $(\pi) = \dfrac{i \times n_2 \times R \times T}{V}$ **(½ Mark)**

i for $K_2SO_4 = 3$ **(½ Mark)**

$n_2 = \dfrac{m_2}{M_2} = \dfrac{2.32 \times 10^{-2} \text{ g}}{174 \text{ g/mol}} = 1.33 \times 10^{-4}$ moles

$\Rightarrow \pi = \dfrac{3 \times (1.33 \times 10^{-4}) \times (0.082) \times (298)}{2}$ **(½ Mark)**

= 0.00487 atm or $4.87 \times 10^{-3}$ atm. **(½ Mark)**

(iii) $\Delta T_f = K_f . m = K_f \left[ \dfrac{1000 \times W_2}{M_2 \times W_1} \right]$ **(½ Mark)**

$\Rightarrow M_2 = \dfrac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$

$= \dfrac{(5.12)(25.6)(1000)}{0.512 \times 1000} = \textbf{256 g}$ **(½ Mark)**

$\Rightarrow$ Molecular formula of Sulphur

$= \dfrac{M_{sulphur}}{At. mass} = \dfrac{256 \text{ g}}{32 \text{ g/mol}} = 8$ **(½ Mark)**

$\Rightarrow$ Molecular formula = $S_8$. **(½ Mark)**

> **Note**
>
> *Relative lowering of vapour pressure, osmotic pressure, elevation in boiling point and depression in freezing point are all colligative properties that are determined by the number of particles of the solute only. Further association or dissociation is determined by the Vant Hoff Factor (i) that gives the actual value of the property.*

**45.** (a) Here $\Delta T_f = (273.15 – 269.15)$ K = 4 K

Molar mass of sugar $(C_{12}H_{22}O_{11})$

$= 12 \times 12 + 22 \times 1 + 11 \times 16 = 342$ g mol$^{-1}$

10% solution (by mass) of sucrose (cane sugar) in water means 10 g of cane sugar is present in $(100 – 10)$g = 90 g of water.

Now, number of moles of cane sugar

$= \dfrac{10}{342} = 0.0292$ mol **(1 Mark)**

Therefore, molality (m) of the solution,

$$= \frac{0.0292 \times 1000}{90} = 0.3244 \, mol \, kg^{-1}$$

Applying the relation, $\Delta T_f = K_f \times m$

$$\Rightarrow K_f = \frac{\Delta T_f}{m} = \frac{4}{0.3244}$$

$$= 12.33 \, K \, kg \, mol^{-1} \qquad \textbf{(1 Mark)}$$

Molar mass of glucose $(C_6H_{12}O_6)$

$$= 6 \times 12 + 12 \times 1 + 6 \times 16$$

$$= 180 \, g \, mol^{-1}$$

10% glucose in water means 10 g of glucose is present in $(100 - 10) \, g = 90 \, g$ of water.

∴    Number of mole of glucose

$$= \frac{10}{180} \, mol = 0.0555 \, mol$$

Therefore, molality (m) of the solution

$$= \frac{0.0555 \times 1000}{90} = 0.6166 \, mol \, kg^{-1}$$

Applying the relation,   $\Delta T_f = K_f \times m$

$$= 12.33 \, K \, kg \, mol^{-1} \times 0.6166 \, mol \, kg^{-1}$$

$$= 7.60 \, K \text{ (approximately)}$$

Hence, the freezing point of 10% glucose solution is $(273.15 - 7.60) \, K = 265.55 \, K$ **(1 Mark)**

(b) **(i)** **Molality :** It is defined as the number of moles of a solute present in 1000 g (1kg) of a solvent.

$$\text{Molality } (m) = \frac{\text{Number of moles of solute}}{\text{Weight of solvent in kg}}$$

**(1 Mark)**

> **Note**
>
> *The relation between molarity and molality is*
>
> $$\text{Molality } (m) = \frac{Molarity(M)}{(Density \, of \, the \, solution(\rho) - molarity)}$$
> $$\times molecular \, wt. \, of \, solute$$
>
> *It can be used to determine the molarity if molality is given or vice versa.*

**(ii)** **Abnormal molar mass :** Due to association or dissociation of molecules, the expected molar mass is either lower or higher than calculated molar mass. Such molar mass is called abnormal molar mass. **(1 Mark)**

> **Note**
>
> *Abnormal molar mass is the experimentally determined molar mass and is used to find the value of van't Hoff factor (i). To account for the extent of dissociation or association following relation can be used.*
>
> $$i = \frac{Normal \, molar \, mass}{Abnormal \, molar \, mass}.$$

**46.** (a)   It is given that vapour pressure of water, $P_1° = 23.8$ mm of Hg

Weight of water taken, $w_1 = 846$ g

Weight of urea taken, $w_2 = 30g$

Molecular weight of water, $M_1 = 18 \, g \, mol^{-1}$

Molecular weight of urea, $M_2 = 60 \, g \, mol^{-1}$

Now, we have to calculate vapour pressure of water in the solution we take vapour pressure as $P_1$.

Relative lowering of vapour pressure equation can be written as :

$$\frac{P_1^0 - P_1}{P_1^0} = \frac{n_2}{n_1 + n_2}$$

For dilute solution $(n_2 \ll n_1)$

$$\frac{P_1^0 - P_1}{P_1^0} = \frac{n_2}{n_1} \qquad \textbf{(1 Mark)}$$

$$\Rightarrow \frac{23.8 - P_1}{23.8} = \frac{(30/60)}{(846/18)} \qquad \textbf{(1 Mark)}$$

$$\Rightarrow \frac{23.8 - P_1}{23.8} = \frac{1}{94}$$

$$\Rightarrow \quad P_1 = 23.5501 \text{ mm of Hg}$$

Hence, the vapour pressure of water in the given solution is 23.5501 mm of Hg and its relative lowering is 0.0105. **(1 Mark)**

(b)   Ideal solutions and non-ideal solutions

|   | **Ideal Solutions** | **Non-Ideal Solutions** |
|---|---|---|
| 1. | Solutions which obey Rault's law over the entire range of concentration are known as ideal solutions. | Solutions which do not obey Raoult's law over the entire range of concentration are known as non-ideal solutions. |
| 2. | Intermolecular force of attraction between the molecules of solute (A – A) and those between the molecules of solvent (B – B) are nearly equal to those between solute and solvent molecules (A – B). | Intermolecular force of attraction between the molecules of solute (A – A) and those between the molecules of solvent (B – B) are not equal to those between solute and solvent molecules (A – B). |

**(1 + 1 = 2 Marks)**
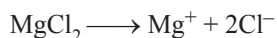
**47.** (a) Given

$K_f$ = 1.86 K kg mol$^{-1}$

mass of solute = 1.9 g

mass of solvent = 50 g

Therefore,

Molality of the solution, $m = \dfrac{\text{no. of mole of solute}}{\text{wt. of solvent in kg}}$

$= \dfrac{1.9 \times 1000}{95 \times 50} = 0.4$ m                    **(1 Mark)**

$MgCl_2 \longrightarrow Mg^+ + 2Cl^-$

No. of ion = 3

$i = 3$

$\Delta T_f = i\, K_f\, m$

$= 3 \times 1.86 \times 0.4$

$= 2.232$ K                    **(1 Mark)**

$T_f(MgCl_2) = T_f(\text{water}) - \Delta T_f$

$= 273 - 2.232$

$= 270.77$ K                    **(1 Mark)**

(b) (i) The elevation in the boiling point of a solution is a colligative property, therefore it is affected by the number of particles of the solute. Since the amount of solute is higher in 2M glucose solution as compared to 1M glucose solution, the elevation in the boiling point is higher. Hence, 2M glucose solution has a higher boiling point than 1 M glucose solution.

**(1 Mark)**

(ii) When the external pressure applied become more than the osmotic pressure, pure solvent starts flowing out of the solution through the semipermeable membrane. This process is known as reverse osmosis.                    **(1 Mark)**

**48.** (a) Weight of sulphur ($w_2$) = 2.56 g, $M_2$ = 32 g/mol

Weight of solvent = 100 g

$K_f$ = 3.83 K kg/mol

$\Delta T_f = K_f \times \dfrac{W_2}{M \times w_1} \times 1000$                    **(1 Mark)**

$0.383 = \dfrac{3.83 \times 2.56 \times 1000}{M \times 100}$

$M = 256$ g/mol                    **(1 Mark)**

Formula of sulphur

One atom of S = 32 g/mol$^{-1}$

so atoms of S in molecule = $\dfrac{256}{32} = 8$

Formula = $S_8$                    **(1 Mark)**

(b) (i) 1.2% Sodium chloride is hypertonic with respect to 0.9% sodium chloride, hence cells will shrink and water flows out of the cells. Plasmolysis will take place.                    **(1 Mark)**

(ii) 0.41% Sodium chloride solution is hypotonic with respsect to 0.9% sodium chloride. Hence water flows into the cell and cells will swell. Endo osmosis will take place.                    **(1 Mark)**

> **Note**
>
> *Isotonic solution : Concentration of solute inside the cell is same as in the solution outside.*
> *Hypotonic solution : Outside solution has lower concentration of solute than inside the cell.*
> *Hypertonic solution : Outside solution has greater solute concentration than inside the cell.*

**49.** (a) (i) **Molarity:** It is defined as number of moles of solute per litre of the solution. Its units are mol L$^{-1}$.

$\text{Molarity (M)} = \dfrac{\text{No. of moles of solute}}{\text{Volume of solution}}$

**(1 Mark)**

(ii) **Molal elevation constant (Kb):** It is defined as the elevation in boiling point when the molality of the solution is unity, i.e., 1 mole of the solute is dissolved in 1 kg of the solvent.

**(1 Mark)**

(b) **Given:**

| Urea | Glucose |
|------|---------|
| $w_1$ = 15 g | $M_2$ = 180 g |
| $M_1$ = 60 g | |

**To find:** $w_2$ = ?

As the solutions are isotonic, we have

$\pi_1 = \pi_2$                    **(½ Mark)**

$C_1 RT = C_2 RT$

$C_1 = C_2$                    **(½ Mark)**

$\dfrac{n_1}{V_1} = \dfrac{n_2}{V_2}$

$\Rightarrow \quad n_2 = \dfrac{n_1}{V_1} \times V_2$

$V_1 = V_2$ as vol. is 1 litre

$\therefore \quad n_2 = n_1$

$$\frac{w_2}{M_2} = \frac{w_1}{M_1}$$ **(1 Mark)**

$$w_2 = \frac{w_1}{M_1} \times M_2$$

$$= \frac{15}{60} \times 180 = 45$$

∴ mass of glucose = 45 g **(½ + ½ = 1 Mark)**

**50.** (a) A mixture of ethanol and acetone shows positive deviation from Raoult's law. This is because acetone molecules enter between alcohol molecules thus breaking the H-bonds between ethanol molecules and hence showing +ve deviation.

**(1 + 1 = 2 Marks)**

(b) **Given:** 10% solution of glucose $\Rightarrow$ 10 g of glucose in 100 g of solution

molar mass of glucose , $M_2 = 180$ g mol$^{-1}$

density of solution, $d = 1.2$ g mL$^{-1}$

**To find:** (i) molality, $m$

(ii) molarity, $M$

(i) Molality,

$$m = \frac{\text{Moles of solute}}{\text{Mass of solvent (in g)}} \times 1000$$ **(½ Mark)**

$$m = \frac{(10/180)}{(100-10)} \times 1000$$

$$m = \frac{10}{180 \times 90} \times 1000 = \frac{100}{18 \times 9}$$

$$m = 0.617 \text{ mol kg}^{-1}$$ **(1 Mark)**

(ii) Molarity,

$$m = \frac{\text{Moles of solute}}{\text{Volume of solution (in mL)}} \times 1000$$ **(½ Mark)**

$$M = \frac{(10/180)}{V_{sol}} \times 1000$$

$$V_{sol} = \frac{m_{sol}}{d} = \frac{100}{1.2}$$

$$\therefore \quad M = \frac{10/180}{100/1.2} \times 1000 = \frac{2}{3}$$

$$\therefore \quad M = 0.66 \text{ mol L}^{-1}$$ **(1 Mark)**

**51.** (a) **Raoult's law :** For a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.

For two components A and B

$$p_B = p_B^\circ x_B \qquad p_A = p_A^\circ \times x_A$$ **(1 Mark)**

**Raoult's law as a special case of Henry's law :**

According to Raoult's law, for any volatile component of the solution.

$$p_A = p_A^\circ \times x_A$$

Now, for a solution in which a gas is the solute and liquid is the solvent, then according to Henry's law

$$p_A = k_H \times x_A$$

i.e., partial pressure of the volatile component (gas) is directly proportional to the mole fraction of that component (gas) in the solution.

Thus, Raoult's law and Henry's law become identical except that their proportionality constants are different. **(2 Marks)**

(b) $W_2 = 1.00$ g

$W_1 = 50$ g

$\Delta T_f = 0.40$ K

$K_f = 5.12$ K kg mol$^{-1}$

$$M_2 = \frac{1000 \times K_f \times W_2}{W_1 \times \Delta T_f}$$ **(1 Mark)**

$$= \frac{1000 \times 5.12 \times 1.00}{50 \times 0.40}$$

$$= 256 \text{ g mol}^{-1}$$ **(1 Mark)**

**52.** (a) (i) **Ideal solution :** (I) The solution which obey Raoult's law at all temperatures and concentrations (II) $\Delta H_{mix} = 0$ i.e. no heat is evolved or absorbed when components are mixed to form the solution (III) $\Delta V_{mix} = 0$ i.e. no change in volume. **(1 Mark)**

(ii) **Azeotrope :** A liquid mixture, having a definite composition, and boiling point like a pure liquid, is called a constant boiling mixture or an azeotrope. **(1 Mark)**

(iii) **Osmotic pressure :** The minimum excess pressure that has to be applied to the solution to prevent the entry of the solvent into the solution through the semipermeable membrane due to osmosis is called the osmotic pressure. **(1 Mark)**

(b)  10% glucose solution by weight means

Mass of solute $(W_2)$ = 10 g

Mol. mass of solute $(M_2)$ = 180 g mol$^{-1}$

Mass of solvent $(W_1)$ = 100 – 10 = 90 g

Molality (m) = $\dfrac{W_2}{M_2} \times \dfrac{1000}{W_1}$                    **(1 Mark)**

$= \dfrac{10}{180} \times \dfrac{1000}{90}$

= 0.617 m                                                 **(1 Mark)**

**53.** The melting point of ice is the freezing point of water. We can use the depression in freezing point property in this case.

(a) 3rd reading for 0.5 g there has to be an increase in depression of freezing point and therefore decrease in freezing point so also decrease in melting point when amount of salt is increased but the trend is not followed on this case.                                **(1 Mark)**

(b) two sets of reading help to avoid error in data collection and give more objective data.  **(1 Mark)**

(c)  $\Delta T_f$ (glucose) = $1 \times K_f \times \dfrac{0.6 \times 1000}{180 \times 10}$      ....(1)

**(½ Mark)**

$\Delta T_f$ (NaCl) = $2 \times K_f \times \dfrac{0.6 \times 1000}{58.5 \times 10}$       **(½ Mark)**

$3.8 = 2 \times K_f \times \dfrac{0.6 \times 1000}{58.5 \times 10}$       ....(2)

Divide equation 1 by 2

$\dfrac{\Delta T_f \text{ (glucose)}}{3.8} = \dfrac{58.5}{2 \times 180}$       **(½ Mark)**

$\Delta T_f$ (glucose = 0.62 Freezing point or Melting point
= – 0.62 °C                                              **(½ Mark)**

**OR**

depression in freezing point is directly proportional to molality (mass of solute when the amount of solvent remains same)                             **(1 Mark)**

0.3 g depression is 1.9 °C

0.6 g depression is 3.8 °C

1.2 g depression will be 3.8 × 2 = 7.6 °C  **(1 Mark)**

# CONCEPT MAP

## ELECTROCHEMISTRY

| Name of cell/Battery | Anode (−) | Cathode (+) | Electrolyte | Reactions at electrodes | $E_{cell}$ |
|---|---|---|---|---|---|
| • Dry cell (primary cell) | Zn container | Graphite rod | Powdered $MnO_2$+C +Paste of $NH_4Cl$+ $ZnCl_2$ | **Anode:** $Zn(s) \rightarrow Zn^{2+}(aq)+2e^-$ **Cathode:** $NH_3$ forms complex with $Zn^{2+}$ to give $[Zn(NH_3)_4]^{2+}$ $MnO_2 + 2NH_4^+ + e^- \rightarrow$ $MnO(OH) + NH_3$. $NH_3$ Forms Complex with $Zn^{2+}$ to give $[Zn(NH_3)_4]^{2+}$ | 1.25 to 1.5 V |
| • Lead storage Battery (secondary cell) | Pb | Pb + $PbO_2$ | 38% by mass $H_2SO_4$ (d=1.30 g cm$^{-3}$) | **Anode:** $Pb(s) + SO_4^{2-}(aq) \rightarrow$ $PbSO_4(s)+ 2e^-$ **Cathode:** $PbO_2(s) + SO_4^{2-}(aq)$ $+ 4H^+(aq) + 2e^- \rightarrow$ $PbSO_4(s) + 2H_2O(l)$ On applying a potential slightly greater than the potential of battery, battery can be recharged. | 12 V consists of 6 cell each producing 2 V |
| • Fuel cell ($H_2$–$O_2$) | Porous carbon containing catalyst (finely divided Pt and Pd) | Porous carbon containing catalyst (finely divided Pt and Pd) | Concentrated NaOH solution | **Anode:** $2H_2(g) + 4OH(aq) \rightarrow$ $4H_2O(1) + 4e^-$ **Cathode:** $O_2(g) + 2H_2O(1) + 4e^- \rightarrow$ $4OH(aq)$ | 0.09 V |

A commercial dry cell consists of a graphite (carbon) cathode in a zinc container; the latter acts as the anode.

Carbon rod (cathode)

Zinc cup (anode)

$MnO_2$ + carbon black + $NH_4Cl$ paste

**Conductance of Electrolytic Solutions:**

- Conductance $(G) = \dfrac{1}{\text{Resistance}}$

  Unit : $ohm^{-1}$ or Siemens

- Specific conductivity $(\kappa) = G \dfrac{l}{a}\left( \dfrac{l}{a} = \text{cell constant} \right)$

  Unit $= ohm^{-1} \, cm^{-1}$ or $S \, cm^{-1}$

- Molar conductance $(\Lambda_m) = \dfrac{1000 \times k}{M}$

  Unit $= S \, cm^2 \, mol^{-1}$

- Equivalent conductance $(\Lambda_{eq}) = \dfrac{1000 \times k}{N}$

  Unit $= cm^2 \, ohm^{-1} \, g\text{-eq}^{-1}$

  Conductance $(G)$, molar conductivity $(\Lambda_m)$ and equivalent conductivity $(\Lambda_{eq})$ increase with dilution where as specific conductivity $(\kappa)$ decrease with dilution

  Effect of concentration on $\Lambda_m$:

- **For strong electrolytes,** $\Lambda_m$ increases slowly with dilution and can be represented by the equation : $\Lambda_m = \Lambda_m^\circ - AC^{1/2}$ **(Debye–Huckel Onsager equation)**

Molar conductivity versus c½ for acetic acid (weak electrolyte) and potassium chloride (strong electrolyte) in aqueous solutions.

KCl

$CH_3COOH$

$c^{1/2}$ / (mol/L)$^{1/2}$

$\Lambda_m/(\text{S cm}^2 \text{mol}^{-1})$

400

200

0    0.2    0.4

Regardless whether a cell is a voltaic or an electrolytic-cell,

—The anode is the electrode at which oxidation occurs
—The cathode is the electrode at which reduction occurs

| | **Voltaic cell** | **Electrolytic-cell** |
|---|---|---|
| Anode | Oxidation, Negative(−) terminal | Oxidation positive (+) terminal |
| Cathode | Reduction Positive (+) terminal | Reduction negative (−) terminal |

- **Electrode potential**

  $E_{cell} = E^\circ_{right} - E^\circ_{left}$

  For SHE, $E^\circ_{cell} = 0$

- **Nernst equation :**

  For reaction, $M^{n+} + ne^- \rightarrow M(s)$

  $E = E^\circ - \dfrac{2.303RT}{nF} \log \dfrac{1}{[M^{n+}]}$

- **For reaction :**

  $aA + bB \rightarrow cC + dD$

  $Ec_{cell} = E^\circ_{cell} - \dfrac{2.303RT}{nF} \log \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$

  At equilibrium $E_{cell} = 0$

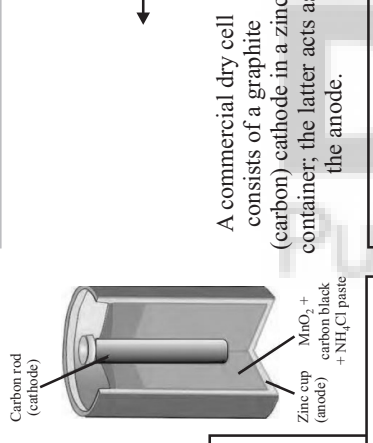  $E^\circ_{cell} = \dfrac{2.303RT}{nF} \log K_C$

  $\Delta_r G = -nFE_{cell}$ or $\Delta_r G = -n F E^\circ_{cell}$

  or $\Delta_r G^\circ = -RT \ln K = -2.303 RT \log K$

- **Electrochemical series:** Arrangement of elements in order of increasing value of $E^\circ_{red}$. Reducing nature decreases form top to bottom in the series.

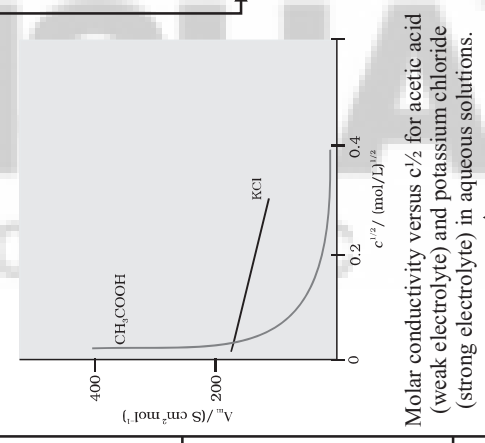Plot of $\Lambda_m$ against $C^{1/2}$ is a straight line with intercept equal to $\Lambda_m^\circ$ and slope equal to '−A.' Thus, $\Lambda_m$ decreases linearly with $\sqrt{C}$ , when $C = 0$, $\Lambda_m = \Lambda_{mo}$ and $\Lambda_m^\circ$ can be determined experimentally.

- **For weak electrolytes,** $\Lambda_m$ increases as C decreases but does not reach a constant value even at infinite dilution. Hence, $\Lambda_m^\circ$ cannot be determined experimentally.

- **Kohlrausch's Law :** $\Lambda_m = v_+ \lambda^\circ_+ + v_- \lambda^\circ_-$

  Where $\lambda^\circ_+$ is the limiting molar conductivity of the cation and $\lambda^\circ_-$ is the limiting molar conductivity of the anion at infinite dilutions. $v_+$ and $v_-$ are number of cations and anions in one formula unit of electrolyte.