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ANALYSIS

Table 1.1: IAT 2024 Final Closing Ranks (Category-wise)

Programme	GEN	OBC-NCL	SC	ST	EWS
IISER Berhampur BS–MS	4484	2407	965	475	782
IISER Bhopal BS–MS	3136	1712	707	349	526
IISER Kolkata BS–MS	1987	1377	502	276	380
IISER Mohali BS–MS	3034	1781	679	333	473
IISER Pune BS–MS	1023	938	340	222	247
IISER TVM BS–MS	3447	1634	858	417	625
IISER Tirupati BS–MS	4325	2318	953	483	782
IISER Bhopal B.Tech.	2141	944	624	144	207
IISER Bhopal BS Econ. Sci.	2837	1017	700	347	306

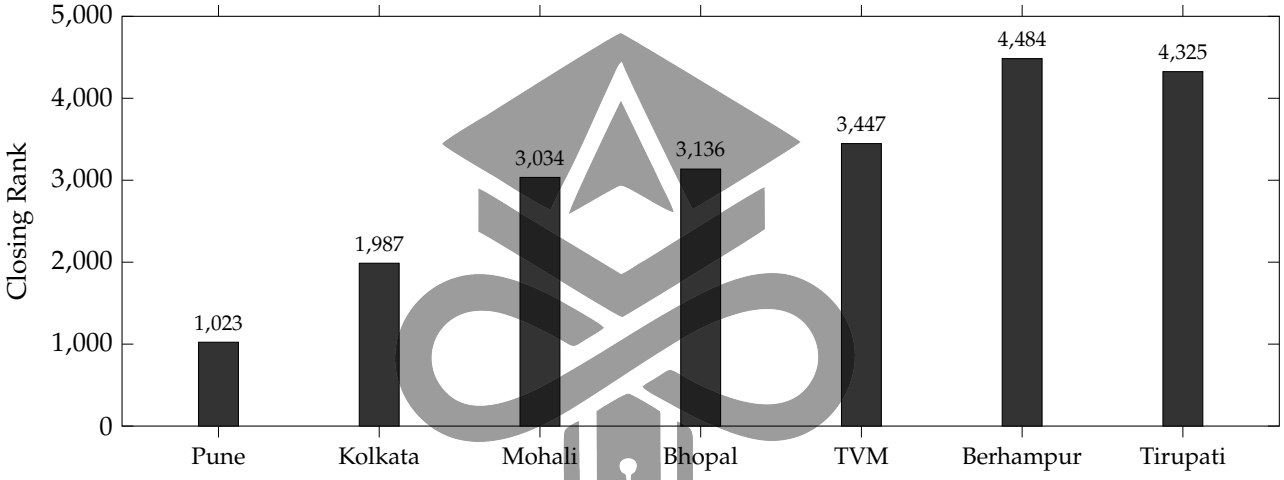


Figure 1.1: 2024 General Category Closing Ranks

Table 1.2: IAT 2025 Final Closing Ranks (Category-wise)

Programme	GEN	OBC-NCL	SC	ST	EWS
IISER Berhampur BS–MS	8769	4749	1693	802	1883
IISER Bhopal BS–MS	5624	3289	1327	679	1160
IISER Kolkata BS–MS	4758	3516	1129	675	1005
IISER Mohali BS–MS	4939	3680	1186	557	1114
IISER Pune BS–MS	1671	1101	398	214	464
IISER TVM BS–MS	6506	3171	1472	724	1434
IISER Tirupati BS–MS	8328	4360	1651	728	1651
IISER Bhopal B.Tech.	3169	2113	1377	715	–
IISER Bhopal BS Econ. Sci.	5668	2113	1377	715	–
IISER Kolkata BS–MS CDS	1839	1015	434	393	425
IISER Tirupati BS Econ.	8023	4006	1663	768	1375

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Table 2: *Biology Priority Guide for IAT Preparation*

BIOLOGY PRIORITY GUIDE — IAT PREPARATION		
MUST COVER — All-year coverage; highest question frequency		
Must	**Principles of Inheritance & Variation** 9.33%	Mendel's laws; dihybrid crosses; chromosomal theory; linkage; mutations; pedigree analysis.
Must	**Biotechnology: Principles & Processes** 9.33%	Recombinant DNA; restriction enzymes; PCR; gel electrophoresis; cloning vectors; bioreactors.
Must	**Molecular Basis of Inheritance** 6.67%	DNA replication; transcription; translation; lac operon; Human Genome Project.
Must	**Organisms and Populations** 6.00%	Population attributes; logistic & exponential growth; species interactions; niche; age pyramids.
Must	**Cell Cycle and Cell Division** 5.33%	Cell cycle phases; mitosis; meiosis I & II; checkpoints and regulation.
Must	**Human Health and Disease** 5.33%	Innate & adaptive immunity; vaccines; AIDS; cancer biology; malaria; drugs & alcohol.
Must	**Photosynthesis in Higher Plants** 4.67%	Light-dependent & dark reactions; C_3/C_4/CAM pathways; photorespiration.
Must	**Biomolecules** 4.67%	Carbohydrates; proteins; lipids; nucleic acids; enzyme kinetics & inhibition.
Must	**Reproduction — Human & Plants** 4.67% each	Gametogenesis; fertilization; embryo development; pollination; double fertilization.
GOOD TO COVER — Moderate frequency; review before exam		
Good	**Excretory Products & Elimination** 4.00%	Kidney structure; nephron function; urine formation; dialysis; osmoregulation.
Good	**Respiration in Plants** 4.00%	Glycolysis; Krebs cycle; electron transport chain; fermentation; respiratory quotient.
Good	**Structural Organisation in Animals** 3.33%	Epithelial, connective, muscular & neural tissues; frog anatomy; organ systems.
Good	**Locomotion and Movement** 3.33%	Muscle fibre types; sliding filament theory; joints; skeletal disorders.
Good	**Animal Kingdom & Classification** 3.33% each	Five-kingdom classification; major phyla; chordates vs. non-chordates; key features.
Good	**Ecology — Ecosystem, Biodiversity & Microbes** 1.33% each	Energy flow; food chains; biogeochemical cycles; biodiversity threats & conservation.
OPTIONAL — Low frequency; major concepts only		
Opt.	**Evolution** 2.00%	Darwinism; neo-Darwinism; Hardy–Weinberg equilibrium; speciation.
Opt.	**Morphology & Anatomy of Plants** 2.67% + 1.33%	Root, stem & leaf structure; monocot vs. dicot; floral formula & diagrams.
Opt.	**Breathing, Body Fluids, Neural & Chemical Coordination** 1.33% each	Lung volumes; haemoglobin; ABO blood groups; neuron structure; endocrine hormones.

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Mathematics Weightage Analysis

Based on IAT 2017–2026 (150 Questions)

Figure 1: Grouped Topic-wise Share of Mathematics Questions (IAT 2017–2026)

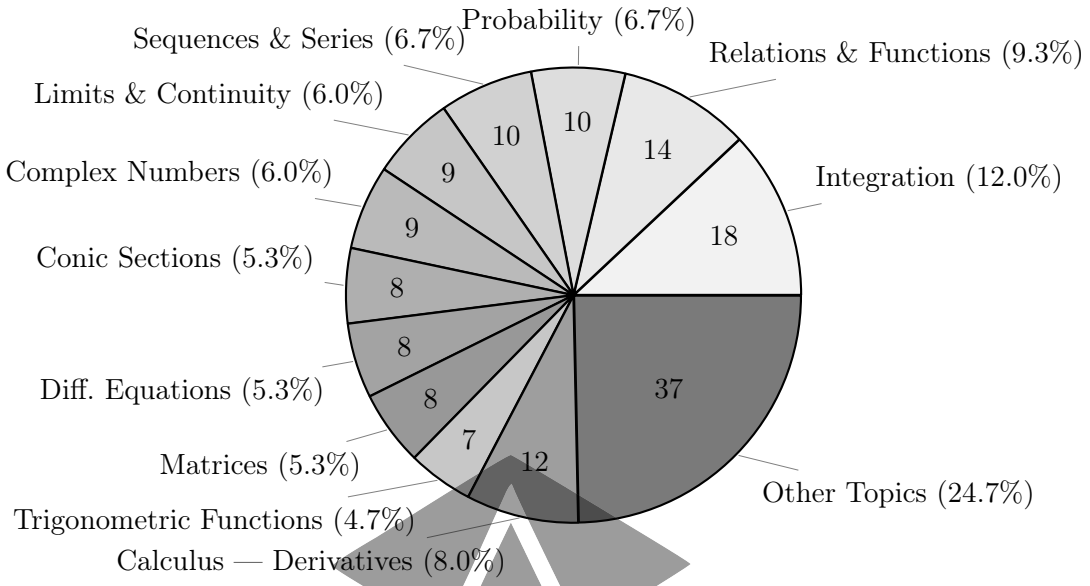
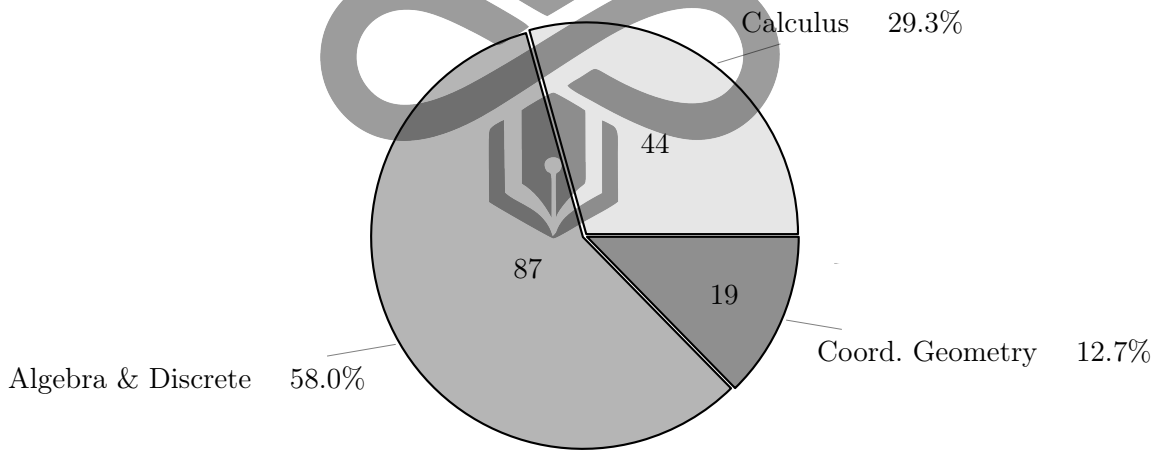


Figure 2: Calculus / Algebra & Discrete / Coordinate Geometry Weightage



Category	Qs	Share
Algebra & Discrete	87	58.0%
Calculus	44	29.3%
Coord. Geometry	19	12.7%
Total	**150**	**100%**

Figure 2: *Mathematics Weightage Distribution Analysis*

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BIOLOGY

Biological Classification

1. Which of the following produces a dikaryotic phase in Basidiomycetes? IAT 2019

(a) Karyogamy **(b)** Plasmogamy
(c) Apogamy **(d)** Karyokinesis

2. Which one of the following helps in bacterial motility? IAT 2019

(a) Centrioles **(b)** Fimbriae
(c) Microtubules **(d)** Flagella

3. Which of the following is not an asexual reproductive structure? IAT 2021

a. Conidia of Penicillium
b. Isogametes of Cladophora
c. Zoospores of Chlamydomonas
d. Gemmules in a sponge

4. During the COVID-19 pandemic, SARS-CoV2 virus mutated multiple times giving rise to many variants. What is the genetic material of the SARS-CoV2 virus? IAT 2022

(a) Double stranded RNA **(b)** Double stranded DNA
(c) Single stranded RNA **(d)** Single stranded DNA

5. What are retroviruses? IAT 2025

a. A group of viruses with DNA genome and no reverse transcriptase activity
b. A group of viruses with DNA genome and reverse transcriptase activity
c. A group of viruses with RNA genome and reverse transcriptase activity
d. A group of viruses with RNA genome and no reverse transcriptase activity

6. If cell wall was used as the only criterion for classifying organisms, then *Mycoplasma* would have belonged to which one of the following groups? IAT 2026

(a) Fungi **(b)** Protists
(c) Animals **(d)** Plants

Animal Kingdom

1. Match the following features to the animals. Which is the correct combination?
1. Open circulatory system 3. Earthworm 5. Nephridia
2. Closed circulatory system 4. Malpighian tubules
6. Cockroach IAT 2017

(a) 1, 3, 4 and 2, 5, 6 **(b)** 1, 4, 6 and 2, 3, 5
(c) 1, 3, 5 and 2, 4, 6 **(d)** 1, 5, 6 and 2, 3, 4

2. Which of the following is exclusively marine? IAT 2018

(a) Cnidaria **(b)** Echinodermata
(c) Annelida **(d)** Porifera

3. Radial symmetry is NOT found in which of the following taxa? IAT 2020

(a) Echinodermata **(b)** Cnidaria
(c) Ctenophora **(d)** Cyclostomata

4. Organisms in which of the following phyla are triploblastic, acoelomate and have bilateral symmetry? IAT 2022

(a) Mollusca **(b)** Arthropoda
(c) Hemichordata **(d)** Platyhelminthes

5. Which one of the following statements is correct? IAT 2024

a. Hemichordata is a chordate sub-phylum with a protonotochord.
b. Hemichordata is a chordate sub-phylum with proper notochord and gill slits.
c. Hemichordata is not a chordate sub-phylum due to water vascular system.
d. Hemichordata is not a chordate and possesses a protonotochord called stomochord.

6. Match the entries in column I and column II.

Column I	Column II
P. Notochord and hollow nerve cord present	i. Cyclostomata
Q. Ectoparasite with 6-15 pairs of gills and closed circulation	ii. Chondrichthyes
R. Marine animals with persistent notochord and placoid scales	iii. Hemichordata
S. Animals with open circulatory systems, and stomochord	iv. Chordata

Which one of the following combinations is correct? IAT 2025

a. P - iv; Q - ii; R - i; S - iii
b. P - i; Q - iii; R - ii; S - iv
c. P - iv; Q - i; R - ii; S - iii
d. P - iii; Q - i; R - ii; S - iv

Morphology of Flowering Plants

1. In the standard nomenclature used for depicting floral formula, which type of flower is represented by K(5)? IAT 2019

(a) Polysepalous **(b)** Syncarpous
(c) Gamosepalous **(d)** Gamopetalous

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2. Which of the following root modifications is observed in maize? IAT 2020

(a) Fibrous roots **(b)** Lateral root
(c) Prop roots **(d)** Stilt

3. Which of the following floral formulae represents a zygomorphic and superior ovary? IAT 2021

a. $\% \, \phi K_{(5)} \, C_{(5)} \, A_2 \, G_{\underline{1}}$
b. $\oplus \, \phi K_{(5)} \, C_{(5+5)} \, A_{(\infty)} \, G_{\underline{1}}$
c. $\% \, \phi K_{(5)} \, C_{(5+5)} \, A_{(\infty)} \, G_{\overline{1}}$
d. $\% \, \phi K_{(5)} \, C_{1+2+(2)} \, A_{(9)+1} \, G_{\overline{1}}$

4. Which one of the following statements regarding seed structure is **INCORRECT**? IAT 2023

a. The endosperm is not present in some of the mature dicot seeds.
b. In dicots, the outer layer of the seed coat is called testa.
c. Coleoptile and coleorhiza are found in monocotyledonous seeds.
d. In monocot seeds, the membraneous seed coat that is fused with the fruit wall is called the aleurone layer.

Anatomy of Flowering Plants

1. Match the features of plant cells listed in Column I with their corresponding examples in Column II.

Column I	Feature	Column II	Example
i.	Cell with cytoplasm and no nucleus	p.	Pollen grain
ii.	Cell lacking both cytoplasm and nucleus	q.	Synergid
iii.	Cell containing more than two nuclei	r.	Tracheid
iv.	Haploid cell produced by mitosis	s.	Tapetum
		t.	Mature sieve tube
		u.	Phloem companion cell

Choose the correct combination. IAT 2022

a. i and u; ii and r; iii and s; iv and p
b. i and u; ii and r; iii and q; iv and p
c. i and t; ii and r; iii and s; iv and q
d. i and r; ii and t; iii and s; iv and q

2. Which one of the following anatomical features of wood can be used to estimate the **age of a tree** growing in a temperate climate? IAT 2023

a. Heart wood and sap wood.
b. Spring wood and late wood.
c. Spring wood and heart wood.
d. Autumn wood and sap wood.

3. Which of the following is NOT derived from the epidermal cell layer in plants? IAT 2024

a. Casparian strip from rice root
b. Trichomes from maize leaf
c. Subsidiary cells from rice leaf
d. Bulliform cells from grass

4. Which one of the following choices matches the organs in column I with their vascular system arrangement described in column II?

Column I		Column II	
P.	Dicot root	i.	Radial, open, diarch to tetrarch
Q.	Dicot stem	ii.	Ring, conjoint, open
R.	Monocot root	iii.	Radial, closed, polyarch
S.	Monocot stem	iv.	Scattered, conjoint, closed

IAT 2026

a. $P-(ii); Q-(i); R-(iv); S-(iii)$
b. $P-(iii); Q-(iv); R-(i); S-(ii)$
c. $P-(iv); Q-(iii); R-(ii); S-(i)$
d. $P-(i); Q-(ii); R-(iii); S-(iv)$

Structural Organisation in Animals

1. Which one of the following statements best defines properties of a compound epithelium? IAT 2017

a. It is multilayered and mainly protects from chemical and mechanical stresses.
b. It is multilayered and covers the outer lining of secretory glandular epithelium.
c. It is multilayered and help binding tissues together and their eventual organization.
d. It is multilayered and actively participates in secretion and absorption.

2. Which one of the following statements is TRUE? IAT 2019

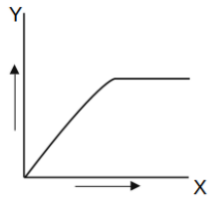
a. Blood is a connective tissue which does not secrete collagen
b. Tendons are a type of dense, irregular connective tissue
c. Adipose tissue is an example of a fluid connective tissue
d. Saliva is secreted by an endocrine gland

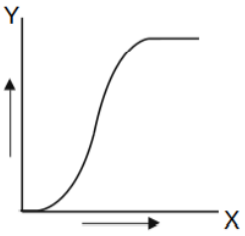
3. Which one of the following epithelial cell types is commonly found in the inner surface of the fallopian tubes? IAT 2021

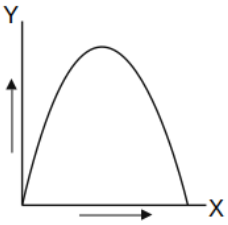
(a) Cuboidal **(b)** Columnar
(c) Squamous **(d)** Ciliated

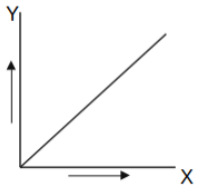
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5. The following graph options show the relationship between light intensity and photosynthesis rate. Which graph correctly represents this relationship? IAT 2024

a.


b.


c.


d.


6. Which one of the following statements about a plant carotenoid is FALSE? IAT 2025

a. It provides precursor for the synthesis of stress hormone in plants.
b. It is an accessory pigment which absorbs light at 600-700 nm.
c. It protects chlorophyll a from photo-oxidation.
d. It accumulates in chromoplasts during fruit ripening.

7. Which of the following processes result in development of a proton gradient across the thylakoid membrane during photosynthesis?

i. Release of protons into the lumen of the thylakoid by plastoquinone
ii. Consumption of protons in the stroma during the reduction of $NADP^+$
iii. Release of protons into the lumen of the thylakoid by ATP synthase
iv. Release of protons into the lumen of the thylakoid by water splitting reaction

IAT 2026

(a) i, iii and iv **(b)** i, ii and iii
(c) i, ii and iv **(d)** ii, iii and iv

Respiration in Plants

1. During oxidative phosphorylation the terminal electron acceptor is — IAT 2017

(a) FAD **(b)** NAD^+
(c) Oxygen **(d)** Cytochrome C

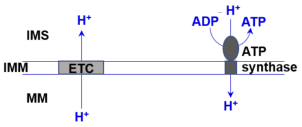
2. Shown below are some of the reactions in the metabolic pathway leading to complete oxidation of glucose during aerobic respiration:

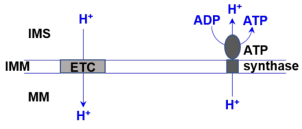
i. Pyruvate ⟶ Acetyl CoA
ii. Dihydroxy acetone phosphate ⟶ Glyceraldehyde-3-phosphate
iii. Oxaloacetate ⟶ Citrate
iv. Fumarate ⟶ Malate

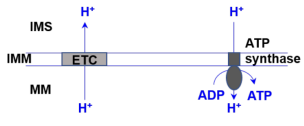
Choose the CORRECT sequence of reactions during the complete oxidation of glucose. IAT 2022

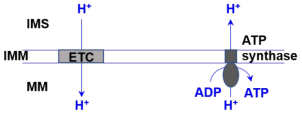
(a) i; iii; iv; ii **(b)** i; ii; iii; iv
(c) ii; iii; i; iv **(d)** ii; i; iii; iv

3. Which of the following figures CORRECTLY represents the chemiosmotic hypothesis of ATP synthesis occurring in a mitochondrion? IAT 2022

a.


b.


c.


d.


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5. What are the types of immunity acquired by (i) transfer of antibodies to the foetus via the placenta and (ii) vaccination of an infant? IAT 2019

a. Both are active immunity
b. Both are passive immunity
c. Active and passive immunity, respectively
d. Passive and active immunity, respectively

6. Which of the following is the correct description of interferon? IAT 2020

a. A synthetic neurotransmitter used to treat neuronal diseases
b. A class of proteins secreted by B-lymphocytes that categorically attack and destroy virus-infected cells
c. Signalling molecules that interfere with its own synthesis inside a secretory cell
d. A class of proteins secreted by virus infected cells and are involved in protecting uninfected cells

7. Some individuals start sneezing when the pollen content is high in the air. Primarily which Ig isotype will these individuals produce as an immune response? IAT 2021

(a) IgM **(b)** IgA
(c) IgE **(d)** IgG

8. For which one of the following diseases does the causative agent require the **splicing of their hnRNA** to generate mature mRNA? IAT 2023

(a) Malaria **(b)** Typhoid
(c) Pertussis **(d)** Tuberculosis

9. Match the list of conditions (Column I) with the list of affected physiological processes (Column II).

Column I		Column II	
P	Allergy	i	Excess secretion of growth hormone
Q	Uremia	ii	Exaggerated immune response to environmental substances
R	Myasthenia gravis	iii	Autoimmune disorder affecting the neuromuscular junction
S	Acromegaly	iv	Malfunctioning of kidneys which can lead to urea accumulation in the blood

Which of the following combinations is correct? IAT 2024

a. P - (ii); Q - (iv); R - (iii); S - (i)
b. P - (iii); Q - (iv); R - (i); S - (ii)
c. P - (iv); Q - (iii); R - (i); S - (ii)
d. P - (ii); Q - (i); R - (iv); S - (iii)

10. Which of the following is routinely performed to detect typhoid? IAT 2024

(a) RT-PCR **(b)** Widal test
(c) ELISA **(d)** Gel electrophoresis

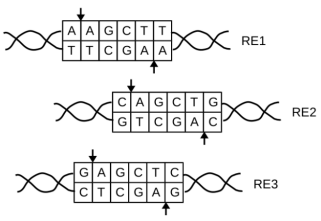
Microbes in Human Welfare

1. Which compound given below inhibits cholesterol synthesis in humans? IAT 2018

(a) Streptokinase **(b)** Statins
(c) Penicillin **(d)** Cyclosporin A

Biotechnology: Principles and Processes

1. Provided below are recognition sequences for restriction enzymes 1 (RE1), 2 (RE2) and 3 (RE3). Arrows indicate the positions where the enzymes digest on the two strands. Which of the following can the RE1 digested DNA ligate to?



IAT 2017

a. All three RE1, RE2 and RE3 digested DNA.
b. Only to RE1 digested DNA.
c. Only to RE1 and RE3 digested DNA.
d. Only to RE1 and RE2 digested DNA.

2. DNA fragments of 100 base pairs (bp), 300 bp and 500 bp were separated by agarose gel electrophoresis. Pick the correct arrangement of the fragments separated on the gel in the increasing order of their migration from the wells. IAT 2018

a. 500 bp < 300 bp < 100 bp
b. 100 bp < 300 bp < 500 bp
c. 100 bp > 300 bp > 500 bp
d. 500 bp > 300 bp > 100 bp

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DETAILED SOLUTIONS

Some Basic Concepts of Chemistry

SOL 1

Step 1 — Initial moles of NaOH:

$$n = MV = 1.0 \times 0.100 = 0.10 \text{ mol}$$

Step 2 — After dilution to 1.0 L:

$$M = \frac{0.10}{1.0} = 0.10 \text{ M}$$

Concentration is unchanged by dilution; moles remain 0.10 mol.

Step 3 — Half solution discarded:
Volume remaining = 0.5 L. Since concentration is unaffected by discarding:

$$n_{\text{remaining}} = 0.10 \times 0.5 = 0.05 \text{ mol}$$

Step 4 — Addition of 100 mL of 0.5 M NaOH:

$$n_{\text{added}} = 0.5 \times 0.100 = 0.05 \text{ mol}$$

Step 5 — Final solution:

$$n_{\text{total}} = 0.05 + 0.05 = 0.10 \text{ mol}$$

$$V_{\text{total}} = 0.5 + 0.1 = 0.6 \text{ L}$$

$$M_{\text{final}} = \frac{0.10}{0.6} = 0.1\overline{6} \text{ M} \approx \mathbf{0.17} \text{ M}$$

Structure of Atom

SOL 1

- Na: atomic number = 11 (protons), mass number = 23 $\Rightarrow$ neutrons = 23 − 11 = 12.
- **Number of protons** = 11 (unchanged; atomic number defines the element).
- **Number of neutrons** = 12 (unchanged; nuclear property).
- **Neutral atom condition**: total positive charge = total negative charge.
- If charge of proton = $2e$ (where e = magnitude of electron charge):
  - Total positive charge = $11 \times 2e = 22e$.
  - Each electron has charge = e.
  - Electrons needed = $\frac{22e}{e} = \mathbf{22}$.

$\Rightarrow$ P = 11, N = 12, **E = 22**.

SOL 2

1. Using Einstein's photoelectric equation: $KE = h(\nu - \nu_0)$.
2. **Equation 1:** $K = h(3.8 \times 10^{16} - \nu_0)$.
3. **Equation 2:** $\frac{K}{2} = h(2.4 \times 10^{16} - \nu_0)$.
4. Dividing Eq. 1 by Eq. 2:

$$2 = \frac{3.8 \times 10^{16} - \nu_0}{2.4 \times 10^{16} - \nu_0}$$

5. Solving: $2(2.4 \times 10^{16} - \nu_0) = 3.8 \times 10^{16} - \nu_0$
6. $4.8 \times 10^{16} - 2\nu_0 = 3.8 \times 10^{16} - \nu_0$
7. $\nu_0 = 4.8 \times 10^{16} - 3.8 \times 10^{16} = \mathbf{1.0 \times 10^{16}}$ **Hz**.

SOL 3

- **Angular nodes** (nodal planes) = ℓ
- **Radial nodes** (spherical nodes) = $n - \ell - 1$
- **Total nodes** = $\ell + (n - \ell - 1) = n - 1$
- Example: 3p orbital ($n = 3, \ell = 1$): angular nodes = 1, radial nodes = 1, total = 2.

SOL 4

- For a 1s orbital, the **wave function** ψ_{1s} is maximum at $r = 0$ (at the nucleus).
- **Probability density** = $|\psi|^2$; since ψ is maximum at nucleus, $|\psi|^2$ is also maximum there.
- Total number of nodes for 1s = $n - 1 = 0$; hence no radial nodes, and the function decays monotonically.
- Note: The **radial distribution function** $4\pi r^2|\psi|^2$ is maximum at the Bohr radius — but **probability density** $|\psi|^2$ itself is maximum at the nucleus.
- Hence, the correct answer is **(A) at the nucleus**.

SOL 5

The wave function shown has one node (crosses zero once) and starts positive. This corresponds to the 2s orbital of hydrogen. The 2s wave function is:

$$\psi_{2s} = \frac{1}{4\sqrt{2\pi}} \left(\frac{1}{a_0}\right)^{3/2} \left(2 - \frac{r}{a_0}\right) e^{-r/2a_0}$$

which has a node at $r = 2a_0$ and matches the shape shown.

SOL 6

Radial nodes = $n - l - 1$. For a 4s orbital: $n = 4,\ l = 0$.

$$\text{Radial nodes} = 4 - 0 - 1 = \mathbf{3}$$

Note: The electronic configuration of Ca^+ is [Ar] $4s^1$, so the valence electron is in 4s.

SOL 7

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The threshold wavelength is

$$\lambda_0 = 500\,\text{nm}.$$

Hence, the work function of the metal is

$$\phi = \frac{hc}{\lambda_0} = \frac{(6.6\times10^{-34})(3\times10^{8})}{500\times10^{-9}} = 3.96\times10^{-19}\,\text{J}.$$

The incident radiation has wavelength

$$\lambda = 300\,\text{nm},$$

so the energy of each photon is

$$E = \frac{hc}{\lambda} = \frac{(6.6\times10^{-34})(3\times10^{8})}{300\times10^{-9}} = 6.6\times10^{-19}\,\text{J}.$$

Therefore, the maximum kinetic energy of each emitted photoelectron is

$$K_{\max} = E - \phi = 6.6\times10^{-19} - 3.96\times10^{-19} = 2.64\times10^{-19}\,\text{J}.$$

Since the entire power of the bulb is incident on the metal,

$$P = 100\,\text{W} = 100\,\text{J s}^{-1}.$$

The number of incident photons per second is

$$N = \frac{P}{E} = \frac{100}{6.6\times10^{-19}} = 1.515\times10^{20}\,\text{s}^{-1}.$$

Assuming one photon ejects one electron, the total kinetic energy of all emitted photoelectrons per second is

$$NK_{\max} = \left(\frac{100}{6.6\times10^{-19}}\right)\left(2.64\times10^{-19}\right) = 40\,\text{J}.$$

SOL 8

From Bohr's model, the time period of revolution of an electron in the n^{th} orbit is given by:

$$T_n = \frac{4\pi^2 m n^3 a_0^2}{hZ^2}$$

For $n = 4$ and $Z = 2$ (as in He^+):

$$T_4 = \frac{64}{4}T_1 = 16T_1$$

where

$$T_1 = \frac{4\pi^2 m a_0^2}{h} = 1.52\times10^{-16}\,\text{s} = 0.152\,\text{fs}$$

$$\therefore\ T_4 = 16\times0.152\,\text{fs} = 2.43\,\text{fs}$$

Hence, the correct option is 2.4 femtoseconds.

SOL 9

From Bohr's model, the velocity of an electron in the n-th orbit of a hydrogen-like ion with nuclear charge Z is:

$$v_n \propto \frac{Z}{n}$$

For Be^{3+} ($Z = 4$) in the fourth orbit ($n = 4$):

$$v_1 \propto \frac{4}{4} = 1$$

For He^+ ($Z = 2$) in the second orbit ($n = 2$):

$$v_2 \propto \frac{2}{2} = 1$$

$$\frac{v(Be^{3+}, n=4)}{v(He^+, n=2)} = \frac{Z_1/n_1}{Z_2/n_2} = \frac{4/4}{2/2} = \frac{1}{1}$$

The ratio is **1 : 1**.

Classification of Elements and Periodicity in Properties

SOL 1

- Correct order: $Al < S < Si < P < Mg$
- **Mg**: high IP due to stable, fully filled $3s^2$ orbital.
- **Al**: lower than Mg (electron removed from higher energy 3p orbital).
- **P**: higher than S because P has stable half-filled $3p^3$ configuration.
- **S**: lower than P due to electron-electron repulsion in paired $3p^4$.
- Statement A: "$P < S$" is **INCORRECT** ($P > S$ in ionization potential).

SOL 2

For X: IE_4 shows a very large jump (from 28.4 to 120.0 eV), indicating that the 4th electron is being removed from a core shell. Therefore X has 3 valence electrons (Group 13). For Y: IE_5 shows the large jump (from 45.1 to 166.7 eV), indicating that the 5th electron is core. Therefore Y has 4 valence electrons (Group 14). Hence X has 3 and Y has 4 valence electrons.

SOL 3

An element with atomic number 120 comes at the second position after the last noble gas, Oganesson ($Z = 118$). After filling a noble gas shell, the next two groups are 1 and 2. Thus, element 119 goes into the 8th period of group 1, and element 120 into the 8th period of group 2. Therefore, an element with $Z = 120$ is a member of the **alkaline earth metals**.

Chemical Bonding and Molecular Structure

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$$\mu = P_{Cl}$$

(iii) For the bent molecule having bond angle 60°,

$$\mu = \sqrt{P_{Cl}^2 + P_{Cl}^2 + 2P_{Cl}^2 \cos 60^\circ}$$

Since,

$$\cos 60^\circ = \frac{1}{2}$$

$$\mu = \sqrt{2P_{Cl}^2 + P_{Cl}^2}$$

$$\mu = \sqrt{3}\, P_{Cl}$$

(iv) Similarly,

$$\mu = \sqrt{P_F^2 + P_F^2 + 2P_F^2 \cos 60^\circ}$$

$$\mu = \sqrt{3}\, P_F$$

Since fluorine is more electronegative than chlorine,

$$P_F > P_{Cl}$$

Hence,

$$\sqrt{3}\, P_F > \sqrt{3}\, P_{Cl} > P_{Cl} > 0$$

Therefore, the correct order of dipole moment is:

$$\boxed{(iv) > (iii) > (ii) > (i)}$$

SOL 8

Molecules with unpaired electrons are paramagnetic (attracted to magnetic fields).

- **O_2:** Bond order 2, **2 unpaired electrons** in degenerate π^* MOs — paramagnetic.
- **B_2:** Bond order 1, **2 unpaired electrons** in degenerate π MOs — paramagnetic.
- **N_2:** Bond order 3, all electrons paired — diamagnetic.
- **F_2:** Bond order 1, all electrons paired — diamagnetic.

Therefore **O_2 and B_2** are attracted to an external magnetic field.

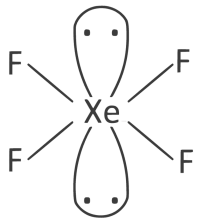
SOL 9

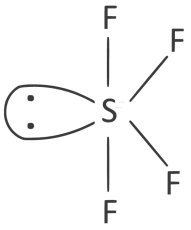
Since the total number of electrons in N_2, CO, and NO^+ is 14, they are isoelectronic.
According to their molecular orbital diagrams, the bond order of N_2, CO, and NO^+ is 3.

SOL 10

According to the VSEPR (Valence Shell Electron Pair Repulsion) theory:

- **XeF_4:** Xenon has **4 bond pairs** and **2 lone pairs** (AX_4E_2). The electron-pair geometry is octahedral, with the two lone pairs occupying opposite positions to minimize repulsion. Therefore, the molecular shape is **square planar**.
- **SF_4:** Sulfur has **4 bond pairs** and **1 lone pair** (AX_4E). The electron-pair geometry is trigonal bipyramidal. The lone pair occupies an equatorial position, resulting in a **see-saw** molecular shape.





Hence,

$\boxed{XeF_4 \text{ is square planar, while } SF_4 \text{ is see-saw.}}$

SOL 11

Bond Order:

$$BO = \frac{N_b - N_a}{2}$$

Paramagnetic: unpaired electrons
Diamagnetic: all electrons paired

1. $N_2 \rightarrow N_2^+ + e^-$
   N_2: BO = 3, diamagnetic
   N_2^+: BO = 2.5, paramagnetic
   BO decreases; magnetic nature changes.
2. $O_2 \rightarrow O_2^+ + \mathbf{e^-}$
   O_2: BO = 2, paramagnetic
   O_2^+: BO = 2.5, paramagnetic
   BO increases; magnetic nature unchanged.
3. $O_2 + e^- \rightarrow O_2^-$
   O_2: BO = 2, paramagnetic
   O_2^-: BO = 1.5, paramagnetic
   BO decreases; magnetic nature unchanged.

Conclusion
Only process

$$O_2 \rightarrow O_2^+ + \mathbf{e^-}$$

shows an **increase in bond order** without any change in **paramagnetic behaviour**.

SOL 12

We are given dipole moments of three AB_3-type molecules:

- I = 0.0 D
- II = 0.2D
- III = 1.5D

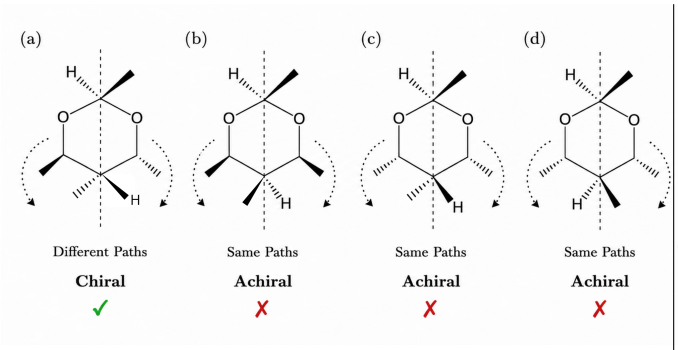
I: BF_3 → Dipole Moment = 0.0D

- Geometry: Trigonal planar
- Symmetrical, individual bond dipoles cancel out
- Dipole moment = 0 D

II: NF_3 → Dipole Moment ≈ 0.2D

- Geometry: Trigonal pyramidal (like NH_3), but fluorine is more electronegative

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(a) The two paths attached to the stereogenic center are different; no plane of symmetry is present. Hence, the molecule is **chiral**.
(b) The two paths are identical and a plane of symmetry is present. Hence, the molecule is **achiral**.
(c) A plane of symmetry is present. Hence, the molecule is **achiral**.
(d) A plane of symmetry is present. Hence, the molecule is **achiral**.

Therefore, only (a) is chiral.

Alcohols, Phenols and Ethers

SOL 1

Generally, carboxylic acids (N) are more acidic than phenols (M, P, Q). However, picric acid (P), with three electron-withdrawing nitro groups, is exceptionally acidic—more than benzoic acid. Nitro groups stabilize the phenoxide anion via resonance/induction. p-Nitrophenol (Q) is more acidic than phenol (M) due to nitro substitution. Thus, the order is: P (picric acid) > N (benzoic acid) > Q (p-nitrophenol) > M (phenol)

SOL 2

Reaction Breakdown

1. **Hydroboration–oxidation**
   - Reagents: $(BH_3)_2$, followed by $H_2O_2/NaOH$
   - Adds water across a double bond in an **anti-Markovnikov fashion**.
   - OH group is added to the **less substituted carbon**.
2. **Oxidation with CrO_3**
   - Converts the resulting **secondary alcohol to a ketone**.

Aldehydes, Ketones and Carboxylic Acids

SOL 1

- α-hydrogen abstraction occurs only when the base removes a hydrogen from the carbon adjacent to the carbonyl group to form an enolate ion.
- **Option A**: Carbonyl compound possessing α-hydrogens ⇒ base can abstract the α-H to form an enolate.
- **Option B**:

$$CH_3CH_2CH_2COOH$$

  is butyric acid (carboxylic acid).
- Carboxylic acids contain a highly acidic proton of the

$$-COOH$$

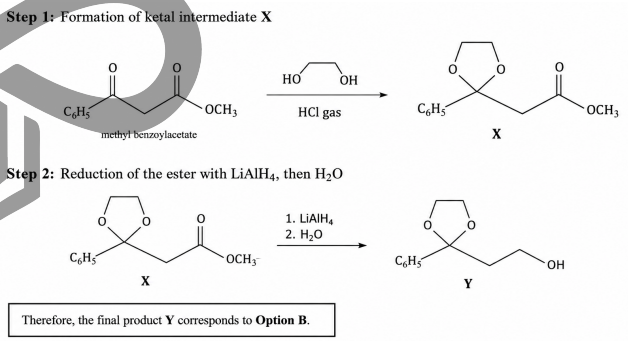
  group.
- On treatment with **one equivalent of base**, the base preferentially abstracts the acidic proton of the hydroxyl group:

$$RCOOH + OH^- \rightarrow RCOO^- + H_2O$$

- Therefore, the α-hydrogen is **not abstracted** because deprotonation of the acidic O–H bond occurs much more readily.
- **Options C and D**: do not possess such an acidic O–H proton, therefore the base abstracts the available α-hydrogen.

⇒ Correct option: **Option B**.

SOL 2

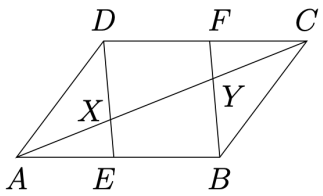


SOL 3

- Imine formation (nucleophilic addition of amine to carbonyl): rate depends on **electrophilicity of carbonyl carbon**.
- **Electron-withdrawing groups (EWG)** increase electrophilicity of C=O ⇒ increase reactivity.
- **Electron-donating groups (EDG)** decrease electrophilicity ⇒ decrease reactivity.
- A (4-OCH_3): EDG (para) ⇒ least reactive.
- B (4-NO_2): EWG (para) ⇒ highly activates; para position best for resonance stabilization of TS.
- C (4-CN): EWG (para) ⇒ also activates.
- D (2-NO_2): EWG but ortho position causes **steric hindrance** to amine approach.
- **4-NO_2**: strong EWG at para with no steric issue ⇒ **highest reactivity**.

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1. Consider the parallelogram $ABCD$ as shown in the figure, where $\frac{AE}{AB} = \frac{CF}{CD} = \frac{1}{n}$ for some positive integer n. Suppose the length of AC is a. Then the length of XY is



IAT 2019

a. $\frac{a}{n}$
b. $\frac{na}{n+1}$
c. $\frac{(n-1)a}{n+1}$
d. $\frac{(n-1)a}{n}$

2. Let $\hat{i}$, $\hat{j}$ and $\hat{k}$ denote the standard unit vectors in $\mathbb{R}^3$ along the x-axis, y-axis and z-axis, respectively. Consider the sets

$$X = \{a\hat{i} + b\hat{j} + c\hat{k} : a, b, c \in \{-1, 0, 1\}\}$$

and

$$Y = \{(\vec{v}_1, \vec{v}_2, \vec{v}_3) : \vec{v}_1, \vec{v}_2, \vec{v}_3 \in X \text{ and } \vec{v}_1, \vec{v}_2, \vec{v}_3 \text{ are mutually perpendicular unit vectors}\}.$$

Then, the number of elements in Y is IAT 2019

(a) 27 **(b)** 24
(c) 36 **(d)** 48

3. Let S be the set of all unit vectors in the XY-plane. Then the set S has IAT 2022

a. 2 elements
b. 4 elements
c. 8 elements
d. Infinitely many elements

4. Consider vectors

$$\vec{a} = \hat{i} + x\hat{j} + 2\hat{k}, \qquad \vec{b} = \hat{i} + 2\hat{j} + x\hat{k},$$

$$\vec{c} = 2\hat{i} + \hat{j} + 3\hat{k}$$

The values of x for which there is at least one nonzero vector perpendicular to all three are IAT 2022

(a) $-2, 2$ **(b)** $4, -2$
(c) $0, 2$ **(d)** $\frac{7}{2}, 0$

5. Let $\vec{a}$ and $\vec{b}$ be two vectors such that $|\vec{a} + \vec{b}| = 15$ and

$$\vec{a} \times (3\hat{i} - 4\hat{j} + 5\hat{k}) = (3\hat{i} - 4\hat{j} + 5\hat{k}) \times \vec{b}.$$

What is the value of $|(\vec{a} + \vec{b}) \cdot (2\hat{i} + 3\hat{j} + \hat{k})|$? IAT 2025

(a) $\frac{3}{\sqrt{2}}$ **(b)** 0
(c) $\sqrt{2}$ **(d)** 3

6. Consider the points $A(4\hat{i}+\hat{j}+3\hat{k})$, $B(2\hat{j})$ and $C(-4\hat{i}+3\hat{j}-5\hat{k})$. Which of the following statements is TRUE? IAT 2026

a. A, B and C are collinear.
b. $\overrightarrow{AB} + 3\overrightarrow{BC}$ is perpendicular to $\overrightarrow{AC}$.
c. $\overrightarrow{AB} \times \overrightarrow{BC} = \hat{i} + \hat{j} + \hat{k}$.
d. $\overrightarrow{AB}$, $\overrightarrow{BC}$ and $\overrightarrow{CA}$ are mutually perpendicular.

Three Dimensional Geometry

1. Let ℓ_0 be the line defined by the vector equation $\hat{i} + 2\hat{j} + 3\hat{k} + \lambda(\hat{i} + \hat{j} + \hat{k})$, with λ real. Which of the following vector equations, with μ real, defines a line which intersects ℓ_0? IAT 2018

a. $2\hat{i} + 3\hat{j} + \mu(\hat{i} - \hat{j})$.
b. $3\hat{i} - 2\hat{j} + \hat{k} + \mu(-\hat{i} + \hat{j})$.
c. $\hat{i} + 3\hat{j} + 5\hat{k} + \mu(2\hat{i} + 3\hat{j} + 4\hat{k})$.
d. $-\hat{i} - 2\hat{j} - 3\hat{k} + \mu(-\hat{i} - \hat{j} - \hat{k})$.

2. Let $P_1 : x + y + z = 1$, $P_2 : 2x + y + z = 3$ be two planes, and let L denote the line of intersection of P_1 and P_2. Let P be the plane passing through the point $(1, 2, 1)$, and normal to L. Which of the following equations represents P? IAT 2021

(a) $y - z = 1$ **(b)** $x + z = 2$
(c) $x + 2y + z = 6$ **(d)** $x + y + 2z = 5$

3. Let L be a straight line passing through the origin, and it makes angles α, β and γ with the positive X, Y and Z-axes, respectively. What is the value of $\cos 2\alpha + \cos 2\beta + \cos 2\gamma$? IAT 2023

(a) 3 **(b)** 1
(c) -3 **(d)** -1

4. Consider the lines L_1: $x = 2 + \lambda$, $y = 3 + 2\lambda$, $z = 4 + 3\lambda$; and L_2: $x = 4 + \lambda$, $y = 4$, $z = 4 + \lambda$. If (2,3,4) on L_1 is closest to L_2, then which point on L_2 is closest to L_1? IAT 2024

(a) (3, 4, 4) **(b)** (3, 4, 3)
(c) (5, 4, 5) **(d)** (4, 4, 4)

5. Let l_1 be the line joining $(1, 1, 1)$ and $(3, 1, 3)$ and let l_2 be the line joining $(0, 2, -1)$ and $(2, 0, 3)$. What is the angle between l_1 and l_2? IAT 2026

(a) 60° **(b)** 30°
(c) 45° **(d)** 90°

Linear Programming

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$\mathcal{E} = -\dfrac{d\phi_B}{dt} = \phi_0\omega \sin \omega t$.

$|\mathcal{E}| = \phi_0\omega|\sin \omega t|$ is maximum when $|\sin \omega t| = 1$, i.e., $\omega t = \dfrac{\pi}{2}$, giving $t = \dfrac{\pi}{2\omega}$.

Answer: **(d)**.

SOL 5

As the metallic frame shrinks, the magnetic flux through it decreases, inducing an azimuthal electric field that **opposes** the particle's motion. This reduces the particle's speed.

Since $r = \dfrac{mv}{qB}$, a decrease in speed reduces the radius.

Angular frequency $\omega = \dfrac{v}{r}$; with both v and r decreasing (but r decreasing proportionally more), ω increases.

Hence, the radius decreases and the frequency increases.

SOL 6

Step 1: As the radius of the solenoid increases,

$$A = \pi R^2$$

increases, so the external magnetic flux

$$\Phi_{\text{ext}} = BA$$

increases.

Step 2: By Lenz's law, the induced current opposes this increase in flux.

For the closed circuit,

$$B_{\text{in}}A = \text{constant}.$$

Hence,

$$B_{\text{in}} \propto \frac{1}{A}.$$

Therefore,

$$\boxed{B_{\text{in}} \text{ decreases}}.$$

Step 3: Magnetic energy stored inside the solenoid is

$$U_{\text{in}} \propto B_{\text{in}}^2 A.$$

Using $B_{\text{in}} \propto 1/A$,

$$U_{\text{in}} \propto \left(\frac{1}{A}\right)^2 A = \frac{1}{A}.$$

Thus,

$$\boxed{U_{\text{in}} \text{ decreases}}.$$

$$\boxed{\text{Therefore, } B_{\text{in}} \text{ decreases and } U_{\text{in}} \text{ decreases.}}$$

Alternating Current

SOL 1

The circuit is a high-pass RC filter with output taken across the resistor.

The magnitude of the voltage gain is

$$\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}.$$

Given

$$\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{1}{\sqrt{2}},$$

we have

$$\frac{R}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} = \frac{1}{\sqrt{2}}.$$

Squaring both sides,

$$2R^2 = R^2 + \left(\frac{1}{\omega C}\right)^2,$$

which gives

$$R = \frac{1}{\omega C}.$$

Therefore,

$$\omega = \frac{1}{RC}, \qquad f = \frac{1}{2\pi RC}.$$

Given

$$R = 1000\ \Omega, \qquad C = \frac{1}{6}\,\text{pF} = \frac{1}{6} \times 10^{-12}\,\text{F},$$

$$f = \frac{1}{2\pi(1000)\left(\frac{1}{6} \times 10^{-12}\right)} = \frac{6 \times 10^9}{2\pi}.$$

$$f \approx 9.55 \times 10^8\ \text{Hz}.$$

Hence, the closest approximate frequency is

$$\boxed{10^9\ \text{Hz}}.$$

SOL 2

Since the current through resistor A is in phase with the applied voltage

$$V = V_0 \sin(\omega t),$$

the circuit is at resonance. Hence, the net reactive component of the impedance must be zero.

For the given bridge circuit, the resonance condition is

$$X_C = 2X_L.$$

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