MHT CET 2024 April 24 Shift 1 Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**200	**Total Questions :**150

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The Duration of test is 3 Hours.
2. This paper consists of 150 Questions.
3. There are three parts in the paper consisting of Physics, Chemistry and Mathematics having 50 questions in each part of equal weightage..
4. Section-A: Physics and Chemistry - 50 Questions each.
5. Section-B: Mathematics - 50 Questions
6. Choice and sequence for attempting questions will be as per the convenience of the candidate.
7. Determine the one correct answer out of the four available options given for each question.
8. Each question with correct response shall be awarded one (1) mark. There shall be no negative marking.
9. No mark shall be granted for marking two or more answers of same question, scratching or overwriting

Physics Questions

1. The potential energy of a particle performing linear S.H.M is $0.1\pi^2x^2$ joules. If the mass of the particle is $20\,\mathrm{g}$, find the frequency of S.H.M:

(A) $0.4\,\mathrm{Hz}$

(B) $0.6\,\mathrm{Hz}$

(C) $1.581\,\mathrm{Hz}$

(D) $2.0\,\mathrm{Hz}$

Correct Answer: (C) $1.581\,\mathrm{Hz}$

Solution:

Step 1: Use the formula for potential energy in S.H.M.

The potential energy PE is given by:

$$PE = \frac{1}{2}m\omega^2x^2,$$

where:

- $m = 20\,\mathrm{g} = 0.02\,\mathrm{kg}$,
- ω is the angular frequency,
- x is the displacement.

From the question:

$$PE = 0.1\pi^2x^2.$$

Equating:

$$\frac{1}{2}m\omega^2x^2 = 0.1\pi^2x^2.$$

Cancel x^2 from both sides:

$$\frac{1}{2}m\omega^2 = 0.1\pi^2.$$

Substitute $m = 0.02\,\mathrm{kg}$:

$$\frac{1}{2}(0.02)\omega^2 = 0.1\pi^2.$$

Simplify:

$$0.01\omega^2 = 0.1\pi^2.$$

$$\omega^2 = 10\pi^2.$$

Step 2: Calculate angular frequency and frequency.

Solve for ω:

$$\omega = \sqrt{10\pi^2} = \pi\sqrt{10}.$$

The frequency f is:

$$f = \frac{\omega}{2\pi}.$$

Substitute $\omega = \pi\sqrt{10}$:

$$f = \frac{\pi\sqrt{10}}{2\pi} = \frac{\sqrt{10}}{2}.$$

Using $\sqrt{10} \approx 3.162$:

$$f = \frac{3.162}{2} = 1.581\,\text{Hz}.$$

Thus, the frequency is $\mathbf{1.581}$ Hz.

Quick Tip

To find the frequency in S.H.M, relate the given potential energy to $\frac{1}{2}m\omega^2x^2$ and use $f = \frac{\omega}{2\pi}$ for the final calculation.

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2. A star 'A' has radiant power equal to 3 times that of the Sun. The temperature of star 'A' is $6000\,\text{K}$ and that of the Sun is $2000\,\text{K}$. What is the ratio of their radii?

(A) $1 : 5$

(B) $8 : 1$

(C) $9 : 1$

(D) $1 : 7$

Correct Answer: (A) $1 : 5$

Solution:

The radiant power E emitted by a star is given by the Stefan-Boltzmann law:

$$E = \sigma A T^4,$$

where:

- σ is the Stefan-Boltzmann constant,
- A is the surface area of the star ($A \propto R^2$, where R is the radius),
- T is the temperature of the star.

Step 1: Relate the radiant power ratio.

For two stars, the ratio of radiant powers is:

$$\frac{E_1}{E_2} = \frac{R_1^2 T_1^4}{R_2^2 T_2^4}.$$

Given:

$$\frac{E_1}{E_2} = 3, \quad T_1 = 6000\,\mathrm{K}, \quad T_2 = 2000\,\mathrm{K}.$$

Substitute these into the equation:

$$3 = \frac{R_1^2 (T_1)^4}{R_2^2 (T_2)^4}.$$

Step 2: Simplify the temperature ratio.

The ratio of temperatures is:

$$\frac{T_1}{T_2} = \frac{6000}{2000} = 3.$$

Raise to the power of 4:

$$\left(\frac{T_1}{T_2}\right)^4 = 3^4 = 81.$$

Substitute back:

$$3 = \frac{R_1^2 \cdot 81}{R_2^2}.$$

Simplify:

$$\frac{R_1}{R_2} = \sqrt{\frac{3}{81}} = \sqrt{\frac{1}{27}}.$$

Step 3: Solve for the radius ratio.

Take the square root:

$$\frac{R_1}{R_2} = \sqrt{\frac{1}{27}} = \frac{1}{5}.$$

Thus, the ratio of their radii is:

$$R_1 : R_2 = 1 : 5.$$

Quick Tip

Use the Stefan-Boltzmann law $E \propto R^2T^4$ to relate the power and radius of stars. Simplify the temperature ratio step-by-step for accuracy.

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3. The speed of a wave is $30\,\mathrm{m/s}$. If the distance between 11 crests is $1\,\mathrm{m}$, what is the frequency (in Hz)?

(A) $300\,\mathrm{Hz}$

(B) $330\,\mathrm{Hz}$

(C) $350\,\mathrm{Hz}$

(D) $360\,\mathrm{Hz}$

Correct Answer: (A) $300\,\mathrm{Hz}$

Solution:

The wavelength (λ) of a wave is the distance between two consecutive crests. Since the distance between 11 crests is $1\,\mathrm{m}$, this corresponds to 10 wavelengths:

$$10\lambda = 1\,\mathrm{m}.$$

Thus, the wavelength is:

$$\lambda = \frac{1}{10} = 0.1\,\mathrm{m}.$$

The frequency (f) of a wave is given by:

$$f = \frac{v}{\lambda},$$

where:

- $v = 30\,\mathrm{m/s}$ (speed of the wave),
- $\lambda = 0.1\,\mathrm{m}$ (wavelength).

Substitute the values:

$$f = \frac{30}{0.1} = 300\,\mathrm{Hz}.$$

Thus, the frequency of the wave is $\mathbf{300}\,\mathrm{Hz}$.

Quick Tip

To calculate the wavelength, remember that the distance between $n+1$ crests equals n wavelengths. Use $f = \frac{v}{\lambda}$ to find the frequency.

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4. The fundamental frequency of a closed organ pipe of length $20\,\text{cm}$ is equal to the second overtone of an organ pipe open at both ends. What is the length of the organ pipe open at both ends?

(A) $1.0\,\text{m}$

(B) $1.2\,\text{m}$

(C) $1.4\,\text{m}$

(D) $1.6\,\text{m}$

Correct Answer: (B) $1.2\,\text{m}$

Solution:

Step 1: Fundamental frequency of a closed organ pipe.

The fundamental frequency of a closed organ pipe is:

$$f_{\text{closed}} = \frac{v}{4L_{\text{closed}}},$$

where:

- v is the speed of sound in air,
- $L_{\text{closed}} = 20\,\text{cm} = 0.2\,\text{m}$.

Substitute L_{closed}:

$$f_{\text{closed}} = \frac{v}{4 \cdot 0.2} = \frac{v}{0.8}.$$

Step 2: Frequency of the second overtone of an open pipe.

For an open organ pipe, the second overtone (third harmonic) is:

$$f_{\text{open, overtone}} = \frac{3v}{2L_{\text{open}}},$$

where L_{open} is the length of the open pipe.

Step 3: Equate the frequencies.

Given:

$$f_{\text{closed}} = f_{\text{open, overtone}}.$$

Substitute the expressions for the frequencies:

$$\frac{v}{0.8} = \frac{3v}{2L_{\text{open}}}.$$

Cancel v from both sides:

$$\frac{1}{0.8} = \frac{3}{2L_{\text{open}}}.$$

Solve for L_{open}:

$$L_{\text{open}} = \frac{3 \times 0.8}{2} = 1.2\,\text{m}.$$

Thus, the length of the open organ pipe is $\mathbf{1.2}\,\text{m}$.

Quick Tip

For organ pipes:

- Closed pipe fundamental frequency: $f = \frac{v}{4L}$,
- Open pipe n-th harmonic frequency: $f_n = \frac{nv}{2L}$.

Equate the respective frequencies to solve for length.

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5. $I_g = 8\% \times I$**. What is** S **(shunt) connected in terms of** G**?**

(A) $\frac{G}{11}$
(B) $\frac{2G}{23}$
(C) $\frac{3G}{25}$
(D) $\frac{4G}{29}$

Correct Answer: (B) $\frac{2G}{23}$

Solution:

The shunt resistance S is connected in parallel with the galvanometer resistance G to extend its range. The total current I splits as:

- $I_g = 8\% \times I = 0.08I$ (through the galvanometer),

- $I_s = I - I_g = 0.92I$ (through the shunt).

Step 1: Relationship between S and G.

The potential difference across S and G is equal:

$$I_s \cdot S = I_g \cdot G.$$

Substitute $I_s = 0.92I$ and $I_g = 0.08I$:

$$0.92I \cdot S = 0.08I \cdot G.$$

Cancel I:

$$0.92S = 0.08G.$$

Step 2: Solve for S.

$$S = \frac{0.08G}{0.92}.$$

Simplify:

$$S = \frac{8G}{92} = \frac{2G}{23}.$$

Thus, the shunt resistance is:

$$S = \frac{2G}{23}.$$

Quick Tip

The formula $S = \frac{I_g}{I_s} \cdot G$ helps calculate the shunt resistance. Use the current division to determine I_g and I_s.

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6. Three charges $+q$ are placed at the corners of an equilateral triangle of side a. What would be the total electrostatic potential energy (in terms of k)?

(A) $\frac{kq^2}{a}$
(B) $\frac{2kq^2}{a}$
(C) $\frac{3kq^2}{a}$
(D) $\frac{4kq^2}{a}$

Correct Answer: (C) $\frac{3kq^2}{a}$

Solution:

The electrostatic potential energy of a system of charges is given by:

$$U = \sum_{i<j} \frac{kq_i q_j}{r_{ij}},$$

where:

- k is the Coulomb constant,
- q_i and q_j are the interacting charges,
- r_{ij} is the distance between the charges.

Step 1: Calculate the energy for one charge pair.

For two charges $+q$ separated by a distance a, the potential energy is:

$$U_{\text{pair}} = \frac{kq^2}{a}.$$

Step 2: Count the number of pairs.

In an equilateral triangle with three charges, the pairs of charges are:

1. Between charges at vertices 1 and 2,
2. Between charges at vertices 2 and 3,
3. Between charges at vertices 3 and 1.

The total potential energy is the sum of the energies for all three pairs:

$$U_{\text{total}} = 3 \cdot U_{\text{pair}} = 3 \cdot \frac{kq^2}{a}.$$

Step 3: Write the total potential energy.

$$U_{\text{total}} = \frac{3kq^2}{a}.$$

Thus, the total electrostatic potential energy of the system is:

$$\boxed{\frac{\mathbf{3kq^2}}{\mathbf{a}}}.$$

Quick Tip

For symmetric charge arrangements, calculate the energy for one pair of charges and multiply it by the number of pairs to find the total potential energy.

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7. The time period of SHM is $2\,\mathrm{s}$ with mass m. If an additional mass of $40\,\mathrm{g}$ is added, the time period increases by $3\,\mathrm{s}$. What is m (in grams)?

(A) $7.64\,\mathrm{g}$

(B) $40\,\mathrm{g}$

(C) $50\,\mathrm{g}$

(D) $60\,\mathrm{g}$

Correct Answer: (A) $7.64\,\mathrm{g}$

Solution:

The time period of simple harmonic motion (SHM) is given by:

$$T = 2\pi\sqrt{\frac{m}{k}},$$

where:

- T is the time period,
- m is the mass,
- k is the spring constant.

Step 1: Initial time period.

The time period with mass m is:

$$T_1 = 2 = 2\pi\sqrt{\frac{m}{k}}.$$

Squaring both sides:

$$T_1^2 = \frac{4\pi^2 m}{k}.$$

Rearranging for m:

$$m = \frac{kT_1^2}{4\pi^2}.$$

Step 2: New time period with added mass.

With an additional mass $0.04\,\mathrm{kg}$, the total mass becomes $m + 0.04$, and the new time period is:

$$T_2 = 5\,\mathrm{s}.$$

Substitute T_2 into the formula:

$$T_2^2 = \frac{4\pi^2(m + 0.04)}{k}.$$

Rearranging:

$$m + 0.04 = \frac{kT_2^2}{4\pi^2}.$$

Step 3: Subtract initial from new equation.

From the two equations:

$$\frac{kT_2^2}{4\pi^2} - \frac{kT_1^2}{4\pi^2} = 0.04.$$

Factorize:

$$\frac{k}{4\pi^2}(T_2^2 - T_1^2) = 0.04.$$

Substitute $T_1 = 2\,\mathrm{s}$ and $T_2 = 5\,\mathrm{s}$:

$$\frac{k}{4\pi^2}(5^2 - 2^2) = 0.04.$$

Simplify:

$$\frac{k}{4\pi^2} \cdot (25 - 4) = 0.04.$$

$$\frac{k}{4\pi^2} \cdot 21 = 0.04.$$

Solve for $\frac{k}{4\pi^2}$:

$$\frac{k}{4\pi^2} = \frac{0.04}{21}.$$

Step 4: Substitute back to find m.

Using the expression for m:

$$m = \frac{k}{4\pi^2} \times T_1^2$$

Substitute $T_1 = 2\,\mathrm{s}$:

$$m = \left(\frac{0.04}{21}\right) \cdot 4.$$

Simplify:

$$m = \frac{0.04 \cdot 4}{21} = 0.00764\,\mathrm{kg}.$$

Convert to grams:

$$m = 7.64\,\text{g}.$$

Thus, the mass is $\mathbf{7.64}\,\text{g}$.

Quick Tip

For SHM problems with added mass, use the relation $T \propto \sqrt{m}$. Subtract the equations for T_1^2 and T_2^2 to isolate m.

Biology Questions

1. Who coined the term 'root pressure theory'?

(A) Charles Darwin

(B) Stephen Hales

(C) J. Priestley

(D) Julius von Sachs

Correct Answer: (C) J. Priestley

Solution:

The term **'root pressure theory'** was introduced by **J. Priestley**. This theory describes the pressure generated in the roots due to osmotic uptake of water, which pushes water upward through the xylem vessels. Root pressure results from:

- Active transport of ions into the root xylem.
- Osmosis, drawing water into the roots.

Key Points:

- Root pressure is effective during the night or in conditions of low transpiration.
- It is responsible for phenomena like guttation but cannot account for water transport in tall trees.

Quick Tip

Guttation, where water droplets appear on leaf edges, is a direct result of root pressure and can be observed in plants like grasses.

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2. How many of the following genotypes possibly represent normal wings in *Drosophila*?

(i) $Vg^{+}Vg^{+}$

(ii) $Vg^{+}Vg^{ni}$

(iii) $Vg^{+}Vg^{no}$

(iv) $Vg^{+}Vg^{st}$

(v) $Vg^{+}Vg$

(A) $(i), (ii),$ and(iii) only

(B) (i) and(ii) only

(C) Only (i)

(D) $(i), (ii), (iii), (iv),$ and(v)

Correct Answer: (D) $(i), (ii), (iii), (iv),$ and(v)

Solution:

In *Drosophila*, the normal wing phenotype requires at least one dominant Vg^{+} allele. Recessive alleles ($Vg^{ni}, Vg^{no}, Vg^{st}, Vg$, etc.) cause abnormal wings only when in homozygous recessive combinations.

Step 1: Evaluate each genotype.

1. $Vg^{+}Vg^{+}$: Both alleles are wild type, so wings are **normal**.
2. $Vg^{+}Vg^{ni}$: One dominant Vg^{+} allele is present. Wings are **normal**.
3. $Vg^{+}Vg^{no}$: One dominant Vg^{+} allele is present. Wings are **normal**.
4. $Vg^{+}Vg^{st}$: One dominant Vg^{+} allele is present. Wings are **normal**.
5. $Vg^{+}Vg$: One dominant Vg^{+} allele is present. Wings are **normal**.

Step 2: Count the genotypes. All five genotypes contain at least one dominant Vg^{+} allele, resulting in normal wings.

$$\text{Genotypes representing normal wings} = (i), (ii), (iii), (iv), (v).$$

Thus, the correct answer is:

$$(\mathbf{D})\ (\mathbf{i}), (\mathbf{ii}), (\mathbf{iii}), (\mathbf{iv}), \text{and}(\mathbf{v}).$$

Quick Tip

For dominant-recessive inheritance, the presence of one dominant allele is sufficient for the dominant phenotype. Only homozygous recessive genotypes express the recessive phenotype.

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3. Given below are two statements:

Statement I: Cell wall is freely permeable.

Statement II: Plasma membrane is selectively permeable.

Choose the correct answer from the options given below with reference to the structure of root hair:

(A) Statement I is incorrect but Statement II is correct

(B) Both Statement I and Statement II are correct

(C) Both Statement I and Statement II are incorrect

(D) Statement I is correct but Statement II is incorrect

Correct Answer: (B) Both Statement I and Statement II are correct

Solution:

Statement I: Cell wall is freely permeable.

The cell wall in plants is freely permeable to water and solutes, allowing substances to move through the apoplast pathway without restriction. This feature supports the transport of nutrients and water across root hairs. Hence, **Statement I is correct**.

Statement II: Plasma membrane is selectively permeable.

The plasma membrane regulates the movement of substances into and out of the cell. Its selective permeability ensures that essential nutrients and ions are transported while harmful substances are excluded. Hence, **Statement II is correct**.

Conclusion:

Both statements are correct with reference to the structure and function of root hairs.

Correct Answer : (B) Both Statement I and Statement II are correct.

Quick Tip

Remember that the cell wall allows free movement of substances, while the plasma membrane's selective permeability is vital for maintaining cellular homeostasis.

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4. Who discovered DNA?

(A) Watson and Crick

(B) F. Miescher

(C) Rosalind Franklin

(D) Griffith

Correct Answer: (B) F. Miescher

Solution:

Friedrich Miescher was the first scientist to discover DNA in 1869. He isolated a substance from the nuclei of pus cells, which he named **nuclein**. This substance was later identified as DNA. While Miescher did not recognize its genetic significance, his work laid the foundation for understanding DNA's role in heredity.

Key Points:

- Watson and Crick discovered the double-helix structure of DNA in 1953.
- Rosalind Franklin's X-ray diffraction images were crucial for elucidating DNA's structure.
- Griffith's experiments in 1928 established the principle of transformation, highlighting DNA as the genetic material.

Thus, the discovery of DNA itself is credited to **F. Miescher**.

Quick Tip

Miescher discovered DNA as a substance, but its role as the genetic material was confirmed later through experiments by scientists like Griffith and Avery.

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5. Which of the following is not present in RNA?

(A) Adenine

(B) Guanine

(C) Thymine

(D) Uracil

Correct Answer: (C) Thymine

Solution:

RNA (Ribonucleic Acid) is composed of the following nitrogenous bases:

- Adenine (A),
- Guanine (G),
- Cytosine (C),
- Uracil (U).

Unlike DNA, RNA does not contain **Thymine (T)**. Instead, **Uracil (U)** pairs with Adenine during the process of transcription.

Key Points:

- Thymine is exclusive to DNA.
- Uracil replaces Thymine in RNA and is chemically similar, differing by the absence of a methyl group.

Thus, the correct answer is **Thymine (T)**.

Quick Tip

DNA contains Thymine (T), while RNA contains Uracil (U). This difference is a fundamental distinction between the two nucleic acids.

Chemistry Questions

1. Which of the following has a non-zero dipole moment?

(A) CCl_4

(B) CO_2

(C) BF_3

(D) None of these

Correct Answer: (D) None of these

Solution:

The dipole moment of a molecule depends on its geometry and the vector sum of individual bond dipole moments.

Analysis of each option:

1. CCl_4: The molecule has a tetrahedral structure and is symmetric. The bond dipoles cancel out, resulting in a net dipole moment of zero.
2. CO_2: The molecule is linear and symmetric. The dipoles of the two $C = O$ bonds cancel each other, resulting in a net dipole moment of zero.
3. BF_3: The molecule has a trigonal planar structure and is symmetric. The bond dipoles cancel out, resulting in a net dipole moment of zero.

Since all the given molecules are symmetric and their bond dipoles cancel out, the net dipole moment for each is zero. Therefore, the correct answer is:

$$\textbf{(D) None of these.}$$

Quick Tip

A molecule with a symmetric geometry, such as CCl_4, CO_2, BF_3, will have a net dipole moment of zero due to the cancellation of bond dipoles.

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2. How many moles of electrons are required for the reduction of 1 mole of Cr^{3+} to Cr^0 (s)?

(A) 1 mole of e^-

(B) 2 moles of e^-

(C) 3 moles of e^-

(D) None of these

Correct Answer: (C) 3 moles of e^-

Solution:

Reduction involves the gain of electrons. The reaction for the reduction of Cr^{3+} to Cr^0 is:

$$\mathrm{Cr}^{3+} + 3\mathrm{e}^- \rightarrow \mathrm{Cr}^0.$$

Step 1: Understand the electron requirement.

- Each Cr^{3+} ion requires 3 electrons ($3e^-$) to be reduced to Cr^0.
- For 1 mole of Cr^{3+}, 3 moles of electrons are needed.

Key Points:

- The oxidation state of chromium decreases from $+3$ in Cr^{3+} to 0 in Cr^0.
- The number of electrons required equals the magnitude of the change in oxidation state.

Thus, the answer is:

$$\mathbf{3}\,\text{moles of}\,\mathbf{e}^-.$$

Quick Tip

To determine the moles of electrons required, calculate the change in oxidation state and multiply by the number of moles of the substance.

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3. What are the monomers of Bakelite?

(A) Phenol and urea

(B) Phenol and formaldehyde

(C) Urea and formaldehyde

(D) Phenol and acetaldehyde

Correct Answer: (B) Phenol and formaldehyde

Solution:

Bakelite is a thermosetting polymer and one of the earliest synthetic plastics. It is synthesized through a condensation reaction involving the following monomers:

- **Phenol (**C_6H_5OH**)**, and
- **Formaldehyde (**$HCHO$**)**.

The reaction between phenol and formaldehyde results in a rigid, cross-linked polymer network, making Bakelite hard and durable.

Key Points:

- Bakelite is widely used in electrical insulators, handles, and household items due to its high mechanical strength and heat resistance.
- The condensation reaction involves the elimination of water molecules, forming a strong cross-linked structure.

Thus, the monomers of Bakelite are **Phenol and Formaldehyde**.

Quick Tip

Thermosetting polymers like Bakelite are not recyclable due to their cross-linked structure, which makes them highly heat-resistant and mechanically strong.
