Model Question Papers

With Solutions

STD. XII Sci.

Salient Features

• A set of 4 Question Papers with solutions each for Physics, Chemistry, Maths & Biology (Total 16 Question Papers)
• Prepared as per the new board paper pattern.
• Includes Board Question Papers of 2015 and 2016.
• Complete answers to every question with relevant marking scheme.
• Graphs and diagrams provided wherever necessary.
• Simple and lucid language.
• Self-evaluative in nature.

Solutions with relevant marking scheme to Board Question papers available in downloadable PDF format at www.targetpublications.org/tp10121

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**Preface**

HSC is the cornerstone of a student’s career as it opens up the doors to turn their dreams into reality. It acts as a platform for students to specialize in a field that interests them the most. However, to achieve this it becomes imperative to get into the details of each subject and to clarify its fundamentals. Adequate knowledge base thus helps kids to boost their self confidence and pave their way up in the final examinations.

It is rightly said, ‘practice makes a man perfect’. Keeping this adage in mind, we are proud to introduce “**Std XII Science Model Question Papers**”. This set of question papers provides students thorough practice for preparation of their final examinations. The book consists of 16 question papers in all based on Physics, Chemistry, Maths and Biology (*a set of four question papers for each subject*). Along with the question papers, we’ve provided model answers with relevant marking schemes so as to make sure that students understand the importance of each question. These question papers reflect the latest changes in content and paper pattern as updated by the Board of Higher Secondary Education.

Furthermore we have also included Board Question Papers of March, October 2015 and March, July 2016 examinations, solutions to which are available in downloadable PDF format at our website [www.targetpublications.org](http://www.targetpublications.org). The purpose behind this is to make students familiar with the current question pattern and marking schemes. It also gives them a holistic understanding of the exact nature of the board question papers.

We are sure that, these question papers would provide ample practice to students in a systematic manner and would boost their confidence to face the challenges posed in examinations.

We welcome your valuable suggestions and feedback towards this book.

*We wish the students all the best for their examinations.*
<table>
<thead>
<tr>
<th>No.</th>
<th>Subject</th>
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<td>Question Papers</td>
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Solutions in downloadable PDF format available at www.targetpublications.org
PHYSICS : MARKING SCHEME

- There will be one single paper of 70 marks in Physics.
- Duration of the paper will be 3 hours.
- Physics paper will consist of two parts viz: Section-I and Section-II.
- Each section will be of 35 marks.
- Same answer sheet will be used for both the sections.
- Each section will consist of 4 questions.
- The sequence of the 4 questions in each section may or may not remain the same.
- The paper pattern for Section–I and Section–II will be as follows:

**Question 1:**

This question will be based on Multiple Choice Questions.
There will be 7 MCQs, each carrying one mark.
One question will be based on calculations.
Students will have to attempt all these questions.

**Question 2:**

This question will contain 8 questions, each carrying 2 marks.
Students will have to answer any 6 out of the given 8 questions.
4 questions will be theory-based and 4 will be numericals.

**Question 3:**

This question will contain 4 questions, each carrying 3 marks.
Students will have to answer any 3 out of the given 4 questions.
2 questions will be theory-based and 2 will be numericals.

**Question 4:**

This question will contain 2 questions, each carrying 7 marks.
Students will have to answer any 1 out of the given 2 questions.
4/5 marks are allocated for theory-based question and 3/2 marks for numerical.

**Distribution of Marks According to Type of Questions**

<table>
<thead>
<tr>
<th>Type of Questions</th>
<th>Marks</th>
<th>Marks with option</th>
<th>Percentage (%)</th>
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<tbody>
<tr>
<td>Objectives</td>
<td>14</td>
<td>14</td>
<td>20</td>
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<td>Short Answers</td>
<td>42</td>
<td>56</td>
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<tr>
<td>Brief Answers</td>
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<td>28</td>
<td>20</td>
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<td>Unit</td>
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<td>Marks with option</td>
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<td>--------</td>
<td>-------------------------------------------</td>
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</tr>
<tr>
<td>1</td>
<td>Circular Motion</td>
<td>04</td>
<td>05</td>
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<tr>
<td>2</td>
<td>Gravitation</td>
<td>03</td>
<td>05</td>
</tr>
<tr>
<td>3</td>
<td>Rotational Motion</td>
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<td>5</td>
<td>Elasticity</td>
<td>03</td>
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<td>6</td>
<td>Surface Tension</td>
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<td>7</td>
<td>Wave Motion</td>
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<td>04</td>
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<td>8</td>
<td>Stationary Waves</td>
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<td>07</td>
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<tr>
<td>9</td>
<td>Kinetic Theory of Gases and Radiation</td>
<td>04</td>
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<td>10</td>
<td>Wave Theory of light</td>
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<td>Interference and Diffraction</td>
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<td>Current Electricity</td>
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<td>14</td>
<td>Magnetic Effects of Electric Current</td>
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<td>04</td>
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<td>15</td>
<td>Magnetism</td>
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<td>04</td>
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<td>16</td>
<td>Electromagnetic Induction</td>
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<td>06</td>
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<td>17</td>
<td>Electrons and Photons</td>
<td>03</td>
<td>04</td>
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<tr>
<td>18</td>
<td>Atoms, Molecules and Nuclei</td>
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<td>20</td>
<td>Communication Systems</td>
<td>02</td>
<td>03</td>
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CHEMISTRY : MARKING SCHEME

- There will be one written paper of 70 Marks in Chemistry.
- Duration of the paper will be 3 hours.
- Chemistry paper will have two parts viz: Part I of 35 marks and Part II of 35 marks.
- Same Answer Sheet will be used for both the parts.
- In the question paper, for each part there will be 4 Questions.
- The sequence of the 4 Questions in each part may or may not remain same.
- Students have freedom to decide the sequence of answers.
- The paper pattern as per the marking scheme for Part I and Part II will be as follows:

**Question 1:** (7 Marks)
There will be 7 Multiple Choice Questions (MCQs), each carrying 1 mark.
Total marks = 7

**Question 2:** (12 Marks)
There will be 8 Questions out of which 6 Questions are to be answered, each carrying 2 marks.
Total marks = 12

**Question 3:** (9 Marks)
There will be 4 Questions out of which 3 Questions are to be answered, each carrying 3 marks.
Total marks = 9
(There will be 3 Questions based on numericals from Part I)

**Question 4:** (7 Marks)
There will be 2 Questions out of which 1 Question has to be answered.
It will carry 7 marks.
Total Marks = 7
(There will be 2/3 marks Questions based on numericals from Part I)

### Distribution of Marks According to Type of Questions

<table>
<thead>
<tr>
<th>Type of Questions</th>
<th>Marks</th>
<th>Marks with option</th>
<th>Percentage (%)</th>
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</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>14</td>
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<td>20</td>
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<td>Short Answers</td>
<td>42</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Brief Answers</td>
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<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>70</strong></td>
<td><strong>98</strong></td>
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<td>No.</td>
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</tr>
<tr>
<td>1</td>
<td>Solid State</td>
<td>04</td>
<td>06</td>
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<tr>
<td>2</td>
<td>Solutions and Colligative Properties</td>
<td>05</td>
<td>07</td>
</tr>
<tr>
<td>3</td>
<td>Chemical Thermodynamics and Energetics</td>
<td>06</td>
<td>08</td>
</tr>
<tr>
<td>4</td>
<td>Electrochemistry</td>
<td>05</td>
<td>07</td>
</tr>
<tr>
<td>5</td>
<td>Chemical Kinetics</td>
<td>04</td>
<td>06</td>
</tr>
<tr>
<td>6</td>
<td>General Principles and Processes of Isolation of Elements</td>
<td>03</td>
<td>05</td>
</tr>
<tr>
<td>7</td>
<td>p–Block Elements</td>
<td>08</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>d and f–Block Elements</td>
<td>05</td>
<td>06</td>
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<td>9</td>
<td>Coordination Compounds</td>
<td>03</td>
<td>04</td>
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<td>10</td>
<td>Halogen Derivatives of Alkanes and Arenes</td>
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<td>11</td>
<td>Alcohols, Phenols and Ethers</td>
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<tr>
<td>12</td>
<td>Aldehydes, Ketones and Carboxylic Acids</td>
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<td>Compounds Containing Nitrogen</td>
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<td>14</td>
<td>Biomolecules</td>
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<td>15</td>
<td>Polymers</td>
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<td>04</td>
</tr>
<tr>
<td>16</td>
<td>Chemistry in Everyday Life</td>
<td>03</td>
<td>04</td>
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</table>
MATHEMATICS : MARKING SCHEME

- There will be one single paper of 80 Marks in Mathematics.
- Duration of the paper will be 3 hours.
- Mathematics paper will consist of two parts viz: Part-I and Part-II.
- Each Part will be of 40 Marks.
- Same Answer Sheet will be used for both the parts.
- Each Part will consist of 3 Questions.
- The sequence of the Questions will be determined by the Moderator.
- The paper pattern for Part–I and Part–II will be as follows:

**Question 1:**
This Question will carry 12 marks and consist of two sections (A) and (B) as follows: (12 Marks)

(A) This Question will be based on Multiple Choice Questions.
    There will be 3 MCQs, each carrying two marks.

(B) This Question will have 5 sub-questions, each carrying two marks.
    Students will have to attempt any 3 out of the given 5 sub-questions.

**Question 2:**
This Question will carry 14 marks and consist of two sections (A) and (B) as follows: (14 Marks)

(A) This Question will have 3 sub-questions, each carrying three marks.
    Students will have to attempt any 2 out of the given 3 sub-questions.

(B) This Question will have 3 sub-questions, each carrying four marks.
    Students will have to attempt any 2 out of the given 3 sub-questions.

**Question 3:**
This Question will carry 14 marks and consist of two sections (A) and (B) as follows: (14 Marks)

(A) This Question will have 3 sub-questions, each carrying three marks.
    Students will have to attempt any 2 out of the given 3 sub-questions.

(B) This Question will have 3 sub-questions, each carrying four marks.
    Students will have to attempt any 2 out of the given 3 sub-questions.

**Distribution of Marks According to Type of Questions**

<table>
<thead>
<tr>
<th>Type of Questions</th>
<th>Marks</th>
<th>Marks with option</th>
<th>Percentage (%)</th>
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<tr>
<td>Short Answers</td>
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<td>Brief Answers</td>
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### Maths – I

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<tr>
<td>2</td>
<td>Matrices</td>
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<tr>
<td>3</td>
<td>Trigonometric Functions</td>
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<tr>
<td>4</td>
<td>Pair of Straight Lines</td>
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<tr>
<td>5</td>
<td>Vectors</td>
<td>08</td>
</tr>
<tr>
<td>6</td>
<td>Three Dimensional Geometry</td>
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<td>7</td>
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<td>Plane</td>
<td>06</td>
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<td>9</td>
<td>Linear Programming</td>
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<td>Differentiation</td>
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<td>3</td>
<td>Applications of Derivatives</td>
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<td>Applications of Definite Integral</td>
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<td><strong>Total</strong></td>
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</table>
There will be one written paper of 70 Marks in Biology.
Duration of the paper will be 3 hours.
Biology paper will have two parts viz: Part I of 35 marks and Part II of 35 marks
There will be two separate answer sheets for both the parts.
In the same question paper, each part will have 4 Questions.
Sequence of answering the questions can be determined by the students.
The paper pattern for Part I and Part II will be as follows:

**Question 1:** (7 Marks)
There will be 7 multiple choice Questions (MCQs), each carrying one mark.
Total marks = 7

**Question 2:** (12 Marks)
This will have Questions as ‘A’, ‘B’ and ‘C’.
In that,
- **Q.A** will be based on : Answer in one sentence.
  There will be 6 Questions each carrying 1 mark
  Total marks = 6
- **Q.B** will have one Question based on diagrams
  Total Marks = 2
- **Q.C** will have 4 Questions, each carrying 2 marks
  Students will have to answer any 2 out of given 4 Questions
  Total marks = 4
  **Total Marks (A + B + C) = 12**

**Question 3:** (9 Marks)
This will have Questions as ‘A’ and ‘B’
- **Q.A** will have 3 Questions each carrying 3 marks
  Students will have to answer any 2 out of given 3 Questions
  Total Marks = 6
- **Q.B** will have one Question based on diagrams
  Total Marks = 3
  **Total Marks (A + B) = 9**

**Question 4:** (7 Marks)
In this Question, 2 Questions will be asked each carrying 7 marks.
Students will have to answer any one out of given 2 Questions
Total Marks = 7

### Distribution of Marks According to Type of Questions

<table>
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<th>Type of Questions</th>
<th>Marks</th>
<th>Marks with option</th>
<th>Percentage (%)</th>
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<td>Objectives</td>
<td>14</td>
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<tr>
<td>Short Answers</td>
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<td><strong>98</strong></td>
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<td>No.</td>
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<td>Genetic Basis of Inheritance</td>
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<td>Gene: It’s Nature, Expression and Regulation</td>
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<td>3</td>
<td>Biotechnology: Process and Application</td>
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<td>5</td>
<td>Microbes in Human Welfare</td>
<td>03</td>
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SECTION – I

Q.1. Select and write the most appropriate answer from the given alternatives for each sub-question: [7]

i. If a wave enters from air to water, then what remains unchanged?
   (A) Frequency  (B) Amplitude  (C) Velocity  (D) Wavelength

ii. If the earth stops rotating, the value of ‘g’ at the equator will _______.
   (A) increase  (B) decrease  (C) remain same  (D) become zero

iii. On being churned the butter separates out of milk due to _______.
    (A) centrifugal force  (B) adhesive force  (C) cohesive force  (D) frictional force

iv. The average kinetic energy of a gas molecule is _______.
   (A) proportional to pressure of gas  (B) inversely proportional to volume of gas
   (C) inversely proportional to absolute temperature of gas  (D) proportional to absolute temperature of gas

v. Speed of sound in air is 300 m/s. The distance between two successive nodes of a stationary wave of frequency 1000 Hz is _______.
   (A) 10 cm  (B) 20 cm  (C) 15 cm  (D) 30 cm

vi. The time period of a spring of force constant k loaded with mass m is _______.
    (A) \[T \propto m\text{ and } T \propto k\]  (B) \[T \propto \sqrt{m}\text{ and } T \propto \frac{1}{\sqrt{k}}\]
    (C) \[T \propto \left(\frac{1}{m}\right)\text{ and } T \propto k\]  (D) \[T \propto \left(\frac{1}{m}\right)\text{ and } T \propto \frac{1}{\sqrt{k}}\]

vii. If a person, sitting on a rotating table, with his arms outstretched and holding heavy dumbbells in each hand, suddenly lowers his hands, then _______.
    (A) his angular velocity decreases  (B) his angular velocity does not change
    (C) his angular momentum increases  (D) his moment of inertia decreases

Q.2. Attempt any SIX: [12]

i. Distinguish between deforming force and stress.

ii. A simple harmonic progressive wave of frequency 5 Hz is travelling along the positive X direction with a velocity of 40 m/s. Calculate the phase difference between two points separated by a distance of 0.8 m.
iii. State Wien’s displacement law. State its significance.

iv. Obtain an expression for time period of a satellite orbiting very close to earth’s surface in terms of mean density.

\[ T = \frac{3\pi}{G\rho} \], where \( \rho \) = mean density of earth

v. Define frequency of S.H.M. Discuss its unit and dimension.

vi. A bullet of mass 10 g and speed 500 m/s is fired into a door and gets embedded exactly at the centre of the door. The door is 1.0 m wide and weighs 9 kg. It rotates about a vertical axis practically without friction. Find the angular speed of the door just after the bullet embeds into it.

vii. A uniform wire under tension is fixed at its ends. If the ratio of tensions in the wire to the square of its length is 320 dyne/cm² and fundamental frequency of vibration of wire is 400 Hz, find its linear density.

viii. A mass of 4 kg is tied at the end of a string 1.2 m long, revolving in a horizontal circle. If the breaking tension in the string is 200 N, find the maximum number of revolutions per minute the mass can make.

Q.3. Attempt any THREE:

i. A cyclist speeding at 18 km/hr on a level road takes a sharp circular turn of radius 4 m without reducing the speed. The coefficient of static friction between the tyres and the road is 0.2. Will the cyclist slip while taking the turn? Calculate maximum safety speed. Will it be constant always?

ii. A brass wire of radius 2 mm is loaded by a mass of 32.8 kg. What would be the decrease in its radius?

\[ \left( Y = 9 \times 10^{10} \text{ N/m}^2, \text{ Poisson's ratio } \sigma = 0.36 \right) \]

iii. State and prove law of conservation of angular momentum. Give two examples.


Q.4. Discuss analytically the composition of two S.H.M’s of same period and parallel to each other. Obtain their resultant amplitude. Also find the resultant amplitude when phase difference of two S.H.M’s is a. 0 b. π

Find the height of a geostationary satellite (communication satellite) from the surface of the earth.

(Mass of the earth = \( 6 \times 10^{24} \text{ kg} \), radius of the earth = 6400 km, \( G = 6.67 \times 10^{-11} \text{ N.m}^2/\text{kg}^2 \))

OR

Q.4. Derive an expression for the kinetic energy of a body rotating with uniform angular velocity.

A body describes S.H.M in a path 0.16 m long. Its velocity at the centre of the line is 0.12 m/s. Find the period and magnitude of velocity at a distance \( 1.7 \times 10^{-2} \) m from the mean position.

Q.5. Select and write the most appropriate answer from the given alternatives for each sub-question:

i. Velocity of light in air is ‘c’. Its velocity in a medium of refractive index 1.5 will be _______.

\[ \begin{align*} 
\text{(A)} & \quad c \\
\text{(B)} & \quad \frac{c}{1.5} \\
\text{(C)} & \quad c \times 1.5 \\
\text{(D)} & \quad c + 1.5 
\end{align*} \]

ii. For what value of velocity of electrons, the stopping potential will be able to stop them?

\[ \begin{align*} 
\text{(A)} & \quad 10^3 \text{ m/s} \\
\text{(B)} & \quad \text{Very high speeds} \\
\text{(C)} & \quad \text{Very low speeds} \\
\text{(D)} & \quad \text{All speeds} 
\end{align*} \]

iii. If the lengths of two wires of same material are in the ratio 2 : 1, then the ratio of their specific resistances will be _______.

\[ \begin{align*} 
\text{(A)} & \quad 1 : 2 \\
\text{(B)} & \quad 2 : 1 \\
\text{(C)} & \quad 4 : 1 \\
\text{(D)} & \quad 1 : 1 
\end{align*} \]
iv. If ‘R’ and ‘L’ stand for the resistance and inductance respectively, then among the following the one having the dimensions of frequency is _______.
   (A) \( \frac{R}{L} \)  (B) \( \frac{L}{R} \)  (C) \( \sqrt{\frac{R}{L}} \)  (D) \( \sqrt{\frac{L}{R}} \)

v. The phenomenon of paramagnetism is a consequence of _______.
   (A) distortion effect  (B) orientation effect  (C) both (A) and (B)  (D) neither (A) nor (B)

vi. In an amplitude modulated wave, the power content of the carrier is maximum for which value of ‘m’?
   (A) zero  (B) 1  (C) 0.1  (D) 0.4

vii. In Boolean algebra, \( A + B = \) _______.
    (A) \( A \cdot B \)  (B) \( A + B \)  (C) \( A \cdot \overline{B} \)  (D) \( \overline{A + B} \)

Q.6. Attempt any SIX: [12]
   i. A solenoid of 100 turns per unit length and cross-sectional area \( 2 \times 10^{-4} \text{ m}^2 \) carries a current of 6 A. It is placed in horizontal axis at 30° with direction of uniform magnetic field of 0.3 T. Calculate magnetic moment of solenoid and torque experienced by solenoid due to the field.
   ii. Four resistances 5 \( \Omega \), 5 \( \Omega \), 5 \( \Omega \) and 15 \( \Omega \) form a Wheatstone’s network. Find the resistance which when connected across the 15 \( \Omega \) resistance, will balance the network.
   iii. Define cut off potential. Show graphically variation of photoelectric current with collector plate potential for different intensity of incident radiation.
   iv. Explain why microscopes of high magnifying power have oil-immersion objectives.
   v. Explain I – V characteristics of zener diode with suitable graph.
   vi. Calculate the de Broglie wavelength of proton if it is moving with speed of \( 8 \times 10^6 \text{ m/s} \).
       \( (m_p = 1.67 \times 10^{-27} \text{ kg}) \).
   vii. An alternating e.m.f \( E = 250 \sin \omega t \text{ V} \) is connected to a 1250 \( \Omega \) resistor. Calculate the rms current through the resistor and the average power dissipated in one cycle.

Q.7. Attempt any THREE [9]
   i. An alternating e.m.f is applied to a circuit containing resistance. Discuss the behaviour of current in the circuit.
   ii. With the help of a neat circuit diagram, explain working of P-N junction diode as a half-wave rectifier.
   iii. A resistance of 5 \( \Omega \) is connected in parallel to a galvanometer of resistance 495 \( \Omega \). Find the fraction of the total current, passing through galvanometer.
   iv. Two parallel plate air capacitors have their plate areas 100 cm\(^2\) and 400 cm\(^2\) respectively. If they have the same charge and potential and the distance between the plates of the first capacitor is 0.4 mm, what is the distance between the plates of the second capacitor?

Q.8. Explain origin of spectral line and obtain Bohr’s formula.
   If the difference in velocities of light in glass and water is \( 0.24 \times 10^8 \text{ m/s} \), find the velocity of light in air (Given : \( \mu_g = \frac{3}{2} \), \( \mu_w = 4/3 \)) [7]

OR

Q.8. Explain principle, construction and working of transformer. Also, derive equation of transformer. When a surface is irradiated with light of wavelength 4950 Å, a photocurrent appears which vanishes if a retarding potential greater than 0.6 V is applied across the phototube. When different source of light is used, it is found that the critical retarding potential is changed to 1.1 V. Find the work function of the emitting surface and the wavelength of the second source. [7]
MODEL ANSWER PAPER SET – I
PHYSICS

SECTION – I

Q.1. Select and write the most appropriate answer from the given alternatives for each sub-question:

i. (A) [1]

ii. (A)  
\[ g_e = g - R\omega^2 \]
For \( \omega = 0 \),  
\[ g'_e = g. \]
\[ g'_e > g_e. \] [1]

iii. (A) [1]

iv. (D)  
Average kinetic energy of a gas  
\[ \frac{1}{2}mv^2 = \frac{3}{2}k_B T \]
\[ \therefore \text{ Kinetic energy of gas } \propto \text{ Temperature } \] [1]

v. (C)  
Distance between two successive antinodes  
\[ \frac{\lambda}{2} \]
\[ = \frac{v}{2n} = \frac{300}{10^3 \times 2} = 15 \times 10^{-2} \text{ m} = 15 \text{ cm}. \] [1]

vi. (B) [1]

vii. (D)  
When the man pulls his arms, the speed of rotation of the table increases but the distance \( R \) of the dumbbells from the axis of rotation decreases. Hence, moment of inertia of the man decreases and angular velocity of turn table increases. [1]

Q.2. Attempt any SIX:

i.  
<table>
<thead>
<tr>
<th>No.</th>
<th>Deforming force</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>It is externally applied force.</td>
<td>It is internal restoring force per unit area.</td>
</tr>
<tr>
<td>ii.</td>
<td>It tries to deform the body.</td>
<td>It opposes the deformation.</td>
</tr>
<tr>
<td>iii.</td>
<td>S.I unit is N.</td>
<td>S.I unit is N/m².</td>
</tr>
<tr>
<td>iv.</td>
<td>Its dimension is [M¹ L⁻¹ T⁻²].</td>
<td>Its dimension is [M¹ L⁻¹ T⁻²].</td>
</tr>
<tr>
<td>v.</td>
<td>It is a vector quantity.</td>
<td>It is a tensor quantity.</td>
</tr>
</tbody>
</table>

(any two correct points of difference) (1 x 2) [2]

ii. Given:  
\[ n = 5 \text{ Hz}, \ v = 40 \text{ m/s}, \ x = 0.8 \text{ m}, \]
To find:  
Phase difference (\( \delta \))

Formulae:  
\[ \text{i. } v = n\lambda \]
\[ \text{ii. } \delta = \frac{2\pi x}{\lambda} \] [1]

Calculation:  
From formula (i),  
\[ \lambda = \frac{v}{n} = \frac{40}{5} = 8 \text{ m} \]
From formula (ii),

\[ \delta = \frac{2 \times \pi \times 0.8}{8} \]

\[ \therefore \quad \delta = 2\pi \times 0.1 \]

\[ \therefore \quad \delta = \frac{\pi}{5} \text{ rad} \]

The phase difference between two points is \( \frac{\pi}{5} \text{ rad} \) \[1\]

iii. Wien’s displacement law: The wavelength (\( \lambda_m \)) emitted with maximum intensity by a black body is inversely proportional to its absolute temperature. Mathematically,

\[ \lambda_m \propto \frac{1}{T} \quad \text{i.e.,} \quad \lambda_m = b \cdot \frac{1}{T} \]

where \( b \) = constant called Wien’s constant. \[1\]

Significance:

a. It can be used to estimate very high temperature such as surface temperature of stars, sun, moon, celestial bodies etc.

b. It explains the common observation of the change of colour of a solid from dull red to yellow and then to white on heating.

c. As the temperature increases, the maximum intensity of radiation shifts towards the shorter wavelength side. Thus Wien’s law is also called displacement law. \( \text{(any two points of significance)} \quad (\frac{1}{2} \times 2) \) \[1\]

iv. Time period in terms of mean density:

a. Since \( T = 2\pi \sqrt{\frac{(R+h)^3}{GM}} \) \[\text{...(i)}\]

b. Mass of the earth, \( M = \frac{4}{3} \pi R^3 \rho \) \[\frac{1}{2}\]

where \( \rho \) = mean density of the earth

c. Substituting, the value of \( M \) in the equation (i),

\[ T = 2\pi \sqrt{\frac{(R+h)^3}{G \times \frac{4}{3} \pi R^3 \rho}} \]

\[ \therefore \quad T = \sqrt{\frac{3\pi(R+h)^3}{GR^3 \rho}} \quad \text{...(ii)} \] \[1\]

d. When satellite is orbiting very close to the earth, \( h \approx 0 \).

\[ \therefore \quad \text{Equation (ii) becomes,} \]

\[ T = \sqrt{\frac{3\pi R^3}{G \rho}} \]

\[ \therefore \quad \text{We get,} \quad T = \sqrt{\frac{3\pi}{G \rho}} \]

\[ \frac{1}{2}\]

v. a. The number of oscillations performed by a particle executing S.H.M. per unit time is called frequency of S.H.M. \[1\]

It is given by \( n = \frac{1}{T} = \frac{\omega}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \)

b. Unit: Hz or c.p.s or r.p.s in SI system. \[\frac{1}{2}\]

c. Dimension: \([M^0L^0T^{-1}]\) \[\frac{1}{2}\]
vi. Given: \( m = 10 \ g = 10 \times 10^{-3} \ kg, \ v = 500 \ m/s, \ r = 0.5 \ m, \ l = 1 \ m, \ m = 9 \ kg, \)

To find: Angular speed (\( \omega \))

Formulae: 

i. \( L = mvr \) 

ii. \( I = \frac{ml^2}{3} \) 

iii. \( L = I\omega \) \[1\]

Calculation: From formula (i),

\[
L = (10 \times 10^{-3}) \times 500 \times 0.5
\]

\[
L = 2.5 \ \text{kg m}^2/\text{s}
\]

From formula (ii),

\[
I = \frac{9 \times l^2}{3} = 3 \ \text{kg m}^2
\]

From formula (iii),

\[
\omega = \frac{L}{I} = \frac{2.5}{3} = 0.83 \ \text{rad/s}
\]

Angular speed of the door is 0.83 rad/s. \[1\]

vii. Given: \( \frac{T}{l^2} = 320 \ \text{dyne/cm}^2, \ n = 400 \ \text{Hz}, \)

To find: Linear density (m)

Formula: \( n = \frac{1}{2\sqrt{\frac{T}{m}}} \) \[\frac{1}{2}\]

Calculation: From formula,

\[
m = \frac{1}{4n^2} \times \frac{T}{l^2}
\]

\[
m = \frac{1}{4 \times (400)^2} \times 320
\]

\[
m = \frac{80}{160000}
\]

\[
m = 5 \times 10^{-4} \ \text{kg/m}
\]

Linear density of the wire is \( 5 \times 10^{-4} \ \text{kg/m} \). \[1\]

viii. Given: \( r = 1.2 \ m, \ m = 4 \ kg, \ T = 200 \ N, \)

To find: Maximum no of revolutions (\( n_{\max} \))

Formula: \( T_{\max} = mr\omega^2_{\max} = mr(2\pi n_{\max})^2 \) \[\frac{1}{2}\]

Calculation: From formula,

\[
n^2_{\max} = \frac{200}{4 \times 1.2 \times 4 \times (3.14)^2}
\]

\[
n_{\max} = \left[\frac{200}{16 \times 1.2 \times (3.14)^2}\right]^{\frac{1}{2}}
\]

\[
= \text{antilog} \left\{ \frac{1}{2} \left[ \log(200) - \log(16) - \log(1.2) - 2 \log(3.14) \right] \right\}
\]

\[
= \text{antilog} \left\{ \frac{1}{2} \left[ 2.3010 - 1.2041 - 0.0792 - 2 \times 0.4969 \right] \right\}
\]

\[
= \text{antilog} \left\{ \frac{1}{2} \times 0.0239 \right\}
\]

\[
= \text{antilog} \left\{ 0.0120 \right\}
\]

\[
n_{\max} = 1.028 \ \text{r.p.s.}
\]

\[
n_{\max} = 1.028 \times 60 \ \text{r.p.m.}
\]

\[
n_{\max} = 61.68 \ \text{Hz}
\]

The maximum number of revolutions per minute is 61.68 Hz \[1\]
Q.3. Attempt any THREE:

i. \( v = 18 \text{ km/hr} = \frac{18000}{3600} \text{ m/s} = 5 \text{ m/s}, r = 4 \text{ m}, \mu_s = 0.2 \)
\[ v^2 = 5^2 = 25 \text{ m}^2/\text{s}^2 \]
\[ \mu_s rg = 0.2 \times 4 \times 9.8 = 7.84 \text{ m}^2/\text{s}^2 \]
Condition for safe turning is, \( v^2 \leq \mu_s rg \)
Comparing values of \( v^2 \) and \( (\mu_s rg) \)
\[ 25 \leq 7.84 \]
As condition for safe turning is not met, the cyclist will slip while taking circular turn.
Max. Safe speed, \( v_{\text{max}} = \sqrt{\mu_s rg} = \sqrt{7.84} \)
\[ = 2.8 \text{ m/s} \]
This speed limit is not always constant. It depends upon friction between tyres and roads. For worn-out tyres or road wet with oil or water, magnitude of friction will change. Thus value of maximum safe speed will vary.

ii. Given: \( r = 2 \text{ mm} = 2 \times 10^{-3} \text{ m}, m = 32.8 \text{ kg}, Y = 9 \times 10^{10} \text{ N/m}^2, \)
To find: Decrease in radius (\( \Delta r \))
Formulae: i. \( Y = \frac{FL}{(\pi r^2)l} \) ii. \( \sigma = \frac{L\Delta r}{lr} \)
Calculation: From formula (i),
\[ \therefore \frac{l}{L} = \frac{F}{AY} = \frac{mg}{(\pi r^2)Y} \]
\[ \Rightarrow \frac{l}{L} = \frac{32.8 \times 9.8}{\pi \times (2 \times 10^{-3})^2 \times 9 \times 10^{10}} \]
\[ = \frac{32.8 \times 9.8}{3.14 \times 4 \times 9 \times 10^4} \]
\[ = \{\text{antilog}[\log (32.8) + \log (9.8) - \log (3.14) - \log (4) - \log (9)]\} \times 10^{-4} \]
\[ = \{\text{antilog}[1.5159 + 0.9912 - 0.4969 - 0.6021 - 0.9542]\} \times 10^{-4} \]
\[ = \{\text{antilog} [0.4539]\} \times 10^{-4} \]
\[ = 2.844 \times 10^{-4} \] [1]
From formula (ii),
\[ \Delta r = \frac{1r\sigma}{L} \]
\[ \Delta r = 2.842 \times 10^{-4} \times 2 \times 10^{-3} \times 0.36 \]
\[ \Delta r = \{\text{antilog}[\log (2.842) + \log (2) + \log (0.36)]\} \times 10^{-7} \]
\[ = \{\text{antilog}[0.4539 + 0.3010 + 0.5563]\} \times 10^{-7} \]
\[ = \{\text{antilog}[0.3109]\} \times 10^{-7} \]
\[ \therefore \Delta r = 2.046 \times 10^{-7} \text{ m} \]

The decrease in radius of wire is \(2.046 \times 10^{-7} \text{ m}. \) [1]

iii. Statement:
The angular momentum of a body remains constant, if resultant external torque acting on the body is zero.
Proof:

a. Consider a particle of mass \( m \), rotating about an axis with torque \( \tau \).
Let \( \vec{p} \) be the linear momentum of the particle and \( \vec{r} \) be its position vector.

b. By definition, angular momentum is given by, \( \vec{L} = \vec{r} \times \vec{p} \) ....(i)
c. Differentiating equation (i) with respect to time $t$,

$$\frac{d\vec{L}}{dt} = \frac{d}{dt}(\vec{r} \times \vec{p})$$

$$\therefore \frac{d\vec{L}}{dt} = \vec{r} \times \frac{d\vec{p}}{dt} + \vec{p} \times \frac{d\vec{r}}{dt} \quad \text{...(ii)} \quad [\frac{1}{2}]$$

d. But, $\frac{d\vec{r}}{dt} = \vec{v}$, $\frac{d\vec{p}}{dt} = \vec{F}$ and $\vec{p} = m\vec{v}$

$$\therefore \text{Equation (ii)} \text{ becomes},$$

$$\frac{d\vec{L}}{dt} = \vec{r} \times \vec{F} + 0 \quad [\because \vec{v} \times \vec{v} = v^2 \sin 0^\circ = 0]$$

e. Also, $\tau = \vec{r} \times \vec{F}$

$$\therefore \frac{d\vec{L}}{dt} = \tau \quad [\frac{1}{2}]$$

f. If resultant external torque ($\tau$) acting on the particle is zero, then $\frac{d\vec{L}}{dt} = 0$.

$$\therefore \vec{L} = \text{constant} \quad \therefore I\omega = \text{constant}$$

Hence, angular momentum remains conserved. \[\frac{1}{2}\]

Examples:
1. The angular velocity of revolution of a planet around the sun in an elliptical orbit increases, when the planet comes closer to the sun and vice-versa.
2. A person carrying heavy weights in his hands and standing on a rotating platform can change the speed of the platform.
3. A diver performs somersaults by jumping from a high diving board keeping his legs and arms out stretched first, and then curling his body.

(Any 2 of the above examples) \((\frac{1}{2} \times 2)\) \[1\]

iv. Heat engine:

a. A heat engine is a device which converts heat energy into mechanical energy.
b. This engine works in cyclic process. It takes heat from bodies at higher temperature, converts part of it to mechanical work and remaining to a body at lower temperature.
c. The cycle is repeated again and again to get useful work for some purpose. \[1\]

Working:

a. Suppose,

$Q_1 =$ amount of heat absorbed by the working substance from the source at temperature in one complete cycle.

$Q_2 =$ amount of heat rejected at temperature in the cycle.

$W =$ net amount of external work done by the working substance, on the environment in the cycle.

b. Net amount of heat absorbed in one cycle, $\Delta Q = Q_1 - Q_2$

c. As the working substance returns to its initial state, the change in its internal energy $= 0$

$$\therefore \Delta U = 0$$

According to the first law of thermodynamics,

$$\Delta Q = \Delta U + \Delta W$$

$$\therefore \Delta Q = \Delta W$$

i.e., Net amount of heat absorbed $=$ External work done by the engine

$$\therefore Q_1 - Q_2 = W$$
Thermal efficiency:

a. Thermal efficiency of a heat engine is the ratio of net work done per cycle by the engine to the total amount of heat absorbed per cycle by the working substance from the source.

b. It is given by

$$\eta = 1 - \frac{Q_2}{Q_1}$$

where, $Q_1$ = Heat absorbed by the system in one complete cycle,
$Q_2$ = Heat rejected to the environment.

c. For $Q_2 = 0$, $\eta = 1$, i.e., the engine will have 100% efficiency in converting heat into work.

d. It is not possible experimentally to construct such an ideal engine with $\eta = 1$. 

Q.4. Analytical treatment of composition of two S.H.M’s:

i. Let the two linear S.H.M’s be given by equations,

$$x_1 = A_1 \sin(\omega t + \alpha_1) \quad \ldots(1)$$
$$x_2 = A_2 \sin(\omega t + \alpha_2) \quad \ldots(2)$$

where $A_1$, $A_2$ are amplitudes, $\alpha_1$, $\alpha_2$ are initial phase angles and $x_1$, $x_2$ are the displacement of two S.H.M’s in time ‘t’. $\omega$ is same for both S.H.M’s.

ii. The resultant displacement of the two S.H.M’s is given by,

$$x = x_1 + x_2 \quad \ldots(3)$$

iii. Using equations (1) and (2), equation (3) can be written as,

$$x = A_1 \sin(\omega t + \alpha_1) + A_2 \sin(\omega t + \alpha_2)$$
$$= A_1 \sin \omega t \cos \alpha_1 + A_1 \cos \omega t \sin \alpha_1 + A_2 \sin \omega t \cos \alpha_2 + A_2 \cos \omega t \sin \alpha_2$$
$$= [A_1 \sin \omega t \cos \alpha_1 + A_2 \sin \omega t \cos \alpha_2] + [A_1 \cos \omega t \sin \alpha_1 + A_2 \cos \omega t \sin \alpha_2]$$

$$\therefore \quad x = \sin \omega t [A_1 \cos \alpha_1 + A_2 \cos \alpha_2] + \cos \omega t [A_1 \sin \alpha_1 + A_2 \sin \alpha_2] \quad \ldots(4)$$

iv. Let $A_1 \cos \alpha_1 + A_2 \cos \alpha_2 = R \cos \delta$ \quad \ldots(5)
and $A_1 \sin \alpha_1 + A_2 \sin \alpha_2 = R \sin \delta$ \quad \ldots(6)

v. Using equations (5) and (6), equation (4) can be written as,

$$x = \sin \omega t R \cos \delta + \cos \omega t R \sin \delta$$
$$= R [\sin \omega t \cos \delta + \cos \omega t \sin \delta]$$
$$\therefore \quad x = R \sin(\omega t + \delta) \quad \ldots(7)$$

Equation (7) represents linear S.H.M. of amplitude R and initial phase angle $\delta$ with same period.

Resultant amplitude (R):

Squaring and adding, equations (5) and (6), we get,

\[
(A_1 \cos \alpha_1 + A_2 \cos \alpha_2)^2 + (A_1 \sin \alpha_1 + A_2 \sin \alpha_2)^2 = R^2 \cos^2 \delta + R^2 \sin^2 \delta
\]
$$\therefore \quad A_1^2 \cos^2 \alpha_1 + A_2^2 \cos^2 \alpha_2 + 2A_1 A_2 \cos \alpha_1 \cos \alpha_2 + A_1^2 \sin^2 \alpha_1 + A_2^2 \sin^2 \alpha_2 + 2A_1 A_2 \sin \alpha_1 \sin \alpha_2$$
$$= R^2 (\cos^2 \delta + \sin^2 \delta)$$
$$\therefore \quad A_1^2 (\cos^2 \alpha_1 + \sin^2 \alpha_1) + A_2^2 (\cos^2 \alpha_2 + \sin^2 \alpha_2) + 2A_1 A_2 (\cos \alpha_1 \cos \alpha_2 + \sin \alpha_1 \sin \alpha_2) = R^2$$
$$\therefore \quad A_1^2 + A_2^2 + 2A_1 A_2 \cos (\alpha_1 - \alpha_2) = R^2$$
$$\therefore \quad R = \pm \sqrt{A_1^2 + A_2^2 + 2A_1 A_2 \cos (\alpha_1 - \alpha_2)} \quad \ldots(8)$$

Equation (8) represents resultant amplitude of two S.H.M’s.
Case I: For phase difference = 0
If \( \alpha_1 - \alpha_2 = 0 \) then \( \alpha_1 = \alpha_2 \)
In this case both S.H.M’s have same initial phase angle
\[ \therefore \text{ From equation (viii),} \]
\[ R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2} = \sqrt{(A_1 + A_2)^2} \]
\[ \therefore R = (A_1 + A_2) \]
If \( A_1 = A_2 = A \) then, \( R = 2A \) \[ \frac{1}{2} \]

Case II: For phase difference = \( \pi \)
If \( \alpha_1 - \alpha_2 = \pi \) then, \( \cos(\alpha_1 - \alpha_2) = -1 \)
\[ \text{From equation (viii),} \]
\[ R = \sqrt{A_1^2 + A_2^2 - 2A_1A_2} = \sqrt{(A_1 - A_2)^2} \]
\[ \therefore R = (A_1 - A_2) \]
If \( A_1 = A_2 = A \) then, \( R = 0 \)
Since particle has resultant amplitude zero, therefore it will be at rest. \[ \frac{1}{2} \]

Solution:
Given: \( M = 6 \times 10^{24} \text{ kg}, R = 6400 \text{ km} = 6.4 \times 10^6 \text{ m}, G = 6.67 \times 10^{-11} \text{ N.m}^2/\text{kg}^2 \)
For geostationary satellite, period of revolution is one day.
\[ \therefore T = 1 \text{ day} = (24 \times 3600) \text{ s}. \]
To find: Height (h)

Formula: \( T^2 = \left( \frac{4\pi^2}{GM} \right) (R + h)^3 \) \[ 1 \]

Calculation: From formula,
\[ (R + h)^3 = \frac{GMT^2}{4\pi^2} \]
\[ \therefore R + h = \left[ \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times (24 \times 3600)^2}{4 \times (3.142)^2} \right]^{\frac{1}{3}} \]
\[ = \left[ \frac{6.67 \times 0.6 \times 24^2 \times 36^2 \times 10^{25} \times 10^{-11} \times 10^4}{4 \times (3.142)^2} \right]^{\frac{1}{3}} \]
\[ = \left\{ \text{antilog} \left[ \frac{1}{3} \times (\log 6.67 + \log 0.6 + 2 \log 24 + 2 \log 36 - \log 4 - 2 \log 3.14) \right] \right\} \times 10^6 \]
\[ = \left\{ \text{antilog} \left[ \frac{1}{3} \times (0.8241 + 1.7782 + 2 \times 1.3802 + 2 \times 1.5563 - 0.6021 - 2 \times 0.4972) \right] \right\} \times 10^6 \]
\[ = \left\{ \text{antilog} \left[ \frac{1}{3} \times (0.8241 + 1.7782 + 2.7604 + 3.1126 - 0.6021 - 0.9944) \right] \right\} \times 10^6 \]
\[ = \text{antilog} \left[ \frac{1}{3} \times 4.8788 \right] \times 10^6 \]
\[ = \text{antilog}[1.6263] \times 10^6 \]
\[ \therefore R + h = 4.23 \times 10^7 \text{ m} = 42.3 \times 10^6 \text{ m} \]
\[ \therefore h = R + h = 42.3 \times 10^6 \text{ m} - 6.4 \times 10^6 \text{ m} \]
\[ h = 35.900 \times 10^6 \text{ m} = 35,900 \text{ km} \]
The height of geostationary satellite from the surface of the earth is 35,900 km. \[ 1 \]
Q.4. Expression for kinetic energy of a rotating body:

i. Suppose a rigid body is rotating with constant angular velocity $\omega$ about an axis ZZ' through a point O as shown in the figure.

ii. Let the body consists of n particles of masses $m_1$, $m_2$, $m_3$, ..., $m_n$ situated at distances $r_1$, $r_2$, $r_3$, ..., $r_n$ respectively from the axis of rotation.

iii. Linear velocity of particles of masses $m_1$, $m_2$, .......$m_n$ are given by $v_1 = r_1\omega$, $v_2 = r_2\omega$, $v_3 = r_3\omega$,..., $v_n = r_n\omega$, respectively.

iv. Kinetic energy of particle of mass $m_1$,
   
   \[
   (K.E)_1 = \frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_1 r_1^2 \omega^2
   \]

   Kinetic energy of particle of mass $m_2$,
   
   \[
   (K.E)_2 = \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_2 r_2^2 \omega^2
   \]

v. Similarly kinetic energy of particle of masses $m_3$, $m_4$ ...... $m_n$ are given by,

   \[
   (K.E)_3 = \frac{1}{2} m_3 r_3^2 \omega^2,
   \]

   \[
   (K.E)_4 = \frac{1}{2} m_4 r_4^2 \omega^2,
   \]

   \[
   \vdots
   \]

   \[
   (K.E)_n = \frac{1}{2} m_n r_n^2 \omega^2
   \]

vi. Total K.E of the rotating body is given by,

   \[
   K.E = (K.E)_1 + (K.E)_2 + (K.E)_3 + \ldots + (K.E)_n
   \]

   \[
   = \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \frac{1}{2} m_3 r_3^2 \omega^2 + \ldots + \frac{1}{2} m_n r_n^2 \omega^2
   \]

   \[
   \therefore K.E = \frac{1}{2} \left[ m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots + m_n r_n^2 \right] \omega^2
   \]

   \[
   \therefore K.E = \frac{1}{2} \left[ \sum_{i=1}^{n} m_i r_i^2 \right] \omega^2
   \]

   \[
   \therefore \sum_{i=1}^{n} m_i r_i^2 = I
   \]

   \[
   \therefore K.E = \frac{1}{2} I \omega^2
   \]
Solution:
Given: 2A = 0.16 m \therefore A = 0.08 m,
\[ v_{\text{max}} = 0.12 \text{ m/s}, \quad x = 1.7 \times 10^{-2} \text{m} \]
To find: Period (T), magnitude of velocity (v)

Formulae: i. \[ v_{\text{max}} = A \omega \]
ii. \[ v = \omega \sqrt{A^2 - x^2} \] \[ \text{[1]} \]

Calculation: From formula (i),
\[ \omega = \frac{v_{\text{max}}}{A} = \frac{0.12}{0.08} = 1.5 \text{ rad/s} \]
But \[ \omega = \frac{2\pi}{T} \therefore T = \frac{2 \times 3.14}{1.5} = 4.1865 \text{ s.} \]

The period of body is 4.1865 s. \[ \text{[½]} \]
From formula (ii),
\[ v = 1.5 \times \sqrt{(0.08)^2 - (1.7 \times 10^{-2})^2} \]
\[ = 1.5 \times \sqrt{(0.08)^2 - (1.7 \times 10^{-2})^2} \times 10^{-4} \]
\[ \therefore v = \{\text{antilog}[\log(1.5) + \frac{1}{2} \log(61.11)]\} \times 10^{-2} \]
\[ = \{\text{antilog}[0.1761 + \frac{1}{2} \times 1.7861]\} \times 10^{-2} \]
\[ = \{\text{antilog}[1.0692]\} \times 10^{-2} \]
\[ \therefore v = 11.73 \times 10^{-2} \text{ m/s} = 0.1173 \text{ m/s} \]

The magnitude of velocity is 0.1173 m/s. \[ \text{[1]} \]

SECTION – II

Q.5. Select and write the most appropriate answer from the given alternatives for each sub-question:

i. (B)
\[ \mu_{\text{med}} = \frac{v_{\text{air}}}{v_{\text{med}}} = \frac{c}{v_{\text{med}}} = 1.5 \]
\[ \therefore v_{\text{med}} = \frac{c}{1.5} \]
\[ \text{[1]} \]

ii. (D) \[ \text{[1]} \]

iii. (D)
Specific resistance is the same for two wires as the material is the same. \[ \text{[1]} \]

iv. (A)
\[ L = \frac{(V_s/A)}{R(V/A)} = \frac{V_s}{A} \times \frac{A}{V_s} = s. \text{ Hence option (B) is wrong.} \]
\[ R = \frac{(V/A)}{L(V_s/A)} = \frac{V}{A} \times \frac{A}{V_s} \times \frac{1}{s} \Rightarrow \text{option (A) is correct.} \]
Options (C) and (D) are incorrect. \[ \text{[1]} \]

v. (B) \[ \text{[1]} \]

vi. (A) \[ \text{[1]} \]

vii. (D) \[ \text{[1]} \]
Q.6. Attempt any SIX:

i. Given: \( N = 100 \) turns per unit length, \( A = 2 \times 10^{-4} \) m\(^2\), I = 6 A, \( \theta = 30^\circ \), B = 0.3 T
To find: Magnetic moment (M), torque (\( \tau \))
Formulae: i. \( M = NI\alpha \) ii. \( \tau = MB\sin \theta \) [1]
Calculation: From formula (i),
\[
M = 100 \times 6 \times 2 \times 10^{-4} = 0.12 \text{ Am}^2
\]
\( \therefore \) Magnetic moment of solenoid d is 0.12 Am\(^2\). [½]
From formula (ii),
\[
\tau = 0.12 \times 0.3 \times \sin 30^\circ = 0.018 \text{ N.m}
\]
\( \therefore \) Torque experienced by solenoid is 0.018 N m. [½]

ii. Let \( R_1 = 5 \Omega \), \( R_2 = 5 \Omega \), \( R_3 = 5 \Omega \), \( R_4 = 15 \Omega \).
Let X be resistance connected across R\(_4\).
Equivalent resistance \( R'_4 = \frac{R_4X}{R_4 + X} = \frac{15X}{15 + X} \) [½]
Balancing condition of network,
\[
\frac{R_1}{R_2} = \frac{R_3}{R'_4} \]
\[
\frac{5}{5} = \frac{5}{\frac{15X}{15 + X}}
\]
\( \therefore \) \( 15X = 5(15 + X) \)
\( 3X = 15 + X \) [½]
\( 2X = 15 \Omega \)
\( \therefore \) X = 7.5

The resistance to be connected across \( R_4 \) is 7.5 \( \Omega \) [½]

iii. The minimum negative potential given to collector plate for which photoelectric current stops or becomes zero is called stopping potential or cut off potential. It is denoted by \( V_0 \).
The graph of photoelectric current vs collector plate potential:

![Graph of photoelectric current vs collector plate potential]

\( \therefore \) \( I_1 < I_2 < I_3 \) [1]

iv. a. To avoid obscuration of details of micro-objects by diffraction effects, microscope of high magnifying power must have high resolving power.
b. R.P. of microscope = \( \frac{2\mu \sin \alpha}{\lambda} \), where \( \mu \sin \alpha \) is termed as numerical aperture.
Thus, R.P. \( \propto \mu \sin \alpha \) [½]
c. To increase $\alpha$, the diameter of objective would have to be increased. This would degrade image by decreasing resolving power.  

$[\frac{1}{2}]$

d. Oil has higher refractive index ($\mu_{\text{oil}} > \mu_{\text{air}}$) hence to increase resolving power of microscopes of high magnifying power, the object is immersed in oil that is in contact with objective.

e. Usually cedar oil having refractive index 1.5, close to that of the objective glass is used.  

$[\frac{1}{2}]$

v. I-V characteristic of a zener diode is as shown below:

$$
\text{Zener diode characteristics}
$$

a. Zener diode is p–n junction diode manufactured to operate in breakdown region.

b. Its forward bias characteristic is same as that of ordinary junction diode. This means current does not flow until bias is less than barrier potential. Current increases rapidly beyond it with increase in forward voltage.  

$[\frac{1}{2}]$

c. In reverse bias, initially a small reverse saturated current flows and at particular value of reverse voltage, increases suddenly. This voltage is zener breakdown voltage ($V_z$)  

$[\frac{1}{2}]$

vi. Given: $v = 8 \times 10^6 \text{ m/s}$, $m_p = 1.67 \times 10^{-27} \text{ kg}$, 
To find: de Broglie wavelength ($\lambda_p$)  

Formula:  

$$
\lambda_p = \frac{h}{p} = \frac{h}{m_p v}
$$

Calculation: From formula,  

$$
\lambda_p = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 8 \times 10^6} = 4.9626 \times 10^{-14} \text{ m}
$$

**de Broglie wavelength of given proton is** $4.9626 \times 10^{-14}$ **m.**  

$[1]$

vii. Given: $E = 250 \sin \omega t \text{ V}$ $\Rightarrow E_0 = 250 \text{ V}$, $R = 1250 \Omega$  
To find: R.M.S. current ($I_{\text{rms}}$), average power ($P_{\text{av}}$)  

Formulae:  

a. $I_0 = \frac{E_0}{R}$  

b. $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$  

c. $E_{\text{rms}} = \frac{E_0}{\sqrt{2}}$  

d. $P_{\text{av}} = I_{\text{rms}} \times E_{\text{rms}}$  

Calculation: From formula (a),  

$$
I_0 = \frac{250}{1250} = 0.2 \text{ A}
$$

From formula (ii),  

$$
I_{\text{rms}} = \frac{0.2}{\sqrt{2}} = 0.1414 \text{ A}
$$

$\therefore$ **R.M.S. current through resistor is 0.1414 A**  

$[\frac{1}{2}]$
From formula (iii),
\[ E_{\text{rms}} = \frac{250}{\sqrt{2}} = 176.78 \text{ V} \]
From formula (iv),
\[ P_{\text{av}} = 0.1414 \times 176.78 \]
\[ P_{\text{av}} \approx 25 \text{ W} \]

**Average power dissipated in one cycle** is around 25 W.

viii.

<table>
<thead>
<tr>
<th>No.</th>
<th>Amplitude Modulation</th>
<th>Frequency Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>In AM, alternation in amplitude of the desired signal amounts to marked distortion</td>
<td>Noise can be easily minimised in FM system.</td>
</tr>
<tr>
<td>ii.</td>
<td>In AM, use of an excessively large modulating signal may result in distortion because of over modulation.</td>
<td>No restriction is placed on the modulation index. The instantaneous frequency deviation is proportional to the instantaneous magnitude of the signal.</td>
</tr>
<tr>
<td>iii.</td>
<td>The average power in modulated wave is greater than that contained in unmodulated wave.</td>
<td>The average power in frequency modulated wave is the same as that contained in the unmodulated wave.</td>
</tr>
</tbody>
</table>

*(Any of the above two points)* (1 \times 2) [2]

Q.7. Attempt any THREE

i. A.C circuit with resistance:

a. Suppose an alternating source of e.m.f is applied between the terminals of a resistor of resistance R as shown in figure below.
The instantaneous value of e.m.f is given by, \( e = e_0 \sin \omega t \) ....(i)

\[ \begin{array}{c}
\text{R} \\
\hline
\text{~} \\
\end{array} \]

b. By Ohm’s law, the instantaneous current flowing through the circuit is given by
\[ I = \frac{e}{R} \]
But, \( e = e_0 \sin \omega t \)

\[ \therefore I = \frac{e_0 \sin \omega t}{R} \] ....(ii)

Equation (ii) represents instantaneous current in the circuit.

c. For maximum current through the circuit, \( \sin \omega t = 1 \).
\[ I_{\text{max}} = \frac{e_0}{R} = I_0 \] ....(iii)

Equation (iii) represents peak value of current

d. From equation (ii) and (iii),
\[ I = I_0 \sin \omega t \] ....(iv)

Equation (iv) represents instantaneous current of a.c circuit with resistance only.

e. From equation (iv) it is observed that instantaneous current varies sinusoidally with peak current.

[1]

[½]
ii. Working of P-N junction diode as half-wave rectifier:
   a. A rectifier, which rectifies only one half cycle of each a.c input supply, is called a half wave rectifier.
   b. The circuit diagram is as shown,

   ![Circuit Diagram]

   
   \[
   \begin{align*}
   P_1P_2 &: \text{Primary coil of step down transformer} \\
   S_1S_2 &: \text{Secondary coil of step down transformer} \\
   D &: \text{P-N junction diode} \\
   R_L &: \text{Load resistance}
   \end{align*}
   \]

   c. When a.c input is applied to a junction diode, it gets forward biased during one half cycle and reverse biased during the next opposite half cycle.
   d. The a.c supply is fed across the primary coil \( P_1P_2 \) of a step down transformer. The secondary coil \( S_1S_2 \) of the transformer is connected to the junction diode \( D \) and a load resistance \( R_L \). The output d.c. voltage is obtained across the load resistance \( R_L \).

   The output d.c. voltage is given by \( V_o = I_d \times R_L \).
   e. Suppose that during the first half of the input, a.c voltage terminal \( S_1 \) becomes positive w.r.t \( S_2 \). Then, P region of diode \( D \) becomes positive w.r.t N region. This makes the junction diode forward biased, thus the conventional current flows in the direction of the arrow-heads through \( R_L \).
   f. During the negative half cycle, the terminal \( S_2 \) is at positive potential w.r.t \( S_1 \). Thus, P region of diode \( D \) is negative w.r.t N region. This makes the diode reverse biased. Thus diode does not allow current through it and no current will flow through \( R_L \).
   g. During the next half cycle, output is again obtained as the junction diode gets forward biased. Thus, a half wave rectifier gives pulsating unidirectional and intermittent d.c output voltage \( V \) across the load resistance \( R_L \).
   h. Graph of a.c input and d.c output voltage with respect to time is as shown,

   ![Graph of a.c and d.c voltages]
iii. Given: \( S = 5 \, \Omega, \, G = 495 \, \Omega \)

For parallel combination

\[ V_g = V_S \quad \text{[½]} \]
\[ I_g = (I - I_g)S \quad \text{[½]} \]
\[ I_g = IS - I_gS \quad \text{[½]} \]
\[ I_g = \frac{S}{G+S} \quad \text{[½]} \]
\[
\begin{align*}
I_g & = \frac{5}{495+5} = \frac{5}{500} \\
I_g & = \frac{1}{100} = 1\% 
\end{align*}
\]

The fraction of the total current passing through galvanometer is 1\%.

iv. Given:

\[ A_1 = 100 \, \text{cm}^2 = 100 \times 10^{-4} \, \text{m}^2, \, A_2 = 400 \, \text{cm}^2 = 400 \times 10^{-4} \, \text{m}^2 \]
\[ Q_1 = Q_2, \, V_1 = V_2, \, d_1 = 0.4 \, \text{mm} = 4 \times 10^{-4} \, \text{m} \]

To find: Distance between plates \((d_2)\)

Formulae:

i. \( C = \frac{\varepsilon_0 A}{d} \)

ii. \( C = \frac{Q}{V} \quad \text{[1]} \)

Calculation:

From formula (i),

\[ C_1 = \frac{\varepsilon_0 A_1}{d_1} \quad \text{....(1)} \]
\[ C_2 = \frac{\varepsilon_0 A_2}{d_2} \quad \text{....(2)} \]

Since, \( Q_1 = Q_2, \, V_1 = V_2 \)

From formula (ii),

\[ C_1 = C_2 \quad \text{[½]} \]

From equation (1) and (2),

\[ \frac{\varepsilon_0 A_1}{d_1} = \frac{\varepsilon_0 A_2}{d_2} \]

\[ \therefore \quad d_2 = \frac{A_2}{A_1} d_1 \quad \text{[½]} \]
\[ = \frac{400 \times 10^{-4}}{100 \times 10^{-4}} \times 4 \times 10^{-4} \]
\[ = 16 \times 10^{-4} \, \text{m} = 0.16 \, \text{cm} \]

Distance between plates of the second capacitor is 0.16 cm.

Q.8. Origin of spectral line:

i. According to Bohr’s third postulate, when an electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength called spectral line.

ii. The wavelength of the spectral line depends upon the energy associated with the two energy levels, between which the transition of the electron takes place.

iii. If the energy absorbed is equal to difference between the energies of the two levels then it jumps to a higher permitted orbit and revolves in it. In this case, electron is said to be in the excited state.

iv. In the excited state, the electron is not stable and tries to attain stability by going back to the ground state by emitting the extra amount of energy it had gained in one or more jumps.

v. The energy is emitted as electromagnetic waves and produces a spectral line of the corresponding frequency or wavelength.
Bohr’s formula for spectral lines in hydrogen spectrum:

i. Let, \( E_n = \) Energy of electron in \( n \)th higher orbit
\( E_p = \) Energy of electron in \( p \)th lower orbit

ii. According to Bohr’s third postulate,
\[
E_n - E_p = h \nu
\]
\[
\therefore \quad \nu = \frac{E_n - E_p}{h} \quad \ldots(1) \quad \text{[½]}
\]

iii. But \( E_n = -\frac{me^4}{8\varepsilon_0^2\hbar^2n^2} \) \ldots(2)
\[
E_p = -\frac{me^4}{8\varepsilon_0^2\hbar^2p^2} \quad \ldots(3) \quad \text{[½]}
\]

iv. From equations (1), (2) and (3),
\[
\nu = \frac{me^4}{8\varepsilon_0^2\hbar^2} \left[ \frac{1}{n^2} - \frac{1}{p^2} \right]
\]
\[
\therefore \quad \nu = \frac{me^4}{8\varepsilon_0^2\hbar^2} \left[ \frac{1}{n^2} - \frac{1}{p^2} \right] \quad \text{[½]}
\]
\[
\therefore \quad \lambda = \frac{1}{\nu} = \frac{8\varepsilon_0^2\hbar^2}{me^4} \left[ \frac{1}{n^2} - \frac{1}{p^2} \right] \quad \ldots(4) \quad \text{[1]}
\]

Equation (4) represents Bohr’s formula for hydrogen spectrum.

Solution:

Given:
\[
\mu_g = \frac{3}{2}, \quad \mu_w = \frac{4}{3}, \quad \nu_w - \nu_g = 0.24 \times 10^8 \text{ m/s}
\]

To find: Velocity of light (c)

Formula:
\[
\mu = \frac{c}{\nu}
\]

Calculation: From formula,
\[
\therefore \quad \mu_g = \frac{c}{\nu_g} \quad \text{and} \quad \mu_w = \frac{c}{\nu_w} \quad \text{[½]}
\]
\[
\therefore \quad \nu_g = \frac{c}{\mu_g} \quad \text{and} \quad \nu_w = \frac{c}{\mu_w}
\]
\[
\therefore \quad \nu_w - \nu_g = \frac{c}{\mu_w} - \frac{c}{\mu_g} = c \left[ \frac{1}{\mu_w} - \frac{1}{\mu_g} \right] \quad \text{[½]}
\]
\[
\therefore \quad 0.24 \times 10^8 = c \left[ \frac{1}{4/3} - \frac{1}{3/2} \right] \quad \text{[½]}
\]
\[ 0.24 \times 10^8 = c \left[ \frac{3 \times 2}{4 \times 3} \right] \]
\[ = c \left[ \frac{9 - 8}{12} \right] \]
\[ = c \left[ \frac{1}{12} \right] \]
\[ \therefore c = 0.24 \times 10^8 \times 12 = 2.88 \times 10^8 \approx 3 \times 10^8 \text{ m/s} \]

Velocity of light in air is \(3 \times 10^8 \text{ m/s} \).

**OR**

**Q.8. Principle of transformer:**

It is based on the principle of mutual induction i.e. whenever the magnetic flux linked with a coil changes, an e.m.f is induced in the neighbouring coil.

Construction:

i. A transformer consists of two sets of coils P and S insulated from each other. The coil P is called the primary coil and coil S is called the secondary coil.

ii. The two coils are wound separately on a laminated soft iron core.

iii. The a.c input voltage is applied across the primary and the induced output a.c voltage is obtained across the secondary, which is used to drive current in the desired circuit.

iv. The two coils are electrically insulated from each other but they are magnetically linked.

v. To minimise eddy currents, the soft iron core is laminated.

\[ \text{Working:} \]

i. When an alternating voltage is applied to the primary coil the current through the coil goes on changing. Hence, the magnetic flux through the core also changes.

ii. As this changing magnetic flux is linked with both the coils, an e.m.f is induced in each coil.

iii. The amount of the magnetic flux linked with the coil depends upon the number of turns of the coil.

**Equation of transformation:**

i. Let, ‘\(\phi_p\)’ be the magnetic flux linked per turn with both the coils at certain instant ‘t’.

ii. Let ‘\(N_p\)’ and ‘\(N_s\)’ be the number of turns of primary and secondary coil,

\[ N_p \phi = \text{magnetic flux linked with the primary coil at certain instant ‘t’} \]

\[ N_s \phi = \text{magnetic flux linked with the secondary coil at certain instant ‘t’} \]

iii. Induced e.m.f produced in the primary and secondary coil is given by,

\[ e_p = - \frac{d\phi_p}{dt} = - N_p \frac{d\phi}{dt} \quad \text{....(1)} \]

\[ e_s = - \frac{d\phi_s}{dt} = - N_s \frac{d\phi}{dt} \quad \text{....(2)} \]
iv. Dividing equation (2) by (1),
\[ \frac{e_S}{e_P} = \frac{N_S}{N_P} \quad \text{....(3)} \]
Equation (3) represents equation of transformer. \[1\]

**Solution:**
Given:
- \( \lambda_1 = 4950 \ \text{Å} = 4.95 \times 10^{-7} \text{m} \), \( e = 1.6 \times 10^{-19} \text{ C} \), \( V_{0i} = 0.6 \text{ V} \),
- \( h = 6.63 \times 10^{-34} \text{ J.s} \), \( V_{02} = 1.1 \text{ V} \).

To find: Work function (\( W_0 \)), wavelength of second source (\( \lambda_2 \))

**Formulae:**
- i. \( c = \nu \lambda \)
- ii. \( hv - W_0 = eV_0 \)
- iii. \( \frac{hc}{\lambda} - W_0 = eV_0 \) \[1\]

**Calculation:**
From formula (i),
\[ \nu_1 = \frac{3 \times 10^8}{4.95 \times 10^{-7}} = 6.06 \times 10^{14} \text{ Hz} \]

From formula (ii),
\[ W_0 = 6.63 \times 10^{-34} \times 6.06 \times 10^{14} - (1.6 \times 10^{-19} \times 0.6) \]
\[ = 4.018 \times 10^{-19} - 0.96 \times 10^{-19} \]
\[ = 3.058 \times 10^{-19} \text{ J} \]

\[ W_0 = \frac{3.058 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} \]
\[ W_0 = 1.911 \text{ eV} \]

**The work function of surface is 1.911 eV.** \[1\]

From formula (iii),
\[ \lambda_2 = \frac{hc}{eV_{02} + W_0} \]
\[ = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{(1.6 \times 10^{-19} \times 1.1) + (1.6 \times 10^{-19} \times 1.911)} \]
\[ = \frac{3 \times 6.63 \times 10^{-26}}{(1.1 + 1.911) \times 1.6 \times 10^{-19}} = \frac{19.89}{3.011 \times 1.6} \times 10^{-7} \]
\[ = 4.129 \times 10^{-7} \text{ m} \]

\[ \lambda_2 = 4129 \text{ Å} \]

**The Wavelength of second source is 4129 Å.** \[1\]