

**PHYSICS
PAPER 1
(THEORY)**

21004474

Maximum Marks: 70

Time Allotted: Three Hours

Reading Time: Additional Fifteen Minutes

Instructions to Candidates

1. You are allowed an **additional fifteen minutes** for **only** reading the question paper.
2. You must **NOT** start writing during reading time.
3. This question paper has **12 printed pages**.
4. There are **twenty questions** in this paper. Answer **all** questions.
5. There are **four** sections in the paper: **A, B, C and D**. **Internal choices** have been provided in **two questions** each in **Sections B, C and D**.
6. **Section A** consists of one question having fourteen sub-parts of **one mark** each.
7. While attempting **Multiple Choice Questions** in Section A, you are required to **write only ONE option as the answer**.
8. **Section B** consists of **seven questions** of **two marks** each.
9. **Section C** consists of **nine questions** of **three marks** each.
10. **Section D** consists of **three questions** of **five marks** each.
11. The intended marks for questions are given in brackets [].
12. A list of useful constants and relations is given at the end of this paper.
13. A simple scientific calculator without a programmable memory may be used for calculations.

Instruction to Supervising Examiner

1. Kindly read **aloud** the Instructions given above to all the candidates present in the examination hall.

SECTION A – 14 MARKS

Question 1

- (A) In questions (i) to (vii) given below, choose the correct alternative (a), (b), (c) or (d).
- (i) A positively charged honeybee ($q_1 = +4e$) is attracted towards a flower pollen ($q_2 = -6e$). When the bee is 0.12m away from the flower, what is the **electrostatic potential energy** of the system? [1]
(Assume the bee and the pollen to be point charges.)
- (a) $(-4.608) \times 10^{-26} \text{J}$
(b) $4.608 \times 10^{-26} \text{J}$
(c) $3.84 \times 10^{-25} \text{J}$
(d) $(-3.84) \times 10^{-25} \text{J}$
- (ii) Three long parallel straight wires, X, Y and Z, are **equally** separated and placed in the same plane in a vacuum. They carry a current of I , $2I$ and $4I$ respectively, as shown in **Figure 1**. What is the **force per unit length** acting on wire X? [1]

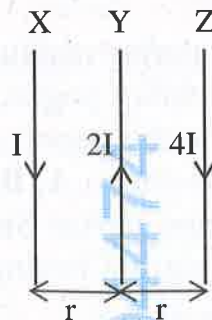


Figure 1

- (a) $\frac{\mu_0 I^2}{\pi r}$
(b) $\frac{\mu_0 I^2}{2\pi r}$
(c) $\frac{\mu_0 I^2}{3\pi r}$
(d) Zero
- (iii) If the wavelength of electromagnetic (em) radiation is equal to the **de Broglie** wavelength (λ) of an electron moving with a velocity of $2 \times 10^6 \text{ms}^{-1}$, then what is **true** about their **momenta**? [1]
- (a) Their momenta are equal.
(b) Photon of electromagnetic radiation has greater momentum than the electron.
(c) Their momenta cannot be compared, as one is a photon and the other is a particle.
(d) Electron has greater momentum than the photon of electromagnetic radiation.

- (iv) If the magnetic susceptibility of a certain magnetic material is 0.0001, what is its **relative permeability**? [1]
- (a) 0.0001
(b) 0.9999
(c) 1.0000
(d) 1.0001
- (v) Which one of the following statements is **true** for the width of the depletion region of a semi-conductor diode? [1]
- (a) Increases during forward bias and remains constant during reverse bias
(b) Increases during forward bias and decreases during reverse bias
(c) Decreases during forward bias and increases during reverse bias
(d) Remains constant during forward bias and increases during reverse bias
- (vi) A microscope is focused on a mark at the bottom of a beaker. Water having refractive index of $\frac{4}{3}$ is poured into the beaker to a height of 4cm. To bring the mark in focus again, the microscope should be moved: [1]
- (a) 1cm upward.
(b) 3cm upward.
(c) $\frac{4}{3}$ cm downward.
(d) 1cm downward.
- (vii) Given below are two statements marked, Assertion and Reason. Read the two statements and choose the correct option. [1]
- Assertion:** When exposed to sunlight, a thin film of oil on water exhibits bright colours.
- Reason:** When white light is passed through a prism, it gets split into its constituent colours due to dispersion of light.
- (a) Both Assertion and Reason are true and Reason is the correct explanation for Assertion.
(b) Both Assertion and Reason are true but Reason is not the correct explanation for Assertion.
(c) Assertion is true and Reason is false.
(d) Assertion is false and Reason is true.

- (B) Answer the following questions briefly:
- (i) How much work is done in carrying a charge 'q' along a circular arc, at the **centre** of which there is a fixed point charge 'Q'? [1]
 - (ii) Explain why the efficiency of a transformer is always less than 100%. [1]
 - (iii) What type of wavefront is associated with sunlight? [1]
 - (iv) State **any one** difference between a primary rainbow and a secondary rainbow. [1]
 - (v) What are **matter waves**? [1]
 - (vi) State **any one** postulate of **Bohr's theory** of hydrogen atom. [1]
 - (vii) Name an element that is used as a **dopant** to convert an intrinsic semiconductor to a 'p' type semiconductor. [1]

SECTION B – 14 MARKS

Question 2 [2]

- (i) You are provided with **three identical** capacitors, each of capacitance $12\mu\text{F}$. Calculate the **range (minimum to maximum)** of capacitance which can be obtained using **all** three of them.

OR

- (ii) (a) An electric dipole having dipole moment 'p' is kept in a uniform electric field **E**, with its axis inclined to the field. Write an expression for the **torque τ** acting on the dipole in **vector** form. (Derivation is not required.)
- (b) What is **Gaussian** surface?

Question 3 [2]

- (i) Two bulbs B_1 and B_2 having ratings (100W, 220V) and (200W, 220V) are connected in **series** to a 220V supply. Perform necessary calculations to find out which bulb glows **brighter**.

OR

- (ii) (a) Many identical cells, each of an emf of **1.5V** and an internal resistance of **2Ω** are available. Calculate the **minimum** number of cells required to form a battery having an emf of 6V and internal resistance of 4Ω .
- (b) Draw a **labelled** diagram of the arrangement.

Question 4**[2]**

Figure 2 below shows a circuit which is used to measure resistance of a piece of metallic wire X.

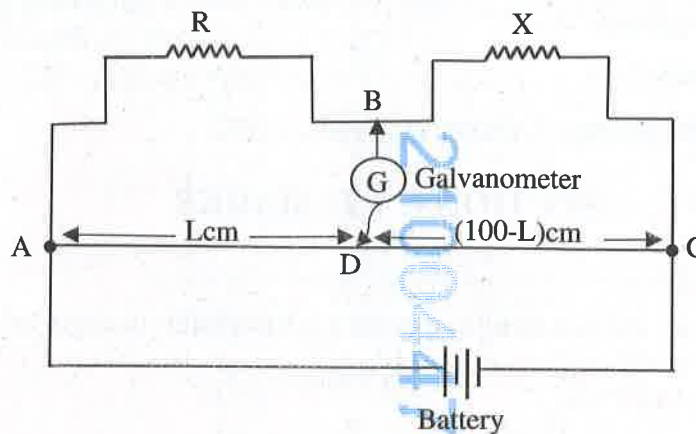


Figure 2

- Write the mathematical formula to determine the value of X.
- What happens to the position of the null point if the wire X is replaced by another wire having **greater** resistance?

Question 5**[2]**

Sketch a **labelled** graph showing variation of impedance **Z** of a series LCR circuit with the frequency **f** of an ac supply. Mark the **resonant frequency** as **f_0** .

Question 6**[2]**

Calculate the position of an object to be placed in front of a convex lens having focal length of 5cm to obtain an image which is **upright** and magnified **four** times.

Question 7**[2]**

With reference to the image of a cash counting machine shown below, answer the questions that follow.



- Name the electromagnetic wave used in the machine to count and authenticate the notes.
- Which electromagnetic radiation has a frequency **greater** than that of ultraviolet radiation but **less** than that of gamma radiation?

Question 8**[2]**

In an experiment on photoelectric effect, **frequency** of incident monochromatic light is increased. What is its effect on:

- (i) photoelectric current?
- (ii) **maximum kinetic energy** of photoelectrons?

SECTION C – 27 MARKS**Question 9****[3]**

Show that the intensity of electric field at a point on **broadside** position of an electric dipole is given by:

$$E = \left(\frac{1}{4\pi\epsilon_0} \right) \frac{p}{(r^2 + l^2)^{3/2}}$$

Where the terms have their usual meaning.

Question 10**[3]**

- (i) Using **Kirchhoff's** laws of electric network, calculate the current flowing through the 5Ω resistor shown in **Figure 3** below.

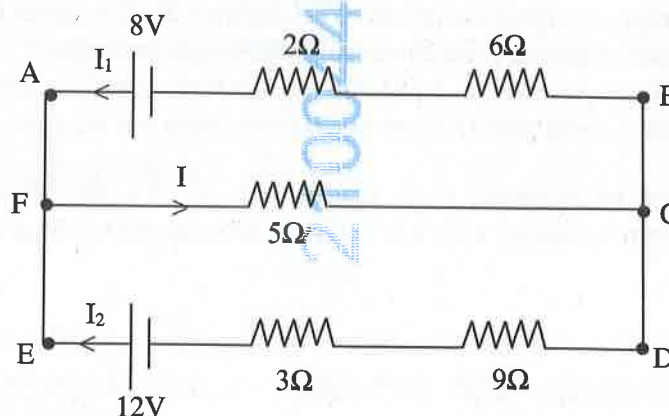


Figure 3

OR

- (ii) **Figure 4** below shows a uniform metallic wire AB which is 1m long. It has a resistance of 15Ω . It is connected in series with a resistor R of resistance 10Ω and a battery E_1 which has an emf of 6V and internal resistance of 2Ω . Calculate the **balancing length** for the cell E_2 of emf 1.5V.

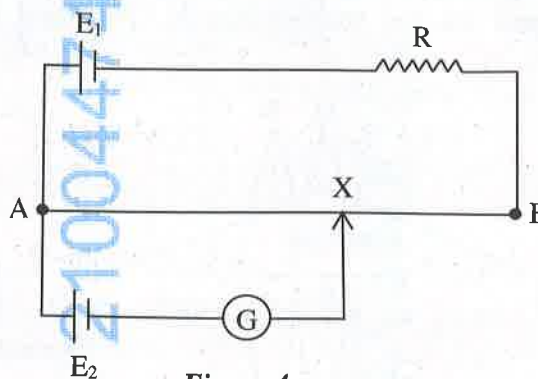


Figure 4

Question 11

[3]

Using **Ampere circuital law**, obtain an expression for magnetic flux density of the magnetic field at a point near a long straight wire, carrying a current I.

Question 12

[3]

- (i) (a) The north pole of a magnet is brought near a metallic ring R as shown in **Figure 5** below. Mark the direction of the current induced in the ring.

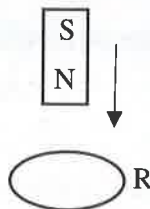


Figure 5

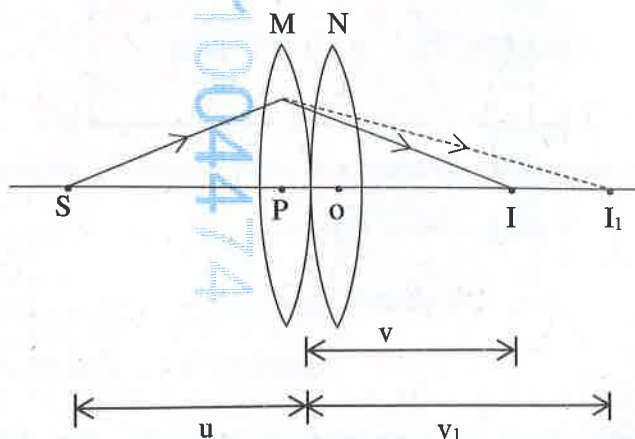
- (b) Keeping the current flowing through a solenoid constant, how does the magnetic field inside the solenoid change if the number of turns per unit length is **doubled**?
- (c) A moving charged particle enters a uniform magnetic field. State when it can travel **undeviated**.

OR

- (ii) (a) Mention **any one** factor on which current sensitivity of a moving coil galvanometer depends.
- (b) Define an **ampere**, SI unit of current, in terms of force between two parallel current carrying conductors.
- (c) State **any one** feature of a moving coil galvanometer due to which it has a **linear** scale.

Question 13**[3]**

Consider two **thin** lenses, M and N having focal lengths of f_1 and f_2 , respectively. They are kept in contact with each other as shown in **Figure 6** below. A point object 'S' is kept on the common principal axis. The first lens M forms an image at I_1 , which serves as a virtual object for the second lens N. The final image formed by the combination is 'I'.

**Figure 6**

- (i) Apply the lens formula for the formation of:
 - (a) Image I_1 by the first lens M.
 - (b) Image I by the second lens N.
- (ii) Hence, obtain an expression for **equivalent focal length (F)** in terms of f_1 and f_2 .

Question 14**[3]**

- (i) A compound microscope has a magnifying power of 30. The focal length of its eye piece is 5cm. If the final image is formed at **least distance of distinct vision** ($D = 25\text{cm}$), find the magnification produced by the **objective** lens.
- (ii) Why are reflecting telescopes preferred to refracting telescopes for astronomical observations?

Question 15**[3]**

Figure 7 below illustrates **Young's double-slit experiment**. S_1 and S_2 are coherent sources emitting light of wavelength 600nm .

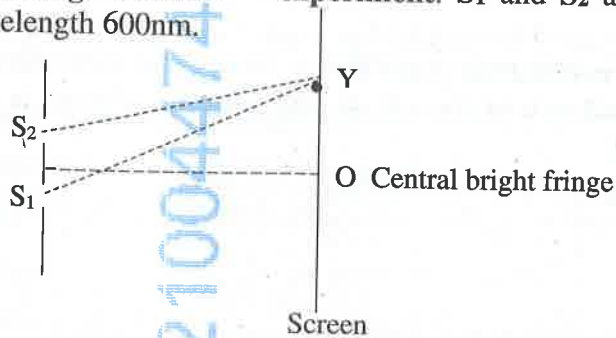


Figure 7

- What are 'coherent sources'?
- Calculate path difference between the two overlapping waves to form the **third bright** fringe at point Y.
- What is the phase difference between the two overlapping waves to obtain the **second dark** fringe?

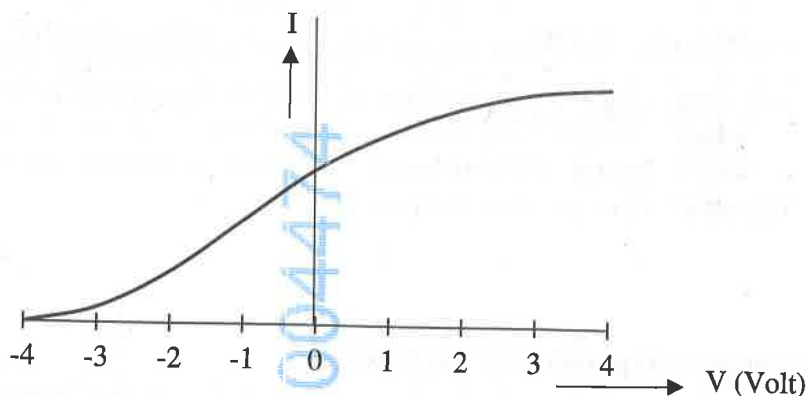
Question 16**[3]**

Answer the following questions with reference to **Fraunhofer** diffraction.

- Why does violet light produce a narrower diffraction pattern than red light?
- What will happen to the diffraction pattern if the slit width is gradually increased?
- Why are alternate dark and bright bands obtained on the screen?

Question 17**[3]**

The graph below shows the variation of photoelectric current (I) with the applied voltage (V).



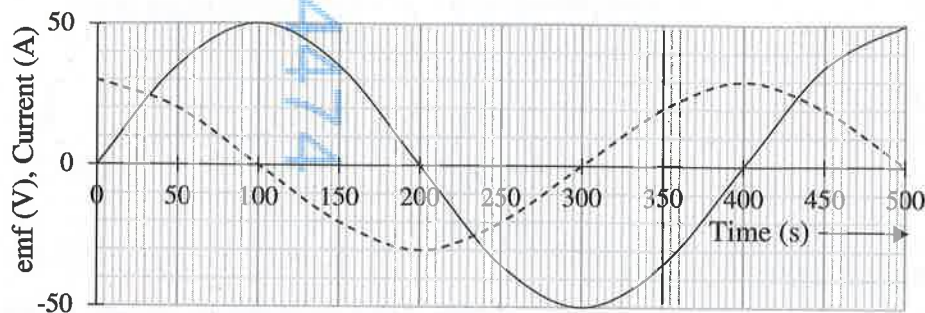
- What does -4V on the graph signify?
- Calculate the **frequency** of the incident ultraviolet radiation, if work function of the metal is 2.63eV .

SECTION D – 15 MARKS

Question 18

[5]

- (i) (a) The **continuous** graph below shows variation of **emf** versus **time** when applied to a component X. The **dotted** line graph is that of **current** versus **time**.



- (1) Identify the component X.
 - (2) Calculate the root mean square value of the current (I_{rms}) flowing in the circuit.
 - (3) Calculate the value of the opposition (in ohm) offered by the component X to the flow of current through it.
- (b) Obtain an expression for the **resonant frequency** (f_0) for a series **LCR** circuit.

OR

- (ii) (a) A train is moving on horizontal tracks 1.2m apart with a constant velocity of 36 km/hr. Vertical component of the earth's magnetic field at that place is $4 \times 10^{-5}\text{T}$. Calculate the emf induced between the two ends of the axle of the train.
- (b) An ac source generates an emf 'e' given by

$$e = 314 \sin (120\pi t)\text{V}$$
 Calculate the root mean square value of the generated emf (E_{rms}).
- (c) A resistor, connected to an ac supply, is carrying some current. It is desired to **reduce** this current by connecting an electrical device 'D' in series with it. Which device is **most** energy efficient: a resistor, an inductor or a capacitor? Give a reason for your answer.

Question 19

[5]

Answer either subparts (i) to (iv) or (v) to (viii).

- (i) Draw a **labelled** circuit diagram of a semiconductor diode when it is **forward biased**.
- (ii) What is meant by 'doping'?
- (iii) Draw a **labelled** energy band diagram of a **semiconductor**.

- (iv) Which diode is used as a **voltage stabiliser**?

OR

- (v) What is the effect of increasing the temperature on **conductivity** of an **intrinsic semiconductor**?
- (vi) Draw a **labelled** energy band diagram of a metal.
- (vii) What is meant by **reverse** biasing of a semiconductor diode?
- (viii) State **any one** advantage of full wave rectification over a half wave rectification.

Question 20

[5]

Read the paragraphs given below and answer the questions that follow.

In a panel discussion on Atomic and Nuclear Physics, one of the panelists explained the discovery of electrons by Sir J J Thomson and his model of the atom. She then elaborated how Geiger and Marsden performed an epoch making alpha particle scattering experiment which enabled their mentor Ernest Rutherford to put forward nuclear model of the atom. She concluded her thoughts by pointing out the drawbacks of Rutherford model and how Niels Bohr overcame them and proposed semi classical semi quantum model.

Another panelist presented his thoughts on Nuclear Physics and explained how Uranium nucleus undergoes fission and releases energy which is harnessed in a nuclear reactor. He also explained how a different type of reaction takes place in sun and releases a lot more energy which could be a potential resource for future harnessing of energy for the benefit of the humankind.

- (i) What conclusion was drawn by Rutherford from Geiger and Marsden's experiment?
- (ii) According to Bohr, how much energy is emitted by a hydrogen atom when its electron goes from third orbit to second orbit? Assume total energy of an electron in n th orbit is given by $E_n = -13.6/n^2 \text{ eV}$.
- (iii) Why is the mass of a stable nucleus always less than the combined mass of its nucleons?
- (iv) What is the function of control rods in a nuclear reactor?
- (v) Write a balanced equation of a nuclear fusion reaction.

USEFUL CONSTANTS AND RELATIONS

1.	Speed of light in vacuum	c	=	$3 \times 10^8 \text{ ms}^{-1}$
2.	Charge of a proton	e	=	$1.6 \times 10^{-19} \text{ C}$
3.	Mass of an electron	m_e	=	$9.1 \times 10^{-31} \text{ kg}$
4.	Planck's constant	h	=	$6.6 \times 10^{-34} \text{ Js}$
5.	Constant for Coulomb's Law	$\left(\frac{1}{4\pi\epsilon_0}\right)$	=	$9 \times 10^9 \text{ mF}^{-1}$
6.	1nm		=	$1 \times 10^{-9} \text{ m}$
7.	1eV		=	$1.6 \times 10^{-19} \text{ J}$
8.	$\sqrt{2}$		=	1.414

SEAL