

PHYSICS

(Paper II)

Time Allowed : Three Hours
Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any three of the following:

(a) A potential field is given by:

$$\phi = (x^2 + y^2 + z^2) \text{ volt.}$$

Find the electric field at a point (x, y, z) and the charge density in the region.

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(b) In the given circuit the output voltage v_0 at time t second after closing the key K is 1 volt. Calculate the rate of change of current in the inductance coil at this moment.

[Figure: Circuit: a 2 V battery on the left side; from its top terminal the top wire runs through key K (open switch) and a 1 Ω resistor to a top rail. Between the top rail and the bottom (return) wire are connected in parallel: a vertical branch containing a 2 Ω resistor, and a second vertical branch containing a 1 Ω resistor in series with a 0.5 H inductance coil (resistor above, coil below). The output voltage V_0 is taken between two terminals at the right-hand ends of the top rail and the bottom wire, i.e. across the parallel combination (across the 2 Ω resistor and across the 1 Ω + 0.5 H branch).]

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(c) An L–C–R circuit has a resistance of 100 ohms, a capacitance of 0.2 μF and an inductance of 5 H. An ac source $E = 50 \sin(1000 t)$ volt is connected in the circuit. Calculate the average power dissipated.

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(d) Simplify the given Boolean expression and draw the corresponding logic circuit using NAND gates:

$$Y = (\bar{A} + B + C) \cdot (\bar{A} + \bar{B} + C)$$

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2. (a) In a series L–C–R circuit connected to an alternating constant voltage source the current amplitude is $(1/n)$ times the amplitude at resonance at frequencies ω_1 and ω_2 . Obtain an expression for its quality factor at resonant frequency.

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(b) Two inductance coils having inductances L_1 and L_2 and negligible resistances are connected in parallel. The coils have a mutual inductance M . Obtain an expression for the effective inductance of the combination.

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3. (a) The electric field vector of a plane electromagnetic wave is given by:

$$\mathbf{E} = E_0 \cos(kz - \omega t + \delta) \hat{x}$$

Write the magnetic field vector. Calculate the average energy per unit volume stored in electromagnetic field and the average energy flux density.

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(b) Calculate the peak values of $\mathbf{E}$ and $\mathbf{B}$ for a laser beam of power 2×10^{10} W and radius 0.1 mm.

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4. (a) Phosphorous is doped in a silicon wafer. The impurity concentration is 10^{13} per cm^3 . If all the donors are active calculate its resistivity at room temperature. The mobility of electrons

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is $1250 \text{ cm}^2/\text{V-s}$.

- (b) How is frequency modulation advantageous compared to amplitude modulation? Still, why are the video signals transmitted by television stations amplitude modulated? **20**
- (c) A junction diode in series with a parallel combination of a large resistor and a capacitor acts as a linear detector of amplitude modulated waves. Explain the action. **20**

SECTION 'B'

5. Answer any three of the following:
- (a) What is spin-orbit coupling? Considering the sodium doublet ($5890 \text{ \AA}$ and $5896 \text{ \AA}$), calculate the effective magnetic field experienced by the electron in the $3p$ state. **20**
- (b) Using the uncertainty principle $\Delta x \cdot \Delta p \sim h/2$, estimate the minimum energy of a particle in a simple harmonic potential $U = 1/2 kx^2$. **20**
- (c) Find the de Broglie wavelength associated with an electron of energy (i) 10 eV and (ii) 10 MeV **20**
- (d) For a particle confined in a one dimensional potential well of length L the wave-function is $\psi(x) = c \sin(\pi x/L)$, $0 < x < L$ and $\psi(x) = 0$ outside. Calculate the expectation values of x and p . **20**
6. (a) What are Compton effect and Compton wavelength? Determine Compton shift. Show that maximum Compton shift is twice the Compton wavelength. **40**
- (b) The specific activity of a sample containing radioactive Co^{58} and non-radioactive Co^{59} was observed to be 2.2×10^{12} disintegrations per second per gm. Half-life of Co^{58} is 71.3 days. Find the percentage of mass of radioactive element in the sample. **20**
7. (a) The following reaction do not take place: (i) $n \rightarrow p + e^- + \nu$ [?] (ii) $p \rightarrow \pi^0 + e^+ + \nu$ [?] Explain the reasons in terms of conservation laws. **20**
- (b) What is Meissner effect? Superconducting tin has a critical temperature of 3.7 K in zero magnetic field and critical field at 0 K is 306 gauss . Determine the critical field at 2 K . **20**
- (c) The frequency of applied voltage in a cyclotron is $1.2 \times 10^7 \text{ Hz}$. Find the magnetic field strength when protons are to be accelerated. If the radius of dees is 0.5 m , what is the energy of the accelerated protons? **20**
8. Give Weiszacker formula for the binding energy of a nucleus. Explain the significance of each term. Derive an expression for the atomic number Z of the most stable nucleus for a given mass number A . Determine the atomic number Z of the stable nucleus having $A = 64$. **60**