Maximum Marks: 70 Marks **Time Allowed**: 3 hours.

General Instructions:

(1) There are 35 questions in all. All questions are compulsory
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
(3) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
(4) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

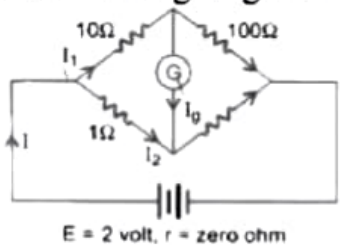
Section A

1. If ϵ_0 and μ_0 are the permittivity and permeability of free space and ϵ and μ are the corresponding quantities for a medium, then refractive index of the medium is: [1]

   a) $\sqrt{\frac{\mu\epsilon}{\mu_0\epsilon_0}}$ b) $\sqrt{\frac{\mu_0\epsilon_0}{\mu\epsilon}}$

   c) 1 d) insufficient information

2. In the adjoining figure, the resistance of the galvanometer G is 50 ohm. Of the following alternatives in which case are the currents arranged strictly in the order of decreasing magnitudes with the larger coming earlier: [1]



   a) I, I_2, I_1, I_g b) I_g, I_1, I_2, I

   c) I, I_g, I_1, I_2 d) I, I_1, I_g, I_2

3. Diode is used as a/an [1]

   a) rectifier b) amplifier

   c) modulator d) oscillator

4. What is the conductivity of a semiconductor sample having electron concentration of 5×10^{18} m^{-3}, hole concentration of 5×10^{19} m^{-3}, electron mobility of 2.0 $m^2V^{-1}s^{-1}$ and hole mobility of 0.01 $m^2V^{-1}s^{-1}$? (Take charge of electron as 1.6×10^{-19} C) [1]

a) $1.20\ (\Omega\text{-m})^{-1}$ b) $0.59\ (\Omega\text{-m})^{-1}$

c) $1.83\ (\Omega\text{-m})^{-1}$ d) $1.68\ (\Omega\text{-m})^{-1}$

5. If $\vec{E}$ is an electric field and $\vec{B}$ is the magnetic induction, then the energy flow per unit area per unit time in an electromagnetic field is given by: [1]

a) $\vec{E} \cdot \vec{B}$ b) $\vec{E} \times \vec{B}$

c) $\frac{E}{B}$ d) $E^2 + B^2$

6. A small circular loop of wire of radius a is located at the centre of a much larger circular wire loop of radius b. The two loops are in the same plane. The outer loop of radius b carries an alternating current $I = I_0 \cos(\omega t)$. The emf induced in the smaller inner loop is nearly: [1]

a) $\frac{\pi\mu_0 I_o}{2} \cdot \frac{a^2}{b}\omega\cos(\omega t)$ b) $\frac{\pi\mu_0 I_0 b^2}{a}\omega\cos(\omega t)$

c) $\pi\mu_0 I_0 \frac{a^2}{b}\omega\sin(\omega t)$ d) $\frac{\pi\mu_0 I_o}{2} \cdot \frac{a^2}{b}\omega\sin(\omega t)$

7. A plane electromagnetic wave propagating in the A-direction has a wavelength of 6.0 mm. The electric field is in the Y-direction and its maximum magnitude is 33 Vm^{-1}. The equation for the electric field as a function of x and t is: [1]

a) $33\sin\pi \times 10^{11}\left(t - \frac{x}{c}\right)$ b) $33\sin\pi\left(t - \frac{x}{c}\right)$

c) $11\sin\pi \times 10^{11}\left(t - \frac{x}{c}\right)$ d) $11\sin\pi\left(t - \frac{x}{c}\right)$

8. In Young's experiment, two coherent sources are placed 0.9 mm apart and the fringes are observed 1 m away. If it produces the second dark fringe at a distance of 1 mm from the central fringe, the wavelength of monochromatic light used would be [1]

a) 10×10^{-5} cm b) 6×10^{-5} cm

c) 10×10^{-4} cm d) 60×10^{-4} cm

9. What is the energy (approximate) of a photon emitted when an electron in a doubly charged lithium-ion Li^{++} (with nuclear charge 3e) undergoes a transition between n = 3 and n = 1 states (n being the principle quantum number? [1]

a) 13.6 eV b) 10.9 eV

c) 122.4 eV

d) 108.8 eV

10. Regarding a semiconductor which one of the following is wrong? [1]

a) The number of free electrons increases with rise of temperature

b) The charge carries electrons and holes

c) There are no free electrons at 0 K

d) There are no free electrons at room temperature

11. When a negatively charged conductor is connected to earth [1]

a) Electrons flow from the earth to the conductor

b) Protons flow from the conductor to the earth

c) No charge flow occurs

d) Electrons flow from the conductor to the earth

12. A soap bubble is given a negative charge; then its radius: [1]

a) nothing can be predicted as information is insufficient

b) decreases

c) increases

d) remains unchanged

13. Electrons used in an electron microscope are accelerated by a voltage of 25 kV. If the voltage is increased to 100 kV, then the de-Broglie wavelength associated with the electrons would [1]

a) increase by 4 times

b) decrease by 2 times

c) increase by 2 times

d) decrease by 4 times

14. The intensity of a plane electromagnetic wave is 5 W/m^2. It is incident on a perfectly reflecting surface. Find the radiation pressure: [1]

a) 3.33×10^{-8} N/m^2

b) 8.0×10^{-9} N/m^2

c) 3.33×10^{-9} N/m^2

d) 8.0×10^{-8} N/m^2

15. A long solenoid has 1000 turns. When a current of 4 A flows through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is: [1]

a) 1 H

b) 4 H

c) 3 H

d) 2 H

16. **Assertion (A):** Mass is not conserved, but mass and energy are conserved as a single entity called mass-energy. [1]

Reason (R): Mass and energy are inter-convertible in accordance with Einstein's relation.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

17. **Assertion (A):** A domestic electrical appliance, working on a three-pin, will continue working even if the top pin is removed. [1]
Reason (R): The third pin is used only as a safety device.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

18. **Assertion (A):** The figure shows a metallic conductor moving in a magnetic field. The induced emf across its ends is zero. [1]

Reason (R): The induced emf across the ends of a conductor is given by e = Bvl sin θ.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

19. The bombardment of lithium with protons gives rise to the following reaction: [2]
$_{3}^{7}Li + {}_{1}^{1}H \rightarrow {}_{2}^{4}He + {}_{2}^{4}He$ + Energy
The atomic masses of lithium, hydrogen and helium are 7.016 amu, 1.008 amu and 4.004 amu respectively. Find the initial energy of each α-particle (1 amu = 931 MeV).

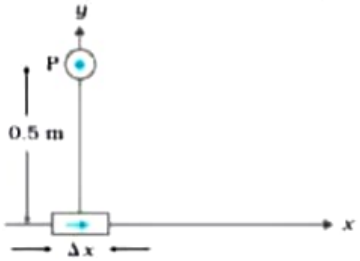
20. Light of intensity 10^{-5} Wm^{-2} falls on a sodium photo-cell of surface area 2 cm^2. Assuming that the top 5 layers of sodium absorb the incident energy, estimate time required for photoelectric emission in the wave-picture of radiation. The work function for the metal is given to be about 2 eV. What is the implication of your answer? [2]

21. The resistivity of pure germanium at a particular temperature is 0.52 Ωm. If the material is doped with 10^{20} atoms m^{-3} of a trivalent impurity material, determine the new resistivity. The electron and hole mobilities are given to be 0.2 and 0.4 $m^2V^{-1}s^{-1}$ respectively. [2]

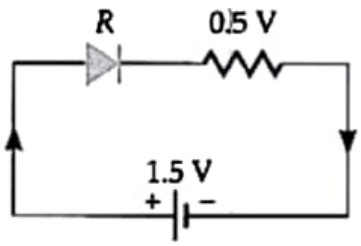
22. An electron does not suffer any deflection while passing through a region. Are you definite there is no magnetic field in that region ? [2]

OR

An element $\Delta\vec{l} = \Delta x\hat{i}$ is placed at the origin and carries a large current I = 10 A (Fig.). What is the magnetic field on the y-axis at a distance of 0.5 m? Δx = 1 cm.



23. A p-n junction diode when forward biased has a drop of 0.5 V which is assumed to be independent of the current. The current in excess of 10 mA through the diode produces a large Joule heating which damages (burns) the diode. If we want to use a 1.5 V battery to forward bias the diode, what should be the value of the resistor used in series with the diode so that the maximum current does not exceed 5 mA? [2]



24. The susceptibility of a magnetic material is -0.085. Identify the magnetic type of the substance. A specimen of this material is kept in a uniform magnetic field. Draw the modified field pattern. [2]

OR

Two short magnets P and Q are placed one over another with their magnetic axes mutually perpendicular to each other. It is found that the resultant field at a point on the prolongation of the magnetic axis of P is inclined at 30° with this axis. Compare the magnetic moments of the two magnets.

25. The spectral line in the spectrum of light from a star is found to be shifted by 0.032% from its normal position towards the red end of the spectrum. Compute the velocity of the star. [2]

Section C

26. The magnetic moment vectors μ_s and μ_l associated with the intrinsic spin angular momentum S and orbital angular momentum l, respectively, of an electron, are predicted by quantum theory (and verified experimentally to a high accuracy) to be given by: [3]

μ_s = -(e/m) S, μ_l = -(e/2m)l

Which of these relations is in accordance with the result expected classically? Outline the derivation of the classical result.

27. Write Coulomb's law in vector form. What is the importance of expressing it in vector form? [3]

28. Name the laws associated with the following equations : [3]

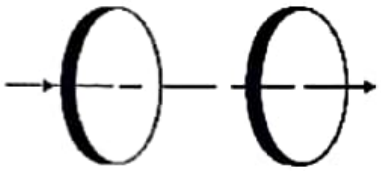
i. $\oint \vec{E} \cdot \overrightarrow{dS} = \frac{q}{\varepsilon_0}$

ii. $\oint \vec{E} \cdot \overrightarrow{dl} = -\frac{d}{dt} \oint \vec{B} \cdot \overrightarrow{dS}$

iii. $\oint \vec{B} \cdot \overrightarrow{dS} = \mu_0 \varepsilon_0 \frac{d}{dt} \oint \vec{E} \cdot \overrightarrow{dS}$

OR

Figure shows a capacitor made of two circular plates each of radius 12 cm, and separated by 5.0 cm. The capacitor is being charged by an external source. The charging current is constant and equal to 0.15 A.



a. Calculate the capacitance and the rate of charge of the potential difference between the plates.

b. Obtain the displacement current across the plates.

c. Is Kirchoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

29. In a Young's double-slit experiment, the slits are separated by 0.5 mm and the screen is placed 1.0 m away. It is found that the ninth bright fringe is at a distance of 8.835 mm from the second dark fringe. Find the wavelength of light used. [3]

OR

Why is interference pattern not detected, when two coherent sources are far apart? In Young's experiment, the width of the fringes obtained with light of wavelength $6000\overset{o}{A}$ is 2.0 mm. Calculate the fringe width if the entire apparatus is immersed in a liquid medium of refractive index 1.33.

30. The current-loop PQRSTP formed by two circular segments of radii R_1 and R_2 carries a current of I ampere. Find the magnetic field at the common centre O. [3]

What will be the field if angle $\alpha = 90^o$?

Section D

31. Two point charges -q and q are located at points (0, 0, - a) and (0, 0, a) respectively. [5]

i. Find the electrostatic potential at (0, 0, z) and (x, y, 0).

ii. How much work is done in moving a small test charge from the point (5, 0, 0) to (- 7, 0, 0) along the x-axis?

iii. How would your answer change if the path of the test charge between the same points is not along the x-axis but along any other random path?

iv. If the above point charges are now placed in the same positions in the uniform external electric field $\vec{E}$, what would be the potential energy of the charging system in its orientation of unstable equilibrium?

Justify your answer in each case.

OR

a. Deduce the expression for the energy stored in a charged capacitor

b. Show that the effective capacitance C of a series combination of three capacitors C_1, C_2 and C_3 is given by $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

32. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state,(n_f). [5]

When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$, identify the spectral series to which the emission lines belong.

OR

In the study of Geiger-Marsden experiment on scattering of a-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

From the relation $R = R_0 A^{\frac{1}{3}}$, where, R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

33. a. Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision. [5]

b. The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The microscope is focused on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm. Calculate the focal length of the objective and the eyepiece.

OR

i. Draw a labelled ray diagram to obtain the real image formed by an astronomical telescope in normal adjustment position. Define its magnifying power.

ii. You are given three lenses of power 0.5 D, 4D and 10 D to design a telescope.

a. Which lenses should be used as objective and eyepiece? Justify your answer.

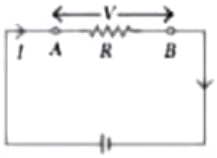
b. Why is the aperture of the objective preferred to be large?

Section E

34. **Read the text carefully and answer the questions:** [4]

Whenever an electric current is passed through a conductor, it becomes hot after some time. The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as

heat. But if the circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc.



(i) Which of the following is a correct statement?

a) Heat produced in a conductor is independent of the current flowing.

b) Heat produced in a conductor varies directly as the square of the current flowing.

c) Heat produced in a conductor varies inversely as the square of the current flowing.

d) Heat produced in a conductor varies inversely as the current flowing.

(ii) If the coil of a heater is cut to half, what would happen to heat produced?

a) Remains same

b) Halved

c) Remains same

d) Doubled

(iii) A 25 W and 100W are joined in series and connected to the mains. Which bulbs will glow brighter?

a) none will glow brighter

b) both bulbs will glow brighter

c) 100 W

d) 25 W

OR

A rigid container with thermally insulated wall contains a coil of resistance 100 Ω, carrying current 1A. Change in its internal energy after 5 min will be

a) 20 kJ

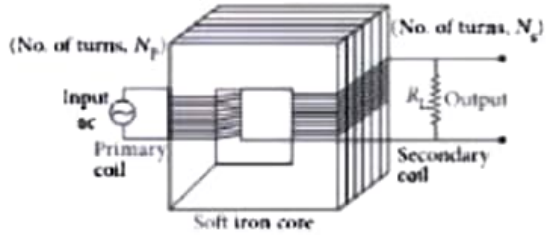
b) 0 kJ

c) 10 kJ

d) 30 kJ

35. **Read the text carefully and answer the questions:** **[4]**

A transformer is an electrical device which is used for changing the a.c. voltages. It is based on the phenomenon of mutual induction i.e. whenever the amount of magnetic flux linked with a coil changes, an e.m.f. is induced in the neighbouring coil. For an ideal transformer, the resistances of the primary and secondary windings are negligible.



It can be shown that $\frac{E_s}{E_p} = \frac{I_p}{I_s} = \frac{n_s}{n_p} = k$

where the symbols have their standard meanings.

For a step-up transformer, $n_S > n_p$; $E_S > E_p$; $k > 1$; $\therefore I_S < I_p$

For a step down transformer, $n_S < n_p$; $E_S < E_p$; $k < 1$

The above relations are on the assumption that efficiency of transformer is 100%.

Infact, efficiency $\eta = \frac{\text{output power}}{\text{intput power}} = \frac{E_s I_s}{E_p I_p}$

(i) The number of turns in the primary coil of a transformer is 20 and the number of turns in a secondary is 10. If the voltage across the primary is 220 ac V, what is the voltage across the secondary?

(ii) In a transformer, the number of primary turns is four times that of the secondary turns. Its primary is connected to an a.c. source of voltage V. What will be the current through its secondary?

(iii) A transformer is used to light 100 W - 110 V lamps from 220 V mains. If the main current is 0.5 A, then what will be the efficiency of the transformer?

OR

Which quantity remains constant in an ideal transformer?