Time : 3 hrs | Max. Marks : 70

General Instructions

1. All questions are compulsory. There are 33 questions in all.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. **Section A** contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, **Section B** has two case based questions of 4 marks each, **Section C** contains nine short answer questions of 2 marks each, **Section D** contains five short answer questions of 3 marks each and **Section E** contains three long answer questions of 5 marks each.
4. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

SECTION-A

All questions are compulsory. In case of internal choices, attempt anyone of them.

1. A parallel plate capacitor, when there is vacuum between the plates, has capacitance C_0. Then, calculate the new capacitance when a sheet of thickness t of relative permittivity K is introduced between the plates. (Take, $t = d$)

2. Draw a graph that represents the correct variation of inductive reactance X_L with angular frequency ω.

Or

If the number of turns in a coil becomes doubled, then what should be its self-inductance?

3. Calculate the internal resistance of a 4 V cell which gives a current of 0.2 A through a resistance of 10 Ω.

4. When an electron makes transition from $n = 4$ to $n = 2$, then emitted line spectrum belongs to which part of the series of hydrogen spectrum?

- You are advised to attempt this sample paper without referring the solutions given here. However, cross check your solutions with the solutions given at the end of paper after you complete the paper.

5. If a positron and an electron annihilate, calculate the energy released in joules by each.

Or

If the nuclear radius of $^{16}_{8}O$ is 3×10^{-15} m, then calculate the density of nuclear matter.

6. Write the expression for the angular magnification of a compound microscope, when the final image is formed at near point.

7. The magnetic flux linked with the coil varies with time as, $\phi = 3t^2 + 4t + 9$. Calculate the magnitude of the induced emf at 2s.

Or

The frequency of an alternating voltage is 50 cycles/s and its amplitude is 120V. Find the rms value of voltage.

8. Sketch a graph showing variation of photoelectric current with applied voltage for two incident radiations of equal intensity and different frequencies. Mark the graph for the radiation of higher frequency.

9. Specify the relation between the number of holes and number of conduction electrons in an

(i) intrinsic semiconductor

(ii) *n*-type semiconductor

Or

Can we measure the potential difference across an unbiased *p-n* junction by connecting a sensitive voltmeter across its terminals? If yes, then why?

10. Calculate the critical angle for a material of refractive index $\frac{2}{\sqrt{3}}$.

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(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 and R is also false.

11. **Assertion** If we increase the current sensitivity of a galvanometer by increasing number of turns, its voltage sensitivity also increases.

Reason Resistance of a wire also decreases with N.

12. **Assertion** If the inner solenoid is much shorter than (and placed well inside) the outer solenoid, then the flux linkage $N_1\phi_1$ can still be calculated.

Reason The inner solenoid is effectively immersed in a uniform magnetic field due to the outer solenoid.

13. **Assertion** Propagation of light through an optical fibre is due to total internal reflection taking place at the core-clad interface.

Reason Refractive index of the material of the core of the optical fibre is greater than that of cladding.

14. **Assertion** The conductivity of an intrinsic semiconductor depends on its temperature.

Reason The conductivity of an intrinsic semiconductor is slightly higher than tha of a lightly doped *p*-type semiconductor.

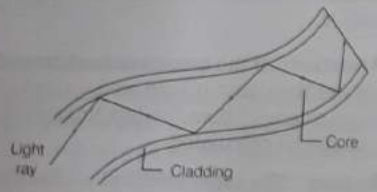
SECTION-B

Questions 15 and 16 are case study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

Optical Fibre

15. An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection.

These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.



(i) Which of the following is based on the phenomenon of total internal reflection of light?

(a) Sparkling of diamond
(b) Optical fibre communication
(c) Instrument used by doctors for endoscopy
(d) All of the above

(ii) A ray of light will undergo total internal reflection inside the optical fibre, if it

(a) goes from rarer medium to denser medium
(b) incident at an angle less than the critical angle
(c) strikes the interface normally
(d) incident at an angle greater than the critical angle

(iii) If in core, incidence angle is equal to critical angle, then refraction angle will be

(a) 0° (b) 45°
(c) 90° (d) 180°

(iv) In an optical fibre (shown), correct relation of refractive indices of core and cladding is

(a) $n_1 = n_2$ (b) $n_1 > n_2$
(c) $n_1 < n_2$ (d) $n_1 + n_2 = 2$

(v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre

(a) 3×10^8 m/s (b) 1.5×10^8 m/s
(c) 6×10^8 m/s (d) 4.5×10^8 m/s

Electrostatic Potential Energy

16. Electrostatic potential energy of a system of point charges is defined as the total amount of work done in bringing the different charges to their respective positions from infinitely large mutual separations.

By definition, work done in carrying charge from ∞ to any point is

$$W = \text{Potential} \times \text{Charge}$$

This work is stored in the system of two point charges in the form of electrostatic potential energy U of the system.

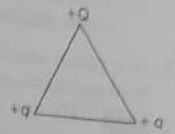
(i) Work done in moving a charge from one point to other inside a uniformly charged conducting sphere is

(a) always zero (b) non-zero
(c) may be zero (d) None of these

(ii) A positively charged particle is released from rest in an uniform electric field. The electric potential energy of the charge

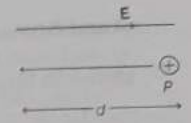
(a) remains a constant because the electric field is uniform
(b) increases because the charge moves along the electric field
(c) decreases because the charge moves along the electric field
(d) decreases because the charge moves opposite to the electric field

(iii) Three charges are placed at the vertex of an equilateral triangle of side l as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) $-q$ (b) $q/2$
(c) $-2q$ (d) $-q/2$

(iv) In the figure, proton moves a distance d in a uniform electric field E as shown in the figure. The work done on the proton by electric field is



(a) negative (b) positive
(c) zero (d) None of these

(v) Two similar positive point charges each of 1 μC have been kept in air at 1m distance from each other. What will be the potential energy?

(a) 1 J (b) 1 eV
(c) 9×10^{-3} J (d) zero

SECTION-C

All questions are compulsory. In case of internal choices, attempt anyone.

17. Define mobility of charge carriers and specify its SI unit. Write its expression in terms of relaxation time also.

18. Obtain with the help of necessary diagram, the expression for the magnetic field in the open space in the interior of a current carrying toroid.

19. The fission properties of $^{239}_{94}$Pu are very similar to those $^{235}_{92}$U. The average energy released per fission is 180 MeV. How much energy, in MeV, is released, if all atoms in 1 kg of pure $^{239}_{94}$Pu undergo fission?

Or

Would the Bohr's formula for the H-atom remains unchanged, if proton had a charge $(+4/3)\,e$ and electron had a charge $(-3/4)e$, where $e = 1.6 \times 10^{-19}$ C. Give reasons for your answer.

20. In a single slit experiment, how is the angular width of central bright maximum changes, when

(i) the slit width is decreased?
(ii) light of smaller wavelength λ is used?

Or

A converging and a diverging lens of equal focal lengths are placed coaxially in contact. Find the power and focal length of the combination.

21. Identify the electromagnetic waves whose wavelengths vary as

(i) 0.1m to 1 mm (ii) 1 nm to 10^{-3} nm

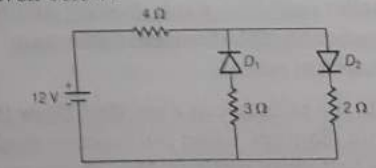
Write one use for each.

22. A hollow charged conductor has a tiny hole which is cut into the surface. Show that the electric field in the hole is $\left(\frac{\sigma}{2\varepsilon_0}\right)\hat{\mathbf{n}}$, where $\hat{\mathbf{n}}$ is the unit vector in the outward normal direction and σ is the surface charge density near the hole.

23. A photodiode is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect wavelength of 6000 nm? Justify.

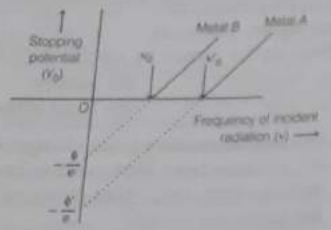
Or

What is the current flowing in the circuit given below?



24. The graph showing the variation of stopping potential with frequency of incident radiation for two photosensitive metals

A and B having threshold frequencies ν_0' and ν_0, respectively ($\nu_0' > \nu_0$) is shown in figure below



Now, evaluate the following questions.

(i) Which of the two metals, A or B has higher work function?

(ii) What information do you get from the slope of the graphs?

25. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2×10^{10} Hz and amplitude 48 V/m.

(i) What is the wavelength of the wave?

(ii) Show that, the average energy density of the **E** field equals the average energy density of the **B** field.

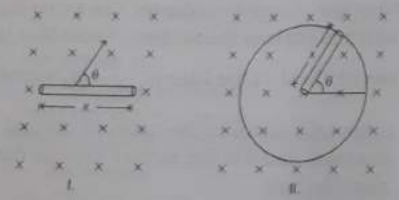
SECTION-D

All questions are compulsory. In case of internal choices, attempt anyone.

26. Calculate the rate at which the flux linked with the generated area changes with time when a rod of length x is

(i) translated,

(ii) rotated in a uniform field of induction B as shown in figures below



Or

A long solenoid S has n turns per metre, with diameter a. At the centre of this coil, we place a smaller coil of N turns and diameter b (where, $b < a$). If the current in the solenoid increases linearly with time, what is the induced emf appearing in the smaller coil? Plot graph showing nature of variation in emf, if current varies as a function of $mt^2 + C$.

27. Write the principle of a rectifier. Draw the circuit diagram, using p-n junction diode for a half-wave rectifier. Also, sketch the input and output waveforms.

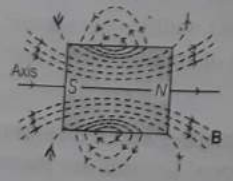
28. Derive the expression for electrostatic potential due to an electric dipole at a point P inclined at an angle θ.

Or

(i) Two long straight parallel wires carry charges λ_1 and λ_2 per unit length. The separation between their axes is d. Find the magnitude of the force exerted on the unit length of one due the charge on the other.

(ii) A point charge placed at any point on the axis of an dipole at some large distance experiences a force F. What will be the force acting on the point charge when its distance from the dipole is doubled?

29. Magnetic field lines are a visual and intuitive realisation of the magnetic field. These are those imaginary lines which continuously represent the direction of the magnetic field. They are in the form of closed loops. Field lines for a bar magnet are as shown in figure below



Now, with the help of above information,

(i) sketch magnetic field lines around a current carrying finite solenoid.

(ii) how is the direction of a magnetic field line represented?

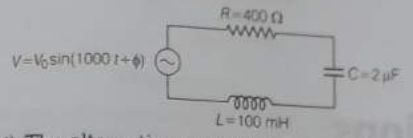
(iii) does these lines resembles to the electric field lines of an electric dipole?

30. Can de-Broglie hypothesis be used to comment on Bohr's second postulate ? If yes, then state the hypothesis and use it to make inferences about Bohr's postulate.

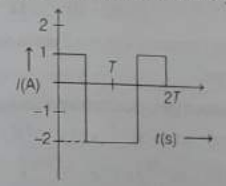
SECTION-E

All questions are compulsory. In case of internal choices, attempt anyone.

31. (i) Determine the value of phase difference between the current and the voltage in the given series L-C-R circuit.



(ii) The alternating current in a circuit is described by the graph shown below. Find the rms current in the graph.



Or

(i) A series L-C-R circuit is connected to an AC source of voltage V and angular frequency ω when only the capacitor is removed, the current lags behind the voltage by a phase angle ϕ and when only the inductor is removed, the current leads the voltage by the same phase angle. Find the current flowing and the average power dissipated in the L-C-R circuit.

(ii) An alternating voltage is given by $V = 140 \sin(314t)$ is connected across a pure resistor of resistance 50Ω. Find

(a) the frequency of the source and

(b) the rms current through the resistor.

32. (i) State the essential condition for diffraction of light to occur.

How does the angular separation between fringes is single slit diffraction experiment change when the distance of separation between the slit and screen is doubled?

(ii) A beam of light consisting of two wavelengths 650 nm and 520 nm, is used to obtain interference fringes in Young's double slit experiment.

(a) Find the distance of the third bright fringe on the screen from the central maximum for the wavelength 650 nm.

(b) What is the least distance from the central maximum, where the bright fringes coincide due to both wavelengths?

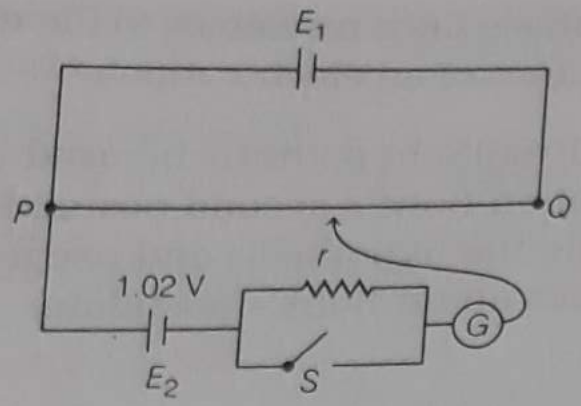
The distance between the two slits is 2 mm and the distance between the plane of the slits and the screen is 120 cm.

Or

An angular magnification (magnifying power) of 30 is desired using an objective of focal length 1.25 cm and an eyepiece of focal length 5 cm. How will you set-up the compound microscope?

33. (i) State with help of circuit diagram, the working principle of meter bridge and write its balance condition.

(ii) Potentiometer wire PQ of 1 m length is connected to a standard cell E_1. Another cell E_2 of emf 1.02 V is connected as shown in the circuit diagram with a resistance r and a switch S. With switch S open, null point is obtained at a distance of 51 cm from P.



Calculate

(a) potential gradient of the potentiometer wire,

(b) emf of the cell E_1 and

(c) when switch S is closed.
Will the null point move towards P or towards Q? Give reason.

Or

(i) State the Kirchhoff's laws and specify the sign convention used.

(ii) Determine the current in each branch of the network shown in figure below