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PHYSICS

(Theory)

Full Marks : 70

Time : 3 hours

The figures in the margin indicate full marks for the questions

General Instructions :

1. There are **33** 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.
3. All the Sections are compulsory.
4. Section—A contains sixteen questions—twelve multiple choice type questions and four very short answer type questions of 1 mark each. Section—B contains five questions of 2 marks each, Section—C contains seven questions of 3 marks each, Section—D contains two case study-based questions of 4 marks each and Section—E contains three long answer type questions of 5 marks each.
5. There is no overall choice. However internal choices have been provided in two questions in Section—A, two questions in Section—B, three questions in Section—C and all three questions in Section—E. You have to attempt only one of the choices in such questions.

(2)

6. You may use the following values of physical constants where necessary :

$$c = 3 \times 10^8 \text{ m/s}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$m_p = 1.7 \times 10^{-27} \text{ kg}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

$$h = 6.63 \times 10^{-34} \text{ J-s}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole}$$

SECTION—A

Choose and write the correct option for the following : 1×12=12

1. A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre

- (a) increases as r increases for $r < R$ and for $r > R$
- (b) is zero as r increases for $r < R$ and decreases as r increases for $r > R$
- (c) is zero as r increases for $r < R$ and increases as r increases for $r > R$
- (d) decreases as r increases for $r < R$ and for $r > R$

(3)

2. The time taken by an AC of frequency 50 Hz to reach from zero to the maximum value is

(a) 50×10^{-3} s

(b) 5×10^{-3} s

(c) 1×10^{-3} s

(d) 2×10^{-3} s

3. The flux on a coil of 50 turns changes from 0.3 Wb to 0.5 Wb in 8 seconds. The induced e.m.f. in the coil is

(a) 10 V

(b) 0.6 V

(c) - 12 V

(d) - 1.25 V

4. Which of the following is not true about infrared rays?

(a) It is used in TV remotes

(b) It is used in fighter aircrafts to see at night

(c) It is used for relieving muscle pulls

(d) It is used to detect cracks in metals

5. The diagram



depicts a

(a) concave lens

(b) convex lens

(c) plane sheet of glass since it is of equal thickness

(d) convexo-concave lens

(4)

6. Select the correct option with respect to the figures given below :

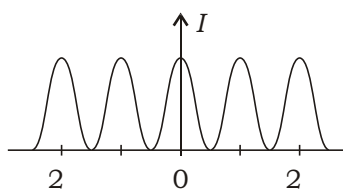


Fig. (i)

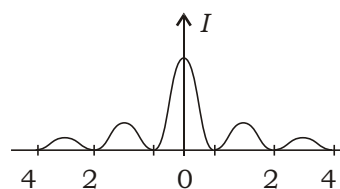
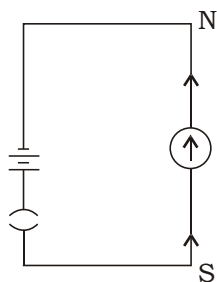


Fig. (ii)

- (a) Fig. (i) depicts diffraction pattern and Fig. (ii) depicts interference pattern
- (b) Both depict interference pattern
- (c) Both depict diffraction pattern
- (d) Fig. (i) depicts an interference pattern due to a double-slit and Fig. (ii) depicts a diffraction pattern due to a single-slit
7. The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true?
- (a) Its kinetic energy increases and its potential and total energies decrease.
- (b) Its kinetic energy decreases, potential energy increases and its total energy remains the same.
- (c) Its kinetic and total energies decrease and its potential energy increases.
- (d) Its kinetic energy, potential energy and total energy all decrease.

(5)

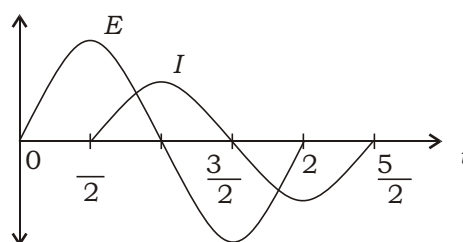
8. If a charged particle enters perpendicularly into a uniform magnetic field, then which of the following statements is true?
- (a) Both energy and momentum remain constant.
 - (b) Energy remains constant, but momentum changes.
 - (c) Both energy and momentum change.
 - (d) Energy changes but momentum remains constant.
9. In the figure shown below, a compass needle is placed under the wire. The wire is aligned in the South-North direction. When a current is made to flow through the wire from S to N, the needle will



- (a) deflect to the right
- (b) deflect to the left
- (c) turn 180°
- (d) remain unaffected

(6)

10. The figure given below shows the phase relationship between voltage E and current I . Which of the following statements is true?



- (a) This phase relationship is for a resistor when AC is passed through it.
 - (b) This phase relationship is for a capacitor when AC is passed through it.
 - (c) This phase relationship is for an inductor when AC is passed through it.
 - (d) This phase relationship is for an L - C - R circuit.
11. Which of the following statements is true regarding the stability of a nucleus?
- (a) Binding energy alone determines nuclear stability.
 - (b) Binding energy per nucleon is a better indicator of nuclear stability than total binding energy.
 - (c) Neither binding energy nor binding energy per nucleon is related to nuclear stability.
 - (d) Only the number of protons and neutrons determine nuclear stability.

(7)

- 12.** Two long straight wires are set parallel to each other. Each carries the same current in the same direction and the separation between them is $2r$. The intensity of the magnetic field midway between them is

(a) $\frac{\mu_0 I}{r}$

(b) $\frac{4 \mu_0 I}{r}$

(c) zero

(d) $\frac{\mu_0 I}{4r}$

Answer the following questions :

1×4=4

- 13.** If the binding energy of an electron in the first orbit of hydrogen atom is 13.6 eV, then what is the binding energy in the orbit $n = 3$?

Or

A hydrogen atom initially in the ground level absorbs a photon which excites it to the $n = 4$ level. Determine the frequency of the photon.

- 14.** What is the fringe width in Young's double-slit experiment if a monochromatic ray of wavelength 5×10^{-5} cm falls on a double-slit separated by a distance of 0.025 mm and the screen is held at a distance of 5 cm?
- 15.** If the angle of minimum deviation of an equilateral prism is 39.5° , find the refractive index of the material of the prism.

(8)

- 16.** A parallel-plate capacitor of plate area 2 m^2 , separated by a distance of 1 mm is immersed in castor oil of dielectric constant 4.7. What is its capacitance?

Or

Two capacitors each charged with $4.8 \times 10^{-8} \text{ C}$ are connected in parallel to each other. If the potential difference of one of the capacitors is 12 V, calculate the total energy stored in both the capacitors.

SECTION—B

- 17.** Name the electromagnetic waves used for (a) treating cancer and (b) night vision. 2
- 18.** On connecting two resistances of 24Ω and 8Ω in parallel across a 12 V battery, a current of 1.5 A is seen to flow. What is the internal resistance of the cell? 2
- 19.** Derive an expression for the torque acting on an electric dipole when placed in a uniform electric field. 2
- 20.** Derive the expression $B = \frac{\mu_0 I}{2r}$ for the magnetic field due to a straight conductor, using Ampere's circuital theorem. 2

Or

What is the magnetic field at the centre of a current-carrying circular coil? Derive the expression.

(9)

21. Draw the binding energy per nucleon curve and in it, mark the positions of ${}^2_1\text{H}$ and Fe. $1+\frac{1}{2}+\frac{1}{2}=2$

Or

An α -particle and a proton are accelerated through the same potential difference. Find the ratios of their velocities. 2

SECTION—C

22. With the help of a diagram, explain the working of full-wave rectifier, using a p - n junction diode. $1+\frac{1}{2}+\frac{1}{2}+1=3$

Or

Draw the forward characteristic curve of a p - n junction diode. Explain the terms depletion region and barrier potential or junction potential. $1+1+1=3$

23. Considering the drift of electrons through a conductor under a potential difference, derive the expression $I = neAv_d$, where the symbols have their usual meanings. 3

Or

Derive Ohm's law from the expressions of drift velocity and current.

24. Derive an expression for the velocity of an electron in the n th orbit of a hydrogen atom according to Bohr. 3

Or

(a) State the postulates of Bohr's theory of hydrogen atom. 2

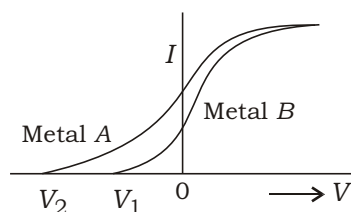
(b) Name the series of hydrogen spectrum lying in ultraviolet and visible region. $\frac{1}{2}+\frac{1}{2}=1$

25. Derive Lens Maker's formula, assuming the results for refraction from rarer to denser and denser to rarer across a convex surface. 3
26. With the help of a proper ray diagram, obtain an expression for the magnification produced by a simple microscope. 3
27. Using Biot-Savart law, find the expression for magnetic field at any point on the axis of a circular coil carrying current. 3
28. Show that $I_{\text{RMS}} = \frac{I_0}{\sqrt{2}}$ for an alternating current. 3

SECTION—D

29. Doping is a process of adding impurities of either of two specific types to a pure semiconductor. This is done specifically to produce a doped semiconductor having tailor-made properties to satisfy specific needs. The addition of an impurity having valency three produces *p*-type semiconductor and the addition of an impurity having valency five produces *n*-type semiconductor.
- (a) What would happen if instead of trivalent or pentavalent impurities, bivalent or hexavalent impurities respectively were added to obtain *p*-type or *n*-type semiconductors? Explain. 2
- (b) In *n*-type semiconductors electrons are majority charge carriers. Is an *n*-type semiconductor negatively charged? Explain. 2

30. In an experiment with two different photosensitive metals, the plot of photo-current (I) versus collector plate potential (V) was obtained as shown in the figure below. The frequency and intensity of incident light was constant :



- (a) What conclusion can be drawn about the work functions of metals A and B from the graph? Explain. 2
- (b) How would the stopping potential of metal A change if the intensity of incident light were increased? 1
- (c) How would stopping potential be affected if the frequency of incident light was increased? 1

SECTION—E

31. What are polar and non-polar dielectrics?

Find an expression for the capacity of a parallel-plate capacitor with plate separation d , in which a dielectric of dielectric constant K is inserted having thickness t d .

2+3=5

Or

- (a) What is an equipotential surface? Show that the work done in moving a charge from one point to another on an equipotential surface is zero.
- (b) Using Gauss' law, derive an expression for the electric field intensity at a point due to an infinitely long straight uniformly charged wire. 2+3=5

(12)

- 32.** In Young's double-slit experiment, obtain the conditions for constructive and destructive interference. $2\frac{1}{2}+2\frac{1}{2}=5$

Or

With the help of a proper ray diagram, obtain the expression for magnification produced by a compound microscope when final image is formed at least distance of distinct vision. $2+3=5$

- 33.** (a) With the use of a phasor diagram, derive an expression for the impedance of a series L - C - R circuit.
(b) What is power factor of an AC circuit? Write its mathematical expression. 5

Or

- (a) With the help of a schematic diagram, explain the theory and working of a transformer. Also show that transformation ratio K depends on the ratio of the number of turns in secondary to primary.
(b) What is copper loss in a transformer? $4+1=5$

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