17/1

2006

PHYSICS

Paper 1

Time : 3 Hours / */ Maximum Marks : 300*

INSTRUCTIONS

Candidates should attempt ***all*** *the questions in Parts A, B & C. However, they have to choose only* ***three*** *questions in Part D. The number of marks carried by each question is indicated at the end of the question.*

Answers must be written in English. Care should be taken not to exceed, as far as possible, the suggested limit of words.

SEAL

This paper has four parts :

A	20 marks
B	100 marks
C	90 marks
D	90 marks

Marks allotted to each question are indicated in each part.

Simple Scientific non-programmable type calculators are permitted.

PART A

$4 \times 5 = 20$

Answer each question in about 50 words. Each question carries 5 marks.

1. (a) What are the requirements for a force to be considered as a central force ? Give two important characteristics of motion under the action of a central force.

   (b) Briefly explain the Joule – Kelvin effect and its practical importance.

   (c) Give a brief description of the concept of mean free path and its variations with pressure.

   (d) Explain Rayleigh's criterion for the resolving power of an optical instrument.

PART B

10×10=100

Answer each question in about 100 words. Each question carries 10 marks.

2. Explain mass energy equivalence. Hence obtain the relativistic expression for the kinetic energy of a particle moving with a velocity v. Hence show that this expression reduces to the non-relativistic one for $v << c$.

3. An oxygen atom has a mass of $2{\cdot}65 \times 10^{-26}$ kg. The rotational inertia of an oxygen molecule about an axis passing through the centre perpendicular to the line joining the two atoms is $1{\cdot}94 \times 10^{-46}$ kg.m^2. At a certain temperature an oxygen molecule has a speed of 500 ms^{-1}. Assume that the molecule possesses rotational motion about the axis referred to above and that the rotational kinetic energy is two-third of its translational kinetic energy. Calculate its angular velocity.

4. Give Bernoulli's equation and explain the terms. Which general principle does it correspond to ? Briefly explain one simple application.

5. Distinguish between isothermal and adiabatic changes. Give typical PV plots for the two changes.

6. What is adiabatic demagnetization ? Explain how this process results in cooling.

7. Explain black body radiation and what are its characteristics. Starting with Planck's distribution for black body radiation, obtain Wien's displacement law.

8. Describe briefly circular polarization. Calculate the polarizing angles for light passing from water to glass and from air to glass, given that the refractive indices of water and glass are respectively 1·33 and 1·51.

9. Explain and distinguish between Fresnel and Fraunhofer diffraction.

10. What are plane and spherical waves ? Give their chief characteristics.

11. Explain Huygen's principle of secondary wavelets. Using this principle, illustrate the refraction of plane wave through a plane refracting surface.

PART C

6×15=90

Answer each question in about 150 words. Each question carries 15 marks.

12. (a) State and explain the two basic postulates of the special theory of relativity.

(b) What is Lorentz transformation ? Write down the simple transformation equations relating (x, t) and (x′, t′) in two reference frames moving relative to each other with a velocity along x-direction. Hence prove that $(ds)^2 = (dx)^2 - (c\,dt)^2$ is an invariant.

13. (a) Derive the relation between the period of revolution of a planet T and the semi-major axis a of its orbit around the Sun.

(b) A hypothetical planet has orbital radius of $6{\cdot}67 \times 10^6$ m and a mass of $4{\cdot}8 \times 10^{20}$ kg. Calculate the areal velocity in square km per hour. How many times in a year will the Sun, the Earth and the planet align in a line if the orbit of the planet and the Earth are in the same plane ?

14. (a) What is meant by a thermodynamic potential ? List the four important thermodynamic potentials.

(b) Using the above potentials, establish the following relations :

(i) $\left(\frac{\partial H}{\partial T}\right)_V = C_V + V\left(\frac{\partial P}{\partial T}\right)_V$

(ii) $\left(\frac{\partial T}{\partial P}\right)_H = \frac{1}{C_P}\left\{T\left(\frac{\partial V}{\partial T}\right)_P - V\right\}$

(iii) $C_P - C_V = T\left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial V}{\partial T}\right)_P$

15. (a) Discuss the salient features of the kinetic theory of gases.

(b) The mass of a hydrogen molecule is $3{\cdot}3 \times 10^{-24}$ g. 10^{23} molecules strike $2{\cdot}0$ cm^2 of a wall per second, at an angle of 45° to the normal with a speed of 1×10^5 cm s^{-1}. What is the pressure exerted on the wall ? If the above speed corresponds to the r.m.s. speed of the molecules, what temperature of the gas does it correspond to ?

16. (a) What is damped harmonic motion ? Develop the differential equation for the same. What are the characteristics of such motion ?

(b) A block having a mass 1·5 kg is suspended at the end of a spring with k = 8 $N.m^{-1}$. A light vane is attached to the bottom of the block and is immersed in water to provide damping force equal to $-bv$ where b = 230 gs^{-1}. Here v is the velocity. The block is pulled down by 12 cm and released. Calculate the time required for the amplitude to reduce to 4 cm. How many oscillations does the block execute in this time ?

17. (a) Explain the phenomenon of polarization. Distinguish between linear, circular and elliptical polarization.

(b) Describe one method to produce linearly polarized light.

PART D

3×30=90

*Answer any **three** of the following questions, each in about 300 words. Each question carries 30 marks.*

18. (a) Explain the two basic conservation laws governing the scattering process involving central forces.

(b) Discuss the concepts of impact parameter and scattering cross-section. Explain how the impact parameter is related to the scattering angle.

(c) Distinguish between laboratory and centre of mass co-ordinate systems, with regard to the velocities of the incident particle before and after the scattering in the two systems.

19. (a) Explain the concepts of angular momentum and torque. Derive the law governing the two quantities.

(b) What is a gyroscope ? Explain precessional motion.

(c) A uniform rod rotates in a horizontal plane about a vertical axis through one end. The rod is 6 m long, weighs 10·0 N and rotates at 240 rev/min. Calculate the rotational inertia of the rod about the axis of rotation and the angular momentum of the rod.

20. (a) What are the basic assumptions of Einstein's theory of specific heat of solids ?

(b) Develope the expression for the specific heat of a solid according to the Einstein model.

(c) What are the shortcomings of the Einstein model ? What was the modification effected in Debye model ?

21. (a) Write down the wave equation and explain the terms. What are harmonic solutions ?

(b) What is meant by superposition of waves ? Give the mathematical basis for this concept.

(c) What are the conditions to be satisfied for observing a stable interference pattern ? Explain how the fringe width in a double slit interference pattern varies with the wavelength of the light and the spacing between the slits.

22. (a) Discuss Fraunhofer diffraction of plane waves at a circular aperture and obtain the condition for obtaining a maximum and a minimum.

(b) Explain the concepts of spatial and temporal coherence.

(c) Give the working of a semiconductor diode laser.

17/2

2006

PHYSICS

Paper 2

Time : 3 Hours / */ Maximum Marks : 300*

INSTRUCTIONS

Candidates should attempt ***all*** *the questions in Parts A, B & C. However, they have to choose only* ***three*** *questions in Part D. The number of marks carried by each question is indicated at the end of the question.*

Answers must be written in English. Care should be taken not to exceed, as far as possible, the suggested limit of words.

SEAL

This paper has four parts :

A	20 marks
B	100 marks
C	90 marks
D	90 marks

Marks allotted to each question are indicated in each part.

Simple Scientific non-programmable type calculators are permitted.

PART A

$4 \times 5 = 20$

Answer each question in about 50 words. Each question carries 5 marks.

1. (a) Compare Gauss's divergence theorems in electrostatics and magnetostatics.

(b) What is Pauli's exclusion principle ? What is its important application ?

(c) Explain fine structure of spectral lines and its origin.

(d) Giving neat diagrams, describe the terms carrier wave and modulation.

PART B

10×10=100

Answer each question in about 100 words. Each question carries 10 marks.

2. Obtain the solution of Laplace's equation for a homogeneous dielectric sphere kept in a uniform electric field.

3. Explain Ampere's law in electromagnetism. Hence obtain an expression for the magnetic field inside a thick conductor carrying a current i.

4. Define Poynting's vector. Give an expression for the same and its significance. Can it be a null vector at any point in a region through which electromagnetic waves are passing ? Explain.

5. Describe the Stern – Gerlach experiment and interpret the result.

6. State and explain uncertainty principle. Given that the dimensions of the nucleus is 5 fermis and the maximum energies of beta particles emitted by radioactive nuclei are around 2 MeV, provide arguments to show that the electron cannot exist inside the nucleus prior to the decay process.

7. Write down and explain Kirchoff's laws. Prove that when a given current is divided between two resistances in accordance with these laws, the heat produced is a minimum.

8. Describe briefly the origin of a potential barrier in alpha decay. Explain three major differences between beta decay and alpha decay.

9. Both fusion of two light nuclei and fission of a heavy nucleus lead to release of energy. Explain why.

10. What is a thermistor ? Describe its working principle.

11. Give the truth table and symbol for a XOR gate. Explain how the XOR gate can be implemented using the basic gates.

PART C

6×15=90

Answer each question in about 150 words. Each question carries 15 marks.

12. (a) State and explain the two important laws governing electromagnetic induction.

(b) A rigid, straight wire of length L rotates about, but is insulated from, a straight, vertical wire carrying a current i. It rotates in a plane perpendicular to the current carrying conductor. Contact is made to the moving wire at the axle and also at the moving end by rails in the form of circular arcs. When the angular speed is ω, what is the induced emf in the wire ?

13. (a) Starting from Gauss's divergence theorem, derive Poisson's and Laplace's equations.

(b) Show that the tangential component of the electric field is continuous across a boundary whereas the normal component is discontinuous.

14. (a) Give the principle of working of a linear accelerator.

(b) What is the disadvantage of a linear accelerator ? Explain how this is overcome in a cyclotron.

15. (a) What are de Broglie waves ?

(b) Explain the concept of wave particle duality as applied to a photon, giving examples of the duality. Show that a photon of energy E has a momentum E/c.

16. (a) What is the origin of energy bands in solids ? Compare insulators, conductors and semiconductors.

(b) Explain the working of a solar cell.

17. (a) Explain the term binding energy as applied to a nucleus. On which important quantity does it depend and how ?

(b) For nuclei of a given mass number A, show that the actual mass of the nucleus follows a quadratic dependence on the atomic number Z. Hence explain why in such a set of isobaric nuclei, all except one will be unstable with respect to beta decay.

PART D

3×30=90

Answer any ***three*** *of the following questions, each in about 300 words. Each question carries 30 marks.*

18. (a) Derive an expression for the resonance frequency of a series LCR resonance circuit.

(b) With reference to a figure, describe how the impedance of such a circuit behaves as a function of frequency across the resonance.

(c) Explain the phase relations which exist between the voltages and currents across the components in the above circuit at resonance, below resonance and above resonance.

19. (a) State and explain Biot – Savart law.

(b) Using the above, obtain an expression for the magnetic field on the axis of a circular coil carrying a current.

(c) An overhead power cable with 50 m spans running due magnetic East-West carries direct current. What voltage will have to be applied across each span in order to render the cable self-supporting in the vertical plane and in which direction ?
(Given : Density of the material = $9{\cdot}2 \times 10^3$ kg m^{-3},
Resistivity = $1{\cdot}8 \times 10^{-8}$ ohm.m and Earth's field = 0·18 gauss).

20. (a) Describe the photoelectric effect and its important features.

(b) Discuss Einstein's photoelectric equation and how it explains the above features.

(c) The work function for zinc is $6{\cdot}8 \times 10^{-19}$ J. What is the threshold frequency for the ejection of a photoelectron from a zinc photocathode ? If light of wavelength 280 nm is incident on the cathode, calculate the stopping potential.

21. (a) Set-up the Schrodinger equation for a harmonic oscillator.

(b) Obtain the eigen functions and eigen values. Explain zero point motion.

(c) Bring out the importance of the wave function of a particle.

22. (a) Distinguish between intrinsic and extrinsic semiconductors. Explain n and p type materials and draw their energy level diagrams.

(b) What is a zener diode ? Draw its IV characteristics and explain the working.

(c) Explain why two back-to-back diodes cannot function as a transistor.