

**2005**  
**PHYSICS**  
**Paper 1**

*Time 3 Hours ]*

*[ Maximum Marks : 300*

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**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. are should be taken not to exceed, as far as possible, the suggested limit of words.*

*This paper has four parts :*

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|----------|-----------|
| <b>A</b> | 20 marks  |
| <b>B</b> | 100 marks |
| <b>C</b> | 90 marks  |
| <b>D</b> | 90 marks  |

*Marks allotted to each question are indicated in each part.*

*Simple Scientific non-programmable type calculators are permitted.*

**PART A**

4x5 = 20

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

1. (a) What was the negative result of the famous Michelson - Morley experiment ? What was the inevitable conclusion from the experiment ?
- (b) Write down and explain Clausius - Clapeyron equation with reference to vaporization of a liquid.
- (c) Explain Huygen's principle in wave optics.
- (d) What is population inversion and what is its importance in a laser.

**PART B**

10×10=100

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

12

What is a gyroscope ? Explain precessional motion of a gyroscope.

Explain Coriolis force and centrifugal force. What are the differences between them ?

Calculate the angular momentum of the earth (i) due to its rotational motion, and (ii) due to its motion around the sun. Given mass of earth =  $5.98 \times 10^{24}$  kg, radius =  $6.37 \times 10^3$  km and mean distance from the sun = 8.33 light minutes. What are the directions of these vectors ?

100

Write down and explain Maxwell's law for distribution of velocities of gas molecules. Establish the relation between the most probable velocity and the absolute temperature of the gas.

What is the usual unit in which the Planck's constant is expressed ? What is its magnitude ? Express the magnitude in units of MeV-sec. What would happen if the magnitude of  $h$  were much larger ?

Compare a dilute solution of the two isotopes of helium to a gas with regard to the important features of the two systems. Explain the principle of dilution refrigeration.

Describe the effect of damping on the amplitude, energy and frequency of oscillation in a simple harmonic oscillator.

What are beats and what is beat frequency ? When two tuning forks are sounded together 5 beats are heard. When one of them is loaded with wax, the beat frequency reduces to 4. What is the original frequency of the loaded tuning fork, if that of the unloaded one is 256 ?

Explain phase and group velocities. What is the relation between them ? Can any of these be larger than the velocity of light in vacuum ? If so, which one ?

What is stimulated emission of radiation ? Explain how this process causes light amplification in a laser.

## PART C

6×15=90

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

1. (a) Explain moment of inertia.  
(b) A hollow sphere of mass 3 kg and radius 0.15 m, with a moment of inertia  $0.04 \text{ kg.m}^2$  about its centre of mass, rolls without slipping up an inclined plane. The plane makes an angle  $30^\circ$  with the horizontal. At a certain initial position, the total kinetic energy of the sphere is 20 J.
  - (i) How much of this energy is rotational ?
  - (ii) What is the speed of the centre of mass at the initial position ?
  - (iii) What are the kinetic energy and the speed of the centre of mass after the sphere has rolled up 1 m from the initial position ?
2. (a) "Bernoulli's theorem is nothing but a statement of the law of conservation of energy in the context of fluid motion." Explain.  
(b) A liquid of density of  $800 \text{ kg m}^{-3}$  flows smoothly through a horizontal pipe which tapers in cross sectional area from  $1.2 \times 10^{-3} \text{ m}^2$  at one end to  $6 \times 10^{-4} \text{ m}^2$  at the other. The pressure head causing this flow is 4120 Pa. What is the volume rate of flow of the liquid ? What is the fluid velocity midway between the end points ?
3. (a) What are isothermal and adiabatic changes ? Explain thermodynamic potentials.  
(b) A gas is subjected to adiabatic expansion from an initial pressure of 200 atm to a final pressure of 1 atm. If the starting temperature was  $0^\circ \text{ C}$ , calculate the final temperature achieved. Given  $\gamma = 1.4$ .
4. (a) Bring out the meaning of the term "mean free path" for gas molecules. What are the factors on which this quantity depends.  
(b) The mean free path of oxygen molecules is 110 nm at NTP. The pressure is now reduced to one-third atmospheric pressure via an isothermal process. What is the new value of the mean free path ?

- i) Explain superposition of waves.
- ii) What are standing waves ? Show how nodes and antinodes are produced. Explain how standing waves are used to determine the wavelength.
- iii) Draw the relevant energy level diagrams and describe how LASER radiation is produced in a He-Ne laser. What is the wavelength ?

## PART D

3×30=90

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

1. (a) What is meant by central force ? Give the important features of motion under a central force.  
(b) Give a mathematical discussion of the central force problem of planetary motion, leading to Kepler's laws.  
(c) What are geostationary satellites ?
2. (a) Obtain the expression for the relativistic variation of mass with velocity.  
(b) Using the above, derive Einstein's mass energy relation.  
(c) Explain the concept of zero rest mass for the photon and the practical limit  $c$  for the velocity of any material particle.
3. (a) Explain resolving power of an optical instrument. What is Rayleigh's criterion for the resolving power ?  
(b) Obtain an expression for the resolving power of a diffraction grating.  
(c) A diffraction grating with  $1.5 \times 10^4$  rulings per inch is illuminated with light from a sodium vapour lamp. At what angle does first order maximum occur ? How close in wavelength can the two yellow lines be and still be resolved in first order ?
4. (a) Give two examples of physical quantities for which Planck's constant  $h$  is important. Explain.  
(b) Write down Planck's formula for black body radiation at an absolute temperature  $T$ . Show that under appropriate conditions this formula reduces to those of Rayleigh-Jean and Wien. Derive an expression for the wavelength of peak emission.  
(c) In the experimental spectrum of a fireball, approximated to a black body, the wavelength of peak emission is  $2.9 \text{ \AA}$ . Calculate the temperature  $T$  of the black body. Also calculate the corresponding value of  $kT$  in keV,  $k$  being Boltzmann constant.

- a) What is meant by polarization of light ? Explain the three types of polarizations.
- b) Explain what is the quarter wave plate. Hence describe how elliptically polarized light can be produced.
- c) A beam of unpolarized light is sent through two polarizing sheets placed one on top of the other. What is the angle between the polarizing directions of the sheets if the intensity of the transmitted light is to be 50% of that of the incident light ?

**2005**  
**PHYSICS**  
**Paper 2**

*Time : 3 Hours ]*

*[ Maximum Marks : 300*

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**INSTRUCTIONS**

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

*This paper has four parts :*

<b>A</b>	20 marks
<b>B</b>	100 marks
<b>C</b>	90 marks
<b>D</b>	90 marks

*Marks allotted to each question are indicated in each part.*

*Simple Scientific non-programmable type calculators are permitted.*

**PART A**

4×5=20

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

- I. (a) "A test charge cannot be kept in stable equilibrium under the action of electrostatic forces alone." Prove the statement.
- (b) Can a free electron absorb an incident photon via photoelectric effect ? Give valid reasons for your answer.
- (c) Explain how a large amount of energy is released both in the fission of a heavy nucleus and in the fusion of two light nuclei.
- (d) Two pn diodes are connected back-to-back and the combination used as a transistor. Will it work ? Explain.

## PART B

10×10=100

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

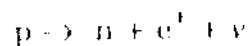
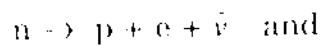
1. A pith ball of mass  $m$ , is covered with a tin sheet and suspended by a fine silk thread in a region where a uniform electric field  $E$  exists. The ball is given a charge  $+q$  coulombs. The ball is found to be displaced by a distance  $d$  from the vertical. If  $l$  is the length of the silk thread, obtain an expression for  $E$ .
2. Discuss the variation of the impedences of a capacitor and an inductance in an LCR circuit as the input frequency is varied across the resonance, from very low values to very high values. What is the role of the resistance?
3. What are magnetic domains? Explain their role in the hysteresis phenomenon in a ferromagnetic material.
4. Illustrate the origin of discrete spectral lines of an atom and explain spectral terms.
5. What are De Broglie waves? Calculate the De Broglie wavelength of neutrons (mass = 1.00867 amu) having an energy of 0.5 eV. Compare this with the first Bohr radius  $a_0$ .
6. Explain the concept of half life of a radioactive nucleus. In a certain experiment 100 grams of a radioactive material was used to start with. After 16 hours, it was observed that only 1.5625 grams of the radioactive material remained. Obtain the value of the decay constant and hence the half life.
7. The drift tubes in a linear accelerator are of increasing lengths. Explain. Is there any case where the tubes are, in fact, approximately of the same lengths? Give reasons for your answer.
8. The Schrodinger equation for a physical system is given by  $\frac{d^2\psi}{dx^2} = -k^2\psi$ . What are the possible solutions? Explain mathematically how  $k$  becomes quantized.
9. What is the depletion region in a pn junction and how does it form? What are the factors on which it depends?
10. Explain how a NAND gate using diodes works. Show how an OR gate can be constructed using NAND gates.

## PART C

6×15=

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

1. Twelve wires, each having the same resistance  $R$  form a cube. Apply Kirchoff's laws to calculate the effective resistance across two diagonally opposite corners.
2. State and explain Biot - Savart law. Use it to obtain the expression for the magnetic field due to a wire of length  $l$  bent into an arc of a circle of radius  $r$ , at the centre of the arc.
3. In the theory of alpha decay, it is assumed that the alpha particle already exists as an entity within the nucleus prior to the decay. Using uncertainty principle, show that this picture is consistent with typical energies of the alpha particles, which are of the order of a few MeV. Show also that the electron cannot pre-exist within a nucleus prior to beta decay.
4. What are the allowed values for the quantum number for a particle in a box? What is the relevance of the quantum number with regard to the energy and the wave function of the particle? Under what conditions can the particle be treated classically?
5. The two beta decay processes are represented by the equations



The above processes take place inside the nucleus. Group the particles involved in the above processes into the well known elementary particle groups. Explain why a free neutron can undergo the decay as given above whereas a free proton cannot.

6. What is a Zener diode? Explain the breakdown process in such a diode. What is the practical application?

## PART D

3×30=90

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

- 1) State and prove Gauss' theorem in electrostatics. Hence obtain Poisson's equation.
- 2) "Poisson's equation gives more information than Gauss theorem." Prove or disprove this statement.
- 3) Consider the two cases : (i) infinitely long conducting cylinder of surface charge distribution  $\sigma$ , and (ii) infinitely long dielectric cylinder of same surface charge density  $\sigma$ . Both cylinders have the same radii  $r$ . Calculate the intensity of the electric field at the surface of each cylinder. Does your answer depend on the value of  $r$ ?
- 4) Write down Maxwell's equations in electromagnetism. Which are the well known theorems from which these equations are derived?
- 5) What was Maxwell's own contribution in the above equations? Explain with an illustration of a physical situation.
- 6) Obtain the wave equation in free space, starting from Maxwell's equations.
- 7) What is meant by electron spin? Explain the direction of the magnetic moment associated with the electron spin.
- 8) Elaborate the idea of spin-orbit interaction and show how this leads to the j-j coupling.
- 9) Give the distribution of the electrons in the various subshells in the ground state of a boron atom. Hence obtain the spectroscopic term.

4. (a) Explain the principle of a cyclotron.
  - (b) Obtain an expression for the cyclotron frequency and the maximum energy of the particles which come out of a cyclotron at a radius  $R$ . Do these quantities depend on the amplitude of the RF voltage? Explain.
  - (c) Explain what happens when one tries to accelerate electrons in a cyclotron.
5. (a) Draw and explain the complete characteristic curve of a pn diode.
  - (b) Illustrate the rectifying action of a diode.
  - (c) A simple rectifier circuit consists of a diode, a resistance  $R$  and a power supply  $V = V_0 \sin \omega t$ . Assume the forward and reverse resistance of the diode to be  $R_f$  and  $R_b$ , respectively. Obtain an expression for the power dissipated in  $R$  as a function of time. Also, plot this as a function of time for one cycle.