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PHYSICS

FIRST PAPER

Full Marks : 200

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **all** questions

Use of non-programmable calculators allowed

GROUP—A

1. (a) Define moment of inertia of a body. Derive an expression for the moment of inertia of a thin spherical shell about a diameter. 2+8=10
- (b) A sphere, a disc and a ring of the same radius are allowed to roll from rest down an incline simultaneously from the same height without slipping. Prove that the sphere reaches down first, the disc next and the ring last. 10

Or

A solid sphere of mass 100 g and radius 2.5 cm rolls without sliding with

8/X—500/63

(Turn Over)

a uniform velocity of 10 cm per second along a straight line on a smooth horizontal table. Calculate its total energy and energy due to rotational motion. 5+5=10

2. (a) Describe an accurate method for the determination of the universal constant of gravitation G . Derive the formula used. 10

(b) Derive Kepler's third law of planetary motion starting from Newton's law of universal gravitation. 5

(c) Calculate the mass of the sun assuming that the earth revolves round the sun in a circular orbit of radius 1.49×10^{11} m in 365 days. Given $G = 6.66 \times 10^{-11}$ S.I. units. 5

Or

Show that the least velocity with which a body must be projected from the surface of a planet of radius R and mean density ρ in order that it may escape completely is $v = R\sqrt{(8\pi G\rho)/3}$. 5

3. (a) If the earth were a homogeneous sphere of radius R and a straight hole were bored through its center, show that a particle dropped into the hole will execute a simple harmonic motion. Find also its time period. 8+2=10

(3)

Or

A vertical U tube of uniform cross-section contains mercury up to height 20 cm. Show that if the liquid on one side is depressed and then released, its motion up and down the two sides of the tube is simple harmonic. Also calculate the time period. $8+2=10$

(b) Give the theory of a compound pendulum and show that the centres of suspension and oscillation are interchangeable. $7+3=10$

4. (a) Derive the relation connecting Young's modulus Y , bulk modulus K and the Poisson's ratio σ . What is the theoretical limit of the Poisson's ratio σ and why? $8+2=10$

(b) A uniform beam is fixed at one end and loaded at the other. Derive an expression for the depression of the loaded end. 10

Or

Derive Poiseuille's formula for the volume of a liquid flowing through a tube per second. What are the limitations of the formula? $8+2=10$

5. (a) Derive an expression for the excess pressure inside a spherical soap bubble. 8

Or

If a number of little droplets of water, all of the same radius r coalesce to form a single drop of radius R , show that the rise in temperature is given by

$$\frac{3T}{J} \left(\frac{1}{r} - \frac{1}{R} \right)$$

where T is the surface tension of water and J is the mechanical equivalent of heat. 8

- (b) Calculate the work done in blowing a soap bubble of radius 10 cm. What additional work is required in further blowing it so that the radius doubles? Given surface tension of soap solution $T = 30$ dyne/cm. 6

- (c) A copper wire is held at the two ends by rigid supports. At 30°C the wire is just taut with negligible tension. Find the speed of the transverse wave in the wire when the temperature is reduced to 10°C . Given $Y = 1.3 \times 10^{11} \text{ N/m}^2$, coefficient of linear expansion of copper $\alpha = 1.7 \times 10^{-5} /^\circ\text{C}$ and density of copper $\rho = 9 \times 10^3 \text{ kg/m}^3$. 6

(5)

GROUP—B

6. Obtain the condition that must be satisfied in order that a combination of two lenses of focal lengths f_1 and f_2 separated by a distance d be achromatic.

Calculate the focal length of a lens of flint glass of dispersive power 0.4 which will make an achromatic doublet with a converging lens of crown glass of focal length 0.4 m and dispersive power 0.2.

$$16+4=20$$

Or

With the help of a neat diagram, give the construction and working of a Huygens' eyepiece.

20

7. (a) Show that in the Newton's rings formed by reflected monochromatic light, the radii of the bright rings are proportional to the square root of odd natural numbers.

14

- (b) When a thin sheet of transparent material of thickness 7.2×10^{-6} m is introduced in the path of one of the interfering beams in Young's double-slit experiment, the central fringe shifts to a position occupied by the sixth bright fringe. If the wavelength of light used is $\lambda = 6 \times 10^{-7}$ m, find the refractive index of the material of the sheet.

6

8. (a) Explain what is meant by mean free path of molecules in a gas. Show that the mean free path of the gas molecules in thermal equilibrium is approximately given by $\frac{1}{n\pi\sigma^2}$, where n is the molecular density and σ is the molecular diameter.

4+6=10

Or

What do you mean by kinetic interpretation of temperature? Compute the average translational kinetic energy per molecule in a gas at room temperature and hence calculate the temperature needed to ionize a hydrogen atom. Given room temperature = 27 °C, Boltzmann constant $k = 1.38 \times 10^{-23}$ J/molecule/K and $1\text{eV} = 1.6 \times 10^{-19}$ J.

2+4+4=10

- (b) What is principle of equipartition of energy? Find an expression for the ratio of the specific heats of gases from equipartition theorem. How can you explain Dulong and Petit's law on specific heats of solids from the equipartition theorem?

2+4+4=10

9. From van der Waals' equation of state, obtain expressions for the critical temperature, critical pressure and critical volume in terms of the constants of van der Waals' equation. Show that for a van der Waals' gas $R = 8P_c V_c / (3T_c)$; where P_c , V_c and T_c are the critical values of pressure, volume and temperature respectively. 20

Or

Explain what you understand by the thermodynamic scale of temperature. Show that it agrees with an ideal gas scale. 20

10. Write short notes on any two from the following : 10×2=20

- (a) Brownian motion
- (b) Joule-Thomson effect
- (c) Fermi-Dirac statistics
- (d) Reversible and irreversible processes
