2015

(1st Semester)

PHYSICS

FIRST PAPER

(Mechanics and Thermodynamics)

[For 2014 (Repeaters) and 2015 Batch (Regulars)]

Full Marks : 55

Time : 2½ hours

(PART : B—DESCRIPTIVE)

(*Marks* : 35)

The figures in the margin indicate full marks for the questions

1. *(a)* Two particles of masses m_1 and m_2 separated by a distance r exert gravitational force on each other. If no other force acts on the system, show that the acceleration of centre of mass is zero and the velocity is constant. 5

(b) Suppose the Earth is revolving around the Sun in a circular orbit of radius one AU ($1 \cdot 5 \times 10^8$ km). Find the mass of the Sun.
(Given $G = 6 \cdot 67 \times 10^{-11}$ N m^2 kg^{-2}) 2

Or

A reference frame a rotates with respect to another reference frame b with an angular velocity $\vec{\omega}$. If the position, velocity and acceleration of a particle in frame a are represented by $\vec{r}$, $\vec{v}_a$ and $\vec{a}_a$, then show that the acceleration of the particle in frame b is given by

$$\vec{a}_b = \vec{a}_a + 2\vec{\omega} \times \vec{v}_a + \vec{\omega} \times (\vec{\omega} \times \vec{r}) + \frac{d\vec{\omega}}{dt} \times \vec{r}$$

Explain the significance of various terms in the above expression. 5+2=7

2. *(a)* Calculate the moment of inertia of a thin spherical shell about a diameter. 5

(b) Explain the terms 'moment of inertia' and 'radius of gyration'. 1+1=2

Or

(a) On the basis of Lorentz transformation, derive an expression for length contraction. 5

(b) The half-life of a particle at rest is $17 \cdot 8 \times 10^{-9}$ second. What will be the half-life when its speed is 0·8 c? 2

3. *(a)* Show that a shear is equivalent to an elongation strain and an equal compressional strain at right angles to each other and each is equal to half of the shearing angle. 4

(b) A cube of aluminium of side 10 cm is subjected to a shearing force of 100 N. The top surface of the cube is displaced by 0·01 cm with respect to the bottom surface. Calculate the shearing stress, shearing strain and modulus of rigidity. 1+1+1=3

Or

Derive an expression for the height h through which a liquid of surface tension T will rise in a capillary tube of radius r. What will happen if the length of the tube is smaller than h? 5+2=7

4. *(a)* Derive an expression for the pressure of a gas on the basis of kinetic theory of gases. 5

(b) At what temperature, pressure remaining constant, will the root-mean-square velocity of hydrogen be doubled that of its value at NTP? 2

Or

(a) Derive the reduced equation of state of a gas starting from van der Waals' equation of state. Hence explain the law of corresponding states. 3+2=5

(b) van der Waals' constants for a gas are $a = 6 \cdot 9 \times 10^{-2}$ J m^3 mole^{-2} and $b = 2 \cdot 9 \times 10^{-5}$ m^3 mole^{-1}. The universal gas constant $R = 8 \cdot 315$ J mole^{-1} K^{-1}. Calculate the critical temperature of the gas. 2

5. *(a)* Show that for an adiabatic change in a perfect gas PV^{γ} = constant, where γ is the ratio of specific heats. 4

(b) Derive an expression for work done by an ideal gas during an isothermal process. 3

Or

(a) Describe Carnot's cycle and calculate the work done per cycle. Hence deduce an expression for the efficiency of Carnot's reversible engine. 5

(b) Prove that all reversible engines working between the same two temperatures have the same efficiency. 2

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(PART : A—OBJECTIVE)

(*Marks* : 20)

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SECTION—I

(*Marks* : 5)

Put a Tick (✓) mark against the correct answer in the brackets provided : 1×5=5

1. Two masses M and m $(M > m)$ have the same momentum. If their speeds are small, M will have

(a) less kinetic energy than that of m ( )

(b) more kinetic energy than that of m ( )

(c) same kinetic energy as that of m ( )

(d) zero kinetic energy ( )

2. A rocket has a velocity 0·6 *c*. The velocity of light with respect to the rocket is

(a) 0·5 *c* ( )

(b) 1·6 *c* ( )

(c) 0·4 *c* ( )

(d) *c* ( )

3. Poisson's ratio cannot have the value

(a) 0·7 ( )

(b) 0·2 ( )

(c) 0·5 ( )

(d) 0·35 ( )

4. Molecules of an ideal gas have

(a) only potential energy ( )

(b) only kinetic energy ( )

(c) both kinetic energy and potential energy ( )

(d) neither kinetic energy nor potential energy ( )

5. Internal energy of a real gas depends upon

(a) only on temperature of the gas ( )

(b) only on volume of the gas ( )

(c) both on temperature and volume ( )

(d) only on pressure of the gas ( )

SECTION—II

(*Marks* : 15)

Write short answers to the following questions : 3×5=15

1. Using Newton's law, prove that the angular momentum is conserved for a particle moving under central force.

2. State and prove the theorem of parallel axes for moment of inertia.

3. Deduce the Stokes' formula $F = 6\pi\eta rv$ using the method of dimensions.

4. What considerations van der Waals led to modify the ideal gas equation?

5. Entropy of universe always increases. Explain.

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