2021

PHYSICS — HONOURS

Second Paper

(Group - A)

Full Marks : 50

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer ***question no.* 1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Prove that the total kinetic energy of a system of particles is equal to the kinetic energy of the centre of mass plus the kinetic energy of the particles with respect to the centre of mass.

(b) Write down Euler's equation of motion for a rigid body.

(c) A particle moves under the influence of a force $\vec{F}$ has instantaneous velocity $\vec{v}$. Show that $\frac{dT}{dt} = \vec{F}.\vec{v}$, where T is the kinetic energy.

(d) Assuming the sun as a black body, estimate the temperature of sun from the following data :

Angular diameter of sun from earth = 32 min, solar constant = $1{\cdot}356\ \text{Wm}^{-2}$, $\sigma = 5{\cdot}7\times10^{-8}\ \text{Wm}^{-2}\text{K}^{-4}$.

(e) Calculate the ratio $\frac{C_p}{C_v}$ for a linear triatomic gas molecule.

(f) What are transport phenomena? Indicate in each case the physical quantity that is transported.

2. (a) Show that the acceleration of a particle $\vec{a}$ which travels along a space curve with velocity $\vec{v}$ is given by, $\vec{a} = \frac{d\vec{v}}{dt}\hat{T} + \frac{v^2}{\rho}\hat{N}$, where $\hat{T}$ is the unit tangent vector to the space curve, $\hat{N}$ is the unit normal vector and ρ is the radius of curvature of the path.

(b) Define conservative force. Show that a force is conservative when there exists a scalar potential function corresponding to that force. 5+(2+3)

3. (a) A frame of reference rotates with uniform angular velocity $\vec{\omega}$. For this frame, establish the identity

$$\frac{d}{dt} = \frac{d'}{dt} + \vec{\omega}\times$$

(b) Hence, obtain expressions for centrifugal force and Coriolis force for the motion of a particle with respect to the rotating frame.

(c) A symmetric top, with one point fixed, is rotating about the axis of symmetry. Obtain the total energy of the system. 3+4+3

4. (a) For a uniform square plate of length a, find the (i) moments of inertia, (ii) products of inertia, (iii) principal moments of inertia.

(b) An xyz coordinate system is rotating with respect to an inertial coordinate system XYZ having the same origin (fixed in space). The angular velocity of the xyz system relative to the XYZ system is given by $\omega = 2t\hat{i} - t^2\hat{j} + (2t+4)\hat{k}$, where t is the time. The position vector of a particle at time t as observed in the xyz system is given by $r = (t^2+1)\hat{i} - 6t\hat{j} + 4t^3\hat{k}$. Find the apparent velocity and true velocity at time $t = 1$. (2+1+3)+4

5. (a) The probability of a gas molecule having velocity lying between u and $u + du$ in a definite direction is given by, $f(u)\,du = Ae^{-bu^2}$, where $A = \sqrt{\frac{m}{2\pi kT}}$ and $b = \frac{m}{2kT}$, symbols have their usual meanings. Using the above, derive Maxwell's speed distribution formula.

(b) Calculate average value of u and u^2. 6+2+2

6. (a) Define emissive and absorptive power of a body with respect to thermal radiation.

(b) A cylinder of fixed capacity 44.8 litres contains helium gas at standard temperature and pressure. What is the amount of heat needed to raise the temperature of the gas in the cylinder by 15.0ºC?

(c) Assume the earth's atmosphere is pure nitrogen in thermodynamic equilibrium at a temperature of 300K. Calculate the height above sea-level at which the density of the atmosphere is half the sea level. 2+4+4

7. (a) Establish Fourier equation for one-dimensional heat flow through a bar. Solve the equation in case of lagged bar (a bar where radiation loss is negligible).

(b) State Stefan–Boltzmann law of black body radiation.

(c) What do you mean by Boyle temperature of a real gas? Obtain an expression for it of a van der Waals gas. (3+2)+2+(1+2)