

Total number of printed pages-7

**3 (Sem-6/CBCS) PHY HE 5**

**2023**

**PHYSICS**

(Honours Elective)

Paper : PHY-HE-6056

**(Classical Dynamics)**

Full Marks : 80

Time : Three hours

**The figures in the margin indicate full marks for the questions.**

1. Answer the following questions :

1×10=10

(a) What is conservative force ?  
Give examples.

(b) A gas particle is moving inside a sphere, what will be the type of the constraint in it ?

(c) What will be the number of generalized coordinates of a system of  $N$  particles having  $k$  constraints of motion ?

Contd.





(d) Calculate the potential energy function associated with the force

$$\vec{F} = -yzi\hat{i} - zxj\hat{j} - xyk\hat{k}.$$

(e) Write down the equation of stable equilibrium of system executing small oscillations.

(f) Under what condition Galilean transformation reduces to Lorentz transformation ?

(g) Justify that the earth is not an inertial frame.

(h) State the basic postulates of relativity.

(i) What is critical velocity of a fluid ? Write down its expression in terms of Reynold's number.

(j) Define terminal velocity of an object falling through a fluid.

2. Answer the following questions :

2×5=10

(a) What are generalized coordinates ? If a generalized coordinate has the dimension of momentum, what would be the dimension of generalized velocity ?

- (b) Write the Lagrangian of a charged particle in an electromagnetic field, explaining each term.
- (c) Explain : (i) normal modes of vibration; (ii) normal coordinates and (iii) normal frequencies of a system which undergoes small oscillations.
- (d) 1 kg of a substance is fully converted into energy. Calculate the amount of energy produced.
- (e) Show that the velocity of flow is inversely proportional to the area of cross-section of the tube.

3. Answer the following : **(any four)**

5×4=20

- (a) Show that the path of a charged particle moving perpendicular to an uniform electric field is parabolic in nature.
- (b) Write down the Lorentz transformation equations and obtain Lorentz-Fitzgerald contraction formula.



(c) A massless spring of force constant  $k$  has masses  $m_1$  and  $m_2$  attached to its two ends. The system rests on frictionless horizontal plane. Show that the angular frequency of the system is

$$\sqrt{\frac{k}{\mu}} \text{ where } \mu = \frac{m_1 m_2}{m_1 + m_2}.$$

(d) What is relativistic energy? Show that the relativistic energy  $E$  of a particle is given by is  $E^2 = p^2 c^2 + m^2 c^4$ .

(e) Explain relativistic time dilation. A certain particle has a life time of  $10^{-6}$  sec when measured at rest. How far does it go before decaying if its speed is  $0.9c$  when it is created ( $c$  is the velocity of light in free space)?

(f) Obtain the equation of continuity for an incompressible fluid. An incompressible fluid is flowing through a pipe. If the diameter of the pipe is doubled, what change will occur to the velocity of the fluid?

4. Answer the following : *(any four)*

10×4=40

(a) Obtain Lagrange's equation of motion from D'Alembert's principle. Consider a particle of mass  $m$  moving in a plane in a central force field. Write its Lagrangian in plane polar co-ordinates. Write the equations of motion and obtain the differential equation of the orbit. 5+5=10

(b) Derive Hamilton's canonical equation of motion from Hamilton's principle of least action. A mass  $m$  is suspended by a massless spring of spring constant  $k$ . The suspension point is pulled upwards with constant acceleration  $a_0$ . Find the Hamiltonian of the system and Hamilton's equations of motion. Also find the equation of motion of the system. 5+5=10

(c) Deduce Newton's second law of motion from Hamilton's principle. Masses  $m$  and  $2m$  are connected by a light inextensible string which passes over a pulley of radius  $a$ . Write the Lagrangian and find the acceleration of the system. 5+5=10



(d) Derive the velocity addition theorem using four vectors. A particle of rest mass  $1.67 \times 10^{-27} \text{ kg}$  moves with a velocity  $\frac{c}{\sqrt{2}}$ . Calculate its relativistic momentum, kinetic energy and total energy. 6+4=10

(e) Establish Einstein's mass-energy equivalence principle  $E = mc^2$ . A pion decays into a muon and a neutrino. Show that momentum of muon is given

by 
$$p_{\mu} = \frac{c(m_{\mu}^2 - m_{\pi}^2)}{2m_{\pi}}.$$
 6+4=10

(f) State and explain relativistic transverse Doppler effect. Explain blue shift and red shift in Doppler effect. Calculate the wavelength shift in the relativistic Doppler effect for the frequencies  $H_{\alpha}$  line (6563 Å) emitted by a star receding from the earth with a relative velocity  $0.1c$ . Is the classical result (first order) a good approximation? 2+3+5=10

(g) Derive Poiseuille's equation for the rate of flow of fluid through a capillary tube. A tube of  $0.1\text{ cm}$  in diameter and  $40\text{ cm}$  long has to deliver  $20\text{ kg}$  water in  $25\text{ min}$ . Calculate the constant pressure head to be maintained. The coefficient of viscosity for water is  $8.9 \times 10^{-4}\text{ N-s-m}^{-2}$ .  
6+4=10

(h) What is Reynold's number? Mention various range of values of Reynold's number for different types of flow of fluid. Derive the Navier-Stokes equation for flow of a viscous fluid.  
1+3+6=10