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2021/TDC/CBCS/ODD/ PHSDSE–501T/157

TDC (CBCS) Odd Semester Exam., 2021 held in March, 2022

PHYSICS

(5th Semester)

Course No. : PHSDSE–501T

(Classical Dynamics)

Full Marks : 70
Pass Marks : 28

Time : 3 hours

The figures in the margin indicate full marks for the questions

SECTION—A

Answer any *twenty* of the following as directed : 1×20=20

1. Define centre of mass of a system of particles.
2. Can the centre of mass coincide with centre of gravity?
3. What do you mean by constrained motion?

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4. How much is the degree of freedom for N particles in free space?

5. Whether nuclear force is a central force or not?

6. Both Newton's equations and Lagrange's equations are valid only in inertial frames.
(Write True or False)

7. Can you define a Lagrangian uniquely?

8. What are generalized coordinates?

9. What is the importance of principle of virtual work?

10. Define virtual displacement.

11. Define canonical momenta.

12. Can you define Hamiltonian uniquely?

13. When does Hamiltonian equal to total energy of a system?

14. What is the order of Hamilton's equation of motion?

15. If one represents a central force as $\vec{F} = F(r)\hat{r}$, then the force is attractive, if

(a) $F(r) < 0$

(b) $F(r) > 0$

(c) $F(r) = 0$

(d) None of the above
(Choose the correct answer)

16. What do you mean by small oscillations?

17. Do small oscillations occur both in microscopic and macroscopic world?

18. What do you mean by state of equilibrium?

19. Give an example of metastable equilibrium.

20. What is secular equation?

21. What is Reynolds number?

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22. Define viscosity of a fluid.

23. What do you mean by vortices in connection to fluid motion?

24. What is the kinetic origin of viscosity?

25. Viscosity is a property of

(a) solids only

(b) liquids only

(c) solids and liquids

(d) liquids and gas

(Choose the correct answer)

SECTION—B

Answer any *five* of the following questions : 2×5=10

26. Show that the centre of mass of a body is a fixed point whatever be the coordinate system used.

27. Prove that the aerial velocity of the radius vector of a particle under a central force is constant.

28. Check whether the constraint given by the following equation is holonomic :

$$x\,dx + y\,dy + z\,dz - c^2 t\,dt = 0$$

29. Prove that if Lagrangian of a conservative system does not contain time explicitly, then the total energy is conserved.

30. A particle moves in a circular orbit about the origin under the action of a central force

$$\vec{F} = -\frac{K}{r^3}\hat{r}$$

If potential energy is 0 at infinity, find its total energy.

31. Explain basic difference between Lagrangian and Hamiltonian formulations in mechanics.

32. Define static and dynamic equilibrium.

33. Explain the difference between static and stable equilibrium citing one example.

34. Briefly compare the viscous properties of a liquid and a gas.

35. Explain the importance of Reynolds number.

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SECTION—C

Answer any *five* of the following questions : 8×5=40

36. *(a)* Find the expression of acceleration of centre of mass of a two-particle system. 5

(b) Three particles of masses 50 g, 100 g and 15 g are placed at the vertices of an equilateral triangle of side 1 m. Find the coordinate of centre of mass. 3

37. *(a)* Show that central force is a conservative force. 3

(b) In an attractive inverse square central field, the equation of motion of a particle is

$$\dot{\vec{p}} = -\left(\frac{k}{r^2}\right)\left(\frac{\vec{r}}{r}\right)$$

Show that the angular momentum $(\vec{L})$ is conserved and

$$\dot{\vec{p}} \times \vec{L} = mk\frac{d}{dt}\left(\frac{\vec{r}}{r}\right)$$

where m is the mass. 2+3=5

38. *(a)* State Hamilton's principle. 2

(b) Given

$$L = \frac{1}{2}e^{at}(\dot{x}^2 - p^2x^2)$$

where p is a constant. Using Lagrange's equation, prove that

$$\ddot{x} + a\dot{x} + p^2x = 0$$ 6

39. *(a)* Find the equation of motion of a simple pendulum using Lagrange's equation. Also find its time period. 3+2=5

(b) Write down the Lagrangian equation if the Lagrangian has the form $L = -\sqrt{1-\dot{q}^2}$. 3

40. *(a)* Prove that total energy of a particle of mass m acted upon by a central force is given by

$$E = \frac{L^2}{2m}\left[u^2 + \left(\frac{du}{d\theta}\right)^2\right] + V(r)$$

where $V(r)$ is the potential energy, L is the angular momentum, (r, θ) is the polar coordinate of the particle and $u = \frac{1}{r}$. 5

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(b) Prove that

$$\frac{dH}{dt} = \frac{\partial H}{\partial t}$$

where H is the Hamiltonian function. 3

41. (a) Given the Lagrangian

$$L = \frac{1}{2}m(\dot{r}^2 + r^2\dot{\theta}^2) - V(r)$$

Find the Hamiltonian and hence the equations of motion. 4

(b) Deduce Hamilton's equations of motion. 4

42. (a) Explain the following terms : 3

Normal frequency and Normal mode

(b) Discuss the stability of a simple pendulum and show that it can oscillate about the position of its stable equilibrium. 5

43. (a) Find the normal frequencies and normal coordinates for the Lagrangian given by

$$L = \frac{1}{2}(\dot{x}^2 + \dot{y}^2) - \frac{1}{2}(\omega_1 x^2 + \omega_2 y^2) - \alpha xy$$ 5

(Continued)

(b) A particle moves in a potential energy given by

$$V(x) = bx^2 + \frac{a}{x^2};\ a, b > 0$$

Find its frequency of oscillation. 3

44. (a) Define pressure in a fluid. What is the unit of pressure? Write few properties of pressure in a fluid. 1+1+2=4

(b) Show that the pressure at a depth h in a fluid is equal to the pressure outside the fluid plus the fluid pressure. 4

45. (a) Explain laminar and turbulent flow of fluids in detail. Give examples too. 4

(b) A water hose with a radius of 1 cm is used to fill a 20 litre bucket. If it takes 1 min to fill the bucket, what is the speed at which the water leaves the hose? (1 litre = 10^3 cm^3) 4

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