REV-01
BSP/10/15

2024/05

SET A

B.Sc. PHYSICS
FOURTH SEMESTER
CLASSICAL MECHANICS
BSP - 401

[USE OMR FOR OBJECTIVE PART]

Duration: 3 hrs. **Full Marks: 70**

(Objective)

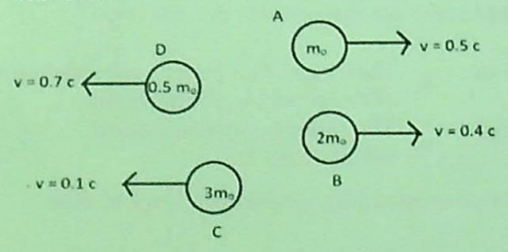
Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1×20=20***

1. According to Einstein's Special Theory of Relativity, laws of physics can be formulated based on _____
   a. Inertial Frame of Reference
   b. Non-Inertial Frame of Reference
   c. Both Inertial and Non-Inertial Frame of Reference
   d. Quantum State

2. A frame of reference has four coordinates, x, y, z, and t is referred to as the_____
   a. Inertial frame of reference
   b. Non-inertial frame of reference
   c. Space-time reference frame
   d. Three-dimensional plane

3. According to Einstein's special theory of relativity, which of these objects should be the heaviest?



   a. A
   b. B
   c. C
   d. D

4. In the case v << c, Lorentz transformation is the same as _____
   a. Einstein's transformation
   b. Galilean transformation
   c. Maxwell's transformation
   d. Planck's transformation

5. When a particle is moving with a velocity of light c relative to S, its velocity as observed by an observer in the frame S' is _____
   a. Zero
   b. 0.5 c
   c. 0.75 c
   d. c

6. The angular momentum is _____ in a central force field.
   a. Zero
   b. Not conserved
   c. Infinity
   d. Conserved

7. For circular orbit the value of eccentricity is _____
   a. $\epsilon > 1$
   b. $\epsilon \geq 1$
   c. $\epsilon < 1$
   d. $\epsilon = 0$

8. For elliptical orbit the values of energy E and eccentricity ϵ are _____
   a. $E = 0$ and $\epsilon > 1$
   b. $E > 0$ and $\epsilon > 1$
   c. $E < 0$ and $\epsilon < 1$
   d. $E > 0$ and $\epsilon = 0$

9. The areal velocity of a particle in a central force field is
   a. Zero
   b. Conserved
   c. Infinity
   d. Not conserved

10. A particle is moving under central force about a fixed center of force. Choose the correct statement:
   a. The motion of particle is always circular
   b. Its angular momentum is conserved
   c. Its KE remain constant
   d. Motion of the Particle is not in a plane

11. The principle of virtual work states that in equilibrium, the virtual work done by external forces on a system is equal to:
   a. The sum of kinetic and potential energy of the system.
   b. The kinetic energy of the system.
   c. The potential energy of the system.
   d. Zero.

12. In classical mechanics, generalized coordinates are preferred over cartesian coordinates because:
   a. They are not affected by the choice of reference frame
   b. They provide a better understanding of the system's configuration.
   c. They allow for easier visualization of the system's motion.
   d. They simplify mathematical calculations.

13. If a generalized coordinate is angle , the corresponding generalized force has the dimension of
   a. momentum
   b. force
   c. torque
   d. energy

14. For a particle constrained to move on the circumference of a circle, the required number of generalized coordinates are
   a. 1
   b. 2
   c. 3
   d. 4

15. Under what condition, a coordinate q_j is said to be cyclic in Lagrangian mechanics?
   a. When its partial derivative with respect to time is zero.
   b. When its conjugate momentum is zero.
   c. When the Lagrangian does not explicitly depend on it.
   d. When the kinetic energy is constant

16. For a system of n degrees of freedom, how many Lagrange equations are there?
    a. n
    b. $n-1$
    c. $n+1$
    d. $2n$

17. Which is the correct expression for the Lagrangian of a simple pendulum?
    a. $\frac{1}{2}mr^2\dot{\theta}^2$
    b. $\frac{1}{2}ml^2\dot{\theta}^2 + mgl\cos\theta$
    c. $-\frac{1}{2}mgl\cos\theta$
    d. $\frac{1}{2}kx^2$

18. In a system with rotational symmetry, what condition must be satisfied for the conservation of angular momentum according to Lagrange's equation?
    a. The Lagrangian must be dependent on linear momentum.
    b. The Lagrangian must be dependent on time.
    c. The Lagrangian must be independent of angular coordinates.
    d. The Lagrangian must contain dissipative force.

19. The product of generalized coordinate and its conjugate momentum has the dimension of
    a. force
    b. energy
    c. linear momentum
    d. angular momentum

20. Fill in the blank:
    In absence of a given component of applied _____ the corresponding component of angular momentum is conserved.
    a. Force
    b. torque
    c. acceleration
    d. energy

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(Descriptive)

Time : 2 hrs. 30 min. **Marks : 50**

[Answer question no.1 & any four (4) from the rest]

1. **a.** Show that the addition of any velocity to the velocity of light merely reproduces the velocity of light. **3+2+5 =10**

   b. Show that for velocity v<<c, Lorentz transformation reduces to Galilean transformations.

   c. Derive Lagrange's Equation from D'Alembert's principle for a conservative system.

2. **a.** Deduce Lorentz transformation equations for two inertial frames S and S'. **5+5=10**

   b. Derive Hamilton's canonical equations of motion for a system of particles.

3. **a.** Derive the Einstein's mass-energy equivalence relation. **7+3=10**

   b. If a rod travels with a speed 0.8c along its length (x-axis), calculate percentage contraction of its length.

4. **a.** Deduce the equation of motion and the first integral for a particle moving under a central force. **7+3=10**

   b. Consider a circular orbit in a central potential $V(r) = k/r^n$, where k >0 and 0<n<2. If the time period of circular orbit of radius R is T_1 and that or radius 2R is T_2. Find T_2/T_1.

5. State and prove Kepler's third law of planetary motion. **10**

6. **a.** State and prove the conservation theorem for linear momentum for a system of N particles. **7+3=10**

   b. The Lagrangian for a problem is

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

   Identify the cyclic coordinate and the corresponding conservation law for the problem.

7. **a.** Apply Lagrange's equation to find the equations of motion for a simple harmonic oscillator described by the Lagrangian $L = \frac{1}{2}m\dot{q}^2 - \frac{1}{2}kq^2$, where m is the mass and k is the spring constant. **5+3+2 =10**

b. The Lagrangian of a particle of mass m moving in a plane is given by $L = \frac{1}{2}m(v_x{}^2 + v_y{}^2) + a(xv_y - yv_x)$, where v_x and v_y are velocity components and a is a constant. Find the expressions for canonical momenta.

c. Explain the principle of virtual work.

8. **a.** Define Hamiltonian H. Give its physical significance. **2+4+4 =10**

b. Deduce the Hamiltonian function and Hamilton's equations for the following systems:
(i) Simple pendulum.
(ii) Motion of a particle in a central force field.

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