2024

(NEP–2020)

(2nd Semester)

PHYSICS (MAJOR)

(Mechanics, Properties of Matter and Oscillation)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. Transverse acceleration in plane polar coordinates (r, θ) is given by

   (a) $r\ddot{\theta} + \dot{r}\dot{\theta}$ ( )

   (b) $r\ddot{\theta} + 2\dot{r}\dot{\theta}$ ( )

   (c) $r\ddot{\theta} + \dot{r}^2\dot{\theta}$ ( )

   (d) $r\ddot{\theta} + 2\dot{r}^2\dot{\theta}$ ( )

[*Contd.*

2. A force $\vec{F}$ is said to be conservative, if

(a) $\nabla \cdot \vec{F} = 0$ ( )

(b) $\nabla \cdot \vec{F} \neq 0$ ( )

(c) $\nabla \times \vec{F} = 0$ ( )

(d) $\nabla \times \vec{F} \neq 0$ ( )

3. If the velocity of a moving object of rest mass m_0 approaches the speed of light c, then its mass

(a) $m \to 0$ ( )

(b) $m \to m_0$ ( )

(c) $m \to \infty$ ( )

(d) $m \to m_0 / c$ ( )

4. If the torque acting on a body is zero, then _____ is conserved.

(a) angular momentum ( )

(b) linear momentum ( )

(c) mass ( )

(d) kinetic energy ( )

5. The dimension of modulus of elasticity is equivalent to the dimension of

(a) stress ( )

(b) strain ( )

(c) Poisson's ratio ( )

(d) force ( )

6. The viscous force on a small sphere of radius r moving in a fluid is proportional to

(a) r^3 ( )

(b) r ( )

(c) $1/r$ ( )

(d) r^2 ( )

7. If the ratio of frequencies of two pendulums is 2 : 3, then their lengths are in the ratio

(a) $\sqrt{2/3}$ ( )

(b) $\sqrt{3/2}$ ( )

(c) 4 / 9 ( )

(d) 9 / 4 ( )

8. The quality factor (Q) is related to damping resistance (r) as

(a) $Q \propto r$ ( )

(b) $Q \propto \frac{1}{r}$ ( )

(c) $Q \propto r^2$ ( )

(d) $Q \propto \frac{1}{r^2}$ ( )

9. The velocity profile of a liquid flowing through a capillary tube is

(a) straight line ( )

(b) circular arc ( )

(c) hyperbolic ( )

(d) parabolic ( )

10. The kinetic energy of a body is equal to its rest mass energy, when its velocity v equals

(a) $\sqrt{2c}$ ( )

(b) $c / 3$ ( )

(c) $c / 2$ ( )

(d) $\sqrt{3}c / 2$ ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 15)

Answer *five* of the following in brief, taking at least *one* from each Unit : 3×5=15

UNIT—I

1. Show that Newton's first law of motion is simply a special case of Newton's second law of motion.

2. Show that the linear momentum of the system is constant when the external force acting on a system vanishes.

UNIT—II

3. Show that the linear momentum of a system of two particles is equal to the linear momentum of the centre of mass.

4. Show that acceleration is invariant under Galilean transformation.

UNIT—III

5. Show that the work done per unit volume $\left(\frac{W}{V}\right)$ in stretching a wire is $\frac{1}{2}$(stress × strain).

6. Show that for an incompressible fluid, the quantity of fluid entering one end of the pipe per second is same as leaving the pipe at the other end per second.

UNIT—IV

7. A simple harmonic oscillator is characterized by $y = a\cos\omega t$. Show that the kinetic energy is equal to the potential energy at $y = \pm\frac{a}{\sqrt{2}}$.

8. A spring and mass system consists of point masses 2 kg and 1 kg attached to the opposite ends of a spring of spring constant 200 N/m. If the system undergoes simple harmonic motion, calculate its natural frequency.

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer *five* of the following, taking at least *one* from each Unit : 10×5=50

UNIT—I

1. *(a)* Derive an expression for the gravitational potential and field for a solid sphere at a point *(i)* outside and *(ii)* inside a solid sphere. 5+2=7

(b) Discuss the effect of altitude on acceleration due to gravity g. 3

2. *(a)* A reference frame a rotates with respect to another reference frame b with angular velocity $\vec{\omega}$. If the position, velocity and acceleration of the particle in the reference frame a are $\vec{r}$, $\vec{v}_a$ and $\vec{a}_a$ respectively, then derive an expression for the acceleration $\vec{a}_b$ of the particle in the frame b. 7

(b) If $x = r\cos\theta$ and $y = r\sin\theta$, prove that $\dot{r} = \frac{x\dot{x} + y\dot{y}}{r}$ and $r\dot{\theta} = \frac{x\dot{y} - y\dot{x}}{r}$. 3

UNIT—II

3. *(a)* State and prove the theorem of parallel axes for moment of inertia. 3

(b) Calculate the moment of inertia of a solid cylinder about *(i)* its axis of cylindrical symmetry and *(ii)* an axis passing through its centre and perpendicular to its axis of symmetry. 7

4. *(a)* State and explain the fundamental postulates of special theory of relativity. 3

(b) Write down Lorentz transformation equations. Hence derive an expression for *(i)* length contraction and *(ii)* time dilation. 7

UNIT—III

5. *(a)* Derive the relation $\frac{9}{Y} = \frac{1}{K} + \frac{3}{\eta}$ connecting the three elastic constants. 7

(b) For two cylinders having same mass, length and made of same material, show that a hollow cylinder is stronger than a solid cylinder. 3

6. *(a)* State and prove Bernoulli's theorem for a fluid in streamline motion. 1+4=5

(b) Derive an expression for the height h through which a liquid of surface tension T will rise in a capillary tube of radius r. 5

UNIT—IV

7. *(a)* Derive an expression for the time period of a compound pendulum, hence obtain the condition for time period to be minimum. 4+2=6

(b) Set up the differential equation of motion and calculate the time period of oscillation for a mass m suspended from a spring of stiffness k executing SHM. What happens to the time period, if a stiffer spring of stiffness k' ($k' > k$) is used? 3+1=4

8. *(a)* Calculate the resultant of two simple harmonic vibrations of same frequency acting along the same line but differing in phase. What is the resultant amplitude when phase difference is $\pi / 2$? 3+1=4

(b) Obtain the condition for maximum amplitude in forced vibration. Discuss resonance and sharpness of resonance. 3+3=6

* * *

2024

(NEP–2020)

(2nd Semester)

PHYSICS (MAJOR)

(Mechanics, Properties of Matter and Oscillation)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. Transverse acceleration in plane polar coordinates (r, θ) is given by

(a) $r\ddot{\theta} + \dot{r}\dot{\theta}$ ( )

(b) $r\ddot{\theta} + 2\dot{r}\dot{\theta}$ ( )

(c) $r\ddot{\theta} + \dot{r}^2\dot{\theta}$ ( )

(d) $r\ddot{\theta} + 2\dot{r}^2\dot{\theta}$ ( )

2. A force $\vec{F}$ is said to be conservative, if

(a) $\nabla \cdot \vec{F} = 0$ ( )

(b) $\nabla \cdot \vec{F} \neq 0$ ( )

(c) $\nabla \times \vec{F} = 0$ ( )

(d) $\nabla \times \vec{F} \neq 0$ ( )

3. If the velocity of a moving object of rest mass m_0 approaches the speed of light c, then its mass

(a) $m \to 0$ ( )

(b) $m \to m_0$ ( )

(c) $m \to \infty$ ( )

(d) $m \to m_0 / c$ ( )

4. If the torque acting on a body is zero, then _____ is conserved.

(a) angular momentum ( )

(b) linear momentum ( )

(c) mass ( )

(d) kinetic energy ( )

5. The dimension of modulus of elasticity is equivalent to the dimension of

(a) stress ( )

(b) strain ( )

(c) Poisson's ratio ( )

(d) force ( )

6. The viscous force on a small sphere of radius r moving in a fluid is proportional to

(a) r^3 ( )

(b) r ( )

(c) $1/r$ ( )

(d) r^2 ( )

7. If the ratio of frequencies of two pendulums is 2 : 3, then their lengths are in the ratio

(a) $\sqrt{2/3}$ ( )

(b) $\sqrt{3/2}$ ( )

(c) 4 / 9 ( )

(d) 9 / 4 ( )

8. The quality factor (Q) is related to damping resistance (r) as

(a) $Q \propto r$ ( )

(b) $Q \propto \frac{1}{r}$ ( )

(c) $Q \propto r^2$ ( )

(d) $Q \propto \frac{1}{r^2}$ ( )

9. The velocity profile of a liquid flowing through a capillary tube is

(a) straight line ( )

(b) circular arc ( )

(c) hyperbolic ( )

(d) parabolic ( )

10. The kinetic energy of a body is equal to its rest mass energy, when its velocity v equals

(a) $\sqrt{2c}$ ( )

(b) $c / 3$ ( )

(c) $c / 2$ ( )

(d) $\sqrt{3}c / 2$ ( )

(SECTION : B—SHORT ANSWERS)

(*Marks* : 15)

Answer *five* of the following in brief, taking at least *one* from each Unit : 3×5=15

UNIT—I

1. Show that Newton's first law of motion is simply a special case of Newton's second law of motion.

2. Show that the linear momentum of the system is constant when the external force acting on a system vanishes.

UNIT—II

3. Show that the linear momentum of a system of two particles is equal to the linear momentum of the centre of mass.

4. Show that acceleration is invariant under Galilean transformation.

UNIT—III

5. Show that the work done per unit volume $\left(\frac{W}{V}\right)$ in stretching a wire is $\frac{1}{2}$(stress × strain).

6. Show that for an incompressible fluid, the quantity of fluid entering one end of the pipe per second is same as leaving the pipe at the other end per second.

UNIT—IV

7. A simple harmonic oscillator is characterized by $y = a\cos\omega t$. Show that the kinetic energy is equal to the potential energy at $y = \pm\frac{a}{\sqrt{2}}$.

8. A spring and mass system consists of point masses 2 kg and 1 kg attached to the opposite ends of a spring of spring constant 200 N/m. If the system undergoes simple harmonic motion, calculate its natural frequency.

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer *five* of the following, taking at least *one* from each Unit : 10×5=50

UNIT—I

1. *(a)* Derive an expression for the gravitational potential and field for a solid sphere at a point *(i)* outside and *(ii)* inside a solid sphere. 5+2=7

(b) Discuss the effect of altitude on acceleration due to gravity g. 3

2. *(a)* A reference frame a rotates with respect to another reference frame b with angular velocity $\vec{\omega}$. If the position, velocity and acceleration of the particle in the reference frame a are $\vec{r}$, $\vec{v}_a$ and $\vec{a}_a$ respectively, then derive an expression for the acceleration $\vec{a}_b$ of the particle in the frame b. 7

(b) If $x = r\cos\theta$ and $y = r\sin\theta$, prove that $\dot{r} = \frac{x\dot{x} + y\dot{y}}{r}$ and $r\dot{\theta} = \frac{x\dot{y} - y\dot{x}}{r}$. 3

UNIT—II

3. *(a)* State and prove the theorem of parallel axes for moment of inertia. 3

(b) Calculate the moment of inertia of a solid cylinder about *(i)* its axis of cylindrical symmetry and *(ii)* an axis passing through its centre and perpendicular to its axis of symmetry. 7

4. *(a)* State and explain the fundamental postulates of special theory of relativity. 3

(b) Write down Lorentz transformation equations. Hence derive an expression for *(i)* length contraction and *(ii)* time dilation. 7

UNIT—III

5. *(a)* Derive the relation $\frac{9}{Y} = \frac{1}{K} + \frac{3}{\eta}$ connecting the three elastic constants. 7

(b) For two cylinders having same mass, length and made of same material, show that a hollow cylinder is stronger than a solid cylinder. 3

6. *(a)* State and prove Bernoulli's theorem for a fluid in streamline motion. 1+4=5

(b) Derive an expression for the height h through which a liquid of surface tension T will rise in a capillary tube of radius r. 5

UNIT—IV

7. *(a)* Derive an expression for the time period of a compound pendulum, hence obtain the condition for time period to be minimum. 4+2=6

(b) Set up the differential equation of motion and calculate the time period of oscillation for a mass m suspended from a spring of stiffness k executing SHM. What happens to the time period, if a stiffer spring of stiffness k' $(k' > k)$ is used? 3+1=4

8. *(a)* Calculate the resultant of two simple harmonic vibrations of same frequency acting along the same line but differing in phase. What is the resultant amplitude when phase difference is $\pi / 2$? 3+1=4

(b) Obtain the condition for maximum amplitude in forced vibration. Discuss resonance and sharpness of resonance. 3+3=6

★ ★ ★