



WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 1st Semester Examination, 2022-23

PHSACOR02T-PHYSICS (CC2)

MECHANICS

Time Allotted: 2 Hours

Full Marks: 40

*The figures in the margin indicate full marks.**Candidates should answer in their own words and adhere to the word limit as practicable.**All symbols are of usual significance.***Question No. 1 is compulsory and answer any two from the rest**1. Answer any *ten* questions from the following:

2×10 = 20

- (a) What is geostationary satellite? What is its time period of revolution?
- (b) A solid sphere and a solid cylinder having same mass and same radii roll down an inclined plane without slipping. Show that the sphere will reach the bottom first.
- (c) Show that theoretically Poisson's ratio lies between -1 and 0.5.
- (d) Show that Lorentz transformation leads to Galilean transformation when the relative velocity (v) is much less than the velocity of light (c).
- (e) Prove that the force field,

$$\vec{F} = (yz - y)\hat{i} + (xz - x - 1)\hat{j} + (xy - 2z)\hat{k}$$
 is conservative. Department of Physics
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- (f) Prove that Kepler's first and second laws lead to the conservation of angular momentum.
- (g) What is Coriolis force? Write down an expression for this force in terms of the angular velocity of the rotating frame of reference.
- (h) What do you understand by the terms "proper length of a body" and "proper time"?
- (i) What do you understand by Quality factor (Q)? Give brief explanation.
- (j) A bar pendulum oscillates about a point 15 cm away from its C.G., with a period of 1 sec. Calculate the distance between the C.G. and centre of oscillation.
- (k) A particle moves along the curve $r = ae^{\theta}$ with constant angular velocity. Show that the radial acceleration is zero and the cross-radial acceleration varies with its distance from the origin.
- (l) Using Newton's law of gravity, determine the dimension of the universal Gravitational constant.
- (m) Calculate the angular momentum $\vec{L}$ of a rigid body spinning steadily about a fixed axis with angular velocity $\vec{\omega}$. Are the directions of $\vec{\omega}$ and $\vec{L}$ necessarily the same? Explain.
- (n) A flat plate of area $2 \times 10^{-2} \text{ m}^2$ is separated from a large flat surface by a film of oil of uniform thickness $1.5 \times 10^{-3} \text{ m}$ and viscosity $2 \text{ N}\cdot\text{s}/\text{m}^2$. Determine the force required to slide the plate over the surface at a velocity of $4.5 \times 10^{-2} \text{ m/s}$.

2. (a) Derive the continuity equation for fluid motion, clearly describing the notations used. 4

(b) Establish the expression for the internal bending moment of a beam. 3

(c) A metal rod of length L and cross-section α suffers a small longitudinal strain and is stretched by l in length. Show that the potential energy stored in the rod due to this strain is $\frac{Y\alpha l^2}{2L}$, where Y is the Young's modulus of the material. 3

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3. (a) Show that the differential equation of motion of a particle of mass ' m ' under the influence of a central force $F(r)$ can be written as 4

$$\frac{d^2 u}{d\theta^2} + u = -\frac{m}{L^2 u^2} F\left(\frac{1}{u}\right),$$

where L is the angular momentum and $u = \frac{1}{r}$, r and θ being the polar coordinates.

(b) Show that under a central force, the total energy of the system remains constant. 3

(c) Two balls of masses m and $3m$ moving with velocities of equal magnitude but opposite direction undergo linear elastic collision. Find the final velocities of the two balls. 3

4. (a) Prove that the total angular momentum of a system of particles about any point is the sum of the angular momentum of the total mass assumed to be located at the centre of mass and the total angular momentum of the system about the centre of mass. 4

(b) Solve the equation of motion of a simple harmonic oscillator subject to the following forces: 3

(i) a damping force which is proportional to velocity and

(ii) an external sinusoidal force.

(c) Show that the self gravitational potential energy of a uniform sphere of mass M and radius R is $-\frac{3}{5} \frac{GM^2}{R}$. 3

5. (a) State the postulates of Galilean relativity and special relativity. 3

(b) Two reference frames S_1 and S_2 are moving with a uniform velocity ' v ' relative to each other. If ' u_1 ' and ' u_2 ' are velocities of a body in the two frames respectively, then using Lorentz transformation equations, show that, 4

$$u_1 = \frac{u_2 + v}{1 + \frac{u_2 v}{c^2}},$$

where ' c ' is the velocity of light.

(c) Quality Factor for a damped oscillator is 10^3 . Its frequency is 512 Hz. Find the time taken for its energy to get reduced to $1/e$ of its energy in the absence of damping. 3

How many oscillations are executed during this time?

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B.Sc. Honours 1st Semester Examination, 2021-22

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Question No. 1 is compulsory and answer any two from the rest

1. Answer any **ten** questions from the following: 2×10 = 20

- (a) Show that Newton's 2nd law is invariant under Galilean transformation.
- (b) An object of mass m slides on the surface of a block, whose coefficient of friction is μ . Initially, the speed of the block is v_0 and it comes to rest after travelling a distance x_0 . Find the value of μ .

- (c) Determine whether the force field,

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$$\vec{F} = (y^2z^3 - 6xz^2)\hat{i} + (2xyz^3)\hat{j} + (3xy^2z^2 - 6x^2z)\hat{k}$$

is "conservative" or not.

- (d) Calculate the angular momentum of a rigid body spinning steadily about a fixed axis with angular velocity $\vec{\omega}$. Are the direction of $\vec{\omega}$ and $\vec{L}$ necessarily the same? Explain.
- (e) Find the moment of inertia of a solid circular cylinder of radius a , height h and mass M , about an axis passing through the center of the cylinder and parallel to its height.
- (f) Show that the areal velocity of a particle moving under central force is constant.
- (g) State Kepler's law of planetary motion.
- (h) What is Reynolds number? What is the significance of it?
- (i) A plate of area 200 cm^2 rests on a layer of castor oil 1 mm thick. The coefficient of viscosity of castor oil is 15.5 poise. Calculate the force required to move the plate horizontally with a speed of 4 cm/sec.
- (j) A rod of circular cross-section of length l and radius r is stretched such that the volume of the rod is not changed. Show that Poisson's ratio is $\frac{1}{2}$.

- (k) The potential energy of a particle is $V = 3x^4 - 8x^3 - 6x^2 + 24x$. Find the points of stable and unstable equilibrium.
- (l) What do you understand by Quality factor? What is its importance?
- (m) What is the 'apparent mass' of an object with 1 kg rest mass when it has been accelerated to 92.9% of light's speed. Speed of light, $c = 3 \times 10^8$ m/sec. Give your answer in kg.
- (n) A particle of mass 100 gm is placed in a field of potential $U = 5x^2 + 10$ ergs/gm. Find the frequency of small oscillations.
2. (a) A body is thrown at an angle with the horizontal. Prove that the mechanical energy is conserved at every point of its motion. 3
- (b) Write the general conditions for equilibrium of a system. What do you mean by stable and unstable equilibrium? 3
- (c) An upward force $F = 196$ Newton is applied on a body of mass 10 kg till it is raised vertically upwards by a distance of 10 meters. Here the work done by F is much greater than the gain in gravitational potential energy. Show that the law of conservation of energy is satisfied here ($g = 9.8 \text{ m/s}^2$). 3
- (d) Define the centre of mass of a body. 1
3. (a) Show that the torsional rigidity of a hollow cylinder of outer and inner radii r_1 and r_2 respectively is given by $\frac{n\pi(r_1^4 - r_2^4)}{2l}$, where l is the length of the cylinder and n is the modulus of rigidity of the material. 4
- (b) Show that for a body undergoing combined rotational and translational motion, the total angular momentum can be written as, $\vec{L} = \vec{L}_{CM} + M(\vec{r}_0 \times \vec{v}_0)$, where, $\vec{L}_{CM}$ is the angular momentum in the center of mass frame, $\vec{r}_0$ is position vector of the center of mass and $\vec{v}_0$ is the velocity of center of mass. 3
- (c) Find the diameter of a gold wire which elongates by 1 mm when stretched by a force of 330 gm-wt and twists through 1 radian when equal and opposite torques of 145 dyne - cm are applied at its ends. Poisson's ratio for gold is 0.435. 3
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4. (a) Derive Poiseuille's formula for the steady flow of an incompressible viscous liquid through a horizontal capillary tube of uniform cross section. 4
- (b) An artificial satellite is moving in a circular orbit 600 km above the surface of a planet of radius 5.85×10^3 km. The period of revolution of the satellite around the planet is 3.5 hours. Determine the average mass density of the planet. 3
- (c) Water flows through a horizontal tube of length 20 cm and internal radius of 0.081 cm under a constant head of the liquid 20 cm high. In 12 minutes 864 c.c. of liquid issue from the tube. Calculate the viscosity of water and verify that the conditions of streamline flow exist. Given $r = 1000$, ρ of water is 1 gm/cc and $g = 981 \text{ cm/s}^2$. 3

5. (a) What is length contraction? Obtain the expression for the relativistic length contraction from Lorentz transformation equation. 3
- (b) Draw the potential energy curve for a simple pendulum with respect to angular position ' θ ', clearly indicating the positions of stable and unstable equilibrium. 2
- (c) What are non-inertial frames and fictitious forces? Is the centrifugal force a fictitious one? Explain. 3
- (d) State the postulates of special theory of relativity. 2

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WEST BENGAL STATE UNIVERSITY
B.Sc. Honours 1st Semester Examination, 2020, held in 2021

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MECHANICS

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Question No. 1 is compulsory and answer any two from the rest

1. Answer any **ten** questions from the following: 2×10 = 20
- (a) A solid spherical ball rolls on a table. What fraction of its total kinetic energy is rotational?
 - (b) What is the significance of “quality factor”?
 - (c) A 5 kg stone is dropped on a nail and drives the nail 0.025 m into a piece of wood. If the stone is moving at 10 m/s, when it hits the nail, calculate the average force exerted by the stone on the nail.
 - (d) A particle of mass m is moving in a circular path of radius r such that its centripetal acceleration a varies with time t as $a = k^2 r t^2$, where k is a constant. Calculate the power delivered to the particle by the forces acting on it.
 - (e) A ball is dropped from a height h . When it bounces off the floor, its speed is 80% of what it was just before it hit the floor. Determine the height up to which the ball will now rise.
 - (f) Find the ratio of the radii of gyration of two objects, one of which is a solid sphere and the other is a thin spherical shell, both having same mass and same radius.
 - (g) A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-n}$, where β and n are constants, and x is the position of the particle. Obtain the acceleration of the particle as a function of x .
 - (h) What is the difference between angle of twist and angle of shear?
 - (i) What is a cantilever? What is its difference with an ordinary lever?
 - (j) A satellite of mass m orbits a planet of mass M in a circular orbit of radius R . Find out the time required for one revolution of the satellite around the planet.
 - (k) A wire of length L and radius r is elongated by applying a force. If the volume of the wire remains unchanged during the process, then determine the Poisson's ratio of the material of the wire.
 - (l) What are the differences between “streamline” flow and “turbulent” flow of fluid?
 - (m) Using Lorentz transformation relations express $(x^2 - c^2 t^2)$ in terms of transformed spacetime coordinates (x', t') .

- (n) A particle moves on the x -axis according to the equation $x = A + B \sin \omega t$. Show that this is a simple harmonic motion.
2. (a) In a nonrelativistic, one dimensional collision, a particle of mass $2m$ collides with a particle of mass m initially at rest. If the particles stick together after the collision, what fraction of the initial kinetic energy is lost in the collision? 3
- (b) The smallest and the largest speeds of a satellite are given by $v_{\min}$ and $v_{\max}$ respectively. The time period is T . Show that the semi major axis of the elliptic orbit is given by $\frac{T}{2\pi} \sqrt{v_{\min} v_{\max}}$. 3
- (c) A cylinder is released from rest from the top of an inclined plane of angle θ . If the cylinder rolls without slipping through a distance l , what will be its final speed? 4
3. (a) Derive the continuity equation for fluid motion, clearly describing the notations used. 4
- (b) The potential of an object is given by $U(x) = 5x^2 - 4x^3$. Determine the positions where the object is in equilibrium and find the nature of the equilibria. 2+2
- (c) If the speed of water in pipe with a diameter of 12 cm is 10 cm/s, what is the speed of water in a pipe with a diameter of 8 cm? 2
4. (a) State the postulates of Galilean relativity. State the postulates of special theory of relativity. 2+2
- (b) Two inertial frames S and S' move with respect to each other with a constant speed $0.8c$ along the common y -axis. Write down the Lorentz transformation equations between the S and S' frames. 3
- (c) Determine the theoretically admissible range of values of the Poisson's ratio. 3
5. (a) Determine the gravitational potential at a distance r from the centre, inside a homogeneous solid sphere of radius R and mass M . 4
- (b) For a damped harmonic oscillator the equation of motion is given by 2+2+2
- $$m \frac{d^2 x}{dt^2} + \gamma \frac{dx}{dt} + kx = 0$$
- Using the solution of the above equation, calculate
- The period of oscillation.
 - The number of oscillations in which its mechanical energy will drop to one-half of its initial value.
 - The quality factor.
- Given that $m = 0.25 \text{ kg}$, $\gamma = 0.7 \text{ kg/s}$ and $k = 85 \text{ N/m}$.

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B.Sc. Honours 1st Semester Examination, 2019

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MECHANICS

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Answer Question No. 1 and any two from the rest

2×10 = 20

1. Answer any **ten** questions from the following:

- (a) Find the equation of motion for center of mass vector of an isolated system consisting of two particles interacting under a central force.
- (b) A solid cylinder of mass 1 kg, length 20 cm and diameter 4 cm rotates about its own axis. Find the kinetic energy necessary to rotate the cylinder at 100 r.p.m.
- (c) Power supplied to a particle of mass 2 kg varies with time as $P = \frac{3t^2}{2}$ Watt (t in second). If velocity of the particle at $t = 0$ is zero. Find the velocity of the particle at $t = 2$ s.
- (d) A rocket is set for vertical projection. If the exhaust speed is 10^3 ms^{-1} , how much gas must be ejected per second to supply the thrust needed (i) to overcome the weight of the rocket (ii) to give the rocket an initial vertical upward acceleration of 19.6 ms^{-2} . Given mass of the rocket = $6 \times 10^3 \text{ kg}$.
- (e) Suppose the radius of gyration and the distance of the centre of mass of a body from the axis of rotation are ' k ' and ' R ' respectively. Explain which of them is bigger.
- (f) Differentiate clearly between inertial and non-inertial frame of reference.
- (g) A metal wire does not change its volume when stretched, find the value of the Poisson's ratio of the metal.
- (h) How much energy would have to be supplied to break up the earth completely (i.e. remove all masses to ∞).
- (i) The radius of the earth is 6400 km, its mean density is $5.62 \times 10^3 \text{ kg} \cdot \text{m}^{-3}$ and the Gravitational constant is 6.658×10^{-11} S.I. units. Calculate the potential at the earth's surface, assuming earth to be a solid sphere.
- (j) Show that areal velocity of a particle moving under central force is constant.
- (k) What do you understand by Quality factor (Q)? Give brief explanation.
- (l) A rod of length 1 m moves past an observer standing on the ground with velocity $3 \times 10^7 \text{ m/s}$, along the direction of its length. What is the apparent length of the rod with respect to the observer?
- (m) What do you understand by the terms "proper length of a body" and "proper time"?
- (n) Describe briefly about trilateration in the case of GPS system.

2. (a) Write down the expression of Newton's 2nd law of motion in an accelerated frame of reference. Give brief explanation of the terms involved. 2
- (b) Starting from Newton's law show that, 2

$$\int_{v_a}^{v_b} F(v) dv = \frac{1}{2} m v_b^2 - \frac{1}{2} m v_a^2$$

- (c) Two balls of masses m and $3m$ moving with velocities of equal magnitude but opposite direction undergo linear elastic collision. Find the final velocities of the two balls. 3
- (d) Define the centre of mass of a body. Show that it is unique for a body. 1+2
3. (a) Determine the moment of inertia of a solid cylinder of mass M , length L and radius R about the axis perpendicular to its length and passing through its centre of mass. 4
- (b) Two horizontal capillary tubes are connected together in series so that a steady stream of water flows through them. The first tube is 0.4 mm in internal radius and 256 cm long while the other is 0.3 mm in internal radius and 40 cm long. The pressure of water at the entrance is 8 cm of mercury above the atmosphere and that at the exit is atmospheric (76 cm of Hg). Calculate the pressure at the junction of the tube. 1
- (c) A horizontal wire of length $2l$ and cross-section α is tightly fixed to rigid supports at both ends. A weight W is suspended from the mid-point of the wire. Show that depression ' d ' of the mid-point is given by 3

$$d^3 = \frac{W l^3}{Y \alpha}$$

4. (a) A particle of mass m moves under the action of a central force whose potential is 4
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 $V(r) = kr^3 (k > 0)$
 For what energy and angular momentum will the orbit be a circular of radius a about the origin.
- (b) An artificial satellite circles around the earth in the plane of the equator concentric with earth in such a way that the direction of rotation of the satellite is same as the direction of rotation of the earth about its own axis. Find the expression for time-period of the revolution of the satellite. Sketch the appropriate figure. 4
- (c) Write down the expression for coriolis force. Describe the effect of coriolis force on moving bodies on earth. 2

5. (a) Find out the energy of a particle executing simple harmonic motion. 3
- (b) Write down the equation of motion of a damped harmonic oscillator and identify the damping factor. Graphically illustrate that how the energy of a damped oscillator varies with time. 2
- (c) Two reference frames S and S' are moving with a uniform velocity ' v ' relative to each other. If ' u ' and ' u' ' are velocities of a body in the two frames respectively, then using Lorentz transformation equations, show that, 5

$$u = \frac{u' + v}{1 + \frac{u'v}{c^2}}$$

' c ' is the velocity of light.

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