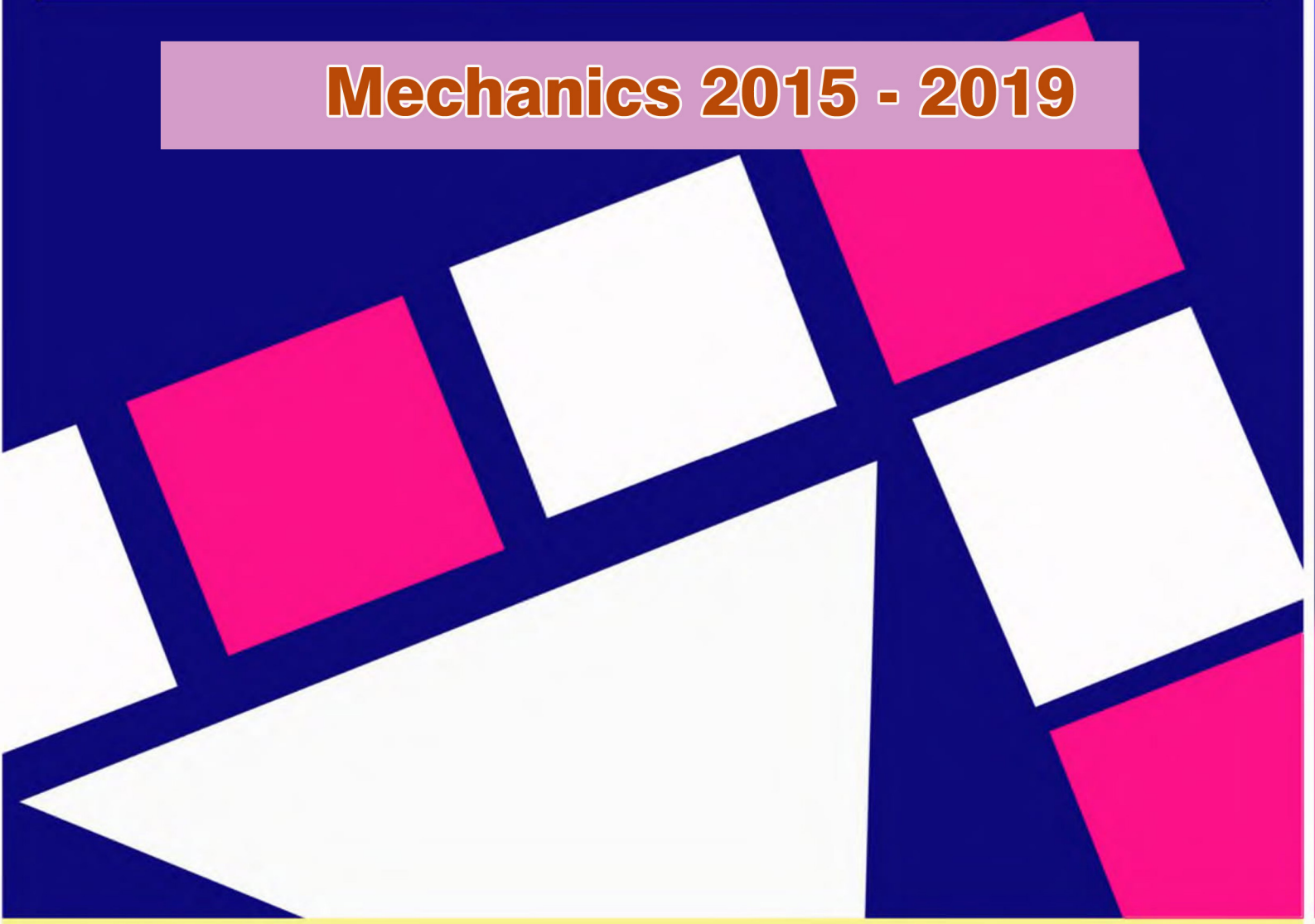
INDIANCIVILS.COM

Online IAS Academy

PHYSICS - Optional

By Venkanna Sir & Manpreeth Sir

Mechanics 2015 - 2019



UPSC – PHYSICS Optional – 2015 Questions

1. Write down precisely the conversation theorems for energy, linear momentum and angular momentum of a particle with their mathematical forms. **[10M]**

2. Prove mathematically that the addition of any velocity of a particle to the velocity of light in free space merely reproduces the velocity of light in free space only. **[10M]**

3. How does one obtain the angular velocity of the Earth about the North Pole with respect to a fixed star as $7.292 \times 10^{-5} sec^{-1}$? Explain your method of calculating the above value. **[10M]**

4. Using Poiseuille's formula, show that the volume of a liquid of viscosity coefficient η passing per second through a series of two capillary tubes of lengths l_1 and l_2 having radii r_1 and r_2 is obtained as $Q = \frac{\pi p}{8\eta} / \left[\frac{l_1}{r_1^4} + \frac{l_2}{r_2^4}\right]$, where p is the effective pressure difference across the series. **[15M]**

5. Show that the moment of inertia of a circular disc of mass M and its radius R about an axis passing through its centre and perpendicular to its plane is $\frac{1}{2}MR^2$. **[15M]**

6. Draw a neat diagram to explain the scattering of an incident beam of particles by a centre of force. **[10M]**

7. Show that the differential scattering cross section can be expressed as $\sigma(\theta) = \frac{s}{\sin\theta}\left|\frac{ds}{d\theta}\right|$, where s is the impact parameter and θ is the scattering angle. **[15M]**

8. Show that the rest mass energy of an electron is 0.51 MeV (use the standard values of the physical parameters). **[10M]**

9. Define coefficients of viscosity and kinematic viscosity of a fluid. What are poise and stokes? **[10M]**

10. Write down Poiseuille's formula and mention its limitations in analyzing the flow of a liquid through a capillary tube. **[10M]**

UPSC – PHYSICS Optional – 2016 Questions

1. (i) The distance between the centers of the carbon and oxygen atoms in the carbon monoxide (CO) gas molecule is 1.130×10^{-10} m. Locate the centre of mass of the molecule reactive to the carbon atom.

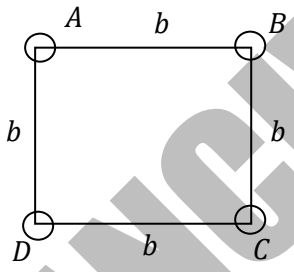
(ii) Find the centre of mass of a homogeneous semicircular plate of radius a.

[10M]

2. Derive the expression for Coriolis force and show that this force is perpendicular to the velocity and to the axis of rotation. What is the nature of this force? **[10M]**

3. Show that the Young's modulus Y, modulus of rigidity n and Poisson's ratio σ are related by the equation $Y = 2n(1 + \sigma)$. **[10M]**

4. Four solid spheres A, B, C and D, each of mass m and radius a, are placed with their centers on the four corners of a square of side b as shown in the figure below:



Calculate the moment of inertia of the system about a diagonal of the square. Also calculate the moment of inertia of the system about a diagonal of the square. **[20M]**

5. Calculate the percentage contraction in the length of a rod in a frame of reference, moving with a velocity 0.8c in a direction (i) parallel to its length and (ii) at an angle of 30^0 with its length. What is the orientation of the rod in the moving frame of reference in case (ii)? **[20M]**

6. A body moving in an inverse square attractive field traverses on elliptical orbit with eccentricity e and periodγ. Find the time taken by the body to traverse the half of the orbit that is nearer the centre of force. Explain briefly why a comet spends only 18% of its time on the half of its orbit that is nearer the sun. **[10M]**

7. A horizontal pipe of a non uniform bore has water flowing through it such that the velocity of flow is 40cm/sec at a point where the velocity of flow is 60cm/sec?(take g=980cm/sec^2 and density of water = 1g/c.c) **[10M]**

8. Given a proton for which β=0.995 measured in the laboratory. What is the corresponding relativistic energy and momentum?
Take, $m_p = 1.67 \times 10^{-24}$. **[10M]**

UPSC – PHYSICS Optional – 2017 Questions

1. Express angular momentum in terms of kinetic, potential and total energy of a satellite of mass m in a circular orbit of radius r. **[10M]**

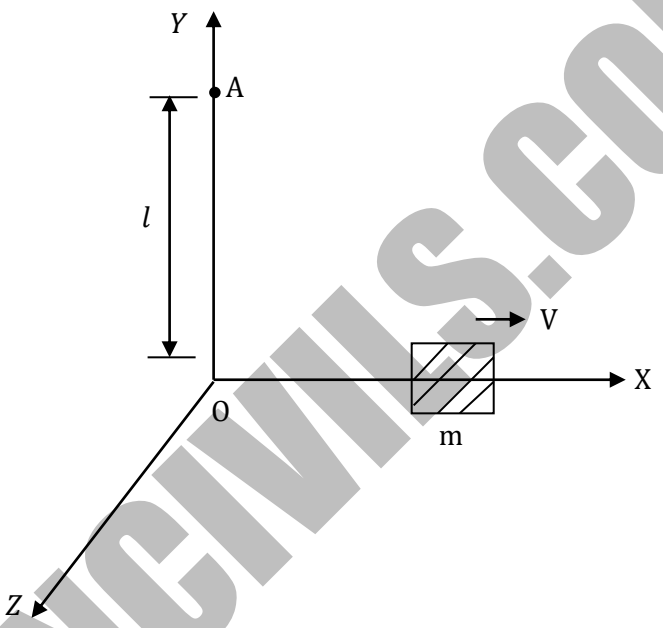
2. A ball moving with a speed of 9 m/s strikes an identical stationary ball such that after the collision the direction of each ball makes an angle 30^0 with the original line of motion. Find the speed of the balls after the collision. Is the kinetic energy conserved in the collision? **[15M]**

3. Prove that $x^2 + y^2 + z^2 = c^2t^2$ is invariant under Lorentz transformation. **[10M]**

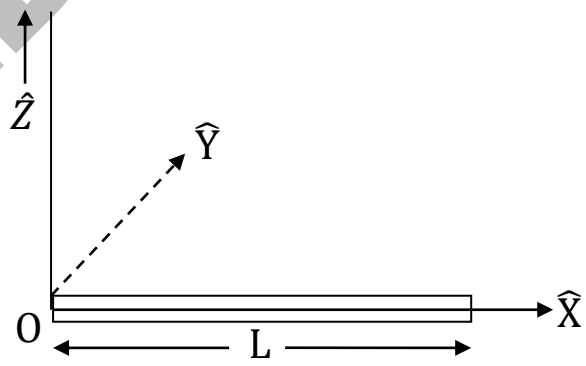
UPSC – PHYSICS Optional – 2018 Questions

1. If a particle of mass m is in a central force field $f(r)\hat{r}$, then show that the path must be a plane curve , where $\hat{r}$ is the unit vector in the direction of position vector $\vec{x}$. **[10M]**

2. A block of mass m having negligible dimension is the sliding freely in the x- direction with velocity $\vec{v} = v\hat{\imath}$ as shown in the diagram. What is its angular momentum $\vec{L}_O$ about the origin O and its angular momentum $\vec{L}_A$ about the point A on y- axis? **[10M]**



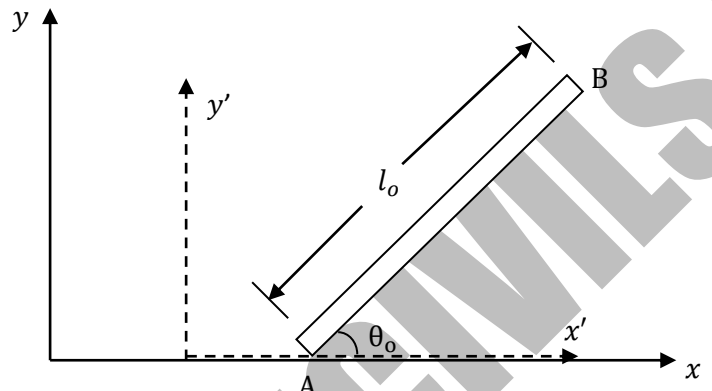
3. A rod of length L has non-uniform linear mass density (mass per unit length) λ, which varies as $\lambda = \lambda_o \left[\frac{S}{L}\right]$; where λ_o is a constant and S is the distance from the end marked 'O' (as shown in figure) . Find the centre of mass of the rod. **[15M]**



4. Two capillary tubes of lengths $2l$ and l with internal radii r and $2r$ respectively are connected in series. Water flows through them in streamline. If the pressure difference across the first capillary is P, Find the pressure difference across the second one. **[10M]**

5. A water drop of radius 0.04 mm is falling through air. If the coefficient of viscosity for air is 1.8×10^{-4} poise, find its terminal velocity. If 100 such drops coalesce, what will be the new terminal velocity? **[10M]**

6. A rod of length l_o is kept at rest in $x'y'$ plane of its rest frame making an angle θ_0 with x' axis. What is the length and orientation of the rod in a laboratory frame (x, y) in which the rod moves to the right with velocity v?



[15M]

UPSC – PHYSICS Optional – 2019 Questions

1. (i) What is a central force? Give two examples of the central force.

(ii) Show that the angular momentum $(\vec{L})$ of the particle in a central force field is a constant of motion. **[10M]**

2. (i) Find the moments of inertia of rigid diatomic molecule about different axes of symmetry through the centre of mass.

(ii) A proton is 1837 times heavier than an electron. Find the centre of mass of hydrogen atom. **[15M]**

3. Write down Euler's dynamical equations of motion (no derivation) of a rigid body about a fixed point under the action of torque. Show that the kinetic energy of the torque – free motion is constant. **[10M]**

4. Show that the cross-section for elastic Scattering of a point particle from an infinitely massive sphere of radius R is $\frac{R^2}{4}$. What is the inference of this result? **[10M]**

5. (i) A reference frame S' moves with respect to rest frame S with a uniform velocity 'v' parallel to x-direction. Show from Lorentz transformation that two events simultaneous ($t_1=t_2$) at different positions ($x_1 \neq x_2$) in S frame are not in general simultaneous in S' frame.

(ii) The mean life of π meson moving with velocity of 0.8c, where c is the velocity of light. **[15M]**

6. Where do you find the applications of gyroscope?

A top of mass 0.200 kg is made up of a thin disc of radius 0.12 m. It is pierced in the centre and a pin of negligible mass is mounted normal to its plane. The pivot under the disc is 0.03m long. The top is made to spin with its axis making an angle $\theta=20^0$ with the vertical and a processional angular speed of 2rad/sec. Calculate the angular speed with it spins. **[15M]**