***Topic 1:*** Accel vector in a curve motion: definition, decomposition of the accel vector into two components (tangential and normal), the magnitude, the direction and the physical meaning of each component. The tangential and normal accels of a uniform circular motion (UCM).

1. Definition:
2. Average Accel

The average accel vector of the particle as it moves from P1 to P2 as the vector change in velocity  , divided by the time interval

1. Instantaneous accel

The instantaneous accel at point P is equal to the instantaneous rate of change of velocity with time:

1. Decomposition of accel vector
2. Tangential accel

* The tangential accel vector has the same direction of the instantaneous velocity.
* The tangential component of affects the speed.

1. Normal accel

* The direction of normal accel vector is perpendicular to the direction of instantaneous velocity.
* The normal component of affects the direction of motion.

1. Accel of a uniform circular motion

-The tangential accel vector has the same direction of the instantaneous velocity.

-The normal accel is directed toward the center of the circle and perpendicular to the instantaneous velocity when a particle moves in a circular path of radius R with constant speed

***Topic 2:*** The definition of momentum for a material point and a system of material points. Derivation of the law of momentum conservation for an isolated system. An example of application of the law. The impulse-momentum theorem. The meaning of the concept of impulse.

1. Definition:
2. The momentum of a material point is a vector quantity equal to the product of the material point’s mass m and the velocity
3. The momentum of a system of material points is the vector sum of the momenta of the individual particles
4. The law of momentum conservation for isolated system:
5. Definition:

If the net external force on a system is zero, the total momentum of the system is constant, or conserved.

1. Derivation from Newton’s Third Law:

The net force on particle A is and the net force on particle B is , so from the rates of change of the momenta of the two particles are:

The momentum of each particle changes, but these changes are related to each other by Newton’s Third Law: . We have:

The rates of change of the two momenta are equal and opposite, so the rate of

change of the vector sum is zero. We now define the total momentum of the system of 2 particles:

Finally:

The time rate of change of the total momentum is zero. Hence the total momentum of the system is constant, even though the individual momenta of the particles that make up the system can change.

1. Example:

When a person shooting a rifle, and exerts negligible horizontal forces on the rifle, the bullets flies out of the gun toward the target.

At the same time it is fired, the rifle produces a “kick” against the shoulder of the person with a velocity in the opposite direction of the bullet's trajectory, has a momentum exactly the same as that of the bullet itself. Hence, momentum is conserved.

1. Impulse – Momentum theorem:

The change in momentum of a particle during a time interval equals the impulse of the net force that acts on the particle during that interval.

***Topic 3:*** The definition of impulse (for a constant net force and for general cases). The impulse-momentum theorem. The meaning of the concept of impulse. SAME TOPIC 2

***Topic 4:*** The method of calculation of the work done by a constant force and a varying force. The work-kinetic energy theorem for the cases of constant and varying forces. Mechanical energy of a system with/without dissipation.

1. The work done by a constant force:

Where is the angle between and

1. The work done by a varying force:

(during a straight- line displacement)

(during a curved path)

1. The work-kinetic energy theorem

When the forces act on a particle while it undergoes a displacement, the particle’s kinetic energy changes by an amount equal to the total work done on the particle by all the forces.

1. Mechanical energy of a system:
2. With dissipation:
3. Without dissipation:

***Topic 5:*** The relations between force and potential energy. The equations that relate force and energy for the gravitational force (near and far from the Earth surface).

1. The relationship between force and potential energy:

* For motion along a straight line, a conservative force is the negative deriv of its associated potential energy function U
* For the 3 dimensions, the components of a conservative force are negative partial derivs of U

1. Force and energy for the gravity force
2. Near the Earth surface:

1. Far from the Earth surface:

***Topic 6:*** Momentum of a material point, of a system of material points, momentum conservation for an isolated system. Example of application. SAME TOPIC 2

***Topic 7:*** Center of mass. Motion of a system of particles. Collision in the center-mass frame of reference. Collisions, elastic and inelastic, radial and non-radial. Radial absolutely elastic and absolutely inelastic collisions.

1. Center of mass:

The position vector of the center of mass of a system of particles,  is a weight average of the positions of the individual particles

1. Motion of a system of particles:

When a collection of particles is acted on by external forces, the center of mass moves just as through all the mass all the mass were concentrated at that point and it were acted on by a net force equal to the sum of the external forces on the system.

1. Collision:

In collision of all kinds in which external forces can be neglected, momentum is conserved, the initial and final total momenta are equal

When

1. Elastic collision:

* The initial and final total kinetic energies are also equal
* The initial and final relative velocities have the same magnitude

1. Inelastic collision:

* The total kinetic energy after the collision is less than before
* If the bodies have the same final velocity, the collision is ***completely inelastic***

1. Radical collision:

* The radical collision is the inelastic collision.
* The direction of movement of bodies are not change

1. Non-radical collision:

* The direction of movement of bodies are change

***Topic 8:*** Moment of inertia for systems of discrete point masses and for a continuous distribution of masses. The parallel-axis theorem (including its derivation)

1. Moment of inertia
2. For systems of discrete point masses

The quantity is obtained by multiplying the mass of each particle by the square of its distance from the axis of rotation and adding these products, is denoted by I and is called the moment of inertia of the body for this rotation axis:

1. For a continuous distribution of masses

Where r is the distance of each mass elements dm from the axis of rotation.

1. Parallel- axis theorem:
2. Definition:

The parallel- axis theorem is a simple relationship between the moment of inertia of a body of mass M about an axis through its center of mass and the moment of inertia about any other axis parallel to the original one but displaced from it by a distance d.

1. Derivation:

* First, we take a very thin slice of the body, parallel to the xy-plane and perpendicular to the z-axis.
* The axis through the center of mass passes through this thin slice at point O, and the parallel axis passes through point
* The distance of this axis from the axis through the center of mass is d
* Let be a mass element in our slice with coordinates
* Then the moment of inertia of the slice about the axis through the center of mass (at O) is:

* The moment of inertia of the slice about the axis through P is:
* We have:
* Consider:

***Topic 9:*** Torque of a force acting on a rotational rigid body (the definition, the components of the torque vector and their physical meaning). Derivation of the fundamental equation for the rotation of a rigid body about a fixed axis.

1. Torque:
2. Definition:

* When a force acts on a body, the torque of that force with respect to a point O has a magnitude given by the product of the force magnitude F and the lever arm l.
* More generally, torque is a vector equal to the vector product of (the position vector of the point at which the force acts) and

1. The components of the torque vector:

Where l is the lever arm of F

1. The physical meaning:

The quantitative measure of the tendency of a force to cause or change a body's rotational motion.

1. Derivation of the fundamental equation for the rotation of a rigid body about a fixed axis.

***Topic 10:*** Angular momentum for a material point and for a rigid body about a fixed axis. The theorem of angular momentum and the law of conservation of angular momentum.

1. Angular momentum:
2. For a material point:

The angular momentum of a particle with respect to point O is the vector product of the

particle’s position vector relative to O and its momentum

1. For a rigid body about a fixed axis:

* The angular momentum of the symmetrical rigid body is the product of its moment of inertia and its angular velocity vector
* If the body is not symmetric or the rotation z- axis is not an axis of symmetric, the component of angular momentum along the rotation axis is:

1. The theorem of angular momentum:
2. The law of conservation of angular momentum:

When the external torque acting on a system is zero, the total angular momentum of the system is constant (conserved)

***Topic 11:*** Definition of a simple harmonic motion (SHM). Derivation of the differential equation for SHM and its solution. The meaning of the parameters in the solution. Derivation of formulae for angular frequencies (periods) of simple, and physical pendulums.

1. Definition of SHM

When the restoring force is directly proportional to the displacement from equilibrium, the oscillation is called simple harmonic motion, abbreviated SHM.

1. Differential equation for SHM

We have:

One of the solutions of the above equation is:

Where: x is the displacement

A is the amplitude

is the angular frequency

is the angle made by phasor and Ox

1. Angular frequency and period (derivation)
2. For simple pendulum

* We have the restoring force is the tangential component of the net force:

* When
* Then

1. For physical pendulum

* We have the restoring torque:
* When
* Then
* Consider:

***Topic 12:*** Energy of harmonic oscillation. Damped oscillation and energy dissipation. Forced oscillation. Resonance. Applications.

1. Energy of harmonic oscillation:
2. Damped oscillation

* The decrease in amplitude caused by dissipative forces is called ***damping*,** and the corresponding motion is called ***damped oscillation.***
* If we apply a periodically varying driving force with angular frequency to a damped harmonic oscillator, the motion that results is called a ***forced oscillation*** or a *driven oscillation.*
* An amplitude peak at driving frequencies close to the natural frequency of the system is called ***resonance.***

***Topic 13:*** Wave propagation in elastic media. Mathematical description of a wave. Phase and energy transmission. Space and time periodicity. Energy. Intensity. Interference. Beats.

1. Wave propagation in elastic media:
2. Mathematical description of a wave:
3. Wave function for a Sinusoidal Wave:

* The wave number:

1. Wave equation:

1. Phase and energy transmission:
2. Space and time periodicity
3. Energy:
4. Intensity:
5. Interference:

* In general, the term “interference” refers to what happens when two or more waves pass through the same region at the same time
* The principle of Superposition:

1. Beat:

The amplitude variation causes variations of loudness called beats, and the frequency with which the loudness varies is called the beat frequency.