Physics 4A

Momentum and Center of Mass

Center of Mass (COM)

The motion of real objects (not particles) is complicated.

⇒ The motion can be simplified if we consider the center of mass (average position of the mass).

Center of Mass (COM)

⇒ The COM of the object behaves like a particle whose mass equals the mass of the object.
Center of Mass (COM)

The motion of the hammer is really the superposition of two separate motions:
⇒ The COM of the hammer travels like a projectile.
⇒ The hammer rotates about its COM.

Impulse

The impulse in the collision is equal to the area under the curve.

\[ J = \int_{t_1}^{t_2} F(t) \, dt \quad \text{(impulse defined)} \]

The average force gives the same area under the curve.

\[ J = F_{\text{avg}} \Delta t \]

There are many situations when the force on an object is not constant.
Impulse-Momentum Theorem

\[ \vec{F}_{\text{ave}} \Delta t = \Delta \vec{p} \rightarrow \vec{F}_{\text{ave}} = \frac{\Delta \vec{p}}{\Delta t} \]

\[ \Rightarrow \] In a collision where an object is brought to rest, the change in momentum is the same whether the collision takes place over a long time or over a short time.

\[ \Rightarrow \] However, the greater the time, the lower the average net force.

Impulse-Momentum Theorem

Decreasing momentum over a long time \( \Rightarrow \) The greater the time a force acts to decrease the momentum, the smaller the average net force

examples: catching an egg toss, padded dashboards, airbags, crumple zones, bungee jumping, dynamic ropes for rock climbing, padded exercise mats, bending knees when jumping down

Collisions

The total linear momentum is conserved when two objects collide, provided they constitute an isolated system.

Elastic collision -- One in which the total kinetic energy of the system after the collision is equal to the total kinetic energy before the collision.

Inelastic collision -- One in which the total kinetic energy of the system after the collision is not equal to the total kinetic energy before the collision; if the objects stick together after colliding, the collision is said to be completely inelastic.