Final Exam: Tuesday, May 13th

Some problems from Exam 1, 2, 3 will be included

“Impulse” and “Momentum”

Last class...

Impulse
Momentum
Impulse-Momentum Theorem

Today...

System of particles
Conservation of Momentum
Elastic vs. Inelastic Collisions
**System of particles, or objects**

So far, we mostly focused on the motion of "one" object.

We now consider system of "multiple" objects, which we can choose any way convenient for us.

For example,

The system: m1, m2 and m3; however m4 and m5 are an external object!

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**Internal vs. External Forces**

Internal forces: Forces between objects within the system

External forces: Forces from outside the system
Net Momentum, Net external force, Net external impulse

Net Momentum of System of Particles (or, Objects)
\[ \vec{P}_{\text{net}} = \vec{p}_1 + \vec{p}_2 + ... = m_1 \vec{v}_1 + m_2 \vec{v}_2 + ... \]

Net external force:
\[ \vec{F}_{\text{net,ext}} = \vec{F}_{\text{ext,1}} + \vec{F}_{\text{ext,2}} + ... \]
sum of all "external" forces acting on the system

Net external impulse:
\[ \vec{I}_{\text{net,ext}} = \vec{F}_{\text{net,ext}} \Delta t \]

Impulse-Momentum Theorem for System of Particles

\[ \vec{I}_{\text{net,ext}} = \vec{P}_{\text{net,f}} - \vec{P}_{\text{net,i}} \]

Net external impulse is equal to net momentum change.

Proof: use Newton's 3rd law (see textbook)

Note: Internal forces do not matter for net momentum change.
Conservation of momentum

If $\vec{I}_{net,ext} = 0$, for example, $\vec{F}_{net,ext} = 0$ (isolated system)

$\Rightarrow \vec{P}_{net,f} = \vec{P}_{net,i}$

If the net external impulse is zero, for example, if the net external force is zero, the net momentum of a system is conserved.

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Elastic vs. Inelastic Collisions

In a collision within a system of particles

Before collision

After collision

Net kinetic energy: $K_{net} = K_1 + K_2 + ... = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 + ...$

If $K_{net,i} = K_{net,f} \Rightarrow$ elastic collision.

If $K_{net,i} \neq K_{net,f} \Rightarrow$ inelastic collision.

If $K_{net,i} \neq K_{net,f}$ and objects move together after collision $\Rightarrow$ perfectly inelastic collision.
Example 1: The archer

An archer stands at rest on frictionless ice and fires a 0.50 kg arrow horizontally at 50.0 m/s. The combined mass of the archer and bow is 60.0 kg. With what velocity does the archer move across the ice after firing the arrow?

Data: Fatality of a driver in head-on collision

(With a passenger) < (Without a passenger)
Example 2

Figure represents two identical cars about to collide head-on in a completely inelastic, one-dimensional collision along an \( x \) axis. Let’s make the reasonable assumption that during the collision the impulse between the cars is so great that we can neglect the relatively minor impulses due to the frictional forces on the tires from the road. Then we can assume that there is no net external force on the two-car system.

The \( x \) component of the initial velocity of car 1 along the \( x \) axis is \( v_{1i} = +25 \text{ m/s} \), and that of car 2 is \( v_{2i} = -25 \text{ m/s} \). During the collision, the force (and thus the impulse) on each car causes a change \( \Delta v \) in the car’s velocity. The probability of a driver being killed depends on the magnitude of \( \Delta v \) for that driver’s car. We want to calculate the changes \( \Delta v_1 \) and \( \Delta v_2 \) in the velocities of the two cars.

(a) First, let each car carry only a driver. The total mass of car 1 (including driver 1) is \( m_1 = 1400 \text{ kg} \), and the total mass of car 2 (including driver 2) is \( m_2 = 1400 \text{ kg} \). What are the changes \( \Delta v_1 \) and \( \Delta v_2 \) in the velocities of the cars?

(b) Next, we reconsider the collision, but this time with an 80 kg passenger in car 1. What are \( \Delta v_1 \) and \( \Delta v_2 \) now?

(c) If there’s a passenger, does the collision become less fatal, or more fatal?