October 24

Linear Momentum: \( \vec{p} = M \vec{v} \)

- It is a vector which may require breaking it into components

Newton’s First Law: A body continues with Constant Linear Momentum unless it is acted upon by a Net External Force.

- More general than our previous statement of Newton’s First law since this one can work for real objects including object’s whose mass changes and not just particles.
- Tells us what forces do (They change an object’s linear momentum)

Impulse: Sometimes a force acts for acts on an object for such a short time that it is impossible to measure the force or the time directly. In these situations, it is often possible to still measure the product od the force and time which we call the impulse.

\[ \vec{I} = \vec{F} \Delta t \]

- In general, the force is not constant over the time so what we are measuring is the area under a force-time graph.
**Newton’s 2\textsuperscript{nd} Law:** The time-rate of change of an object’s linear momentum is equal to the net external force applied to the object.

\[ \sum \vec{F}_{Ext} = \lim_{\Delta t \to 0} \frac{\Delta \vec{p}}{\Delta t} \]

Combining with the concept of impulse:

\[ \vec{I} = \sum \vec{F}_{Ext} \Delta t = \Delta \vec{p} \]

Thus, we can **find the impulse by finding the change in linear momentum** (area under a Force-Time graph).

**Systems Which Conserve Linear Momentum**

**Isolated System** – A system in which the net external force acting upon the system is zero.

**Collisions & Explosions** – These interactions in these systems occur so fast that there is no appreciable area under the force-time graph during the collision or explosion even if external forces are acting so we can ignore these forces.
EXAMPLE: A 2.00 kg ball is traveling at 5 m/s as shown below:

A) What is the ball's linear momentum in polar form?

B) What is the ball's linear momentum in Cartesian form?
Example 2: A 2.00 kg ball initially traveling at 5.00 m/s strikes a wall and bounces backward at the same speed as shown below.

What is the change in the momentum of the ball?

What caused a change in linear momentum?
A cannon of mass 400 kg fires a 3 kg shell at 650 m/s. What is the recoil speed of the cannon?
A 4.4 kg toy race car can move along an \( x \) axis. The figure below gives \( F_x \) of the force acting on the car, which begins at rest at time \( t = 0 \). (The vertical axis is marked in increments of 2.5 N.)

What is the impulse from \( t = 0 \) s to \( t = 6 \) s?
\[ \sum \vec{F}_{\text{Ext}} = \lim_{\Delta t \to 0} \frac{\Delta (M \vec{v})}{\Delta t} \]

\[ \sum \vec{F}_{\text{Ext}} = \lim_{\Delta t \to 0} \left( \frac{\Delta M}{\Delta t} \vec{v} + M \frac{\Delta \vec{v}}{\Delta t} \right) \]

\[ \sum \vec{F}_{\text{Ext}} = \lim_{\Delta t \to 0} \left( \frac{\Delta M}{\Delta t} \right) \vec{v} + M \vec{a} \]

\[ \sum \vec{F}_{\text{Ext}} = \lim_{\Delta t \to 0} \left( \frac{\Delta M}{\Delta t} \right) \vec{v} = M \vec{a} \]
In some problems the change in linear momentum (impulse) is fixed, but the force that causes the change is not!!

In each case the ________________ in ________________ is fixed. However, the ________________ required to produce this ________________ depends dramatically upon the interaction ________________.
A 1.6 kg ball is attached to the end of a 0.4 m string to form a pendulum. The pendulum is released from rest with the string horizontal. At the lowest point of its swing, when it is moving horizontally, the ball collides with a 0.80 kg block initially at rest on a horizontal frictionless surface. The speed of the block just after the collision is 3.0 m/s. What is the speed of the ball just after the collision?

a) 1.3 m/s  
   b) 1.1 m/s  
   c) 1.5 m/s  
   d) 1.7 m/s
A 10 g bullet moving 1000 m/s strikes and passes through a 2.0 kg block initially at rest. The bullet emerges from the block with a speed of 400 m/s. To what maximum height will the block rise above its initial position.

a) 46 cm  

b) 66 cm  

c) 56 cm  

d) 78 cm
A 3.0 kg mass is released from rest at point A of a circular frictionless track of radius 0.40 m as shown in the figure. The mass slides down the track and collides with a 1.4 kg mass that is initially at rest on a horizontal frictionless surface. If the masses stick together, what is their speed after the collision.

a) 2.1 m/s  
b) 1.7 m/s  
c) 1.9 m/s  
d) 1.5 m/s