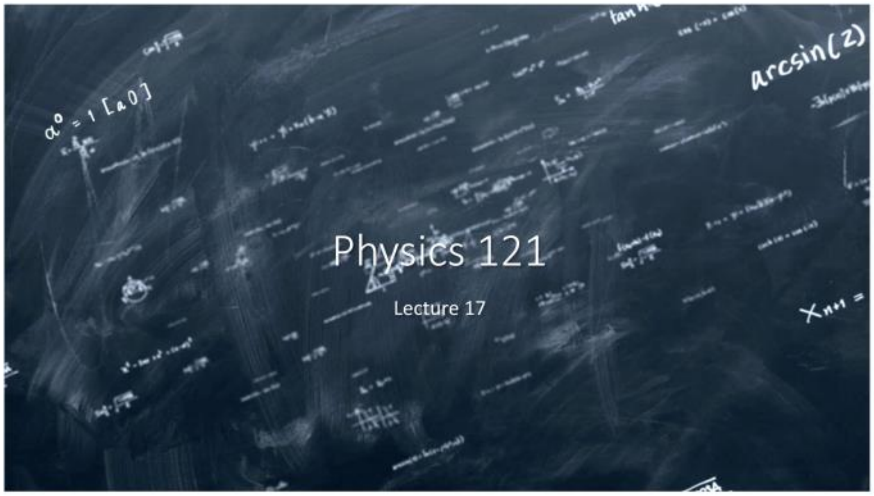
Lecture 17 - 3.9

Thursday, March 9, 2023 9:30 AM



Devotional Thought

Are we getting lost in the side quests?

Who are your antagonists?

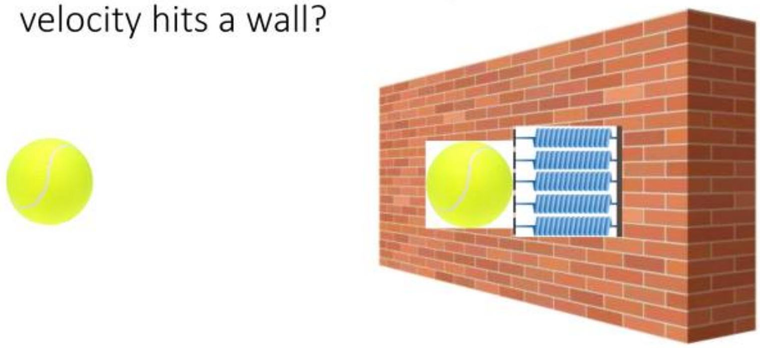
Intentional spiritual creation.

"The desire to create is one of the deepest yearnings of the human soul. No matter our talents, education, backgrounds, or abilities, we each have an inherent wish to create something that did not exist before."

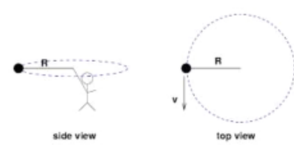
Dieter F. Uchtdorf, 2008

Andra Duke

What happens when an object with constant velocity hits a wall?



Kinetic Energy is not enough



What does Kinetic Energy tell us?

→ How much work can I get out of system.

But what about directions? Need a new quantity!

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$

Momentum

gives a vector

$K = \frac{1}{2} m v^2$

gives us a scalar num that's always positive

$\vec{p} = m \cdot \vec{v}$

Who cares about momentum?

1mi = 1.6 km

Choose your collision partner wisely:

1.5 ton car, 20 miles per hour

A)

0.1 gram fly, 20 miles per hour

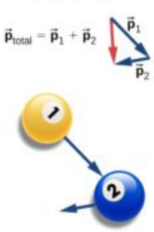
B)

1500 kg ·

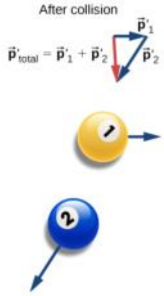
Another Symmetry, another Conservation

Translation (moving things) does not change the laws of physics → Linear Momentum is conserved!

Before collision



After collision



LAW OF CONSERVATION OF MOMENTUM

The total momentum of a closed system is conserved:

$$\sum_{j=1}^{N} \vec{p}_j = \text{constant}.$$

Conservation of Momentum – in Space!

A short derivation of Conservation of Momentum.

$a = \frac{dv}{dt}$

1.) Start from Newtons 3rd law

$F_1 = -F_2$

$m_1 a_1 = -m_2 a_2$

$\frac{m_1 dv_1}{dt} = -m_2 \frac{dv_2}{dt}$

$\frac{d(m_1 v_1)}{dt} = -\frac{d(m_2 v_2)}{dt}$ $\Rightarrow$ $\frac{dp_1}{dt} = \frac{-dp_2}{dt}$

$$\boxed{\frac{d(p_1 + p_2)}{dt} = 0}$$

$p_1 + p_2$ must be constant

Total momentum must be conserved

Discussion: But why do Billiard balls eventually stop rolling?

Momentum is conserved before and after the collisions, but friction can change velocities over time.

friction is really just atomic collisions

What is the relationship between momentum and force?

$$\vec{F} = \frac{d\vec{p}}{dt}$$

$$= \frac{d(m\cdot\vec{v})}{dt}$$

$$= m\cdot\frac{d\vec{v}}{dt} + \vec{v}\cdot\frac{dm}{dt}$$

$$= m\cdot\frac{d\vec{v}}{dt} + \vec{v}\cdot 0$$

$$= m\cdot\frac{d\vec{v}}{dt} = m\cdot\vec{a} = \vec{F}$$

$$\vec{\mathbf{F}} = \frac{d\vec{\mathbf{p}}}{dt}.$$

Two kinds of collisions

ELASTIC

- Objects collide and bounce
- Kinetic energy is conserved
- No permanent deformation of the objects

INELASTIC

- Objects collide and stick
- Kinetic energy is NOT conserved
- Objects stick because they lock together, or are permanently bent, or chemical reaction, or...

$\vec{P} = m \cdot \vec{v}$

INELASTIC COLLISION:
A 10 g bullet moving with a speed of 500 m/s hits and sticks in a stationary 1 kg wooden block. After the collision, the block+bullet system slides across a frictionless surface.
How fast does the bullet+block system move after the collision?

Inelastic

1kg

0.01kg

500ms

$$\underbrace{\frac{0\,m/s}{0} + \frac{\quad}{5}}_{5}$$

$5 = 1.01kg \cdot \vec{v}$

$\frac{5}{1.01} = \boxed{4.95 m/s}$

$\Sigma p = m v_0 + M v = m v_0$

$\Sigma p = (m+M) \cdot v_f$

$m v_0 = (m+M) v_f \Rightarrow v_f = \frac{m}{m+M} \cdot v_0$

$$K = \frac{1}{2} m v^2$$

INELASTIC COLLISION:
A 10 g bullet moving with a speed of 500 m/s hits and sticks in a stationary 1 kg wooden block. After the collision, the block+bullet system slides across a frictionless surface.
What is the change in kinetic energy of the system?

$\to v_0$ $$K = \frac{1}{2} m v_0^2 = \frac{1}{2} \cdot 0.01\,kg \cdot 500\,m/s^2 = 1250\,J$$

$\to v_f$ $$K = \frac{1}{2} m = \frac{1}{2}(m+M) v_f^2 = \frac{1}{2}(1.01)(4.95)^2 = 12.37\,J$$

INELASTIC COLLISION:
A 10 g bullet moving with a speed of 500 m/s hits and sticks in a stationary 1 kg wooden block. After the collision, the block+bullet system slides across a frictionless surface.
Where did that kinetic energy go?

The deformation of the block

How do you play catch with a water balloon?

What do you do?

Why?

How do you play catch with a water balloon?

What do you do?

You cradle the balloon and give it a soft landing

Why?

So the balloon won't explode.

You change the balloon's momentum SLOWLY so that the average FORCE is smaller.

Impulse is change in momentum.

"Impulse"

$$\Delta p = (F) \times (\Delta t) = p_{\text{final}} - p_{\text{initial}}$$

Example: seatbelts vs airbags

- The Change in Momentum is the same if you use a seatbelt or an airbag
- In a crash, a seatbelt changes a person's momentum quickly
  SHORT time, BIG average force
- In a crash, an airbag changes a person's momentum slowly
  LONG time, SMALL average force

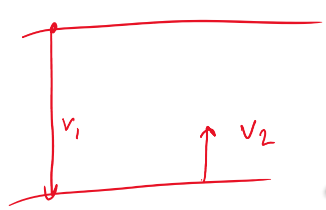
Impulse measures how much momentum changes!

Use to calculate the applied force, or the change of velocity.

$$\Delta p = (F) \times (\Delta t) = \text{“Impulse”}$$

iClicker: A super bouncy ball and a not-so-bouncy ball (made of clay) are dropped from a height of 1 meter. Which experiences the greatest impulse at the floor?

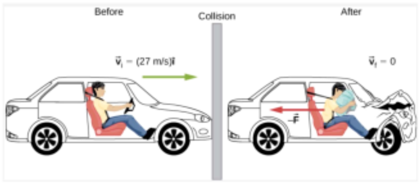
A. Super bouncy ball
B. Not-so-bouncy ball
C. It's the same



bouncy: $mv_2 - -mv_1 \Rightarrow mv_2 + mv_1$

clay: $0 - -m_1 \Rightarrow mv_1$

Useful application = Airbags



Mass of driver = 80 kg
Without airbag 0.2 sec until he rests (forever).
With airbag 2.5 sec until rest.

1. What is the magnitude of the impulse?
2. What is the difference in average force with and without airbag?

$\Delta p = 80\text{kg} \cdot 27\ \text{m/s} \approx -2160\ \text{kg}\ \frac{\text{m}}{\text{s}}$

$\Delta p = \text{Force}_{\text{Avg}} \cdot \Delta t \Rightarrow F_{\text{Avg}} = -\frac{2160\ \text{N}\cdot\cancel{\text{s}}}{0.2\ \cancel{\text{s}}} = -10800\ \text{N}$

$\Rightarrow F_{\text{Avg}_{\text{air}}} = \frac{-2160\ \text{N}\cancel{\text{s}}}{2.5\ \cancel{\text{s}}} = -864\ \text{N}$

Exit Poll

- Please provide a letter grade for todays lecture:

A. A
B. B
C. C
D. D
E. Fail