Momentum

- What properties determine how difficult it will be to stop a moving object?

Momentum

- Inertia of motion
  - Measure of how hard it is to stop something
  - product of mass and velocity (=> vector quantity)
  - Momentum = mv
  - *A moving object can have a large momentum if:*
    - *very massive (Slowly moving freight train)*
    - *high velocity (bullet)*
    - *both large mass and high velocity (Runaway truck)*

Impulse

- What do we need to do to change the momentum of something?

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  - Change its mass and/or its velocity (mass usually fixed)
  - => cause it to accelerate => apply a force!
- How is the length of time that the force is applied related to the change in momentum?

Impulse

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  - Change its mass and/or its velocity (mass usually fixed)
  - => cause it to accelerate => apply a force!
- How is the length of time that the force is applied related to the change in momentum?
  - The longer the force is applied, the greater the momentum change.
- Impulse = Ft

Impulse (cont.)

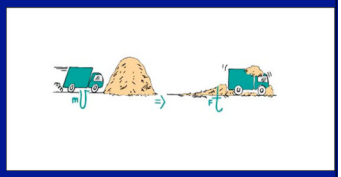
- Impulse equals change momentum
  - $Ft = \Delta(mv) = m(v_2 - v_1)$
- *Example: Increasing Momentum*
  - *Baseball vs. Jai Alai*

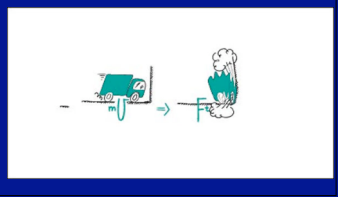
120 mph

180 mph

Impulse (cont.)

- *Example: Decreasing Momentum*
  - *How do the impulses required to stop the truck compare in each case?*
  - *How do the forces compare?*





Units

$Ft = \Delta(mv)$

$= m(v_2 - v_1)$

$$\frac{(kg\ m)\ s}{s^2} = kg\ (m/s)$$

Total Momentum

- A gun is fired.
  - How does the momentum of the bullet change?
  - the gun?
  - entire system (bullet + gun)?

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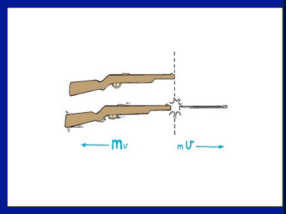


Momenta of bullet and gun are equal and opposite => net change in momentum is zero.

Clicker Question:

What is the momentum of an 0.05 kg bullet moving at 200 m/s?

A: 10 kg m/s

B: 1 kg m/s

C: 2 m/s

D: 0.00025 m/s/kg

Clicker Question:

Can a 0.05 kg bullet from a handgun travelling 200 m/s knock somebody who weighs 100 kg backward at 4 m/s (10 mph)?

A: Yes

B: No

Clicker Question:

Which would be more damaging - driving into a very massive concrete wall with no "give," or having a head-on collision at the same speed with an identical mass car moving toward you with the same speed?

A: wall

B: car

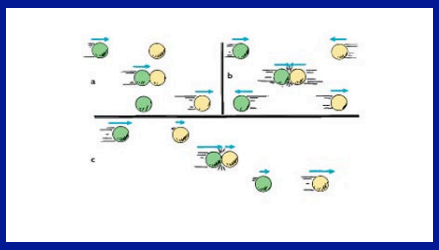
C: both the same

D: impossible to predict without more information

Collisions

- In a closed system
  - Net momentum before collision = net momentum after collision
    - Can predict momenta of objects after collisions
- Elastic Collisions
  - No deformation, no heat generated
  - Examples?
- Inelastic Collisions
  - Deformation and/or heat generation
  - Examples?

Elastic Collisions



What statement could you make that applies to all of the head-on collisions shown above?

Rubber ball Demo, Newton's cradle demo

Example

M = 10 tons, v_{T1} = 30 m/s

m=0.5 tons, v_{B1}= 5 m/s

- Example: Mack truck hits VW bug

  Total momentum of system is conserved, inelastic collision:

  time 1: $Mv_{T1} + mv_{B1}$ = constant

  time 2: $Mv_{T2} + mv_{B2}$ = constant

  suppose v_{T1} = 30 m/s; v_{B1} = 5 m/s

  What is velocity of Mack truck after collision? How much did its velocity change?

  What is velocity of VW bug after collision? velocity change?

  Demo collisions

Lunch Time

- Yellow fish at rest
- Green fish swimming to the right
  - What type of collision is this?
  - How does the velocity of the green fish change?
  - What if the yellow fish is:
    - swimming towards the green fish?
    - trying to get away?

Particle Physics

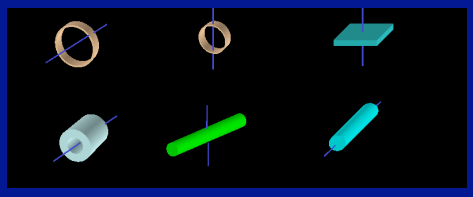
- Momentum conserved in collisions between subatomic particles
  - Not all particles leave tracks in a bubble chamber
  - Can be used to identify (or discover!) "missing" particles

Conservation of Momentum

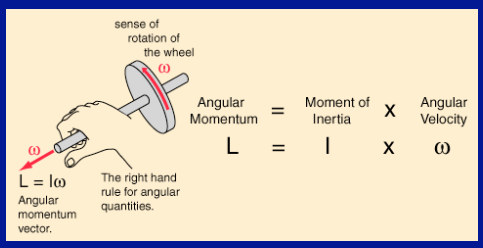
- Only an external impulse can change the momentum
- Internal forces don't change the momentum
  - Molecular interactions in a baseball
  - Pushing on your car dashboard
- Law of Conservation of Momentum
  - *In the absence of an external force, the momentum of a system remains unchanged.*
    - *What consequence does this have for the universe as a whole?*

Moment of Inertia

- I (moment of inertia) similar to M (mass)
- objects in rotation stay in rotation
- I = mass * size



Angular momentum



Torque

torque = r F sin(θ)

Applying a torque will increase an objects rotation

also

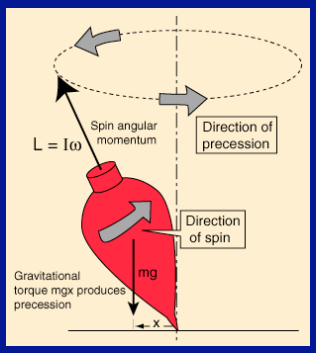
applying a torque to a system will change its angular momentum.

Conservation of Angular Momentum

Just like linear momentum

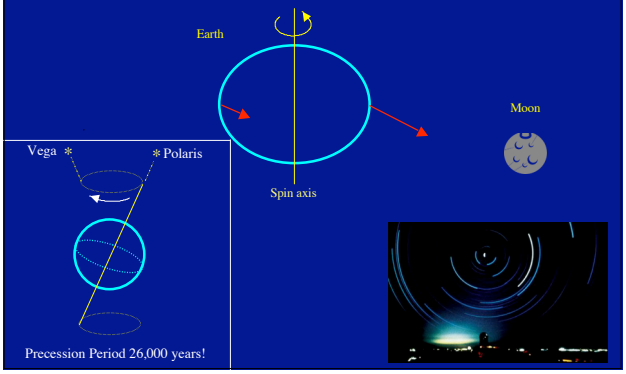
- Only an external torque can change the momentum
- Internal forces don't change the momentum
- Law of Conservation of Angular Momentum
  - *In the absence of an external torque, the momentum of a system remains unchanged.*
    - *What consequence does this have for the universe as a whole?*
- Consider orbits of planets - how do they change?
  - Example - our escaping moon
  - DEMO - Bicycle wheel

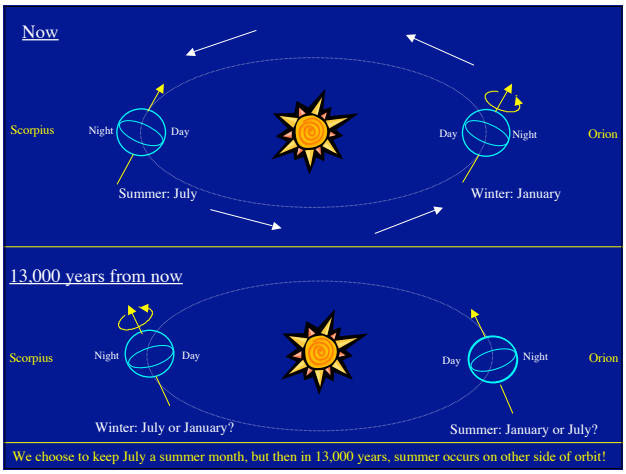
Precession



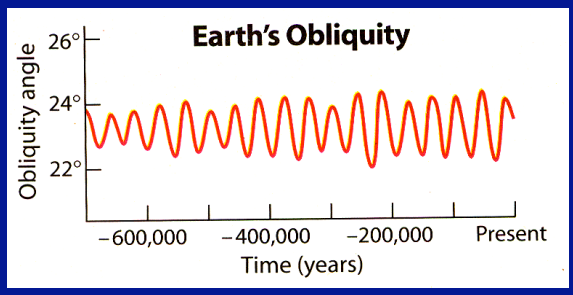
Precession

The Earth has a bulge. The Moon "pulls down" on the side of the bulge closest to it, causing the Earth to wobble on its axis (how do we know this?)





Earth Tilt



Period ~ 40,000 y

Clicker Question:

What is the period of precession of the Earth?

A: 365 days

B: 10 years

C: 26,000 years

D: 13.7 billion years

Clicker Question:

What is the period of precession of the bicycle wheel?

A: 0.3 seconds

B: 3 meters

C: 3 years

D: 3 seconds

Clicker Question:

If the earth collided with a meteor that slowed it down in its orbit, what would happen:

A: It would maintain the same distance from the sun.

B: It would fall closer in to the sun.

C: It would move farther away from the sun.

D: Can't say.