L-8 (I) Physics of Collisions (II) Work and Energy

I. Collisions can be very complicated
- two objects bang into each other and exert <u>strong</u> forces over <u>short time</u> intervals (*impulsive forces*)
- even though we usually do not know the details of the forces, we know from the 3rd law that the forces acting on the colliding objects are equal and opposite
- *Momentum is conserved in collisions*

II. Physics definition of WORK. When am I doing work?

I. Physics of collisions *conservation of momentum*

- The concept of momentum is very useful when discussing how 2 objects interact.
- Suppose two objects are on a collision course. A➔ ➔B
- We know their masses and speeds before they collide
- The momentum concept helps us to see what will happen after they collide.

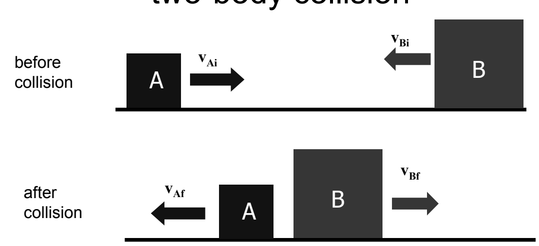
Conservation of Momentum

- One consequence of Newton's 3rd law is that if we add the momentum of both objects before the collision it MUST be the same as the momentum of the two objects after the collision.
- This is what we mean by **conservation**: when something happens (like a collision) **something doesn't change** – that is very useful to know because collisions can be very complicated!

Momentum: p = m v

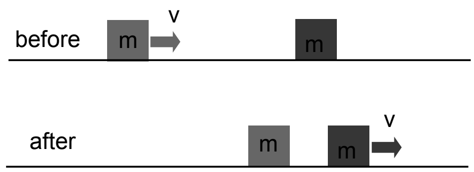
- a 1 kg object moving at 1000 m/s has the same momentum as a 1000 kg object moving at 1 m/s (p = 1000 kg m/s)
- *Impulse* = Δp (delta p means the "change" in momentum, p)
- *Impulse* = F Δt = Δp, so if 2 objects collide, the forces are the same (Newton's 3rd law), and Δt is the same, so Δp is the same for both.
- the momentum lost by one object is gained by the other object ➔ *conservation*

Momentum conservation in a two-body collision



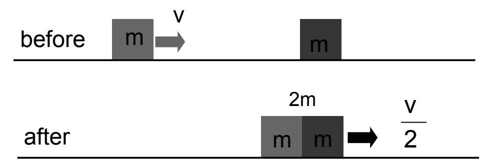
$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$$

elastic collisions: equal masses



momentum before = m v
momentum after = m v

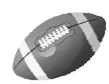
Completely inelastic collisions: objects *stick* together



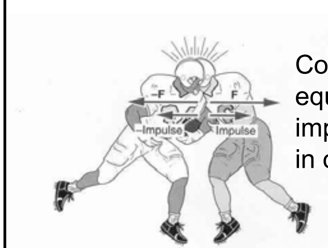
momentum before = m v
momentum after = 2 m v/2 = m v

How much momentum did the stationary object get in the collision?

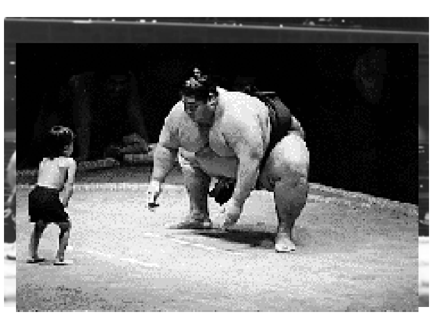
- In the elastic collision the object that was initially at rest got a momentum = m v
- in the inelastic collision the object that was at rest got only m v /2 → half as much!
- This is another example of the fact that more force is involved between bouncy objects (elastic) compared to non-bouncy objects (inelastic)



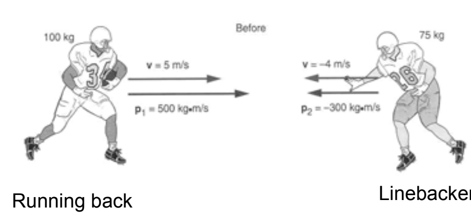
Football: all about collisions!



Colliding players exert equal forces and equal impulses on each other in opposite directions



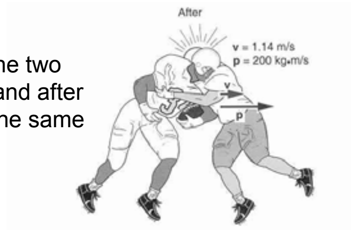
Before the collision



- Momentum of running back is 100 kg x 5 m/s = 500 kg m/s
- Momentum of linebacker is 75 kg x (–4 m/s) = –300 kg m/s
- Total momentum is 500 – 300 = + 200 kg m/s (*to the right*)

After the collision

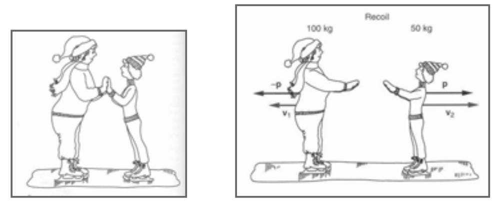
Momentum of the two players before and after the collision is the same (200 kg m/s)



momentum must be 200 kg m/s = total mass x final velocity

200 = 175 x final velocity → final velocity = 200/175 = 1.14 m/s to the right

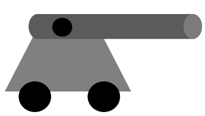
friendly "collisions"



- Two stationary ice skaters push off
- both skaters exert equal forces on each other
- however, the smaller skater acquires a larger speed than the larger skater.
- momentum is conserved!

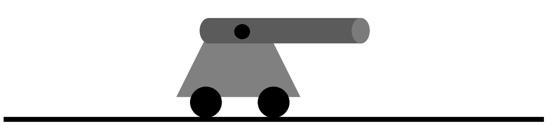
Recoil

- That "kick" you experience when you fire a gun is due to conservation of momentum.
- before firing the cannon → momentum = 0
- conservation of momentum requires that after the cannon is fired the total momentum must still be zero



http://www.youtube.com/watch?v=CQJSZs-euZU

after the cannon is fired



After firing momentum = 0
Since the cannon ball goes to the right, the cannon must go to the left. The speed of the cannon ball is much larger than the recoil speed of the cannon because

$m_{cannonball} v_{cannonball} = m_{cannon} v_{cannon}$

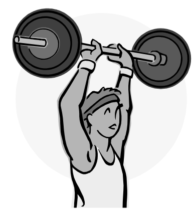
or small mass x big speed = big mass x small speed

Recoil in action → Rockets

II. Work and Energy

- These terms have a common meaning in everyday language which are not the same as the physics definitions
- If we have "energy" we can do things
- Energy is the ability to do work
- But what is energy?

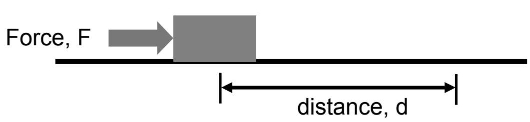
What is work?



- According to the physics definition, you are NOT doing work if you are just holding the weight above your head
- you are doing work only while you are lifting the weight above your head

Work requires two things

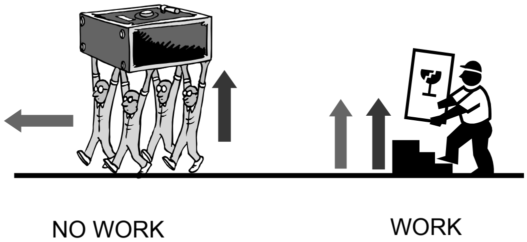
- 1) force
- 2) motion in the direction of the force



Physics definition of WORK

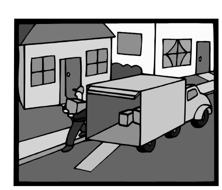
- to do work on an object you have to push the object a certain distance in the direction that you are pushing
- **Work = force x distance = F x d**
- If I carry a box across the room I do not do work on it because the force is not in the direction of the motion

Who's doin the work around here?



A ramp is actually a machine

- A **machine** is any device that allows us to accomplish a task more easily
- it does not need to have any moving parts.



WORK DONE
= big force × little distance or little force × big distance