L-8 (M-7)
I. Collisions   II. Work and Energy

- Momentum: an object of mass m, moving with velocity v has a momentum p = m v.
- Momentum is an important and useful concept that is used to analyze collisions
  - The colliding objects exert strong forces on each other over relatively short time intervals
  - Details of the forces are usually not known, but the forces acting on the objects are equal in magnitude and opposite in direction (3rd law)
  - The law of conservation of momentum which follows from Newton's 2nd and 3rd laws, allows us to predict what happens in collisions

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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 predict what will happen after they collide.

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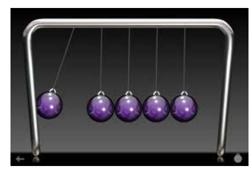
Law of Conservation of Momentum

- A consequence of Newton's 3rd law is that if we add the momentum of both objects before a collision, it is the same as the momentum of the two objects *immediately* after the collision. *The collision redistributes the momentum among the objects.*
- The law of conservation of momentum and the law of conservation of energy are two of the fundamental laws of nature.

Newton's Cradle



During the short time of the collision, the effect of gravity is not important.

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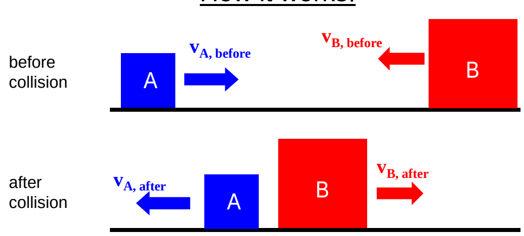
Momentum conservation in a two-body collision, How it works.



$$(p_A + p_B)_{\text{before collision}} = (p_A + p_B)_{\text{after collision}}$$

$$m_A v_{A,\text{before}} + m_B v_{B,\text{before}} = m_A v_{A,\text{after}} + m_B v_{B,\text{after}}$$

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Example: big fish eats little fish

A big fish, M = 5 kg swimming at 1 m/s eats a little fish, m = 1 kg that is at rest. What is the speed of the big fish just after eating the little fish?

- The two fishes form a system and their momentum before the "interaction" is the same as their momentum after the "interaction".
- Momentum before = M V_{before} + m (0) = 5 kg x 1 m/s
- Momentum after = (M + m) V_{after} = (5 + 1) V_{after}
- ➔ 5 kg m/s = 6 V_{after} ➔ V_{after} = 5/6 m/s

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Energy considerations in collisions

- Objects that are in motion have *kinetic energy*: **KE = ½ m v²** (Note that KE does not depend on the direction of the object's motion) more on this . . .
- In the collision of two moving objects, both have KE
- As a result of the collision, the KE of the objects may decrease because the objects get damaged, some heat is produced as well as sound.
- Only if the objects bounce off of each other perfectly, with no permanent damage (perfectly elastic) is the KE conserved. "Real" collisions are never perfectly elastic.

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Types of collisions

- Elastic collision: the two objects bounce off each other with no loss of *energy*.
- Inelastic collision: the two objects bounce off each other but with some loss of *energy*. Most realistic (everyday) collisions are of this type.
- Completely inelastic collision: The two objects stick together after the collision. This type of collision involves the largest possible loss of *energy*.

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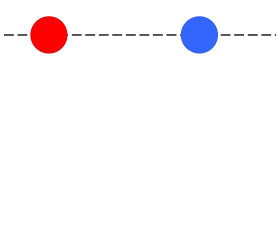
"Super balls" make almost perfectly elastic collisions



- A perfectly elastic "super ball" rebounds to the same height after bouncing off the floor; it leaves the floor with the same KE it had before it hit the floor
- A "real" ball (not perfectly elastic) does not return to the same height; some of its KE is lost

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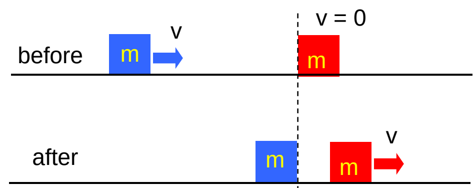
Perfectly elastic collision



momentum before = m v, KE_{before} = ½ mv^2
momentum after = m v, KE_{after} = ½ mv^2
Both momentum and KE are conserved

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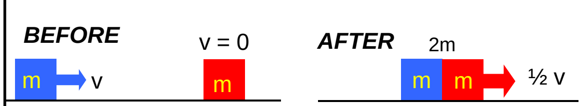
Completely *inelastic* collision: objects *stick* together → momentum is conserved but KE is not conserved



momentum before = m v + m 0 = m v
momentum after = (2 m) v/2 = m v

KE before = ½ mv^2
KE after = ½ $(2m)(v/2)^2$ = $1/4\ mv^2$
= ½ KE before (half of the original KE is lost)

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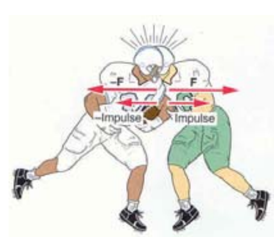
Football: a game of collisions



Football players exert equal forces on each other in opposite directions

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Sumo wrestling

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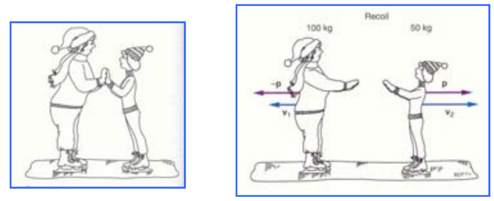
non-violent "collisions"



- 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!

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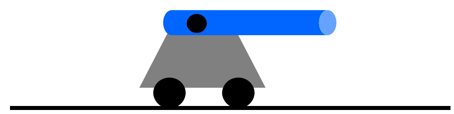
Recoil



- That "kick" you experience when you fire a gun is due to conservation of momentum
- Before firing the cannon its momentum = 0
- Conservation of momentum requires that after the cannon is fired the total (cannon plus ball) momentum must still be zero

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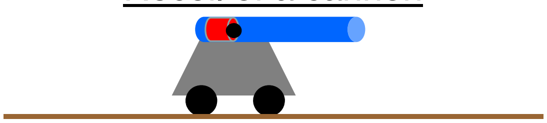
Recoil of a cannon



- Cannon mass M, velocity V; ball mass m, velocity v
- The system (cannon and ball) are initially at rest so the initial momentum = 0
- The momentum remains 0 after the ball is fired, so the final momentum = MV + mv = 0
- The recoil velocity of the cannon in then: V = -mv/M
- V is in the opposite direction to the ball and much less then the speed of the ball, v

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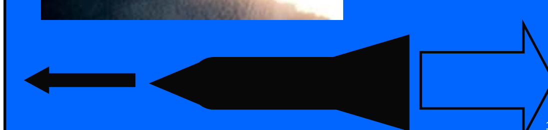
Recoil propels rockets



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II. Work and Energy

- These terms have a common meaning in everyday usage which may not be the same as the physics definitions
- If we have “energy” we can do things: perform work (useful)
- Energy is the ability to do work
- We must give precise definitions to work and energy
- We have already seen that objects in motion have KE = $\frac{1}{2} mv^2$

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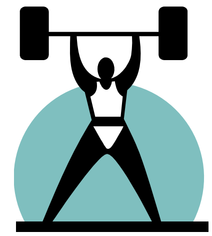
Work and energy

- 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
- In physics, WORK requires both force and motion in the direction of the force



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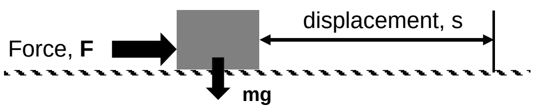
Work requires: (a) force and (b) motion (displacement) in the direction that the force acts



- Work W = force (F) x displacement (s): $W_F = F\,s$
- Unit of work:
  - force (N) x distance (m) = N m
  - 1 N m = 1 J (Joule)
- Gravity, mg also acts on the box but does NO work because there is no vertical motion

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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 displacement = F s**
- 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

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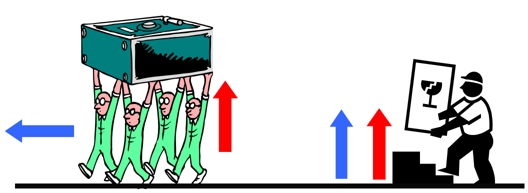
Who’s doin the work around here?



NO WORK

WORK

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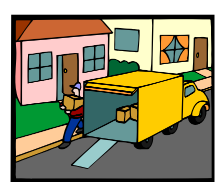
A ramp is actually a machine

- 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

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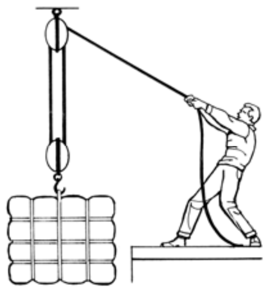
A lifting machine: Block and tackle



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