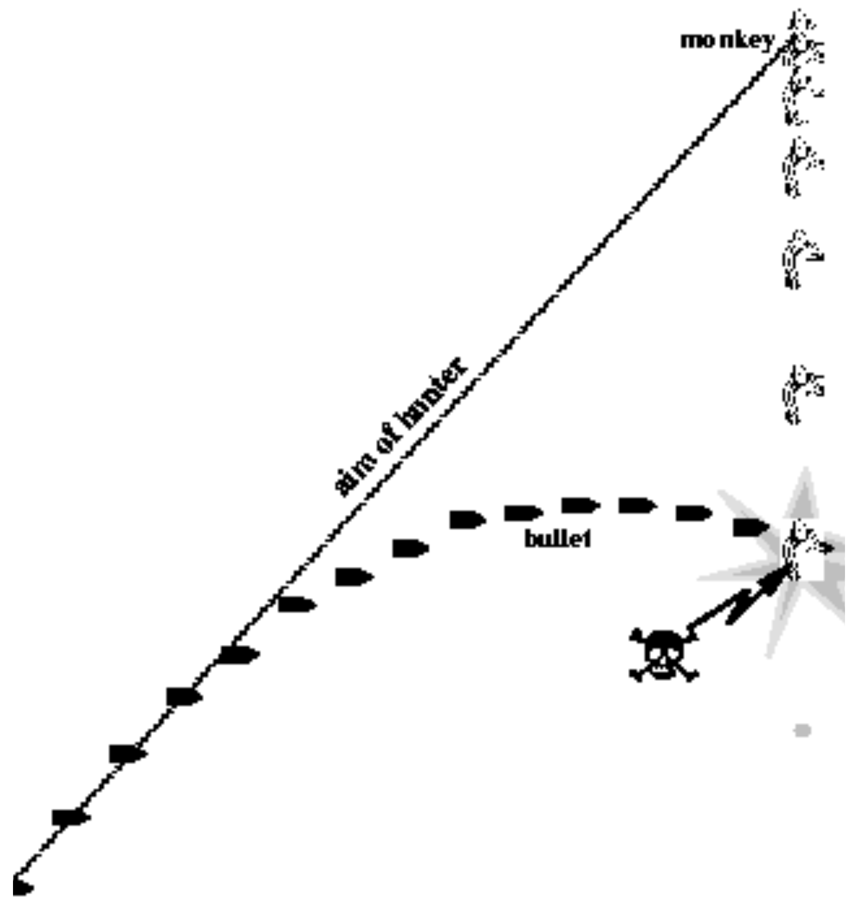
Announcements

- CAPA homework 3 due on Thursday Sept 20 at 10 AM
- Please register your iclicker through LON-CAPA
  - if you want to receive credit
  - only a few of you have not
  - first iclicker question today**: note: if I see anyone with two iclickers, I will take both of them**
- Help room hours (1248 BPS)
  - Ian La Valley(TA)
  - Mon 4-6 PM (except not Monday Sept 17)
  - Tues 12-3 PM
  - Wed 6-9 PM
  - Fri 10 AM-noon
- First exam Tuesday Oct. 2 10:20 AM this room
  - you may bring 1 sheet of hand-written notes; no xeroxing
- Final Exam Tuesday Dec 11 7:45-9:45 AM
- Two guest lecturers next week

'Shoot the monkey'

- We said that the vertical and horizontal motions for projectiles were independent
- Neglecting air resistance, there is an acceleration only in the vertical direction (due to gravity) and it is the same regardless of whether there is horizontal motion or not
- Suppose a hunter is aiming at a monkey hanging in a tree
- The monkey lets go at the same instant that the hunter pulls the trigger
- Does the monkey get hit?
- Yes, if the initial aim is correct, because the monkey and the bullet have the same acceleration

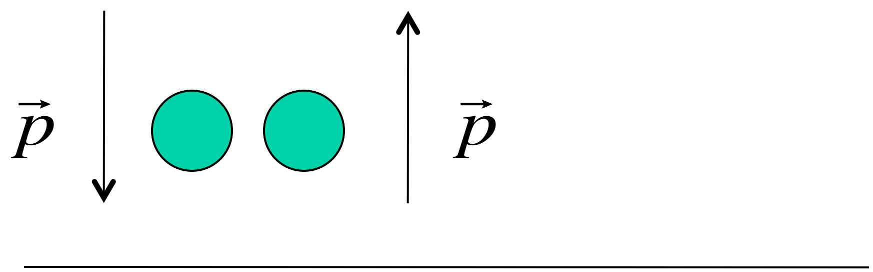
Figure 4.5: Shoot the ``monkey'': an illustration of motion in two dimensions.



…no actual monkeys will be harmed in this demonstration

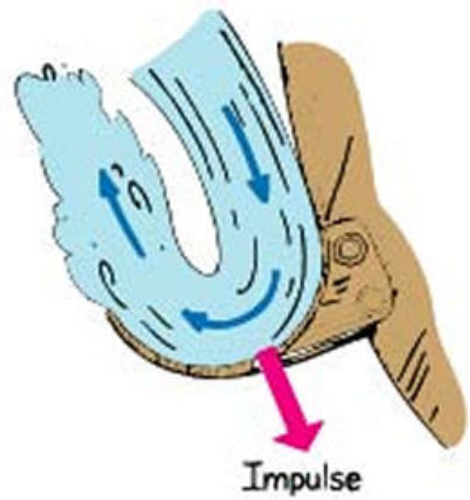
Bouncing ball

- Consider a ball bouncing on the floor in a perfectly elastic collision
- The magnitude of the momentum remains the same but the direction is 180 degrees opposite
- The change of momentum of the ball has a magnitude of 2|p|
- If it were a ball of clay (no bounce), the change of momentum of the ball is |p|
- If the momentum of the ball changes, is momentum not conserved?
- No, the momentum of the Earth has changed



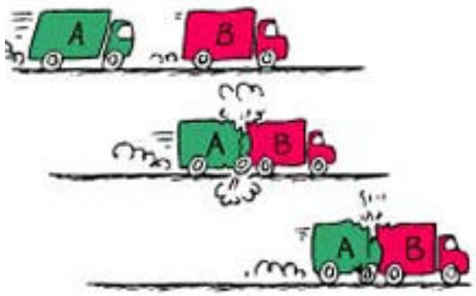
Water wheel

- The water wheels used in the California gold rush were not very effective
- A man named Lester Pelton realized that the impulse (momentum transfer) would be twice as great if he could get the water to “bounce” off the water wheel
- He probably earned more money from this invention than any of the miners earned from their gold strikes



Momentum

- We have been talking about collisions and momentum conservation
- Previously, we discussed elastic collisions
- To the right are two examples of inelastic collisions
- In both cases momentum is conserved
  - the two trucks have the same total momentum after the collision as before
- We've learned that F=Δp/Δt; if there are no external forces, there can be no change in the momentum of the system



$$\vec{P}_{initial} = \vec{P}_{final}$$

Suppose truck A has a mass of 1000 kg
and truck B has a mass of 2000 kg
and truck A is travelling at a speed of 30 m/s
while truck B is travelling at a speed of 20 m/s
The two stick together after the collision. How fast are they moving?

$$\vec{P}_i = \vec{P}_f$$

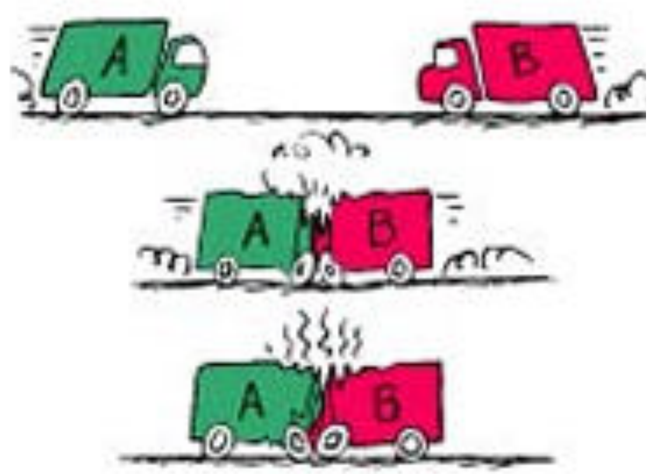
$$m_A v_A + m_B v_B = (m_A + m_B) v_{final}$$

$$(1000kg)(30m/s) + (2000kg)(20m/s) = (3000kg) v_{final}$$

$$v_{final} = 23.3m/s$$

Another example

- Suppose truck A and truck B have the same mass and the same speed
- What is the velocity afterwards



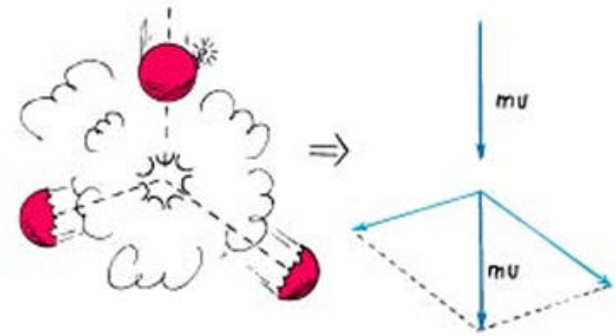
$$\vec{P}_i = \vec{P}_f$$

$$m_A v_A - m_B v_B = (m_A + m_B) v_{final}$$

$$v_{final} = 0 m/s$$

Air track

- Suppose I have a bomb moving with a velocity v and a momentum mv
- It then explodes
- Since there are no external forces, the momentum after the explosion is the same as before



Energy

- A difficult concept, but one central to all of science
- Matter is easy to grasp
  - has mass and occupies space
- Energy is more abstract
  - amazingly enough, the idea was unknown to Newton and existence was still debated in the 1850's
- Energy appears in the form of electromagnetic waves from the Sun
  - we feel it as thermal energy
  - the UV portion causes sun-tans(burns)
  - it is captured by plants and binds molecules together
- Even matter is related to energy by Einstein's famous equation
  - $E=mc^2$

Energy and Work

- In general, energy is the property of a system that enables it to do work
- Work is force acting through a distance
  - Work=Force X Distance
  - W=Fd
  - units = Nm=Joules (J)
- The weightlifter raising the barbells above his head does work
- But he does not do work while merely holding them above his head
- Neither does the guy pushing on the wall
  - force is exerted, and energy is expended, but there's no movement of the wall

Kinetic Energy

- If you push on an object, you can set it in motion
- If an object is moving, then it is capable of doing work
- It has energy of motion or kinetic energy

- The kinetic energy of an object depends both on the mass of an object and its speed
  - just like momentum
- But in this case, the kinetic energy depends on the square of the speed
  - $KE=1/2mv^2$
- and kinetic energy is a scalar quantity
- The kinetic energy of a body is equal to the work required to bring it to that speed from rest
  - net force X distance = kinetic energy
  - $Fd=1/2mv^2$

Einstein’s Big Idea

- Emilie du Chatelet

- Emilie had the insight that the kinetic energy of an object was proportional to the square of its speed

Einstein’s Big Idea

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- Emilie had the insight that the kinetic energy of an object was proportional to the square of its speed
- In an elastic collision, momentum is conserved, but kinetic energy is conserved as well

- Voltaire’s chateau at Ferney-Voltaire near CERN
- Great fireworks on Bastille Day

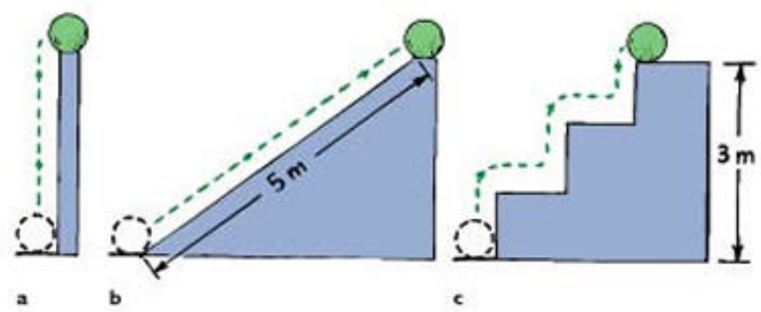
Potential Energy

- An object may store energy by virtue of its position
- The energy stored in this way is called potential energy, because it has the potential for doing work
- A drawn bow has potential energy; the bow can do work on the arrow
- Chemical energy in fuels is also potential energy
  - energy of position at the sub-atomic level
  - energy is available when positions of charges within and between molecules are altered

Gravitational potential energy

- Work is required to elevate objects against Earth's gravity
- The potential energy due to elevated positions is called gravitational potential energy
- The amount of gravitational potential energy possessed by an elevated object is equal to the work done in moving it to its position
- Suppose I have a ball 3 m above the ground
- The work I have to do to lift the ball 3 m above the ground is
  - $W=Fd=(mg)h=mgh$
- This is the gravitational potential energy of the ball
  - $W=(1kg)(9.8N/kg)(3m)=29.4\ J$

1 kg

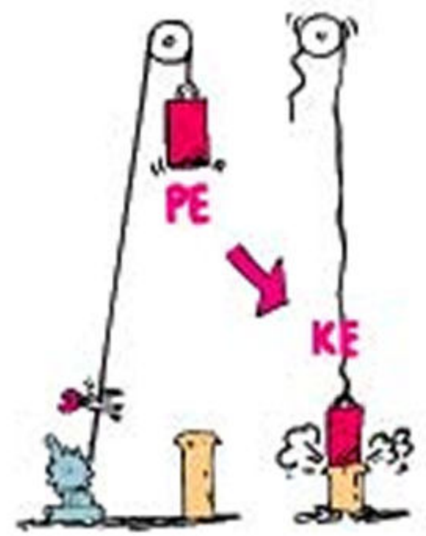


Why mg as a force?
Because gravity is pulling down on the ball with a force mg, and if I want to move it upwards at a constant velocity (no acceleration), then I must exert a force of mg in the opposite direction.

Note that the potential energy is always defined with respect to some reference level, for example the ground or the floor of a building

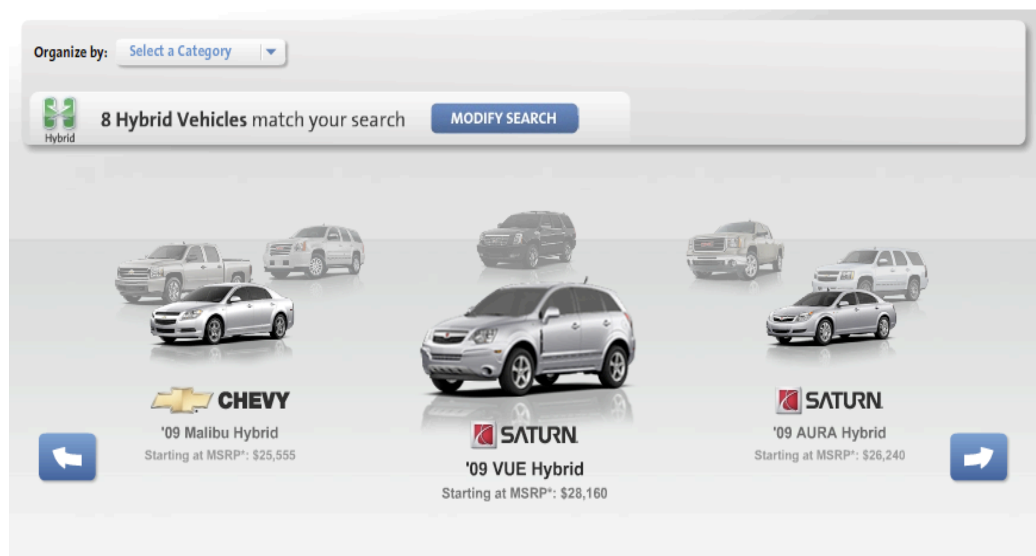
Kinetic<->Potential

- Potential energy can be turned into kinetic energy and vice versa
- That's the whole fun of roller coasters



Work-Energy Theorem

- When a car speeds up, its gain in kinetic energy comes from the work done on it
- Or when a car slows down, work is done to reduce its kinetic energy
- Work=ΔKE
  - work equals the change in kinetic energy
  - applies to potential energy also
- Since KE increases as the square of the speed, the work required to slow a car from a speed v to 0 goes as v^2
- A hybrid car can convert some of that kinetic energy back into chemical energy stored in the battery



Clicker question

- Work is done on a car whenever it slows down
- Suppose two cars of the same mass are travelling on the road
  - car A is going four times as fast as car B
  - both are braked to a complete stop
- How much more work is done on car A than on car B?

- A) the same work is done
- B) twice as much work
- C) four times as much work
- D) sixteen times as much work
- E) sixty-four times as much work

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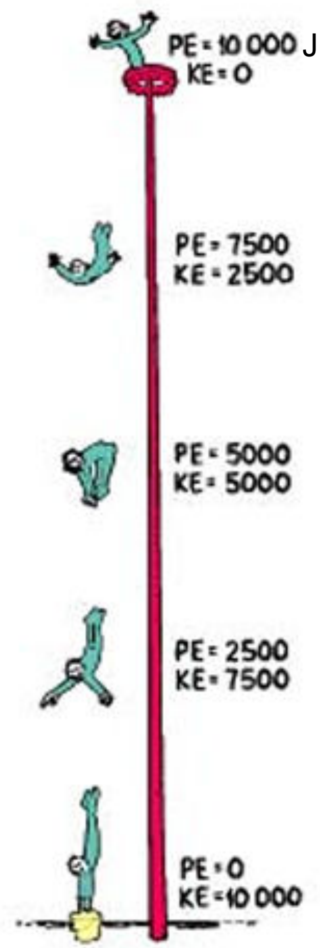
Conservation of energy

- Whenever energy is transformed or transferred, none is lost and none is gained
- In the absence of work input or output, the total energy of a system remains constant
- Consider the circus diver to the right
- As he jumps off the platform, he loses PE but gains an equal amount of KE
- Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes

maximum potential E
mininum kinetic E



minimum potential E
maximum kinetic E

Conservation of energy

- So the circus performer has a PE of 10,000 J (and a mass of 50kg)
- How high up is he?

$$PE = mgh$$

$$h = \frac{PE}{mg} = \frac{10{,}000J}{(50kg)(9.8m/s^2)}$$

$$h = 20.4$$

- What units?
  - J is a unit of energy
  - So 1 J= 1 $kg \cdot m^2/s^2$
  - so h=20.4 m
- How fast is he going when he hits the bucket?

$$KE = \frac{1}{2}mv^2 = \Delta PE = 10000J$$

$$v^2 = \frac{(2)(10000J)}{50kg} = 400J/kg$$

$$v = 20m/s$$