# Momentum

- continued from last time

## Clicker Question:

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

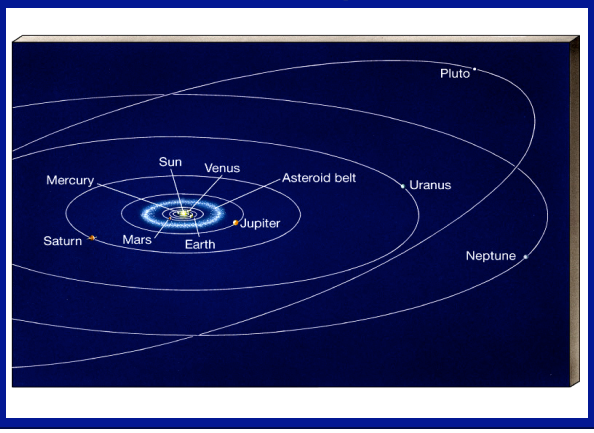
A: It would maintain the same distance from the sun.

B: It would fall closer in to the sun.

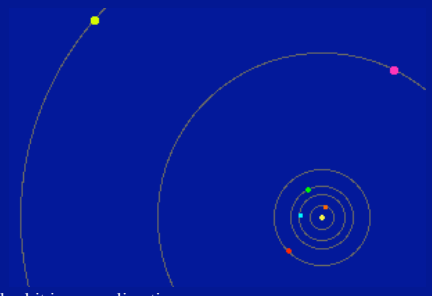
C: It would move farther away from the sun.

D: Can't say.

## Solar System Perspective




## Orbits of Planets



All orbit in same direction.

Most orbit in same plane.

Elliptical orbits, but low eccentricity for most, so nearly circular.

## Why is our Solar System flat?

Pierre Laplace (1749 - 1827): an important factor is "conservation of angular momentum":

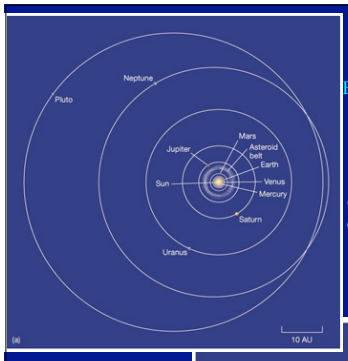
When a rotating object contracts, it speeds up.

"linear momentum" — mass x velocity

"angular momentum" (a property of a spinning or orbiting object) — mass x velocity x "size"

- "size" → of spin or orbit
- "size" → of spinning object or orbit

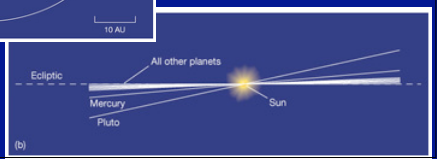
Well demonstrated by ice skaters, or with . . .
Angular momentum Demo #2




Exceptions:

Mercury — orbital tilt 7° — eccentricity 0.21

Pluto (no longer a planet) — orbital tilt 17.2° — eccentricity 0.25



## Energy

- What are some types of energy?

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- What are some types of energy?
  - Electrical
  - Gravitational (potential)
  - Chemical/Biological
  - Heat
  - Light and EM waves
  - Nuclear
- So, what is Energy?

## Matter vs. Energy

- Matter is form or substance
  - Has mass
  - Occupies space
  - Can see, touch, taste, smell, and feel it
- Energy is a process
  - Enables matter to change in some way
    - its position (kinetic energy)
    - its state of motion (work)
    - its chemical bonds, etc.
  - Can be stored in material objects (compressed spring) or propagate through empty space (light from the Sun)

## Momentum vs. Energy

- Momentum is a property of an object
  - Momentum is a vector (has a direction)
- Energy is a process
  - Enables matter to change in some way
    - its position (kinetic energy)
    - its state of motion (work)
    - its chemical bonds, etc.
  - Can be stored in material objects (compressed spring) or propagate through empty space (light from the Sun)
  - Energy is a scalar (has no direction)
- Both are conserved quantities

## Work – Physics Definition

- The work done on an object by an applied force is the product of the force and the distance through which the object is moved:
  - $W = Fd$
  - *Two classes*
    - *(1) Work done against another force*
    - *(2) Work done to change the speed of an object*
    - *What are some examples of each type of work?*

## Work – Physics Definition

- The work done on an object by an applied force is the product of the force and the distance through which the object is moved:
  - $W = Fd$
  - *Two (overlapping) classes*
    - *Work done against another force*
      - *Pulling a bow string (work done against elastic force)*
      - *Pushing a heavy crate across the floor (work done against friction)*
    - *Work done to change the speed of an object*
      - *Speeding up or slowing down an automobile*
      - *Hitting a baseball*
    - *Both types of work involve a transfer of energy!*

## Work (cont.)

- Does the weight lifter do work on the barbell
  - when lifting it over his head?
  - when holding it over his head?
- Is any work being done on the brick wall?
- In which of these situations is energy important?

## Work (cont.)

- Does the weight lifter do work on the barbell
  - when lifting it over his head? Yes
  - when holding it over his head? No
- Is any work being done on the brick wall? No
- In which of these situations is energy important?
  - All of them! Doing work always requires energy, but not all energy is used to do work.

## Clicker Question:

In which of the following is the most work being done:

A: Attending a phys102 lecture

B: Holding a bucket of paint

C: striking a match

D: Falling off a ladder

## Clicker Question:

Which of the following is not a form of energy:

A: light

B: nuclear

C: oil

D: kinetic

## Units

- Time – seconds (s), Distance – meters (m),
- Mass – kilograms (kg)
- Velocity – ???
- Acceleration – ???
- Force - ???
- Work/Energy - ???

## Units

- Time – seconds (s), Distance – meters (m),
- Mass – kilograms (kg)
- Velocity – m/s
- Acceleration – $m/s^2$
- Force – $kg \cdot m/s^2 \equiv N$ (Newton)
- Work/Energy – $N \cdot m \equiv J$ (Joule)

## Power

- Power is the amount of work done per unit time (or the amount of energy expended in a given time)
- $$P = \frac{\text{work done}}{\text{time interval}}$$
- *Units: J/s ≡ W (watt)*
- *Does this mean that a car that is twice as powerful as another car has a top speed that is twice as fast?*

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- *Does this mean that a car that is twice as powerful as another car has a top speed that is twice as fast?*
  - *No. It means that a more powerful engine can accelerate a car up to a given speed faster than a less powerful engine can. In this case, twice as quickly.*

## Types of Energy

- Not only can energy do work, it can also change from one form to another
  - Need to identify different types of energy
- Potential Energy
  - Energy that is stored and held in readiness
    - Has the potential for doing work
    - Examples?

## Types of Energy

- Not only can energy do work, it can also change from one form to another
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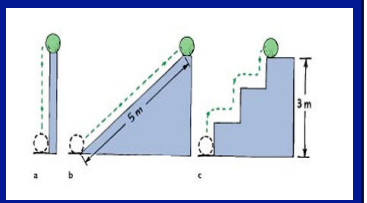
- Potential Energy
  - Energy that is stored and held in readiness
    - Has the potential for doing work
    - Examples?
      - Stretched or compressed spring
      - Stretched rubber band (slingshot)
      - Chemical energy (fossil fuels, batteries, food)
      - Gravitational potential energy

## Gravitational Potential Energy

- Energy possessed by an elevated object
  - Equal to the work done against gravity to lift it
    - No work done (neglecting friction) in moving object horizontally!
    - All three balls at right have same PE!
  - What is the expression for gravitational PE?




$W = Fd$

## Gravitational Potential Energy

- Energy possessed by an elevated object
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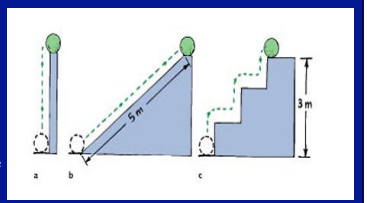
    - All three balls at right have same PE!
  - PE = weight x height
  - PE = $mgh$




$W = Fd$

## Kinetic Energy

- Energy of motion
- KE = ½ mass x speed$^2$
- KE = ½ $mv^2$
  - *If the speed of an object is doubled, how does its kinetic energy change?*

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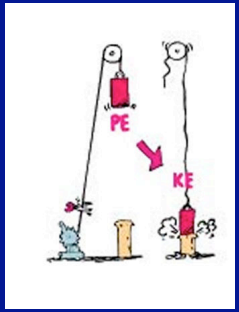
  - *How can gravitational potential energy be converted to kinetic energy?*

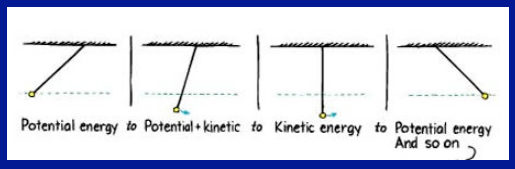
## Kinetic Energy

- Energy of motion
- KE = ½ mass x speed$^2$
- KE = ½ $mv^2$
  - *Doubling the speed of an object quadruples its kinetic energy!*
  - *How can gravitational potential energy be converted to kinetic energy?*
    - *Drop it*
    - *Kinetic energy can then be used to do work*




## Pendulum

- An oscillating pendulum demonstrates how kinetic and potential energies can be transformed into one another.
  - At what point is the pendulum moving fastest? slowest?




Pendulum Demo

Newton's Cradle Demo

## Clicker Question:

Joules/sec are the units for:

A: momentum

B: energy

C: work

D: power

## Clicker Question:

If you are driving at 75 mph, how much more distance do you need to stop yourself than if you were driving at 25 mph?:

A: same distance

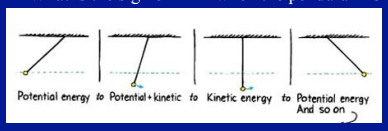
B: twice as far

C: three times as far

D: nine times as far

## Work-Energy Theorem

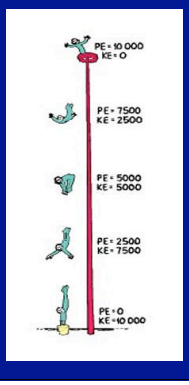
- The work done in changing the speed of an object equals the change in kinetic energy of the object:
  - Work = ΔKE
  - Can be positive, negative, or zero
    - What is the sign of ΔKE when the pendulum is falling?




  - Work is not a form of energy, but a way of transporting energy from one place to another, or changing it from one form to another

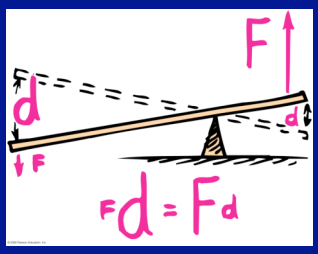
## Conservation of Energy

- Energy cannot be created nor destroyed; it may be transformed from one form into another, but the total amount of energy never changes.
- Where does the diver's energy go when he reaches the ground?
- DEMO - Pendulum




## Machines

We can use simple mechanical machines to multiply forces:

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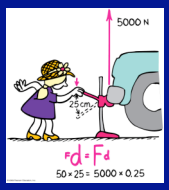


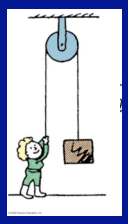

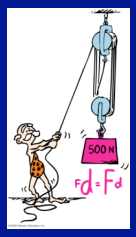


Does this violate conservation of energy?

## Relation between Energy and Mass

$$E = mc^2$$

Famous equation from Einstein,
Energy and matter are related