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" of spin or orbit of spinning object or orbit

Well demonstrated by ice skaters, or with . . .

Angular momentum Demo #2

Exceptions:

<table>
<thead>
<tr>
<th>Planet</th>
<th>Orbital Tilt</th>
<th>Eccentricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>7°</td>
<td>0.21</td>
</tr>
<tr>
<td>Pluto</td>
<td>17.2°</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Mercury (no longer a planet)
Energy

- 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?
- 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? 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 – m/s
- Acceleration – m/s²
- Force - N
- Work/Energy - J

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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: \( J/s \equiv W \) (watt)
- Does this mean that a car that is twice as powerful as another car has a top speed that is twice as fast?

- 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?
      - 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?

\[ W = Fd \]
Kinetic Energy
- Energy of motion
- KE = ½ mass x speed²
- KE = ½ mv²
  - If the speed of an object is doubled, how does its kinetic energy change?

Kinetic Energy
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  - How can gravitational potential energy be converted to kinetic energy?

Kinetic Energy
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  - 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?

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:

\[ F_d = F \cdot d \]

Does this violate conservation of energy?

Relation between Energy and Mass

\[ E = mc^2 \]

Famous equation from Einstein, Energy and matter are related