Today

- Announcements:
  - The average on the first exam was 31/40
  - Exam extra credit is due by 8:00 am Wednesday February 13th.
  - The second homework extra credit is due by Wednesday February 13th.
- F=ma
- Electric Force
- Work, Energy and Power

Newton's Second Law of Force

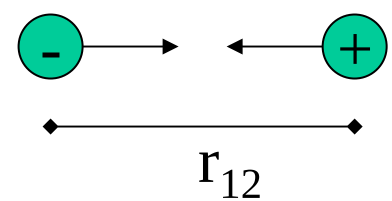
$$F=ma$$

An equation is worth greater than half the words of a picture.

- Force is equal to mass times acceleration.
- For a given force, the amount of acceleration is inversely proportional to the mass.
- Force causes acceleration.
- If you observe acceleration, there must be a force acting.

A new Force!

- Charge is a property of matter. It is measured in Coulombs C.
- Like charges repel, unlike charges attract.
- Coulomb's Law of Electric Force



$$F = \frac{kQ_1Q_2}{r_{12}^2} \qquad k = 8.99E9 \; N \cdot m^2 / C^2$$

Why?

- Coulomb's law looks like Newton's Law of gravity. Why?
- Why does charge come in two types and mass only came in one type?
- Why do we always get r^2? I hate squares.
- Why is $k = 8.99E9\ Nm^2/C^2$ so much bigger than $G = Nm^2/kg^2$?

<u>Two possible answers:</u>

(1) I can't tell you until you are older. (2) I don't know.

Energy

- Energy is the ability to do work
- Energy comes in two forms
  - Kinetic (KE) – energy of motion
  - Potential (PE) – energy of position
- There are many variants on these type main types, e.g. chemical, nuclear, thermal, …

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Energy and Power

- **Energy is the ability to do work**: Work = force x distance = F d
- Energy comes in two forms
  - – Kinetic (KE) – energy of motion
  - – Potential (PE) – energy of position

  Gravitational GPE = m (gh); g = 9.81 m/s^2 on Earth, h height
- **Power** (measured in W = J/s) is the rate of change (or use) of energy

$$KE = \frac{1}{2}mv^2$$

m - mass

v - velocity

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Some Example Problems

Examples:

- A mass of 1.0 kg is raised 1.0 m. How much work was done?

  W = ΔGPE = mgΔh = 1.0 kg x 9.81m/s^2 x 1.0 m = 9.81 J

- A 90.0 kg ISP209 professor walks up two flights of stairs. How much did his/her potential energy increase? DATA 1 flight of stairs = 3.00 m

  ΔGPE = 90.0 kg x 9.81m/s2 x 2 flights x (3 m/flight) = 5.29 kJ

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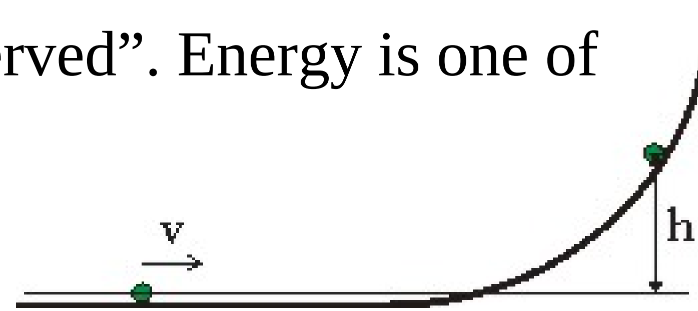
Conservation of Energy

In nature certain quantities are “conserved”. Energy is one of these quantities. Charge is another.

Example: Ball on a hill



A 1.00 kg ball is rolled toward a hill with an initial speed of 5.00 m/s. If the ball roles without friction, how high, h, will the ball go?

$$KE = \frac{1}{2}mv^2 \quad PE = mgh\,;\, g = 9.80\frac{m}{s^2}$$

$$\frac{1}{2}mv^2 = mgh \rightarrow h = \frac{v^2}{2g} = \frac{(5\,m/s)^2}{2\cdot 9.80\frac{m}{s^2}} = 1.28\,m$$

Work

- Work = Force x distance
- Work is a scalar and is measured in Joules, J
- Bill pushes on a wall with 10 N for 33 s. If the wall does not move, how much work is done on the wall?
- Work = 10.0 N x 0.0 m = 0.0 N
- How does that make sense? Work has a strict definition. If the kinetic or potential energy of the wall did not change, no work was done on the wall.
- Work changes energy from one form to another.

Power

- Power is the rate of change of energy
- Power = (change in energy)/(change in time)
- Power is a scalar and is measured in watts.
- Light bulbs are measured in watts
- Sun (a big light bulb) - 3.827×10^{26} W

Information

- Horsepower 746 W = 1 horsepower

  In fourteen hundred and ninety-two
  Columbus sailed the ocean blue.
  And if you divide by two
  You get watts in a horsepower too

- Food energy is measured in kcal
  - 1 food cal = 4.184 J
  - 1 Calorie = 1 kcal (what we call calories are actually kilocalories)

Example Problem

How many kcal are burned by doing 1500 J of work?

DATA: The human body is 10% efficient in converting food energy to work.

$$\text{cal} = \text{energy} \cdot \frac{1\,\text{cal}}{4.184\,\text{J}} \cdot \left(\frac{1}{efficiency}\right)$$

$$1500\,\text{J} \cdot \frac{1\,\text{cal}}{4.184\,\text{J}} \cdot \left(\frac{1}{0.1}\right) = 3590.\text{cal} = 3.59\ \text{kcal}$$