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

$$F = \frac{kQ_1Q_2}{r_{12}^2} \quad k = 8.99 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2$$

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 $k = 8.99 \times 10^9 \text{Nm}^2/\text{C}^2$ so much bigger than $G = \text{Nm}^2/\text{kg}^2$?

Two possible answers:
(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, ...

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

Some Example Problems

Examples:
- A mass of 1.0 kg is raised 1.0 m. How much work was done?
  \[ W = \Delta GPE = mg \Delta h = 1.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 1.0 \text{ m} = 9.81 \text{ J} \]
- 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
  \[ \Delta GPE = 90.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 2 \text{ flights x (3 m/flight)} = 5.29 \text{ kJ} \]

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?

\[
\begin{align*}
KE &= \frac{1}{2}mv^2 \\
PE &= mgh; \quad g = 9.80 \frac{m}{s^2} \\
\frac{1}{2}mv^2 &= mgh \\
\frac{v^2}{2g} &= \frac{(5 \text{ m/s})^2}{2 \times 9.80 \frac{m}{s^2}} = 1.28 \text{ m}
\end{align*}
\]
Work

• Work = Force \times 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 \text{ N} \times 0.0 \text{ m} = 0.0 \text{ 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 = \frac{\text{change in energy}}{\text{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 \times 10^{26} \text{ 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.

\[
\text{cal} = \text{energy} \times \frac{1 \text{ cal}}{4.184 \text{ J}} \times \frac{1}{\text{efficiency}}
\]

\[
1500 \text{ J} \times \frac{1 \text{ cal}}{4.184 \text{ J}} \times \frac{1}{0.1} = 3590 \text{ cal} = 3.59 \text{ kcal}
\]