



## Today

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- 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

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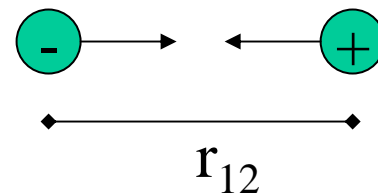
$$F=ma$$

*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



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



# Why?

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

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- 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

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• **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 =  $m (gh)$ ;  $g = 9.81 \text{ m/s}^2$  on Earth,  
h height

• **Power** (measured in  $W = \text{J/s}$ ) is the rate of change (or use) of energy

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

m - mass

v - velocity



## Some Example Problems

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### Examples:

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

$$W = \Delta GPE = mg\Delta h = 1.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 1.0 \text{ m} = 9.81 \text{ J}$$

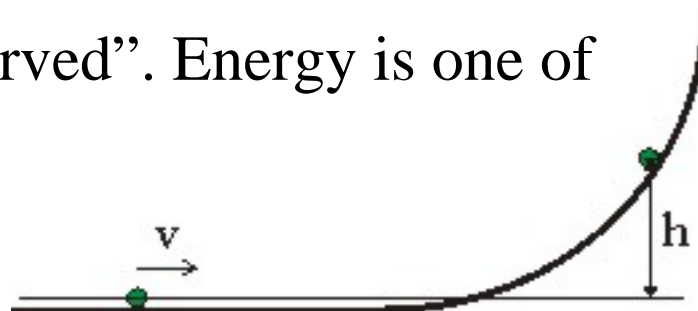
- A 90.0 kg ISP209 professor walks up two flights of stairs. How much did his/her potential energy increase? DATA 1 flight of stairs = 3.00 m

$$\Delta GPE = 90.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 2 \text{ flights} \times (3 \text{ m/flight}) = 5.29 \text{ kJ}$$

## 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 rolls without friction, how high,  $h$ , will the ball go?

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

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



## Work

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- 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

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- 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) -  $3.827 \times 10^{26}$  W



## Information

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- Horsepower  $746 \text{ W} = 1 \text{ horsepower}$   
*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
  - $1 \text{ food cal} = 4.184 \text{ J}$
  - $1 \text{ Calorie} = 1 \text{ kcal}$  (what we call calories are actually kilocalories)



## Example Problem

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

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

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

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