Chapter 05-2

Energy of a Multi-Particle System

## Poll

If a force on a particle is in the *opposite* direction as the displacement (through which it acts), then the work done on the particle by the force is

1. Positive
2. Negative
3. Zero

## Poll

If a force on a particle is in the *same* direction as the displacement (through which it acts), then the work done on the particle by the force is

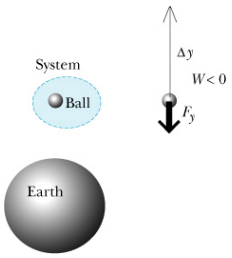
1. Positive
2. Negative
3. Zero

## Poll

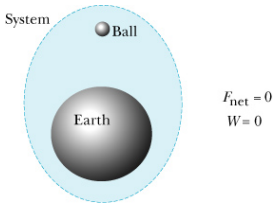
If a force on a particle is perpendicular to the displacement (through which it acts), then the work done on the particle by the force is

1. Positive
2. Negative
3. Zero

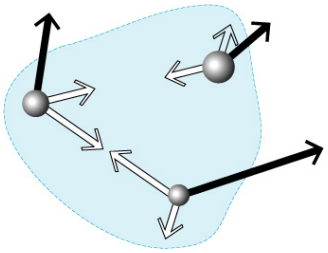
## Single Particle System



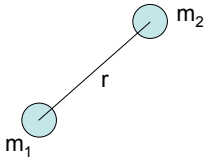

## Multi-Particle System



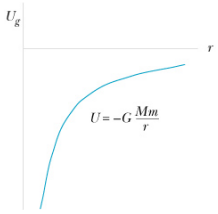
## Potential Energy



## Gravitational Potential Energy




$$U_{grav} = \frac{-Gm_1m_2}{r}$$

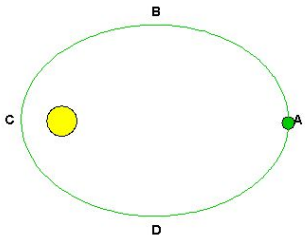



## Energy of a Multi-Particle System

$$E = E_{rest,total} + K_{total} + U_{total}$$

$$E = (m_1c^2 + m_2c^2 + \cdots) + (K_1 + K_2 + K_3 + \cdots) + (U_{1,2} + U_{1,3} + U_{2,3} + \cdots)$$

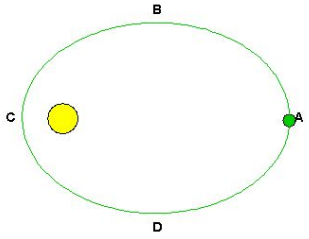
## Example--Orbit




## Poll

As a comet travels from point A to point C, the gravitational potential energy of the sun-comet system

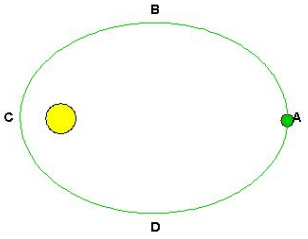
1. Increases
2. Decreases
3. Remains constant




## Poll

As a comet travels from point A to point C, the kinetic energy of the sun-comet system

1. Increases
2. Decreases
3. Remains constant



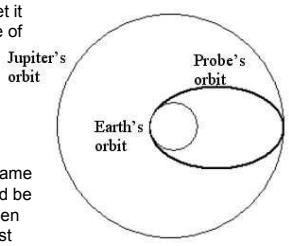
## Energy of for a circular orbit

## Example

A probe is sent to Jupiter. Its orbit is called a "least-energy" orbit because no fuel is necessary to get it to Jupiter; it simply "rides" the gravitational force of the Sun.

The radius of the Earth's nearly circular orbit is $150 \times 10^6$ km, and the radius of Jupiter's nearly circular orbit is $778 \times 10^6$ km.

If the probe's speed at aphelion should be the same as the speed of Jupiter at that point, what should be its speed at perihelion? Once you know that, then your job on the mission is to fire the thrusters just right so that it has the correct velocity at perihelion. Then, you shut off the engines and let Newton do the driving.




## Gravitational Potential Energy near Earth

## Example

The Kingda Ka roller coaster goes to the top of a 139-m tall hill. It drops to a height of 12 m above the ground. What is its speed at the bottom, if its speed at the top is 1.0 m/s?

## Poll

Does your answer to the previous question depend on whether the roller coaster is full of people? (In other words, does your answer depend on mass?)

1. yes
2. no

## Poll

Does the speed of the roller coaster at the bottom of the hill depend on whether it is frictionless or not?

1. yes
2. no

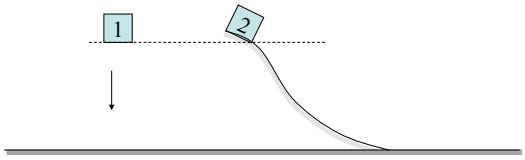
## Example

Suppose that the mass of the Kingda Ka rollercoaster, full of people, is 1800 kg. If its speed at the bottom is 45 m/s, how much mechanical energy is lost due to friction as it travels down the hill?

## Poll

Does your answer to the previous question depend on whether the roller coaster is full of people? (In other words, does your answer depend on mass?)

1. yes
2. no




Two identical blocks are simultaneously released from the same height above a level floor. Block 1 reaches the floor by dropping straight down. Block 2 reaches the floor by sliding down a frictionless ramp. Which of the following correctly compares the two motions?

**A.** Both blocks reach the ground at the same time with the same speed

**B.** Block 2 reaches the ground later but with the same speed.

**C.** Block 2 reaches the ground later and with less speed.

**D.** Block 2 reaches the ground at the same time but with less speed.

## Electric Potential Energy

$$U_{coul} = \frac{(9 \times 10^9) q_1 q_2}{r}$$

## Example

A 2-mm-diameter plastic bead is charged to -1 nC. An alpha particle (He nucleus) is fired at the bead from far away with a speed of $1 \times 10^6$ m/s, and it collides head-on. What is its speed at impact?

## Example

Suppose an electron is fired at the bead from far away and it "reflects" at a distance of 0.1 mm from the surface. What was the electron's initial speed?