Lecture 15
(Kinetic Energy)

Physics 160-01 Fall 2012

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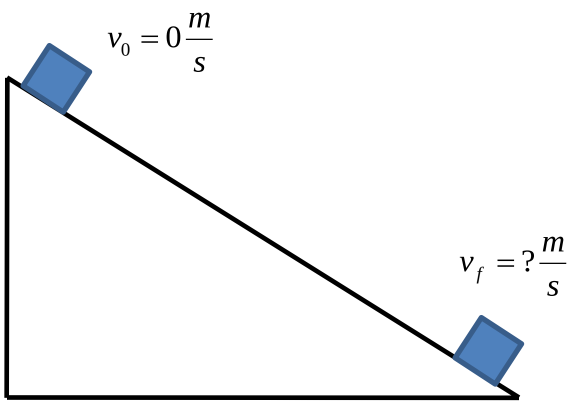
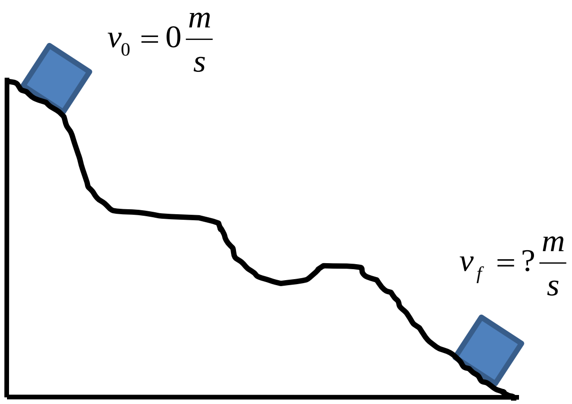
Your Toolbox so far:

- Vectors
  - Components, vector addition, etc.
- Position, velocity, acceleration
  - Constant acceleration equations
- Newton’s laws

Tricks of the trade…

- Newton's Laws are ALWAYS true (that's why their called laws). So, why do we need anything else to describe how nature works?
- Example: Block sliding down an incline…





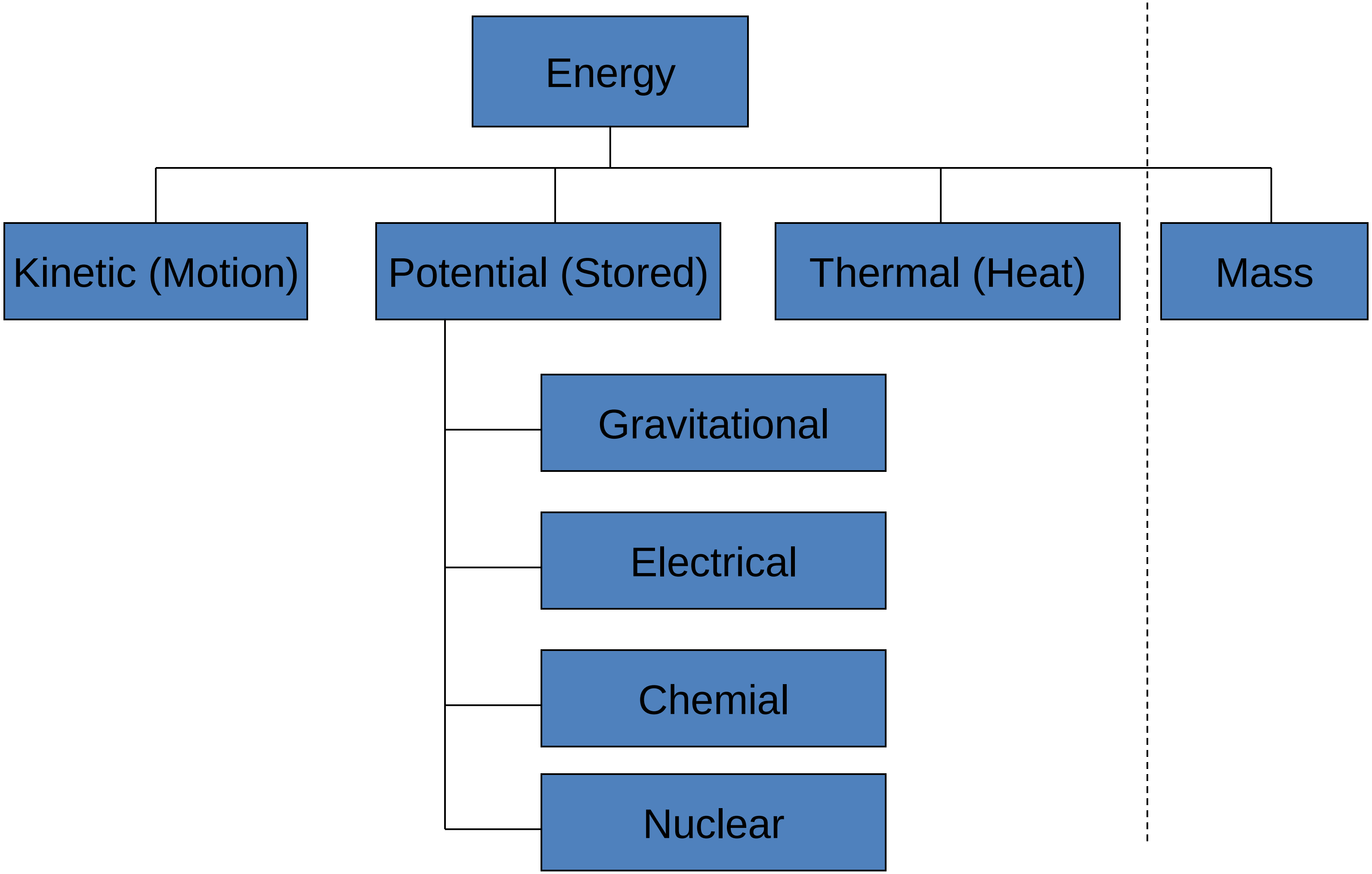
Definition of Energy

- Energy is the capacity to do work

Definition of Work

- Work is something done to change the energy of a system.

Types of Energy



Kinetic Energy

- Energy of Motion
  - KE = ½ x mass x speed^2 [units = kg x m^2/s^2]
  - KE = ½mv^2 [units = Joule = J]
- Unit analysis:
  - [J = kg x m^2/s^2 = kg x m/s^2 x m = N x m]

Kinetic Energy

- Example 1: Car weighing 2000lbs moving at 60miles/hour. KE = ?

$$2000lbs = \frac{1kg}{2.205lbs} \cdot 2000lbs = 907kg$$

$$60mi = \frac{1609m}{1mi} \cdot 60mi = 96540m$$

$$1hr = \frac{60\min}{1hr} \cdot \frac{60s}{1\min} = 3600s$$

$$KE = \frac{1}{2} 907kg \cdot \left(\frac{96540m}{3600s} \right)^2 = 326127 \frac{kg \cdot m^2}{s^2} = 3.2 \times 10^5 J$$

Kinetic Energy

- Example 2: Car weighing 4000lbs moving at 60miles/hour. KE = ?

$$4000lbs = \frac{1kg}{2.205lbs} \cdot 4000lbs = 1814kg$$

$$60mi = \frac{1609m}{1mi} \cdot 60mi = 96540m$$

$$1hr = \frac{60\min}{1hr} \cdot \frac{60s}{1\min} = 3600s$$

$$KE = \frac{1}{2} 1814kg \cdot \left(\frac{96540m}{3600s} \right)^2 = 6.5 \times 10^5 J$$

Kinetic Energy

- Example 3: Car weighing 2000lbs moving at 120miles/hour. KE = ?

$$2000lbs = \frac{1kg}{2.205lbs} \cdot 2000lbs = 907kg$$

$$120mi = \frac{1609m}{1mi} \cdot 120mi = 193080m$$

$$1hr = \frac{60\min}{1hr} \cdot \frac{60s}{1\min} = 3600s$$

$$KE = \frac{1}{2} 907kg \cdot \left(\frac{193080m}{3600s} \right)^2 = 13 \times 10^5 J$$

Kinetic Energy

- Note: Doubling the mass doubles the kinetic energy, but doubling the speed, quadruples the kinetic energy!

Force and Work

- In order to get the car moving (and therefore giving it kinetic energy), we must apply a force over some distance. If we assume that the force that we apply is constant, then the work done by a force is just equal to the force applied time the distance over which it is applied:
- Work = Force x distance (W=Fd) [units = N x m = J]
- This work is then a transfer of energy from the body doing work, to the body that is experiencing the work done on it.

Work-Energy Theorem

- The total work done on an object equals the change in kinetic energy of that object.

$$W_{tot} = KE_f - KE_i = \Delta KE$$

CPS Question 14-1

- **If it takes work W_1 to move a mass m from zero velocity up to a velocity v, how much work would it take to move the same mass from zero velocity up to velocity $2v$?**

  A) $2W_1$.

  B) $3W_1$.

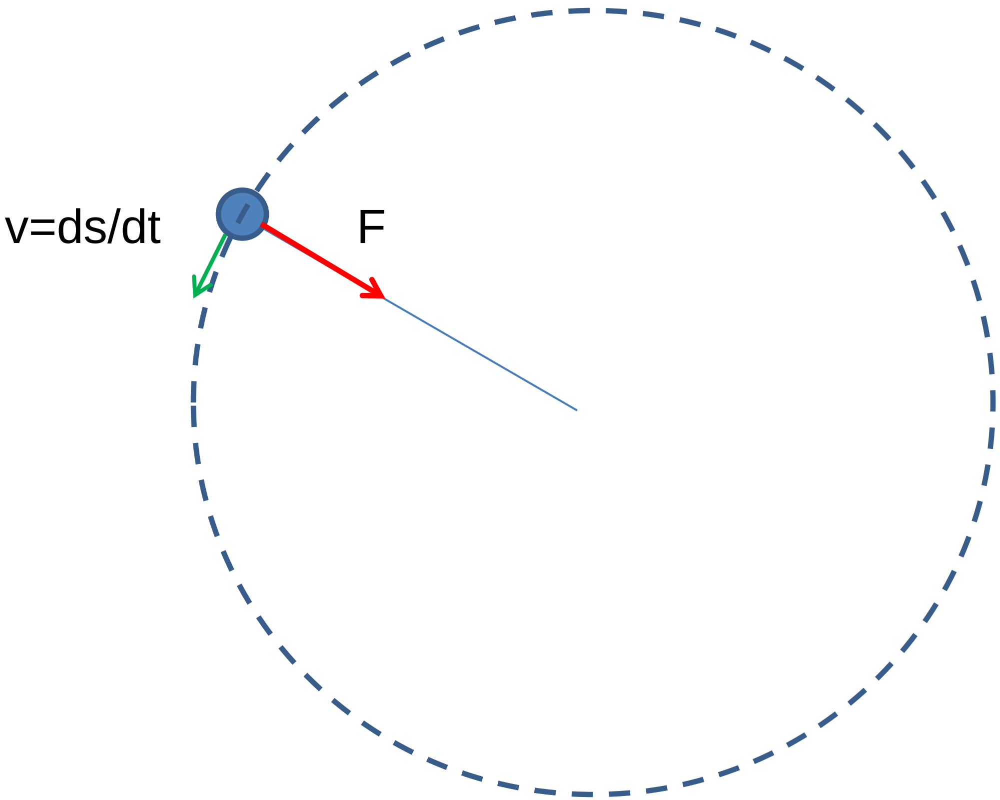
  C) W_1.

  D) $4W_1$.

  E) Not enough information to solve.

But Force is a VECTOR!!!

- Consider me putting a force on a ball in circular motion:



Mathematically Correct Definition of Work

- A little bit of work done by a force on an object moving over a small displacement is:

$$dW = \vec{F} \cdot d\vec{s}$$

- To find the work on an object must sum over all the incremental works:

$$W = \int dW = \int_i^f \vec{F} \cdot d\vec{s}$$

Path integral…

- If the force is constant over the path, AND the angle doesn’t change with respect to the displacement, then:

$$W = \vec{F} \cdot \vec{s}$$

Problem 6.3

6.3. A factory worker pushes a 30.0-kg crate a distance of 4.5 m along a level floor at constant velocity by pushing horizontally on it. The coefficient of kinetic friction between the crate and the floor is 0.25. (a) What magnitude of force must the worker apply? (b) How much work is done on the crate by this force? (c) How much work is done on the crate by friction? (d) How much work is done on the crate by the normal force? By gravity? (e) What is the total work done on the crate?

Problem 6.4

6.4. Suppose the worker in Exercise 6.3 pushes downward at an angle of 30° below the horizontal. (a) What magnitude of force must the worker apply to move the crate at constant velocity? (b) How much work is done on the crate by this force when the crate is pushed a distance of 4.5 m? (c) How much work is done on the crate by friction during this displacement? (d) How much work is done on the crate by the normal force? By gravity? (e) What is the total work done on the crate?

CPS Question 15-2

- **Three forces act on a body of mass *m = 1kg* to move it from rest up to a velocity of *2m/s* (direction unknown). Two of the forces are known – the force of gravity, and a constant upward force of 1N – and the third force is unknown. What is the net work done on the mass?**

A) 2*J*

B) 8.8*J*

C) 4*J*

D) Not enough information to solve.