Lecture 12
(Kinetic Energy)

Physics 160-02 Spring 2017

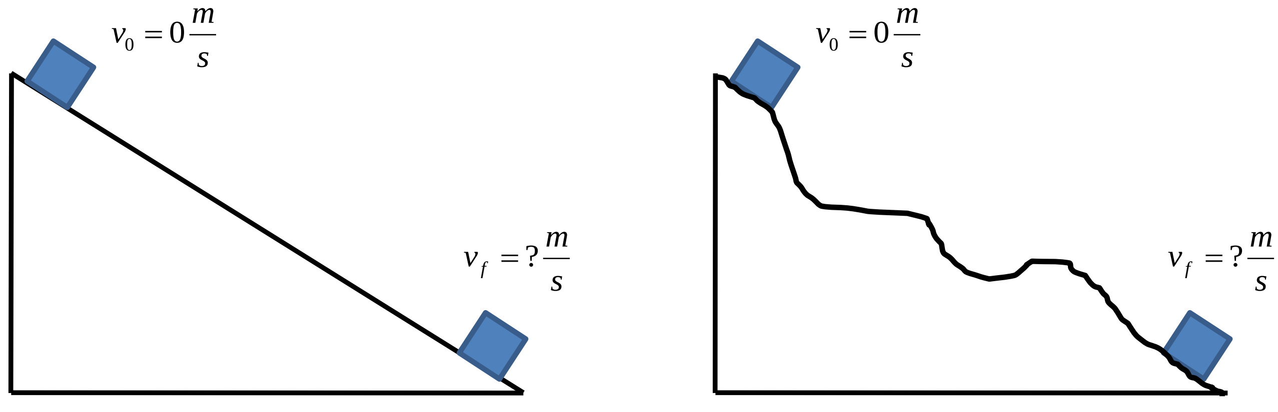
Douglas Fields

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…



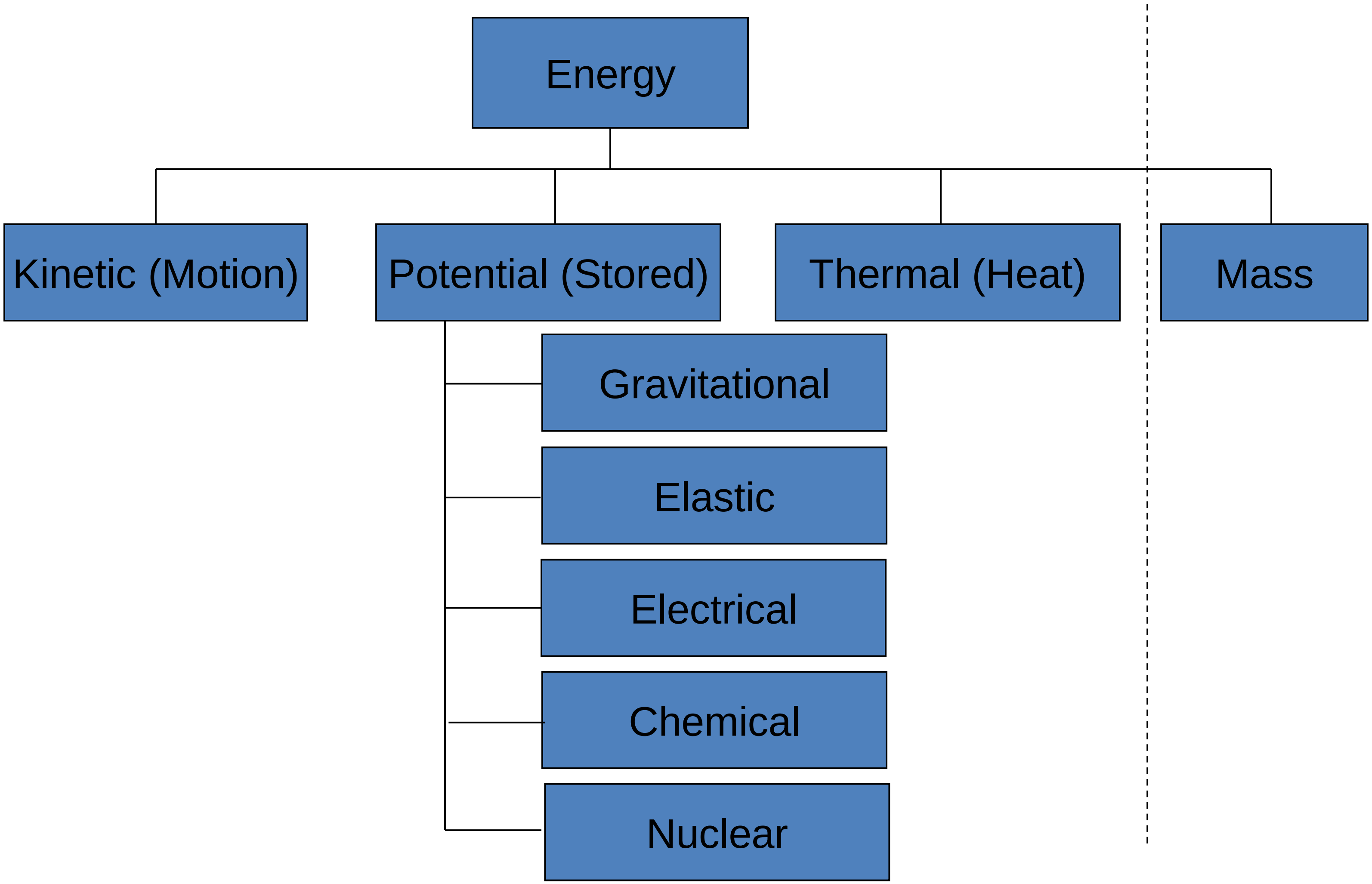
Definition of Energy

- 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]

One joule in everyday life represents approximately:

- The energy required to lift a medium-size tomato (100 g) 1 m vertically from the surface of the Earth.[6]
- The energy released when that same tomato falls back down to the ground.
- The energy required to accelerate a 1 kg mass at 1 $m \cdot s^{-2}$ through a 1 m distance in space.
- The heat required to raise the temperature of 1 g of water by 0.24 °C.[7]
- The typical energy released as heat by a person at rest every 1/60 s (approximately 17 ms).[8]
- The kinetic energy of a 50 kg human moving very slowly (0.2 m/s or 0.72 km/h).
- The kinetic energy of a 56 g tennis ball moving at 6 m/s (22 km/h).[9]
- The kinetic energy of an object with mass 1 kg moving at $\sqrt{2} \approx 1.4$ m/s.
- The amount of electricity required to light a 1 W LED for 1 s.
    - From Wikipedia - Joule

Kinetic Energy

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

$$1kg \text{ weighs } 2.205lbs$$

$$1mi = 1609m$$

$$1hr = 3600s$$

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 times 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) $3W_1$.

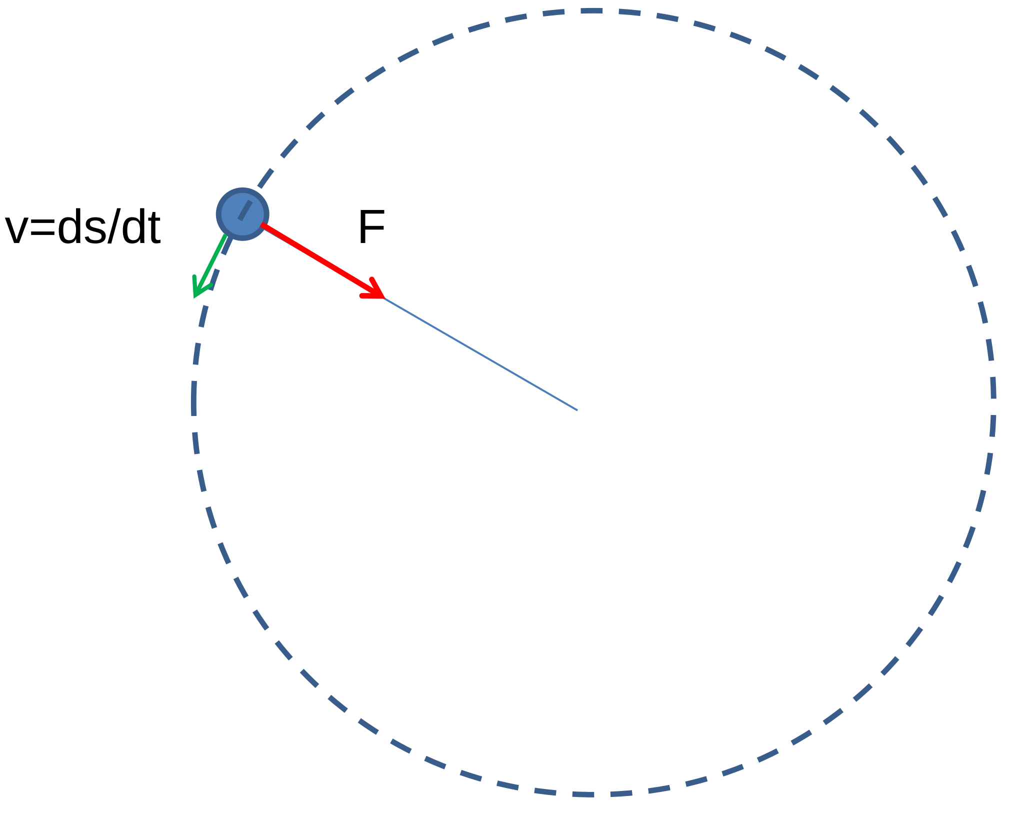
  C) W_1.

  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

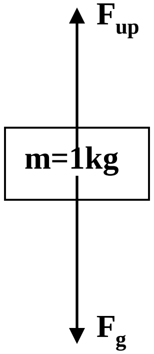
- **Three forces act on a body of mass *m = 1kg* to move it from rest up to a velocity of *2m/s* (direction unknown). Two of the forces are known – the force of gravity, and a constant upward force of 1N – and the third force is unknown. What is the net work done on the mass?**

A) 2*J*

B) 8.8*J*

C) 4*J*

D) Not enough information to solve.



Problem 6.27

6.27. Stopping Distance. A car is traveling on a level road with speed v_0 at the instant when the brakes lock, so that the tires slide rather than roll. (a) Use the work–energy theorem to calculate the minimum stopping distance of the car in terms of v_0, g, and the coefficient of kinetic friction μ_k between the tires and the road. (b) By what factor would the minimum stopping distance change if (i) the coefficient of kinetic friction were doubled, or (ii) the initial speed were doubled, or (iii) both the coefficient of kinetic friction and the initial speed were doubled?

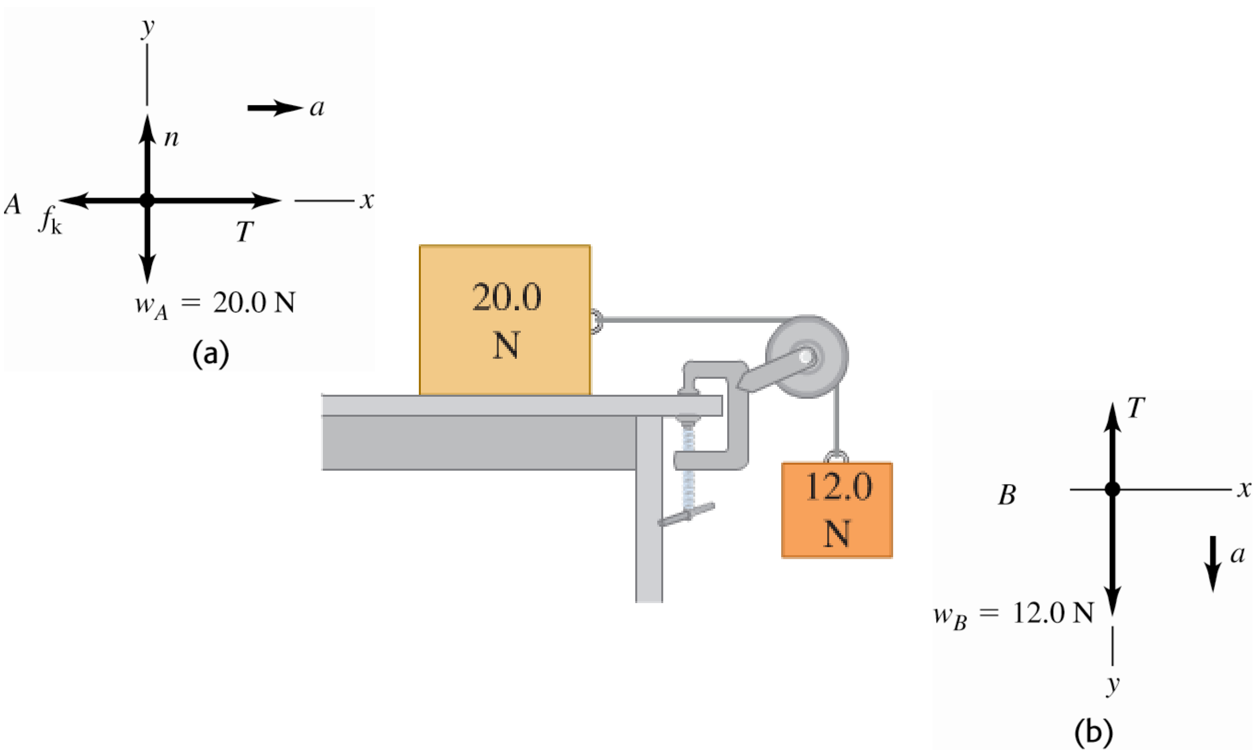
Work-Energy Theorem

$$W_{TOTAL!!} = \Delta KE$$

- For instance, in raising a book from the ground up to a height h, you must consider both the work that I do, plus the work that gravity does!

Problem 6.60

6.60. Consider the blocks in Exercise 6.7 as they move 75.0 cm. Find the total work done on each one (a) if there is no friction between the table and the 20.0-N block, and (b) if $\mu_s = 0.500$ and $\mu_k = 0.325$ between the table and the 20.0-N block.



CPS Question 16-1

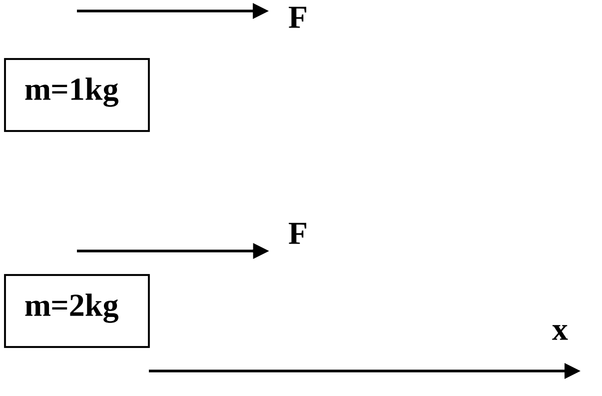
- **Two masses experience the same net force, F, over the same distance, x. Describe the difference in the kinetic energy between the two masses at the end of the path.**

A) The heavier mass has more kinetic energy.

B) The lighter mass has more kinetic energy.

C) They have the same kinetic energy.

D) Not enough information to solve.



Problem 6.62

6.62. A 5.00-kg package slides 1.50 m down a long ramp that is inclined at 12.0° below the horizontal. The coefficient of kinetic friction between the package and the ramp is $\mu_k = 0.310$. Calculate (a) the work done on the package by friction; (b) the work done on the package by gravity; (c) the work done on the package by the normal force; (d) the total work done on the package. (e) If the package has a speed of 2.20 m/s at the top of the ramp, what is its speed after sliding 1.50 m down the ramp?