Spring 2014

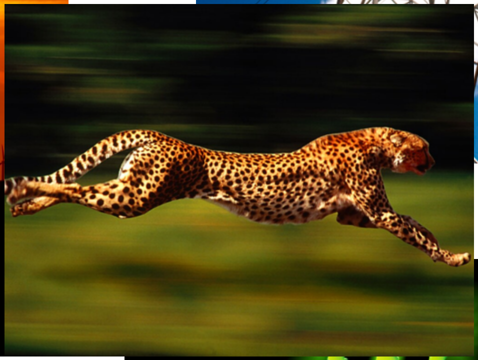
PHYS-2010

Lecture 24

Announcements

- Read Giancoli Chapter 6.
- **CAPA # 8** is due Tuesday at 11 pm.
- **Written homework** due this Friday at 4 pm.
- **Study session** by Prof. Pollock on Tue. March 11, 5-6 pm, Duane G125.
- This week in Section: **Recitation 5:** Work & Energy
- Exam solutions and scores are posted on D2L.

WORK AND ENERGY



What is Energy?

Energy comes in many forms.

Energy can be converted from one form to another.

- Kinetic energy (KE) - energy of motion
- Thermal energy - energy of atomic vibrations
- Potential energy (PE) - energy stored in configuration
  - gravitational
  - electrostatic
  - elastic
  - chemical
  - nuclear

- Radiant (solar) energy – energy of light
- Mass energy – Einstein's $E=mc^2$

To understand energy,
its inter-conversion to different forms,
and its conservation,
we must first define some terms:

Work

Kinetic Energy (KE)

“Work-Energy Principle”

Potential Energy (PE)

What is Energy?

Definition: Energy is the ability to do **"Work"**

Of course now we will need a physics definition of "Work".

Whenever work is being done, energy is being changed from one form to another or being transferred from one body to another.

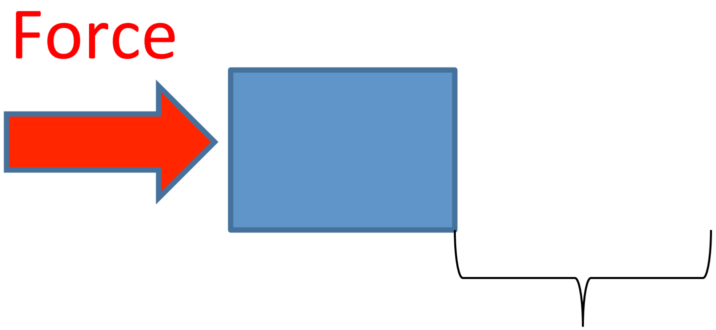
The amount of work done on a system (or by a system) is the change in energy of the system.

Energy is such a useful concept because it is **"Conserved"**.

WORK

Consider a force $\vec{F}$ acting on a moving object.

While the force is applied, if the object moves a distance *d* in the direction of the force vector, then the work done is:



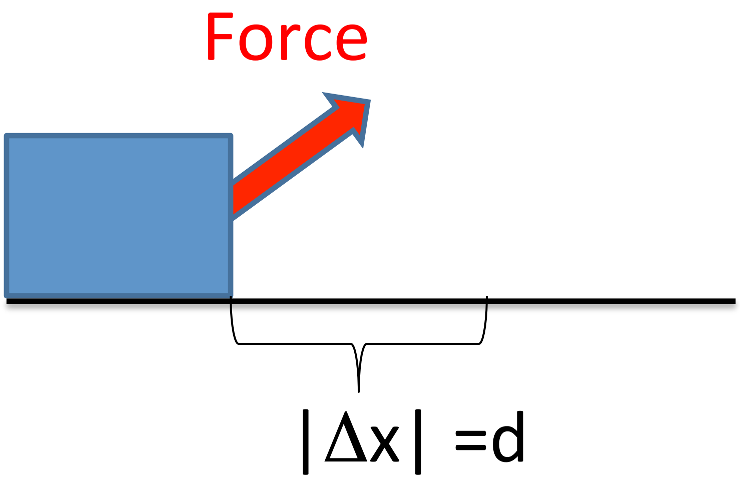
$|\Delta x| = d$

$$\text{Work} = \text{W} = \text{Force} \times \text{Displacement}$$

Work must have units of Newtons x meters = (kg m/s^2) x m = kg m^2/s^2

We also call this **Joules** – the SI unit for work and also energy!

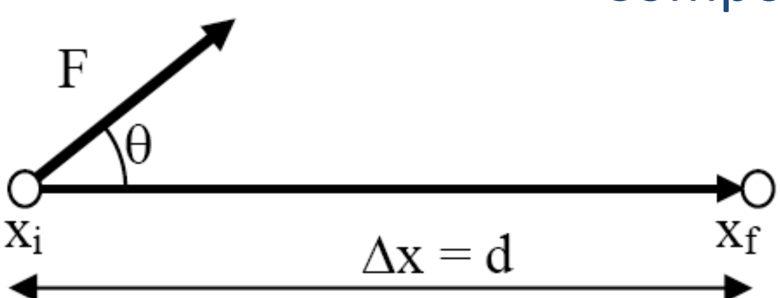
WORK



What if the force vector is at some angle with respect to the displacement vector?

$$\text{Work} = W = F_x \cdot d = F\cos(\theta)\, d = F_{\parallel} d$$

Component of force along the displacement



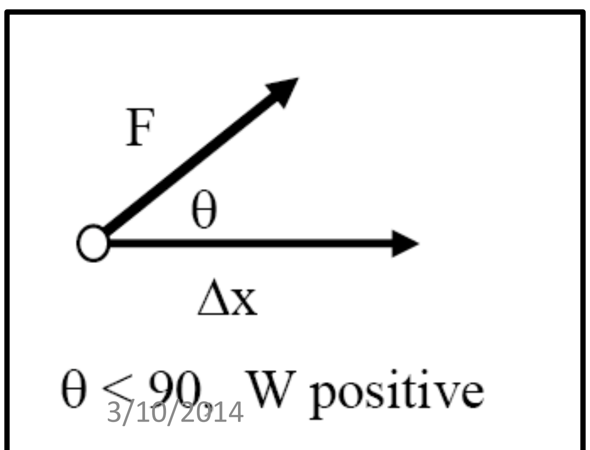
$$W_F \equiv F_x \cdot d = F\cos\theta\, d = F_{||}\, d$$

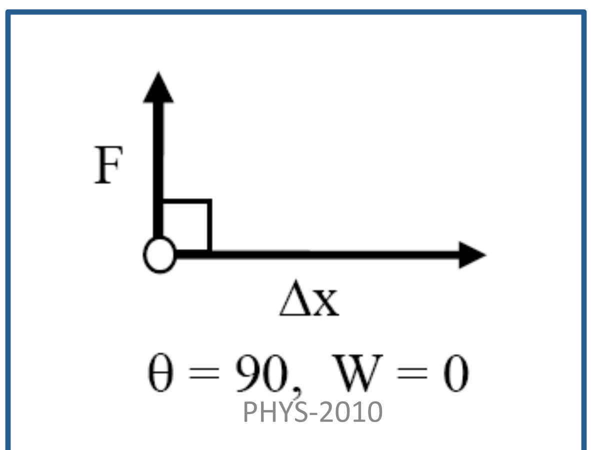
Note: Work is a scalar (not a vector), but it does have a sign.

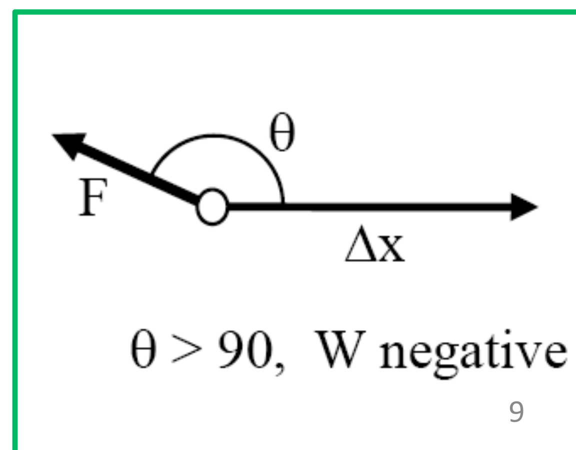
When the component of force in the direction of displacement points along the displacement, **Work is positive**.

When the force is perpendicular to the displacement, **Work is zero**.

When the component of force in the direction of displacement points opposite to displacement, **Work is negative**.







Clicker Question

Room Frequency BA

Atlas holds up the entire earth for 20 seconds.

What can you say about the work done by Atlas?

A) An enormous amount of work (many, many Joules)
B) 20 Joules
C) None

There is no displacement of the earth.

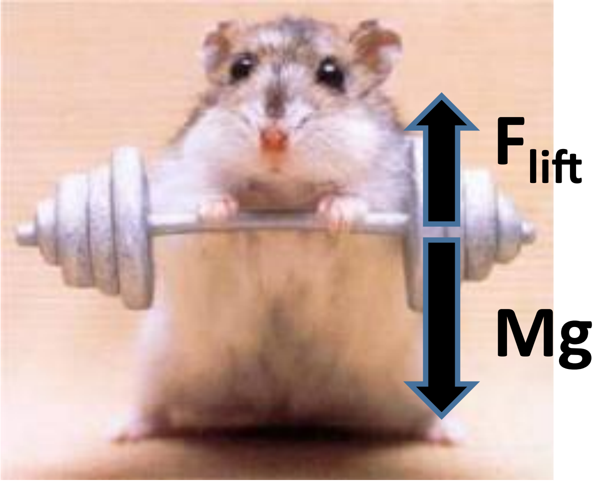
Thus, despite the very large force (Mg) needed to hold up the earth, no work is done.

Clicker Question

Room Frequency BA

You are at the gym and observe this fellow lifting weights.

He lifts 10 kg at constant velocity upwards a distance of 0.1 meters.



What are the forces on the barbell in a free body diagram?

What is true about the work done by the fellow on the barbell (via F_{lift})?

A) Work > 0 B) Work < 0 C) Work = 0

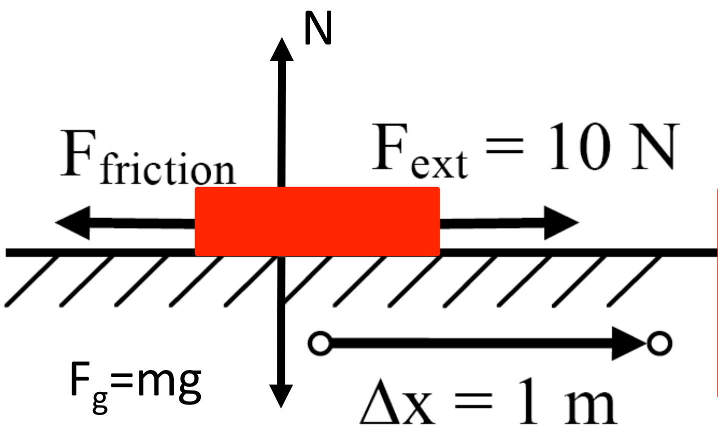
What is true about the work done by the force of gravity on the barbell?

A) Work > 0 B) Work < 0 C) Work = 0

Whenever you talk about "Work Done", you have to be careful to specify ***which force*** does the work!

$$W_F \equiv F_x \cdot d = F\cos\theta\, d = F_{||}\, d$$

Consider an object displaced $\Delta x = +1$ m at a ***constant speed*** on a rough table by a constant external force F = 10 N.



Work done by the external force =

$W_{ext} = +F_{ext}\,\Delta x = (10\text{ N})(1\text{m}) = +10$ J

Work done by the friction force =

$W_{fric} = -F_{fric}\,\Delta x = -(10\text{ N})(1\text{m}) = -10$ J

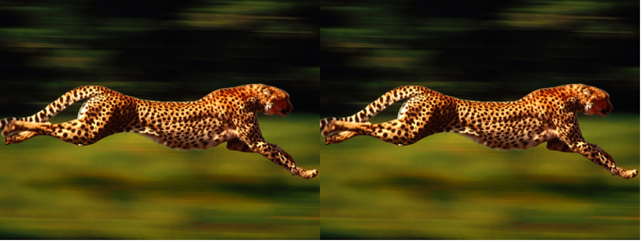
Work done by the normal force =

$W_N = (0)\,\Delta x = 0$ J

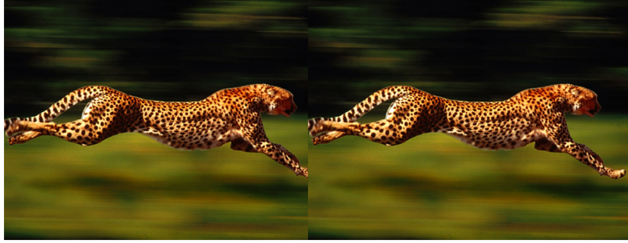
Work done by gravity

$W_g = (0)\,\Delta x = 0$ J

Work done by the net force $= W_{net} = (0)\,\Delta x = 0$ J



Kinetic Energy



The kinetic energy (KE) of an object of mass *m* moving with speed *v* is:

$$\mathrm{KE} = \frac{1}{2} m v^2$$

- KE is the energy of motion.
- KE is always positive (or 0).
- KE and Work are related by the “Work-Energy Principle”
- Units of KE: same as work

$$\mathrm{KE} = \frac{1}{2} m v^2 \Rightarrow [kg][m/s]^2 = \left[\frac{kgm}{s^2} m\right] = \left[Nm\right] = [\mathrm{Joules}]$$

Work-Energy Principle

The work done by the **net force on a single object** is equal to the change in kinetic energy of that object:

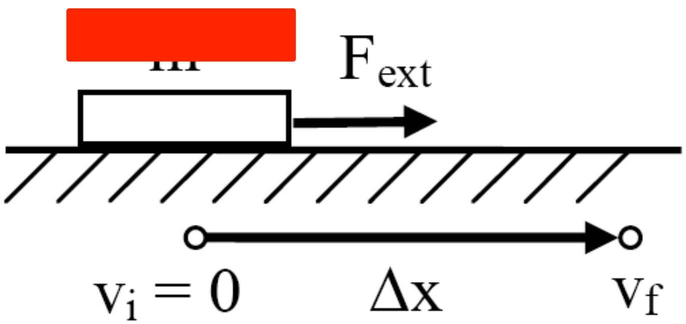
$$W_{net} = W_{F_{net}} = \Delta KE = KE_f - KE_i$$

Since work is a transfer of energy via a force, this is a statement of conservation of energy.

Work-Energy Principle

$$W_{net} = W_{Fnet} = \Delta KE = KE_f - KE_i$$

Push a **book** across a frictionless table with constant force F_{ext}



#1: $F_{net} = F_{ext}$ (since *N* and *mg* cancel)

#2: $F_{net} = ma \rightarrow a = F_{ext} / m$

#3: $W = +F_{ext}\,\Delta x \rightarrow F_{ext} = W / \Delta x$

#4: $v_f^2 - v_i^2 = 2a\,\Delta x$

$$v_f^2 - v_i^2 = 2(F_{ext}/m)\,\Delta x$$

$$v_f^2 - v_i^2 = 2\,[(W/\cancel{\Delta x})/m]\,\cancel{\Delta x}$$

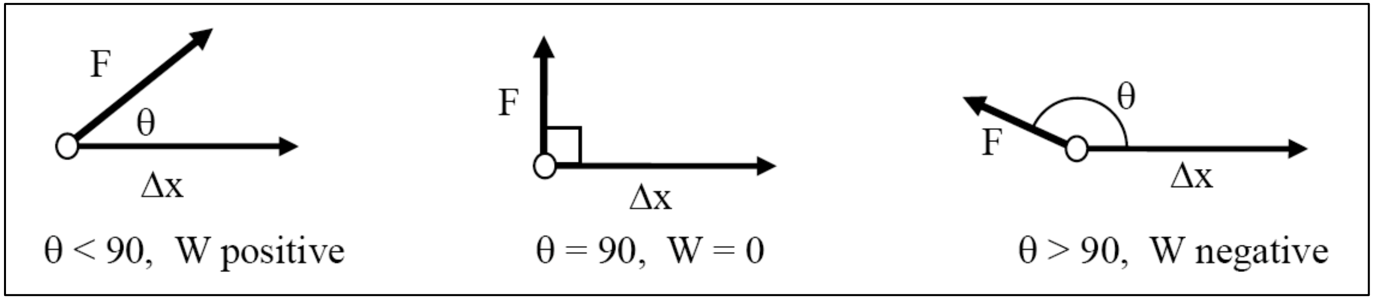
$$\tfrac{1}{2}m(v_f^2 - v_i^2) = W$$

$$\tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 = \Delta KE = W$$

1. Work:

$$W_F \equiv F_x \cdot d = F\cos\theta\, d = F_{||}\, d$$

Component of “specific” force along displacement x displacement:



2. Kinetic Energy:

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

3. Work – Energy Principle:

$$W_{net} = W_{Fnet} = \Delta KE = KE_f - KE_i$$