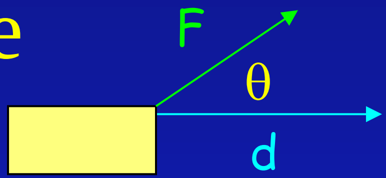
Physics 101: Lecture 10
Potential Energy & Energy Conservation

- Today's lecture will cover Textbook Sections 6.5 - 6.8

Review

- Work: Transfer of Energy by Force
  - $W_F = F\ d\ \cos\theta$



- Kinetic Energy (Energy of Motion)
  - $K = \frac{1}{2} mv^2$

- Work-Kinetic Energy Theorem:
  - $W_{Net} = \Delta K$

Today!

- Potential (Stored) Energy: U

Work Done by Gravity 1

- Example 1: Drop ball

$W_g = Fd\cos\theta$

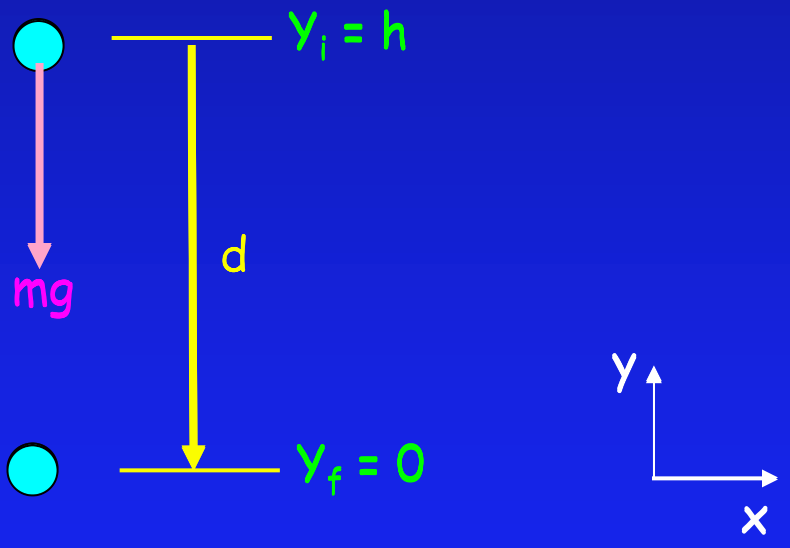
$W_g = (mg)(d)\cos\theta$

$d = h$

$W_g = mgh\cos(0^0) = mgh$

$\Delta y = y_f - y_i = -h$

$W_g = -mg\Delta y$



Work Done by Gravity 2

- Example 2: Toss ball up

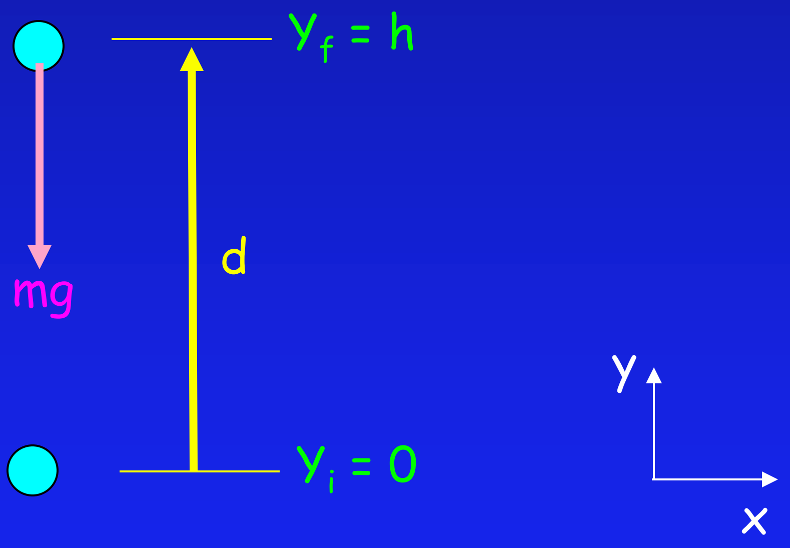
$W_g = (mg)(d)\cos\theta$

$d = h$

$W_g = mgh\cos(180^0) = -mgh$

$\Delta y = y_f - y_i = +h$

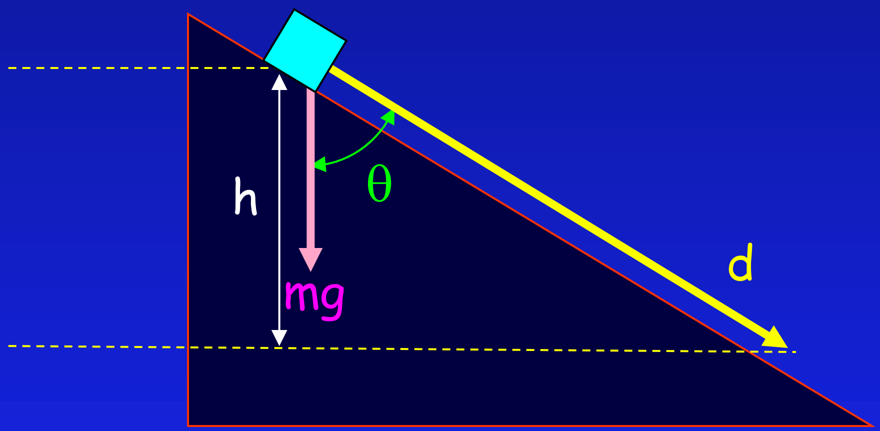
$W_g = -mg\Delta y$



Work Done by Gravity 3

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

- Example 3: Slide block down incline



$W_g = (mg)(d)\cos\theta$

$d = h/\cos\theta$

$W_g = mg(h/\cos\theta)\cos\theta$

$W_g = mgh$

$\Delta y = y_f - y_i = -h$

$W_g = -mg\Delta y$

Work and Potential Energy

- Work done by gravity *independent of path*
  - $W_g = -m\, g\, (y_f - y_i)$

- True for any CONSERVATIVE force, like gravitation, spring, etc. (anything but friction!)
- Define potential energy $U_g = m\, g\, y$

$$W_{cons} = -\Delta U = -(U_f - U_i) = -(m\, g\, y_f - m\, g\, y_i)$$

- Work-Energy theorem

$$W = W_{cons} + W_{nc} = \Delta K$$

$$W_{nc} = \Delta K - W_{cons} = \Delta K + \Delta U$$

Work done by non-conservative force **(frictional force)**

Energy Conservation

$$W_{nc} = \Delta K + \Delta U = \Delta(K + U) = \Delta E$$

The TOTAL energy, E, is sum of kinetic and potential energies:

$$E = K + U$$

If there is no friction

$$W_{nc} = \Delta E = 0$$

The TOTAL energy does not change. E is CONSERVED

$$E_0 = E_f$$

Skiing Example (no friction)

A skier goes down a 78 meter high hill with a variety of slopes. What is the maximum speed she can obtain if she starts from rest at the top?

No friction => Conserve Energy!

Total Energy Before:

$E_0 = K_0 + U_0 = ½\ mv_0^2 + mgy_0 = mgy_0$

Total Energy After:

$E_f = K_f + U_f = ½\ mv_f^2 + mgy_f = ½\ mv_f^2$

Conserve Total Energy!

$E_0 = E_f$

$mgy_0 = ½\ mv_f^2$

$v_f = \text{sqrt}(2gy) = 39\ \text{m/s}$

Pendulum Demo

Conservation of Energy ($E_0 = E_f$)

Total Energy Before:

$E_0 = K_0 + U_0 = mgy_0$

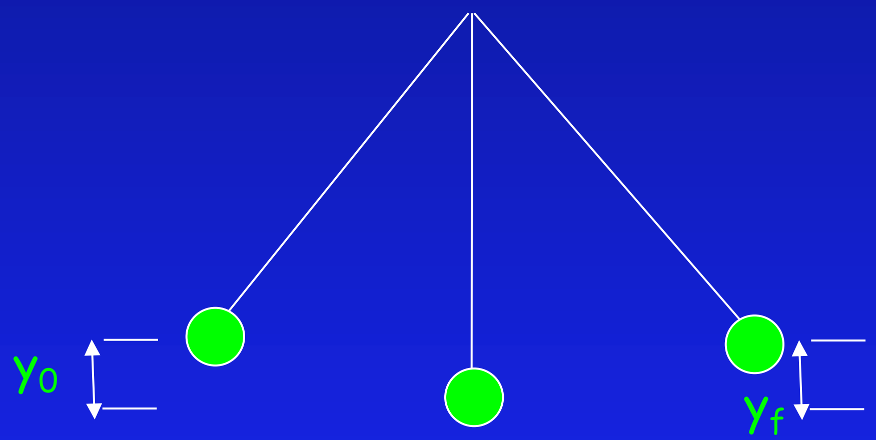
Total Energy After:

$E_f = K_f + U_f = mgy_f$

Conserve Total Energy!

$E_0 = E_f$ $\qquad mgy_0 = mgy_f$

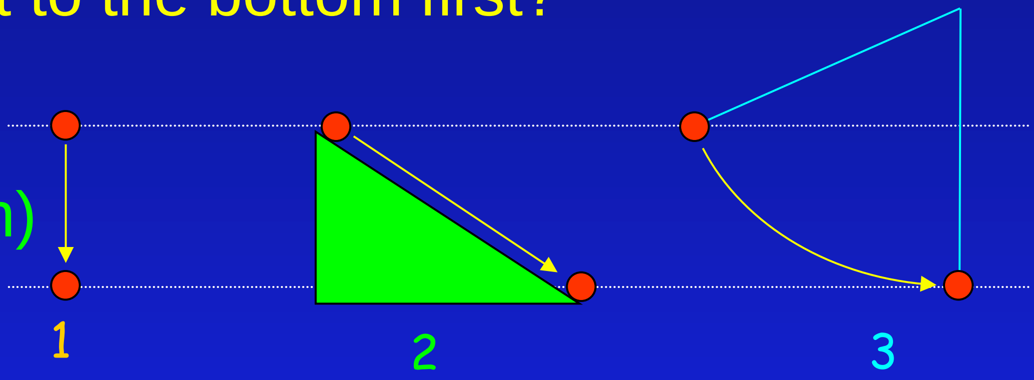
$y_f = y_0$



Lecture 10, Checkpoint 1

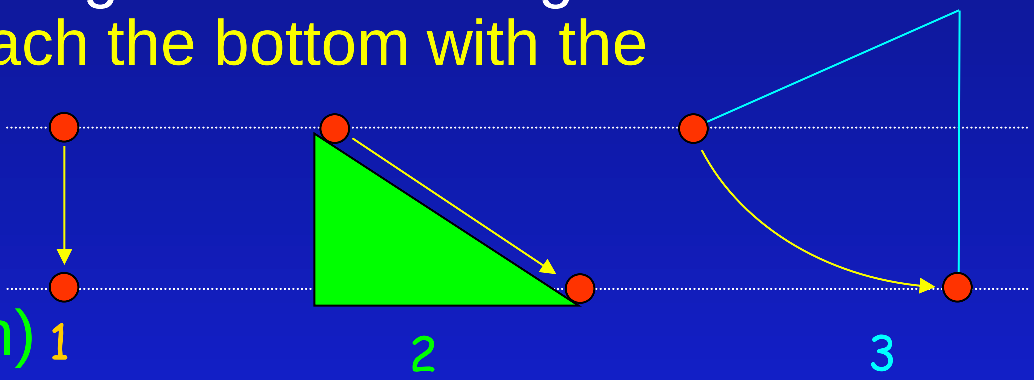
Imagine that you are comparing three different ways of having a ball move down through the same height. In which case does the ball get to the bottom first?

A. Dropping
B. Slide on ramp (no friction)
C. Swinging down
D. All the same



Lecture 10, Checkpoint 2

Imagine that you are comparing three different ways of having a ball move down through the same height. In which case does the ball reach the bottom with the highest speed?



1. Dropping
2. Slide on ramp (no friction)
3. Swinging down
4. All the same

Conservation of Energy ($E_0 = E_f$)

$E_0 = mgh$

$E_f = ½ mv_f^2$

$E_0 = E_f$ -> $mgh = ½ mv_f^2$

$v_f = \text{sqrt}(2\ g\ h)$

Skiing w/ Friction

A 50 kg skier goes down a 78 meter high hill with a variety of slopes. She finally stops at the bottom of the hill. If friction is the force responsible for her stopping, how much work does it do?

Total Energy changes when friction is present!
(friction is NONCONSERVATIVE)

Total Energy Before:

$E_0 = K_0 + U_0 = mgy_0$

Total Energy After:

$E_f = K_f + U_f = 0$

Change in Energy is work done by friction!

$W_{nc} = \Delta E = 0 - mgy_0$

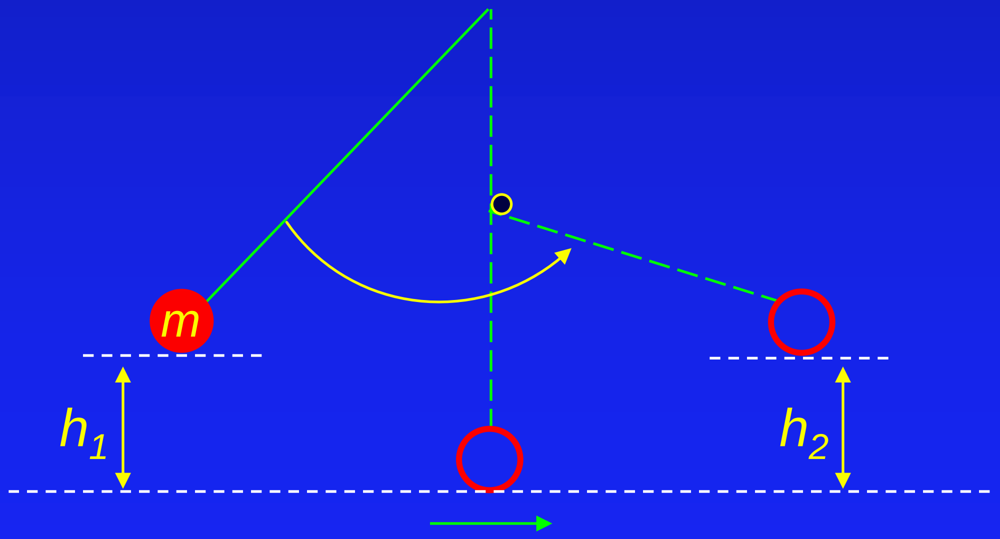
= -38200 Joules

Similar to bob sled homework!

Galileo's Pendulum ACT

How high will the pendulum swing on the other side now?

A) $h_1 > h_2$ B) $h_1 = h_2$ C) $h_1 < h_2$



Summary

- Conservative Forces
  - Work is independent of path
  - Define Potential Energy U
    - $U_{gravity} = m\,g\,y$
    - $U_{spring} = \frac{1}{2}\,k\,x^2$

- Work – Energy Theorem

$$W_{nc} = \Delta E = \Delta(K + U)$$

$$= \Delta K + \Delta U = \Delta K - W_{cons}$$

$$W_{nc} + W_{cons} = \Delta K$$

Power (Rate of Work)

- $P = W / \Delta t$
  - Units: Joules/Second = Watt

- How much power does it take for a (70 kg) student to run up the stairs in 151 Loomis (5 meters) in 7 sec?

$P = W / t$

$= m\,g\,h\ / t$

$= (70\text{ kg})\ (9.8\text{ m/s}^2)\ (5\text{ m})\ /\ 7\text{ s}$

$= 490\text{ J/s}$ or 490 Watts