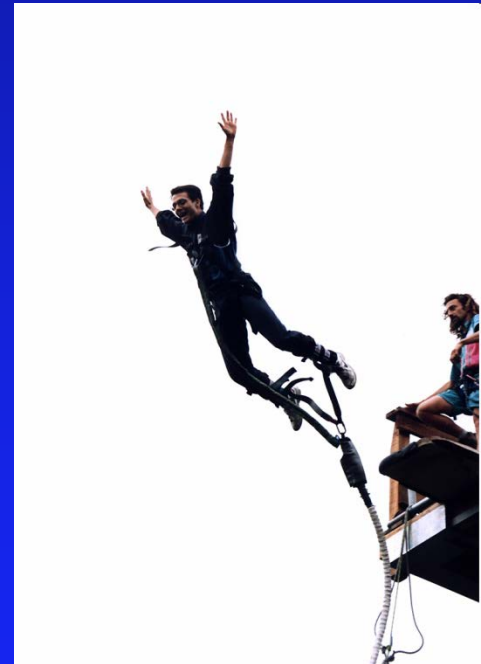


Physics 101: Lecture 10

Potential Energy & Energy Conservation

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

- EXAM 1: 7 pm, Oct. 6; see gradebook for room assignments
- 5:15 pm conflict exam. You are signed up for the regular exam. Go to gradebook and change to conflict exam if you need to.
- Contact Dr. Park if you can not do either exam.



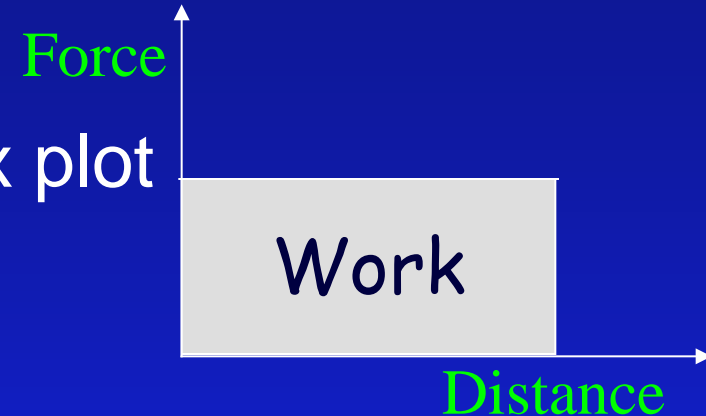
Optional exam preparation

- Later today you will receive an email from the Physics Education Research group asking you to volunteer to participate in an experiment.
- We are doing a study of activities that may improve your understanding of friction (a concept that you will see on the first Physics 101 hour exam).
- The study will take around 2-3 hours of your time and will be followed by an opportunity for optional tutoring for anyone that wants to stick around and get help on any topic in preparation for the exam.
- If you are interested, please read the email later today – it will tell you how to sign up and select times that work with your schedule (this coming Thursday, Friday or Saturday).

Work done by a constant force:

- $W = F_x \Delta x$

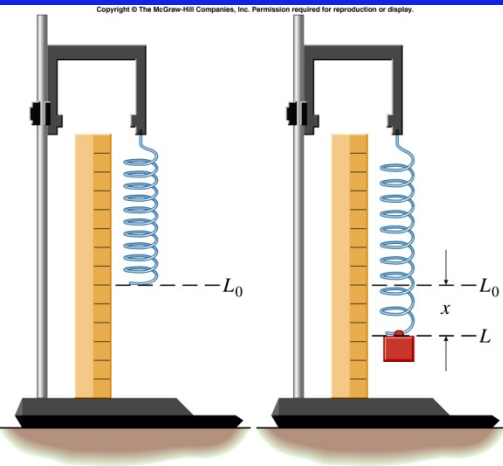
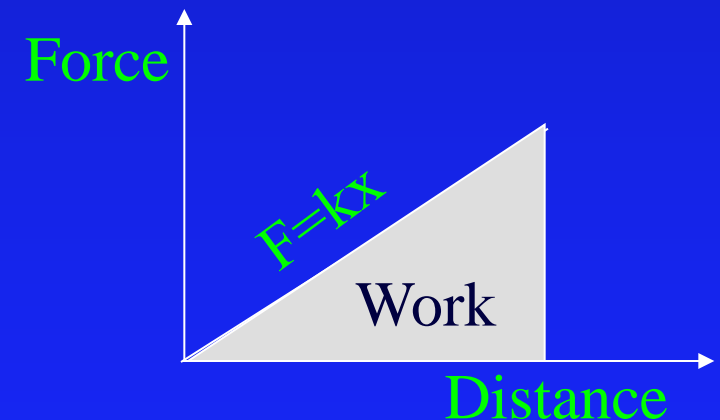
- Work is area under F vs x plot



Work done by a variable force:

- Spring $F = k x$

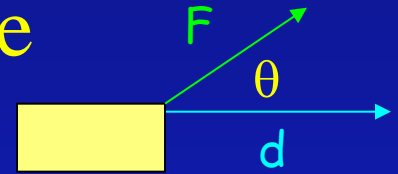
- » $\text{Area} = \frac{1}{2} k x^2 = W_{\text{spring}}$



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:

- $W_{\text{Net}} = \Delta K$

Today!

- Potential (Stored) Energy: U

Work Done by Gravity 1

- Example 1: Drop ball

$$W_g = Fd \cos\theta$$

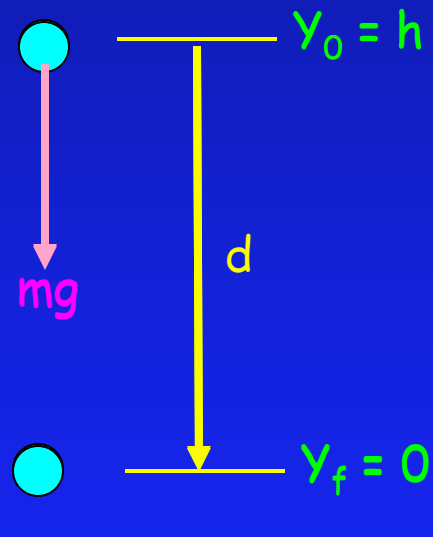
$$W_g = (mg)(d)\cos\theta$$

$$d = h$$

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

$$\Delta y = y_f - y_0 = -h$$

$$W_g = -mg\Delta y$$



Work Done by Gravity 2

- Example 2: Toss ball up

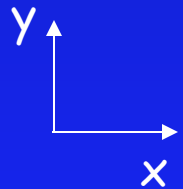
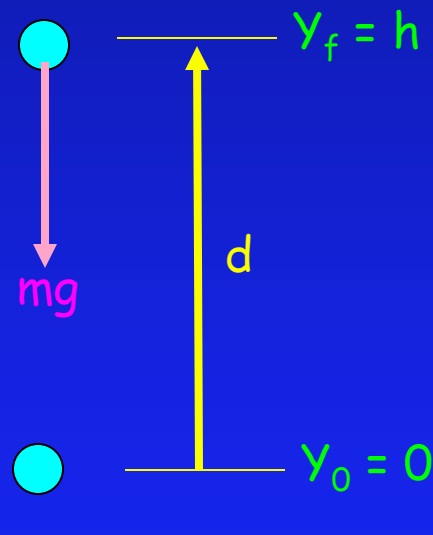
$$W_g = (mg)(d)\cos\theta$$

$$d = h$$

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

$$\Delta y = y_f - y_0 = +h$$

$$W_g = -mg\Delta y$$



Work Done by Gravity 3

A) $W > 0$

B) $W = 0$

C) $W < 0$

- Example 3: Slide block down incline

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

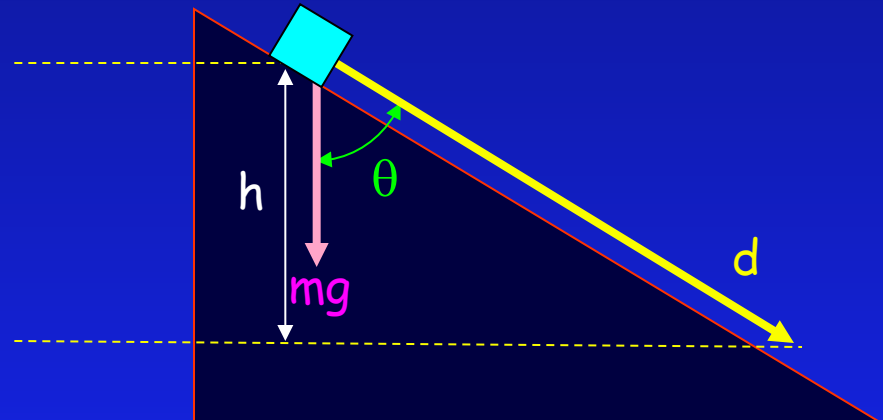
$$d = h/\cos\theta$$

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

$$W_g = mgh$$

$$\Delta y = y_f - y_0 = -h$$

$$W_g = -mg\Delta y$$



Work and Potential Energy

- Work done by gravity *independent of path*

➤ $W_g = -mg(y_f - y_0) = -(mgy_f - mgy_0)$

- True for any **CONSERVATIVE** force, like gravitation, spring, etc. (anything but friction!)

- Define potential energy $U_g = m g y$

$$W_{\text{cons}} = -\Delta U = -(U_f - U_0) = -(m g y_f - m g y_0)$$

- Work-Energy theorem

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

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

Work done by non-conservative force (e.g. 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:

$$E_0 = K_0 + U_0 = \frac{1}{2} m v_0^2 + m g y_0 = m g y_0$$

Total Energy After:

$$E_f = K_f + U_f = \frac{1}{2} m v_f^2 + m g y_f = \frac{1}{2} m v_f^2$$

Conserve Total Energy!

$$E_0 = E_f$$

$$m g y_0 = \frac{1}{2} m v_f^2$$

$$v_f = \sqrt{2 g y} = 39 \text{ m/s}$$



Pendulum Demo

Conservation of Energy ($E_0 = E_f$)

Total Energy Before:

$$E_0 = K_0 + U_0 = mgy_0$$

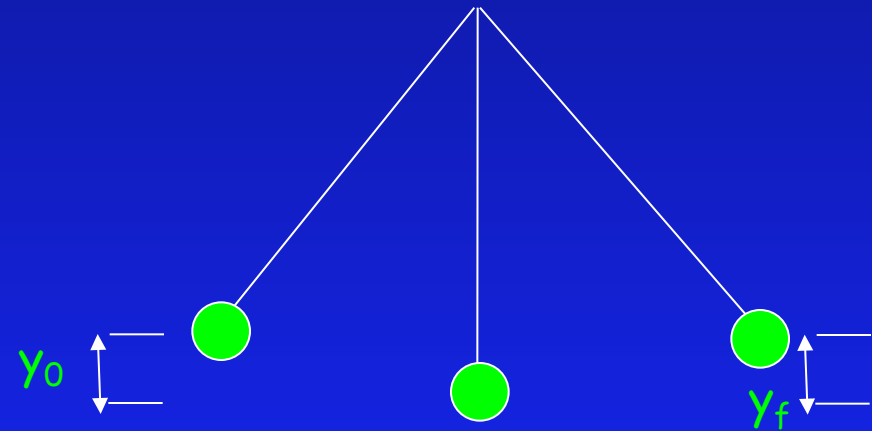
Total Energy After:

$$E_f = K_f + U_f = mgy_f$$

Conserve Total Energy!

$$E_0 = E_f \quad mgy_0 = mgy_f$$

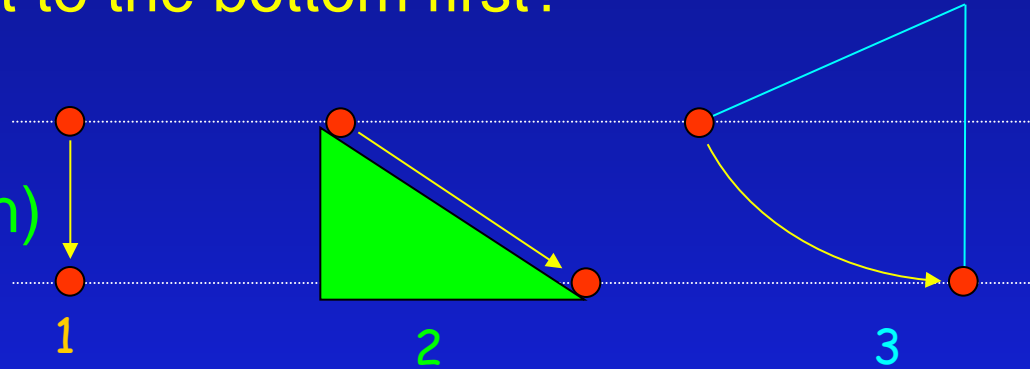
$$y_f = y_0$$



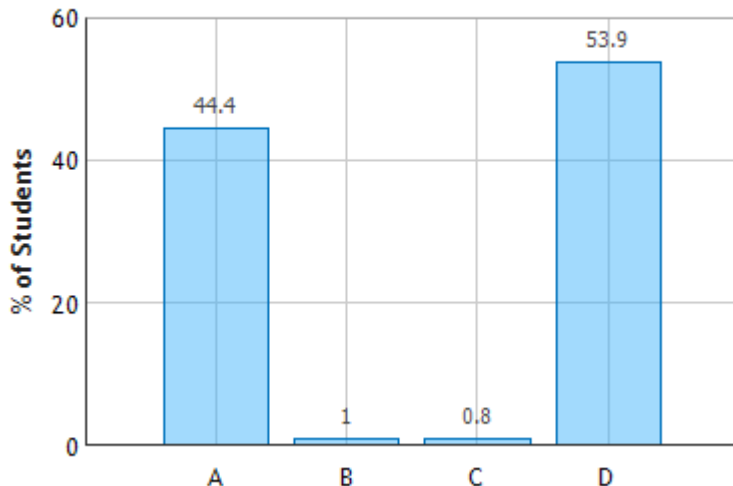
Lecture 10, Checkpoint 1

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 ← correct
- B. Slide on ramp (no friction)
- C. Swinging down
- D. All the same



Let's Play with the Ball: Question 1 (N = 399)

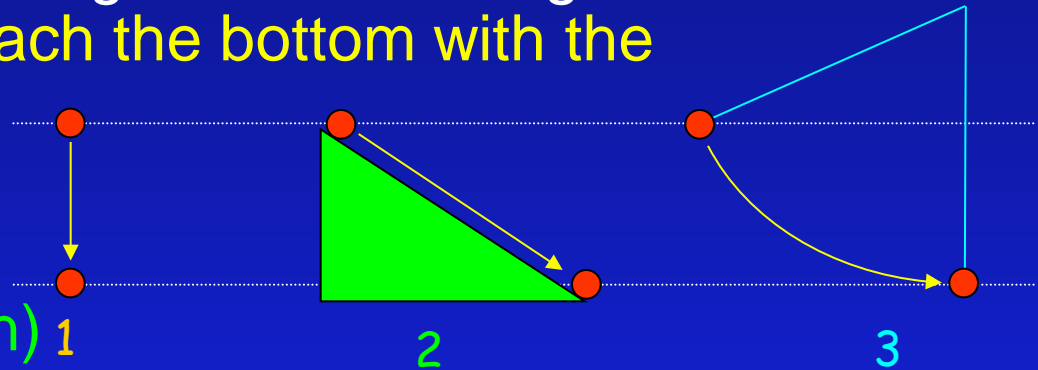


"The ball being dropped will reach the ground fastest since it doesn't have to travel as far."

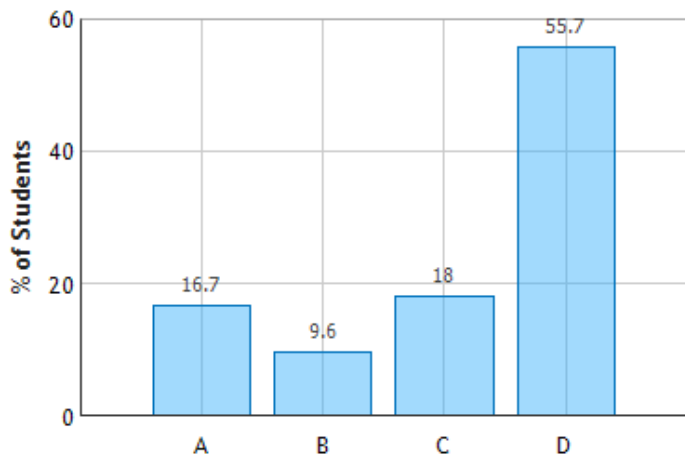
Lecture 10, Checkpoint 2

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 ← correct



Let's Play with the Ball: Question 2 (N = 395)



Conservation of Energy ($E_0 = E_f$)

$$E_0 = mgh$$

$$E_f = \frac{1}{2} mv_f^2$$

$$E_0 = E_f \quad mgh = \frac{1}{2} mv_f^2$$

$$v_f = \sqrt{2gh}$$

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!

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

$$= -38200 \text{ Joules}$$

Similar to bob sled homework!



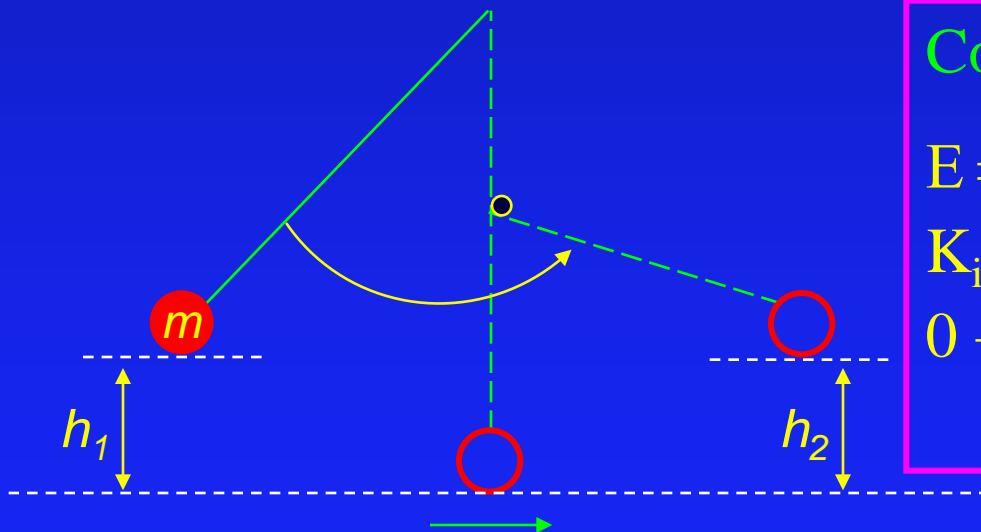
Galileo's Pendulum ACT

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

A) $h_1 > h_2$

B) $h_1 = h_2$

C) $h_1 < h_2$



Conservation of Energy ($E_0 = E_f$)

$$E = K + U$$

$$K_{\text{initial}} + U_{\text{initial}} = K_{\text{final}} + U_{\text{final}}$$

$$0 + mgh_1 = 0 + mgh_2$$

$$h_1 = h_2$$

Summary

➤ Conservative Forces

» Work is independent of path

» Define Potential Energy U

$$\blacksquare U_{\text{gravity}} = m g y$$

$$\blacksquare U_{\text{spring}} = \frac{1}{2} k x^2$$

➤ Work – Energy Theorem

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

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

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

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 141 Loomis (5 meters) in 7 sec?

$$P = W / t$$

$$= m g h / t$$

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

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