Physics 101: Lecture 10
Potential Energy & Energy Conservation

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

Hour Exam 1: Next Monday!

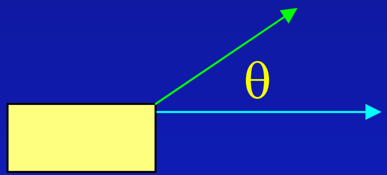
-7 pm, see course site for room assignments

-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. Deadline for changing your exam time is 10 pm Thursday Feb 24.

-Contact Professor Selvin if you can not do either exam.

Review

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



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

- Work-Kinetic Energy Theorem:
  - $\Sigma W = \Delta K$

Preview

- Potential (Stored) Energy: U

Preflight 4

What concepts were most difficult to understand in preparing for this lecture?

"everything" "nothing"

"conservative vs. nonconservative / Wnc"

Studying for the exam

"don't really understand work... "

difference between power and work

"The equations were kind of confusing…"

Defining all of the terms; understanding what each of them means conceptually.

sign of kinetic and potential energies..

Work Done by Gravity 1

- Example 1: Drop ball

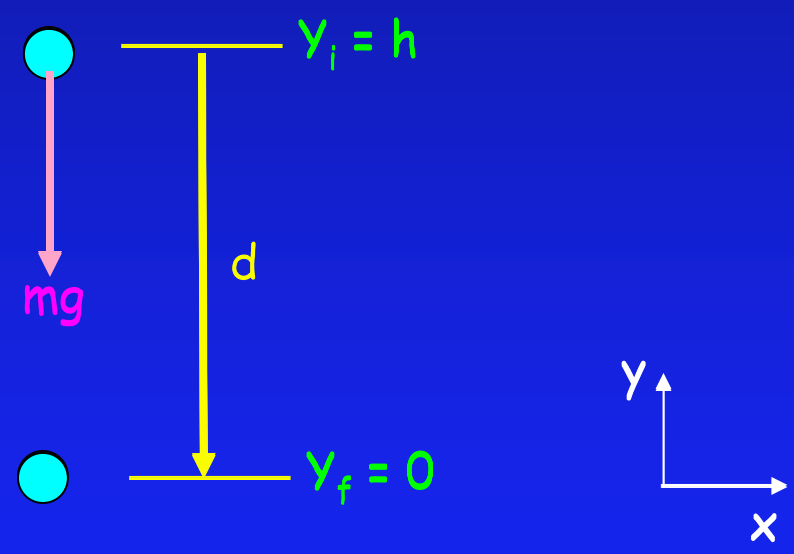
$W_g = (mg)(d)\cos\theta$

$d = h$

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

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

$W_g = -mg\Delta y$



Work Done by Gravity 2

- Example 2: Toss ball up

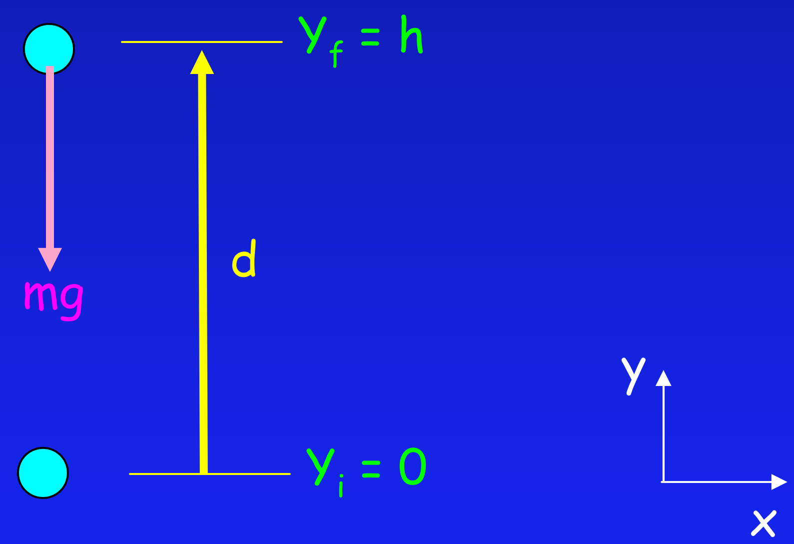
$W_g = (mg)(d)\cos\theta$

$d = h$

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

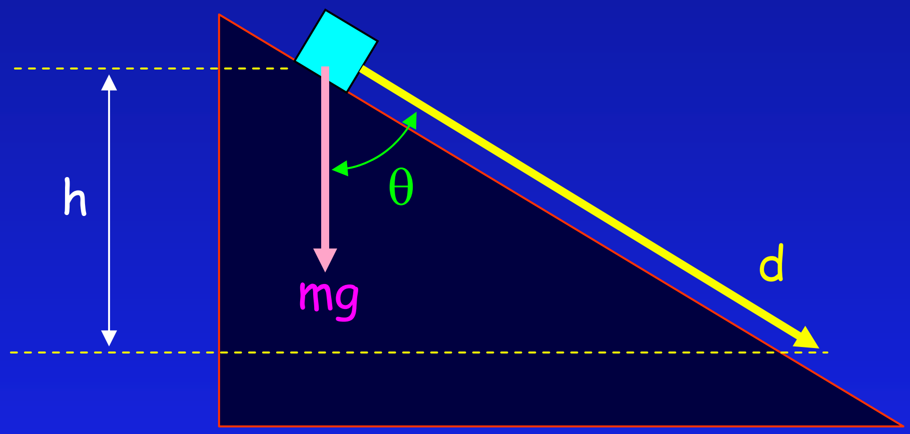
$\Delta y = y_f - y_i = +h$

$W_g = -mg\Delta y$



Work Done by Gravity 3

- 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
  -gravitation, spring, etc.
- Define potential energy $U_g = m\,g\,y$

- Modify Work-Energy theorem

$$\sum W_{nc} = \Delta K + \Delta U$$

Work done by non-conservative force

Example of non-conservative force

-frictional force

Conservation ACT

Which of the following statements correctly define a Conservative Force:

A. A force is conservative when the work it does on a moving object is independent of the path of the motion between the object's initial and final positions.

B. A force is conservative when it does no net work on an object moving around a closed path, starting and finishing at the same point.

C. Both of the above statements are correct. ← correct

D. Neither of the above statements is correct.

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?

Conservation of energy:

$$\Sigma W_{nc} = \Delta K + \Delta U \qquad 0 = K_f - K_i + U_f - U_i$$

$$K_i + U_i = K_f + U_f$$

$$\tfrac{1}{2}\, m\, v_i^2 + m\, g\, y_i = \tfrac{1}{2}\, m\, v_f^2 + m\, g\, y_f$$

$$0 + g\, y_i = \tfrac{1}{2}\, v_f^2 + g\, y_f$$

$$v_f^2 = 2\, g\, (y_i - y_f)$$

$$v_f = \text{sqrt}(\, 2\, g\, (y_i - y_f))$$

$$v_f = \text{sqrt}(\, 2 \times 9.8 \times 78) = 39 \text{ m/s}$$

Pendulum ACT

- As the pendulum falls, the work done by the string is

1) Positive 2) Zero 3) Negative

W = F d cos θ. But θ = 90 degrees so Work is zero.

How fast is the ball moving at the bottom of the path?

Conservation of Energy (W_{nc}=0)

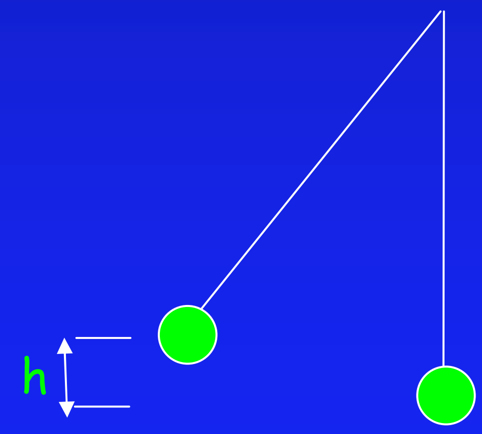
$\Sigma W_{nc} = \Delta K + \Delta U$

$0 = K_{final} - K_{initial} + U_{final} - U_{initial}$

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

$0 + mgh = \frac{1}{2} m v^2_{final} + 0$

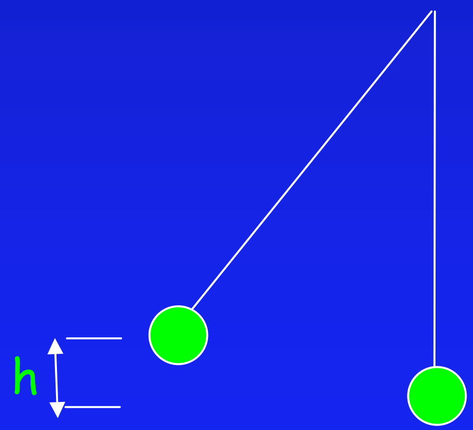
$v_{final} = \text{sqrt}(2\, g\, h)$



Pendulum Demo

With no regard for his own personal safety your physics professor will risk being smashed by a bowling ball pendulum! If released from a height h, how far will the bowling ball reach when it returns?

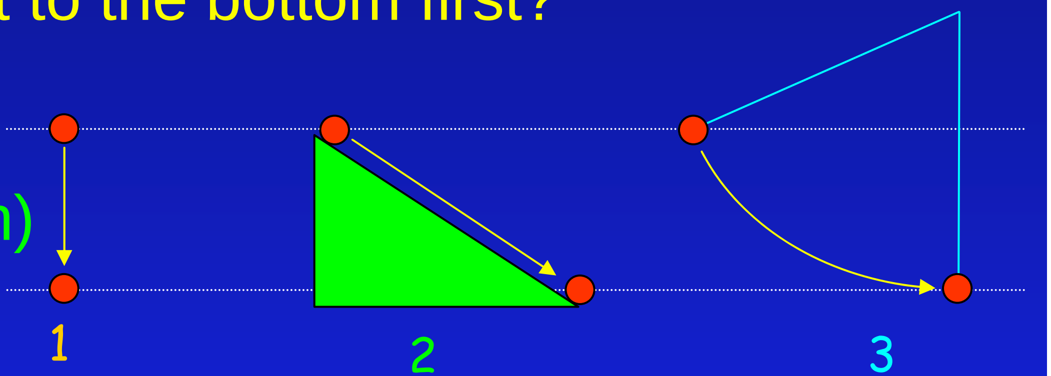
$K_{initial} + U_{initial} = K_{final} + U_{final}$
$0 + mgh_{initial} = 0 + mgh_{final}$
$h_{initial} = h_{final}$

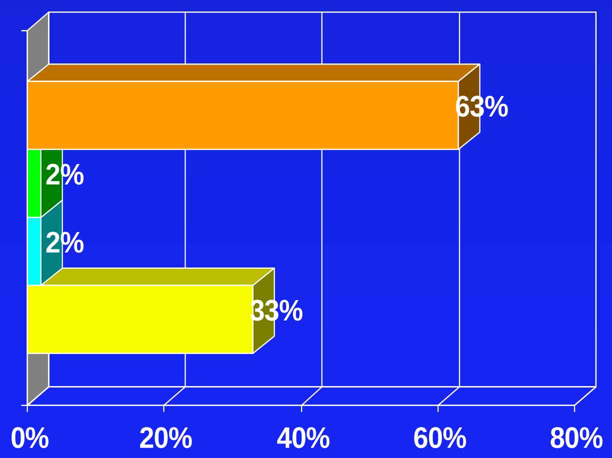


Lecture 10, Preflight 1

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



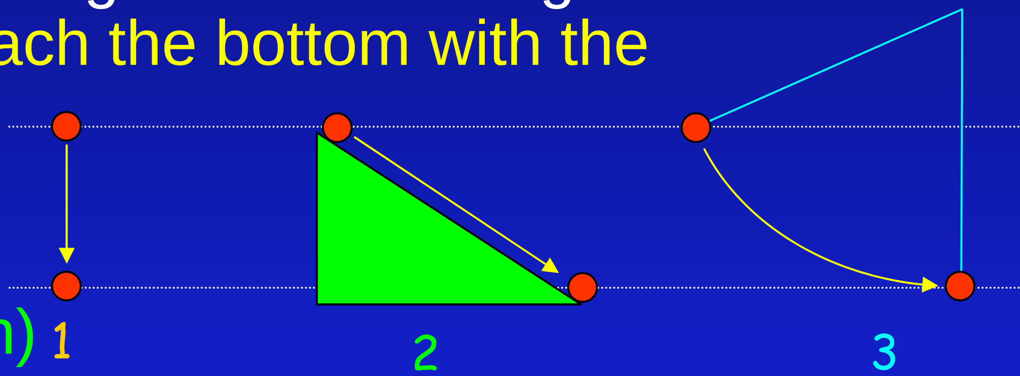


"The ball being dropped will reach the ground fastest since it doesn't have to travel as far and it has the highest acceleration in the direction of motion."

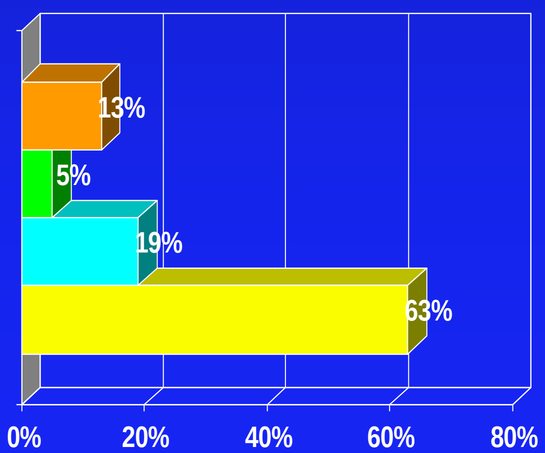
"they will all have the same speed at the bottom."

Lecture 10, Preflight 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



Conservation of Energy ($W_{nc}=0$)

$$\Sigma W_{nc} = \Delta K + \Delta U$$

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

$$0 + mgh = \tfrac{1}{2} m v^2_{final} + 0$$

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

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?

Work Energy Theorem:

$$W_{nc} = K_f - K_i + U_f - U_i$$

$$= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 + m g y_f - m g y_i$$

$$= 0 + 0 + 0 - m g y_i$$

$$= -50 \times 9.8 \times 78 \text{ Joules}$$

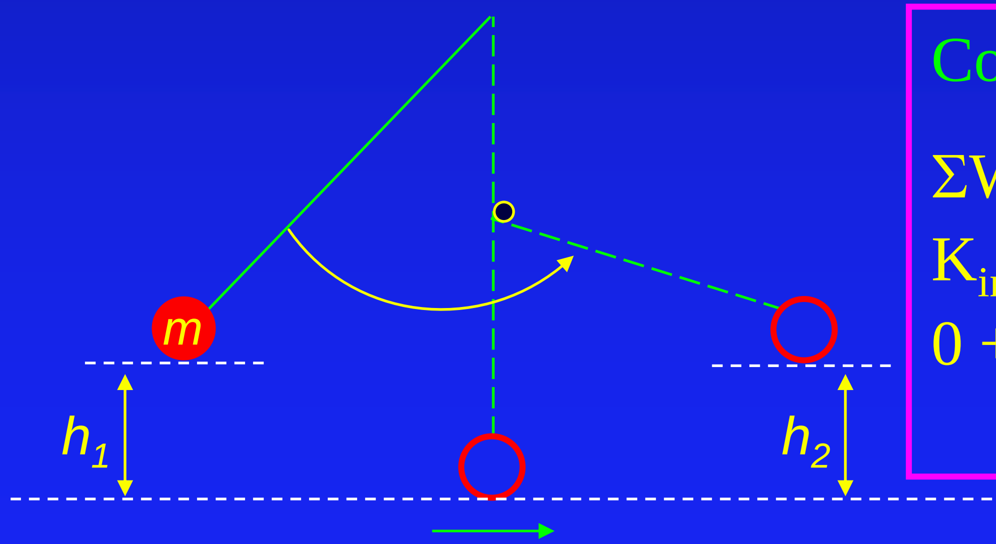
$$= -38200 \text{ Joules}$$

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 ($W_{nc}=0$)

$$\Sigma W_{nc} = \Delta K + \Delta U$$

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

$$0 + mgh_1 = 0 + mgh_2$$

$$h_1 = h_2$$

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?

$P = W / t$

$= m g h / t$

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

$= 490\ J/s$ or 490 Watts

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

$$\sum W_{nc} = \Delta K + \Delta U$$