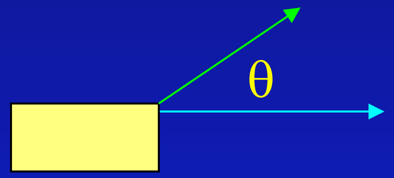
Physics 101: Lecture 10
Potential Energy & Energy Conservation

- 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:
  - $\Sigma W = \Delta K$

Preview

- Potential (Stored) Energy: U

Work Done by Gravity 1

- Example 1: Drop ball

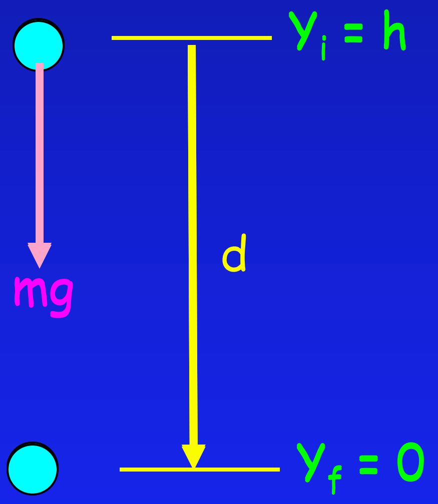
$W_g = (mg)(d)\cos\theta$

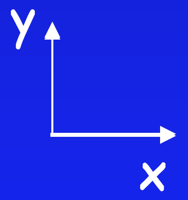
$d = h$

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

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

$W_g = -mg\Delta y$





Work Done by Gravity 2

- Example 2: Toss ball up

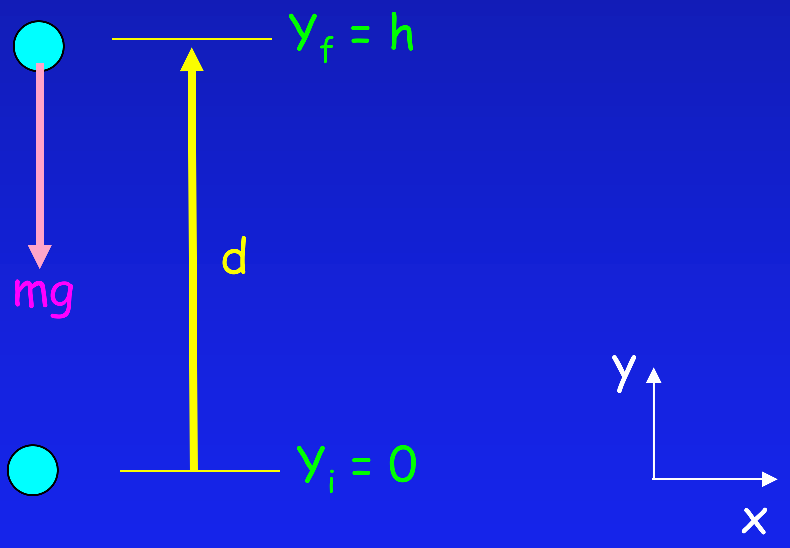
$W_g = (mg)(d)\cos\theta$

$d = h$

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

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

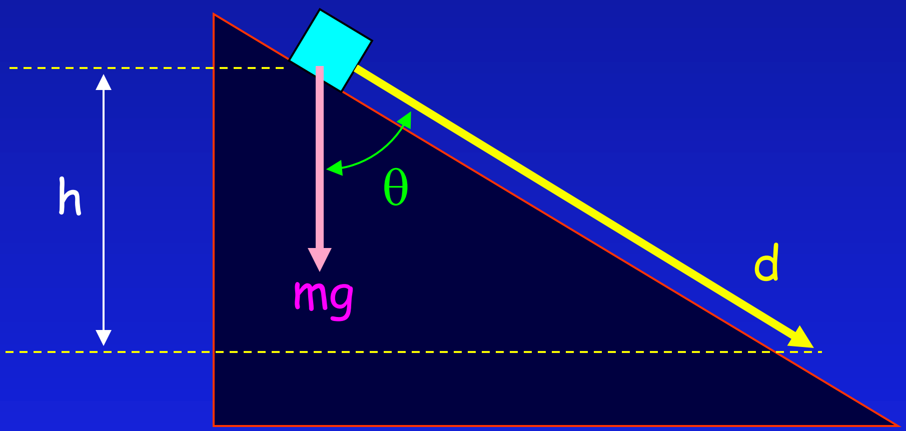
$W_g = -mg\Delta y$



Work Done by Gravity 3

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

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

- Modify Work-Energy theorem

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

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

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

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:

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

$K_i + U_i = K_f + U_f$

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

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

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

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

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

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?

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

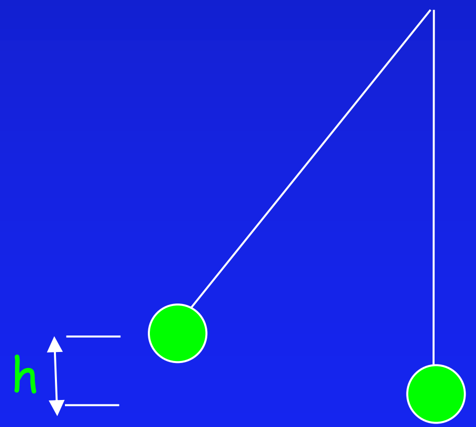
$\Sigma W_{nc} = \Delta K + \Delta U$

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

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

$0 + mgh_{initial} = 0 + mgh_{final}$

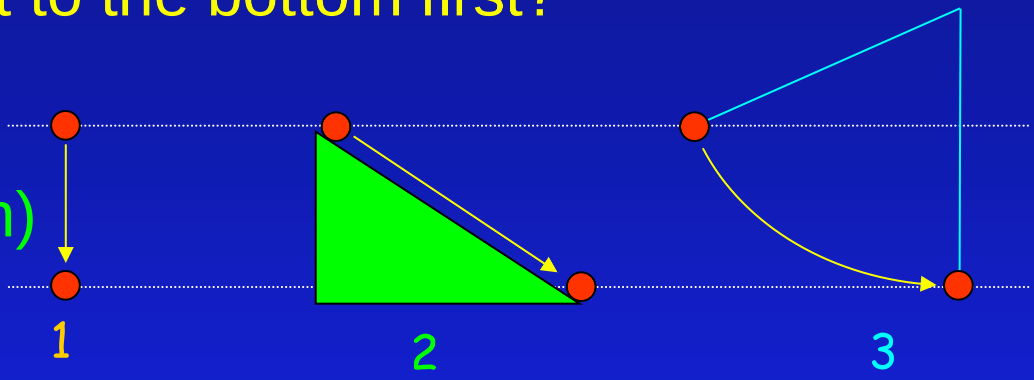
$h_{initial} = h_{final}$

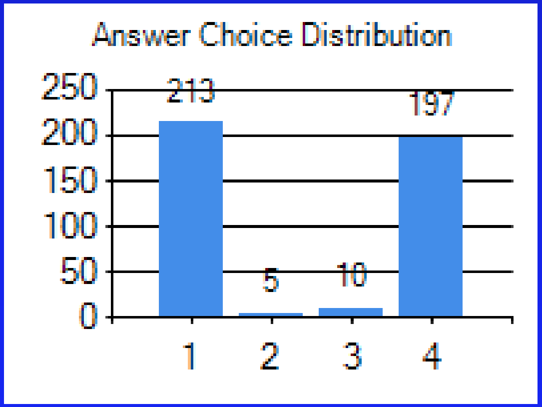


Lecture 10, Checkpoint 1

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



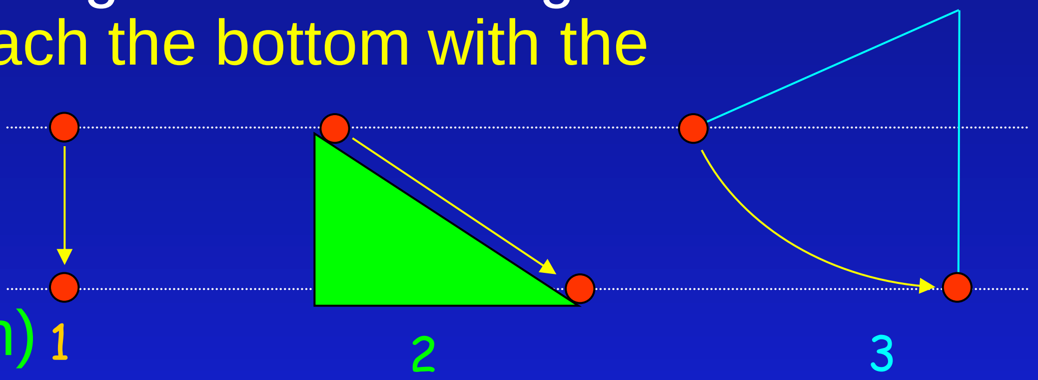


"The ball being dropped will reach the ground fastest since it doesn't have to travel as far."

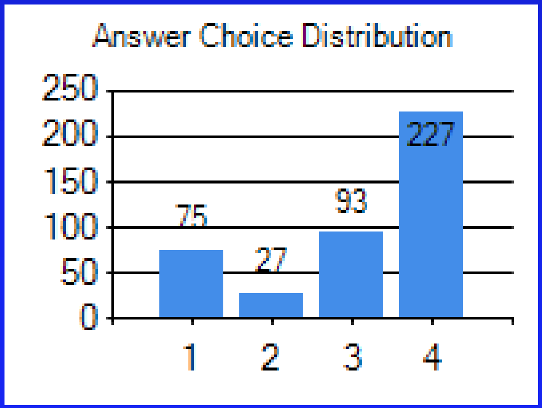
"they will all have the same speed at the bottom."

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



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

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

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

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

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

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:

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

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

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

$$= -764 \times 50 \text{ Joules}$$

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

Similar to bob sled homework

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

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