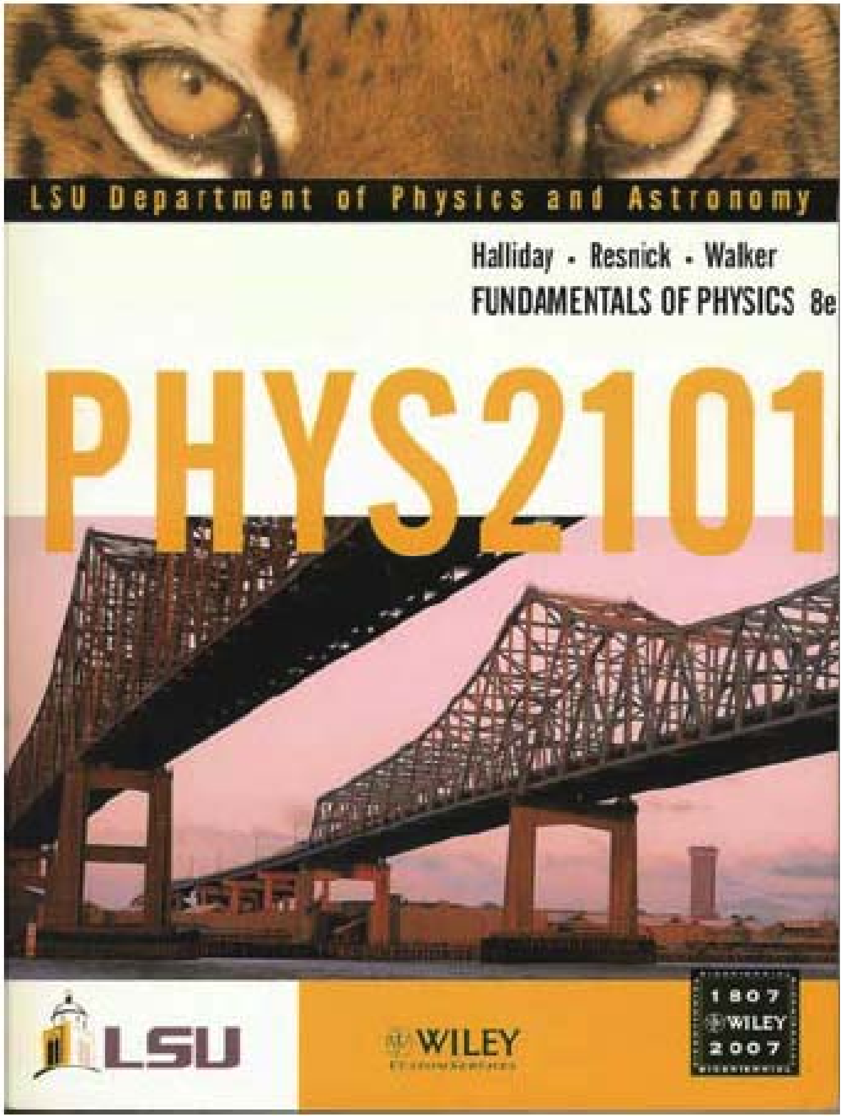
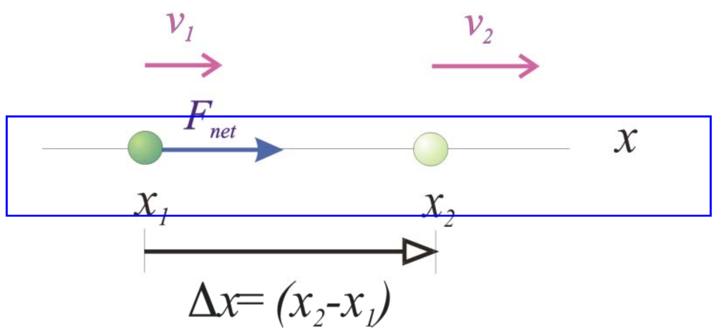



Announcements:

1. Take your 1st quiz back
2. 2nd Quiz will be on Friday
3. This week HW will be due on coming Wed. instead of Mon.

# Power




- The rate at which work is done by a force is **power**.
- Average power is work W done in time Δt

$$P_{ave} = \frac{W}{\Delta t}$$

- The instantaneous rate of doing work (instantaneous power)

$$P = \frac{dW}{dt}$$


- Units: <u>Watt [W]</u>

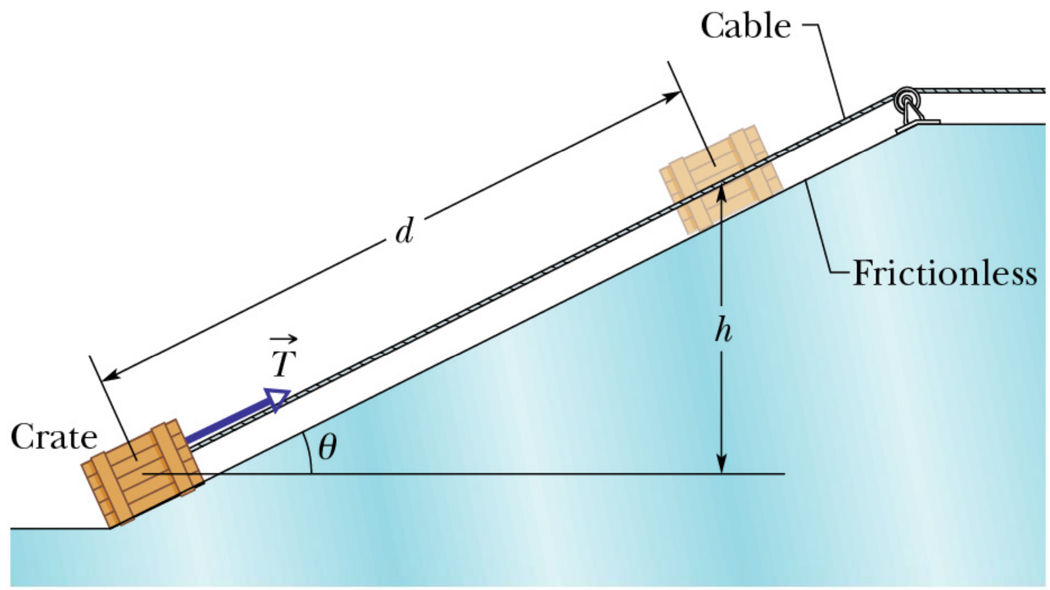
1 W = 1J/s
1 horsepower = 1 hp = 746 W
1 kW-hour = 3.6 MJ

- Power from the time-independent force and velocity:

$$P = \frac{dW}{dt} = \frac{d\left(\vec{F}\cdot\vec{x}\right)}{dt} = \vec{F}\cdot\frac{d\left(\vec{x}\right)}{dt} = \vec{F}\cdot\vec{v}$$

**Instantaneous power !**

# Crate of Cheese VERY SIMILAR TO HW # 6




An initially stationary crate of cheese (mass m) is pulled via a cable a distance d up a frictionless ramp of angle $\theta$ where it stops.

(a) How much work $W_N$ is done on the crate by the Normal during the lift?

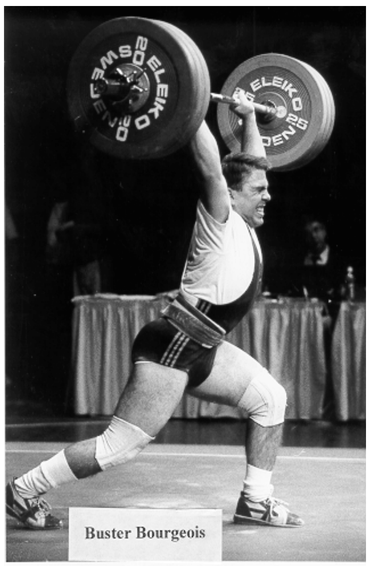
(b) How much work $W_g$ is done on the crate by the gravitational force during the lift?

(c) How much work $W_T$ is done on the crate by the Tension during the lift?

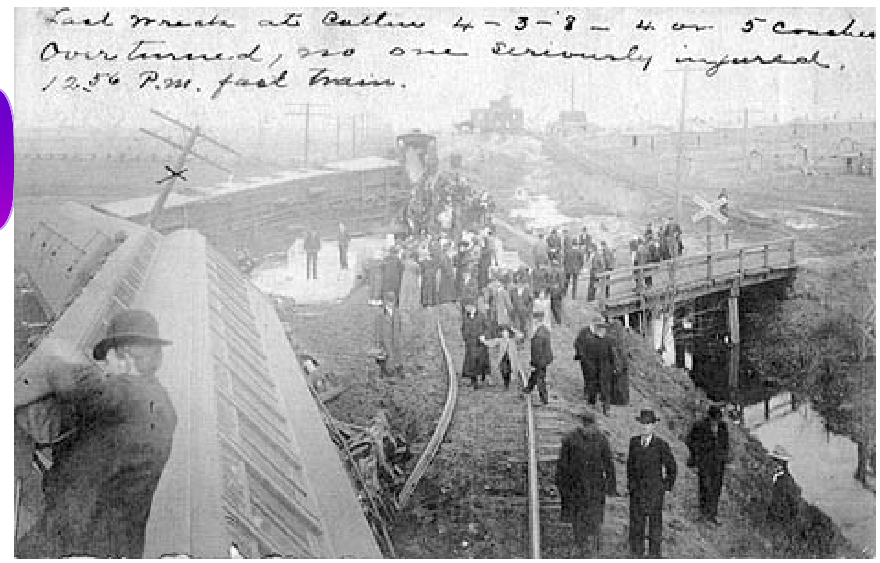
(d) If the speed of the moving crate were increased, how would the above answers change? What about the power?

# Chapter 8: Potential Energy and Conservation of Energy

- Chapter 7: What happens to the KE of when work is done on it.
  [ KE: "energy of motion"  W: energy transfer via force ]
- Chapter 8: Potential energy ??




Force ??

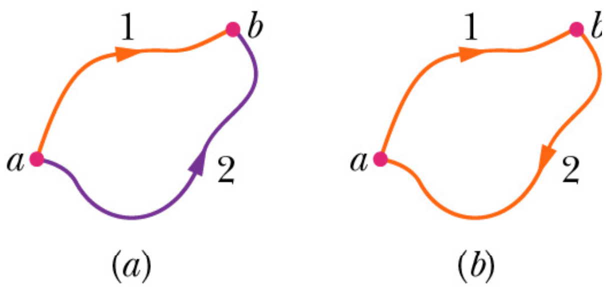



**Conservative vs non-conservative forces**

- **Can you get back what you put in?** $W_{in} = -W_{out}$
- **What happens when you reverse time?**

# Properties of Conservative Forces

•Net work done by a conservative force on a object moving around every closed path is zero.

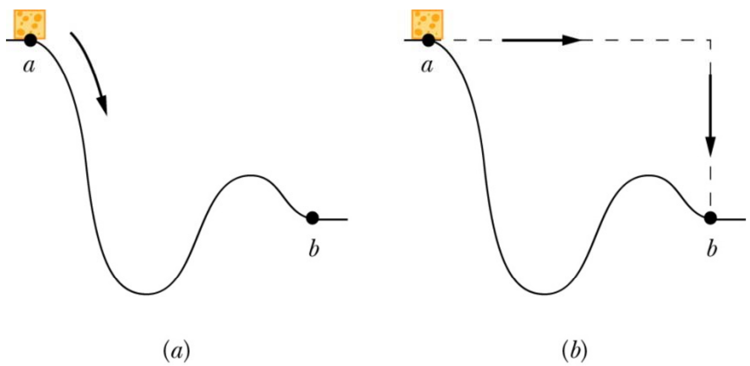



$$W_{ab} = \int_a^b \vec{F}(x) \bullet d\vec{x}$$

$$W_{ab,1} = W_{ab,2} \quad \& \quad W_{ab,1} = -W_{ba,2}$$

**<u>Conservative forces</u>**

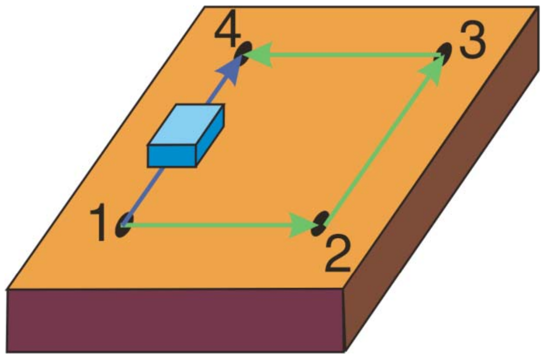
- gravitational force
- spring force



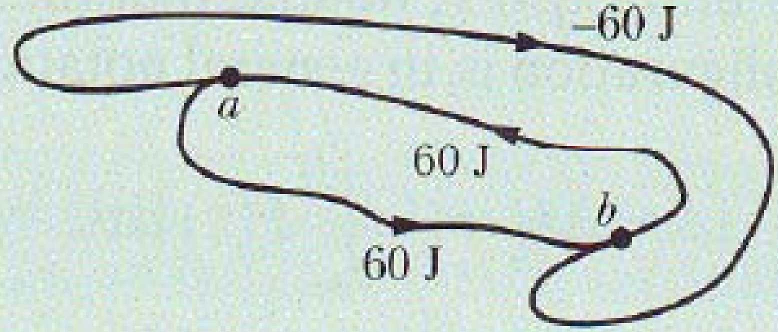

**<u>Non-conservative forces</u>**

- kinetic frictional force

(noise, heat,…)



**CHECKPOINT 1** The figure shows three paths connecting points $a$ and $b$. A single force $\vec{F}$ does the indicated work on a particle moving along each path in the indicated direction. On the basis of this information, is force $\vec{F}$ conservative?



# Potential Energy

**Potential energy**: Energy U which describes the configuration (or spatial arrangement) of a system of objects that exert conservative forces on each other. It's the stored energy in system.

$$\Delta U = -W$$

You can always define the zero (reference value)

**Gravitational Potential energy**: [~associated with the state of separation]

$$\Delta U_{grav} = -\int_{y_i}^{y_f} (-mg)dy = mg(y_f - y_i) = mg\Delta y$$

→ If $U_{grav}(y=0) \equiv 0$ then $U_{grav}(y) = mgy$

**$\Delta U_{grav} \uparrow$ if going up**

**$\Delta U_{grav} \downarrow$ if going down**

**Elastic Potential energy**: [~associated with the state of compression/tension of elastic object]

$$\Delta U_{spring} = \tfrac{1}{2}kx_f^2 - \tfrac{1}{2}kx_i^2$$

→ If $U_{spring}(x=0) \equiv 0$ then $U_{spring}(x) = \tfrac{1}{2}kx^2$

**$\Delta U_{spring} \uparrow$ if x goes $\uparrow$ or $\downarrow$** (any displacement)

# Don't forget...

**Work done by force (general):** $$W = \int \vec{F}(\vec{x}) \bullet d\vec{x} = \vec{F} \bullet \vec{d}$$

**Work by Gravitational force:** $$W_g = \vec{F}_g \bullet \vec{d}$$

**Work by Spring force:** $$W_{spring} = \tfrac{1}{2} k x_i^2 - \tfrac{1}{2} k x_f^2$$

**Work-Kinetic Energy theorem:** $$W_{net} = \Delta KE = KE_f - KE_i$$

**Potential energy (if conservative force):** $$W = -\Delta U$$

$$\Delta U_{grav} = mg\Delta y \longrightarrow \text{If} \quad U_{grav}(y=0) \equiv 0 \quad \text{then} \quad U_{grav}(y) = mgy$$

$$\Delta U_{spring} = \tfrac{1}{2} k x_f^2 - \tfrac{1}{2} k x_i^2 \longrightarrow \text{If} \quad U_{spring}(x=0) \equiv 0 \quad \text{then} \quad U_{spring}(x) = \tfrac{1}{2} k x^2$$

# Mechanical Energy

Note: ALL kinetic energies and ALL potential energies

**Mechanical energy:**

$$E_{mech} = KE + U$$

- <u>Only conservative forces</u> (gravity & spring) cause energy transfer (work)

$$W_{net} = \Delta KE \qquad \text{Sec. 7-3}$$

$$W = -\Delta U \qquad \text{Sec. 8-1}$$

- <u>Isolated system</u>: Assuming only <u>internal forces</u> (no external forces yet - Sec. 8.6)
  - No external force from outside causes energy change inside

$$\Delta E_{mech} = 0 = \Delta\left(KE + U\right)$$

$$\Delta KE = -\Delta U$$

-- Conservation of Mechanical Energy

# How to solved these problems

My preference is to always use Mechanical Energy

$$\mathrm{E}_{mec}(final) = E_{mec}(initial)$$

$$K_f + U_f = K_i + U_i$$

*When* Friction is present, it always removes energy,

so E(final) is less the E(initioal)

$$\mathrm{E}_{mec}(final) = E_{mec}(initial) - Energy \text{ removed by work of friction}$$

$$K_f + U_f = K_i + U_i - F_f \bullet d$$

Always think about the problem and the signs!!

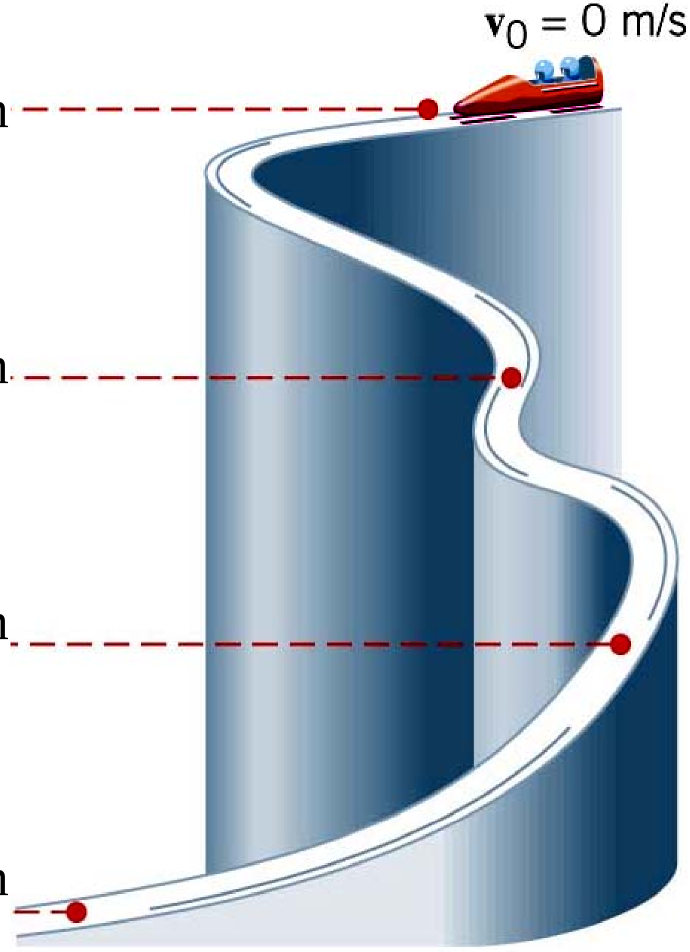
# Gravitational Potential Energy
# Conservative Force Problems

# Example of Conservation of Mechanical Energy

Consider a 100 kg bobsled starting with $v_o$ = 0 on a frictionless track. Compute the KE, PE, and total E at the labeled points. Zero of potential at the bottom.

$$PE = mgh \qquad KE = \frac{1}{2}mv^2 \qquad E_{mech} = KE + PE$$

| $E_{mech}$=KE+PE | KE | PE | Height h |
|---|---|---|---|
| 588,000 J | 0 J | 588,000 J | 600 m |
| 588,000 J | 196,000 J | 392,000 J | 400 m |
| 588,000 J | 392,000 J | 196,000 J | 200 m |
| 588,000 J | 588,000 J | 0 J | 0 m |

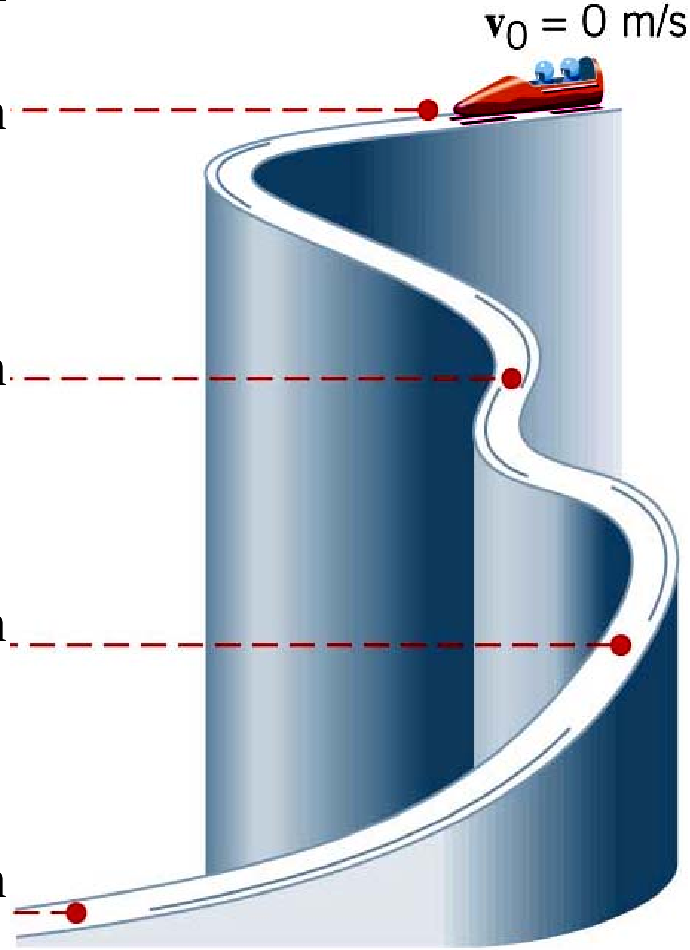


# Example of Conservation of Mechanical Energy

Consider a 100 kg bobsled starting with $v_o = 0$ on a frictionless track. Compute the KE, PE, and total E at the labeled points. Zero at the top!

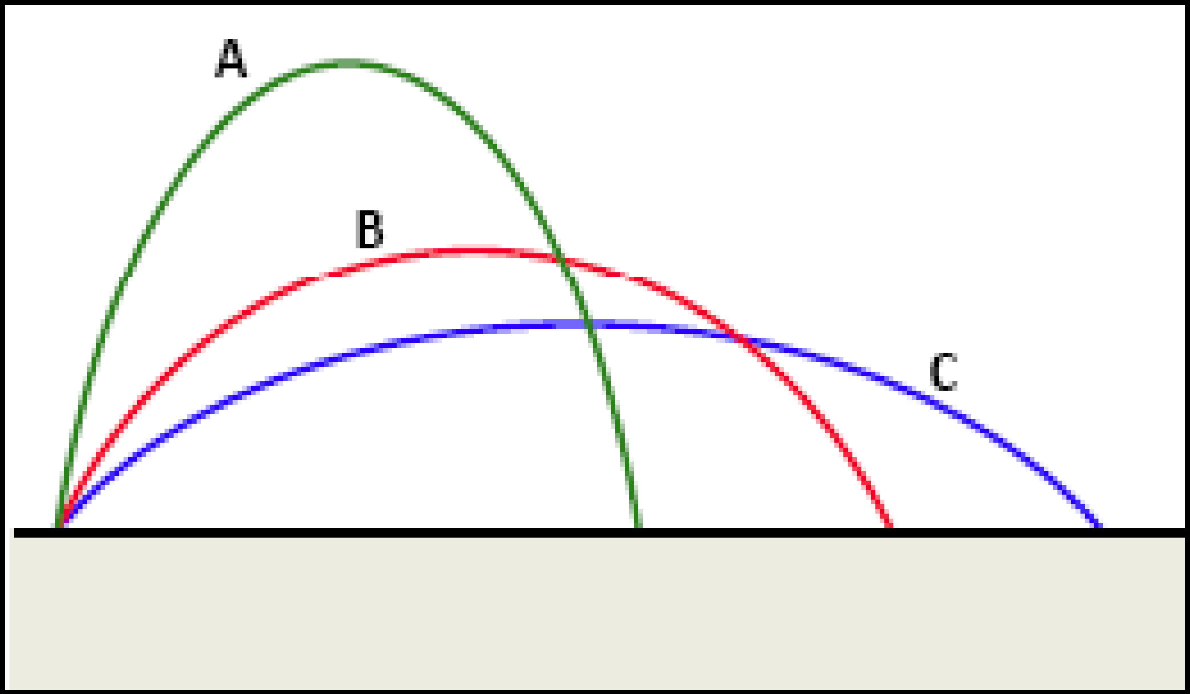
$$PE = -mgh \qquad KE = \frac{1}{2}mv^2 \qquad E_{mech} = KE + PE$$

| $E_{mech}$=KE+PE | KE | PE | Height h |
|---|---|---|---|
| 0 J | 0 J | 0 J | 0 m |
| 0 J | 196,000 J | -196,000 J | -200 m |
| 0 J | 392,000 J | -392,000 J | -400 m |
| 0 J | 588,000 J | -588,000 J | -600 m |



## Question

Three identical projectiles are fired at different launch angles and with different initial velocities. Which projectile has the greatest potential energy when it's at the peak in its trajectory?




1. A
2. B
3. C
4. All are equal

Can you tell me anything about the kinetic energies?

## Question

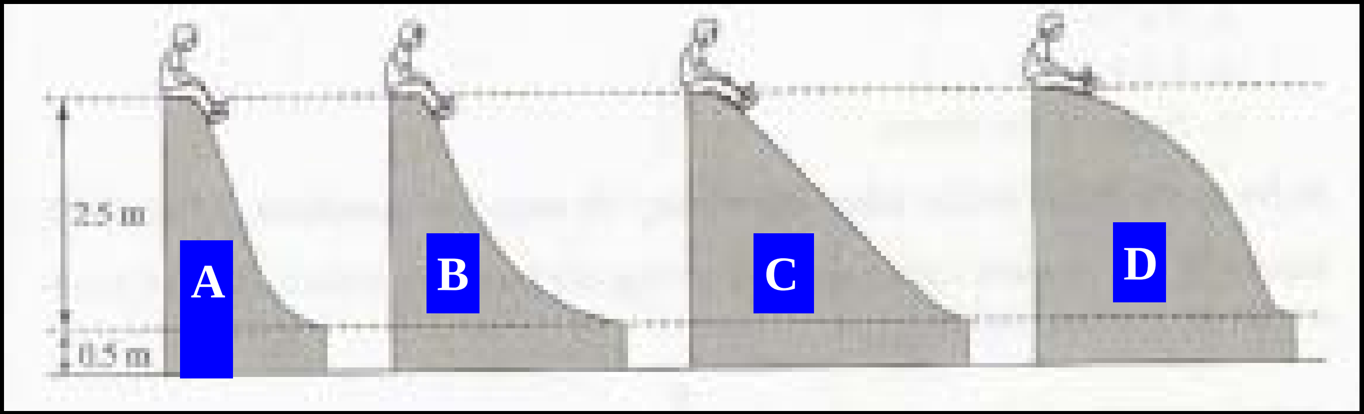
A block initially at rest slides down a frictionless ramp and attains a speed of v at the bottom. To achieve a speed of 2v, how many times as high must a new ramp be?

$$\tfrac{1}{2} m v_f^2 = mgh$$

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6

## Question

A young girl wishes to select one of the frictionless playground slides below to give her the greatest possible speed when she reaches the bottom of the slide. Which one should she choose?




1. A
2. B
3. C
4. D
5. Any of them