Spring 2014

PHYS-2010

Lecture 25

Clicker Question

Room Frequency BA

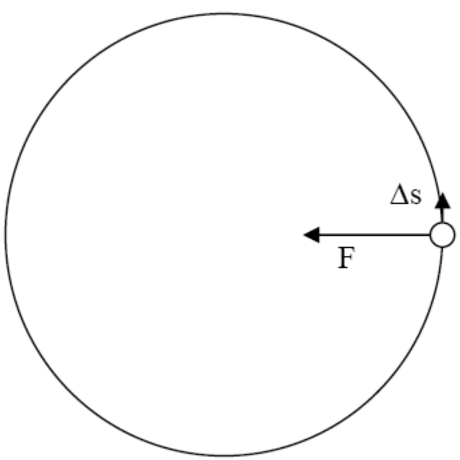
A rock of mass *m* is twirled on a string in a horizontal plane.

The work done **by the tension in the string on the rock is**

A) Positive

B) Negative

C) Zero



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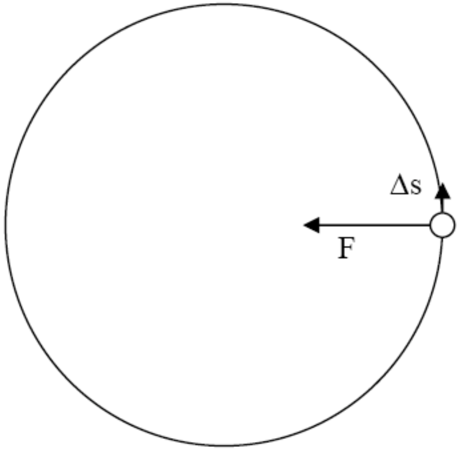


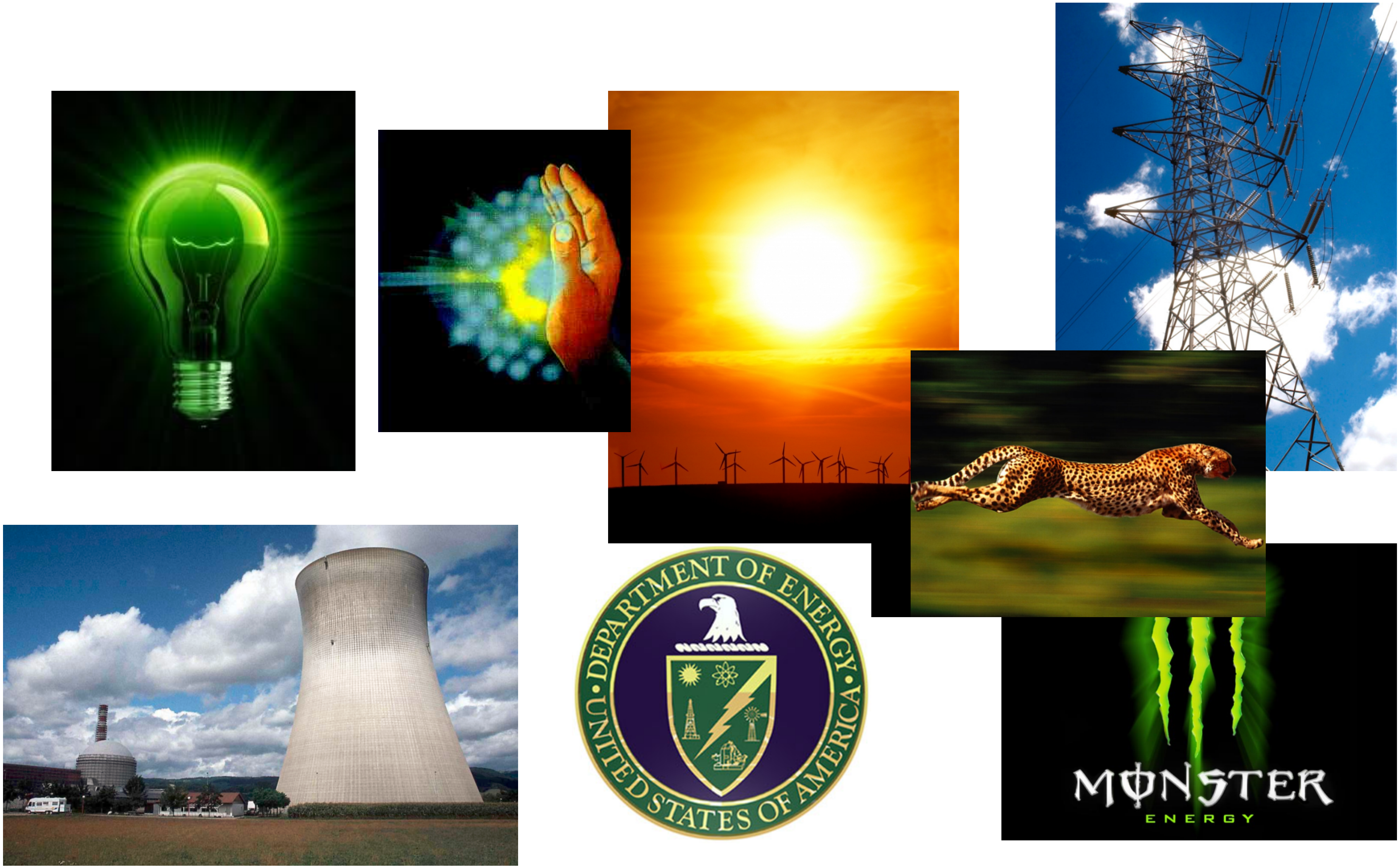
The work done by the tension force is zero, because the force of the tension in the string is perpendicular to the direction of the displacement:

$W = F \cos 90° = 0$

Announcements

- Read Giancoli **Chapter 6**.
- **Written homework** due this Friday at 4 pm.
- Prof. Pollock will be out of town this Friday (no office hours on Friday).
- I will be **out of town next week**; lectures will be given by Prof. Pollock.

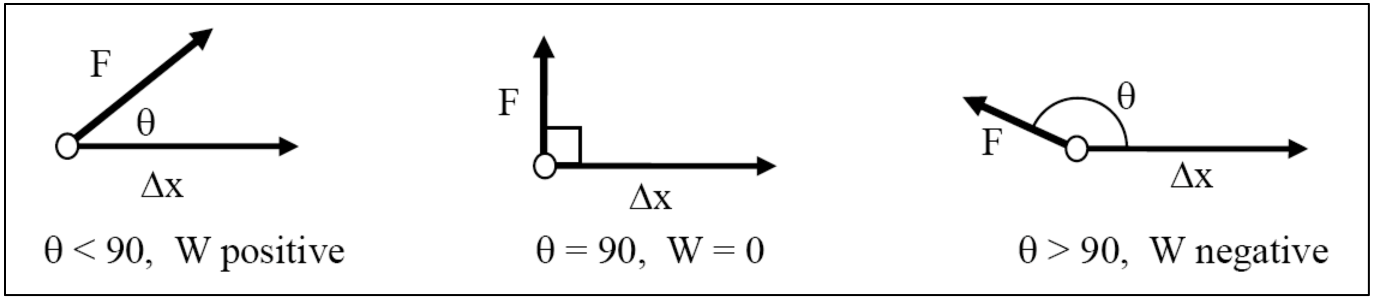
WORK AND ENERGY



1. Work:

$$W_F \equiv F_x \cdot d = F\cos\theta\, d = F_{||}\, d$$

Component of "specific" force along displacement x displacement:



2. Kinetic Energy:

$$KE = \frac{1}{2} m v^2$$

3. Work – Energy Principle:

$$W_{net} = W_{Fnet} = \Delta KE = KE_f - KE_i$$

Potential Energy (PE)

PE is a **stored** energy associated with the position or geometry of a physical system

Several varieties: gravitational, elastic/spring, electric…

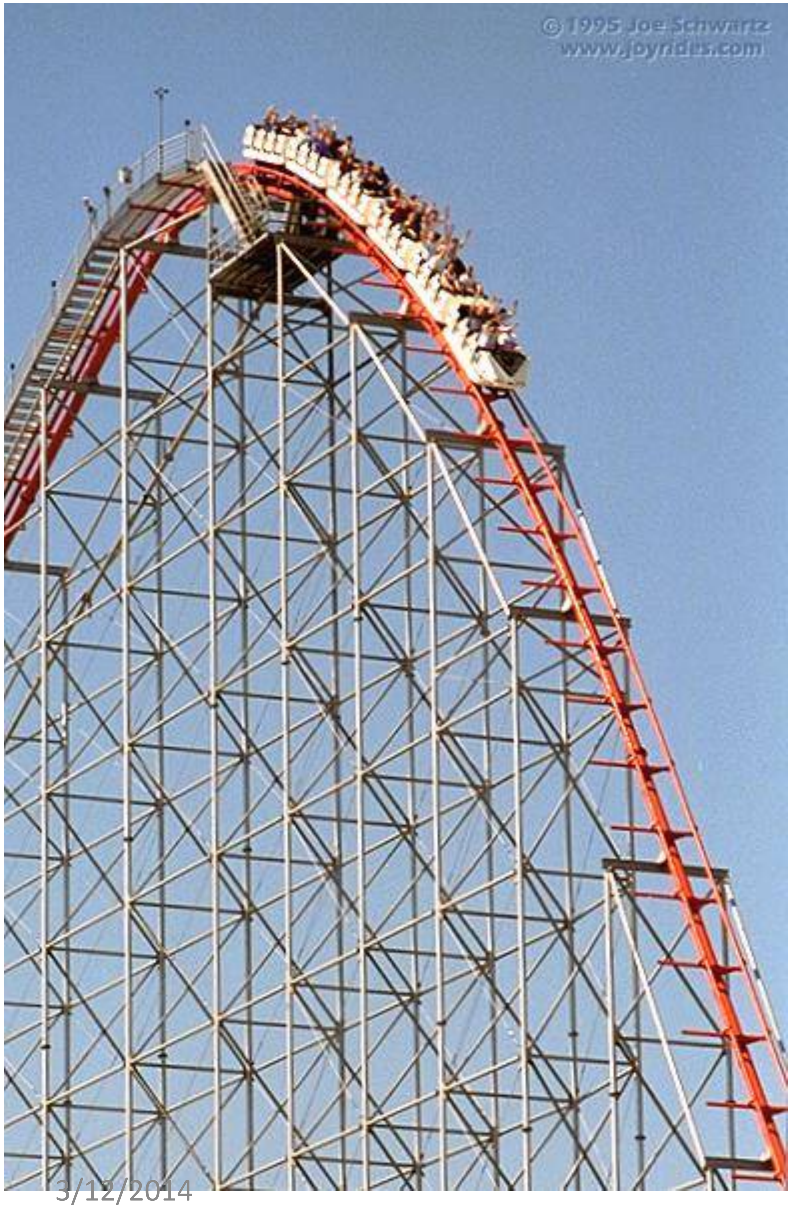
Definition:

Potential Energy (PE) is the amount of work done on a system by an external force when Kinetic Energy does not change and no heat energy flows in or out of the system.

$$\Delta PE = W_{ext} \quad \text{when } \Delta KE = 0$$

Again, effectively a re-statement of conservation of energy.

Gravitational Potential Energy



For a moment, they are at rest near the top (KE = 0).

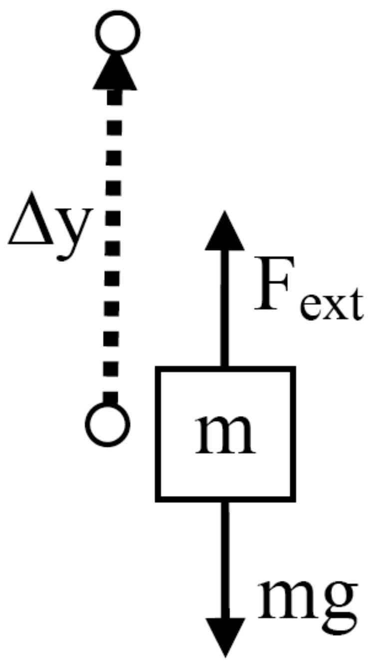
Later, they are moving quite fast (large KE).

Where did the energy come from, since energy is conserved?

Gravitational Potential Energy

Gravitational Potential Energy

Lift mass ***m***
at a constant speed
by a height **Δy**



$F_{net} = ma = F_{ext} - mg = 0$

$F_{ext} = mg$

As height increases, PE_{grav} increases.

$$\Delta PE_{grav} = W_{ext}$$

$$\Delta PE_{grav} = + F_{ext}\, \Delta y$$

$$\Delta PE_{grav} = + mg\, \Delta y$$

Often define $PE_{grav} = 0$ when $y = 0$.

$$PE_{grav} = mgy$$

PE is always defined relative to a "reference level" where it is zero.

Mechanical Energy

$$E_{mechanical} = KE + PE$$

Conservation of Mechanical Energy:

KE can change into PE and PE into KE, but the total (KE+PE) is constant for an *isolated* system with no lost energy (dissipation).

$$E_{mechanical} = (KE + PE) = \text{constant}$$

$$\Delta E_{mechanical} = \Delta(KE + PE) = 0$$

Investigate swing: http://phet.colorado.edu/sims/pendulum-lab/pendulum-lab_en.html

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*Mechanical Energy of a system is conserved if there is **no dissipation**.*

A physical system with no "dissipation" is one in which:

(A) There is no friction.

(B) There is friction.

(C) No external forces are applied.

(D) External forces are applied.

(E) Energy is not conserved.

Friction results in energy transferred to heat and thus loss of mechanical energy.

Clicker Question

Room Frequency BA

*Mechanical Energy of a system is conserved if the system is **isolated**.*

An "isolated" physical system is one in which

(A) There is no friction.

(B) There is friction.

(C) No external forces are applied.

(D) External forces are applied.

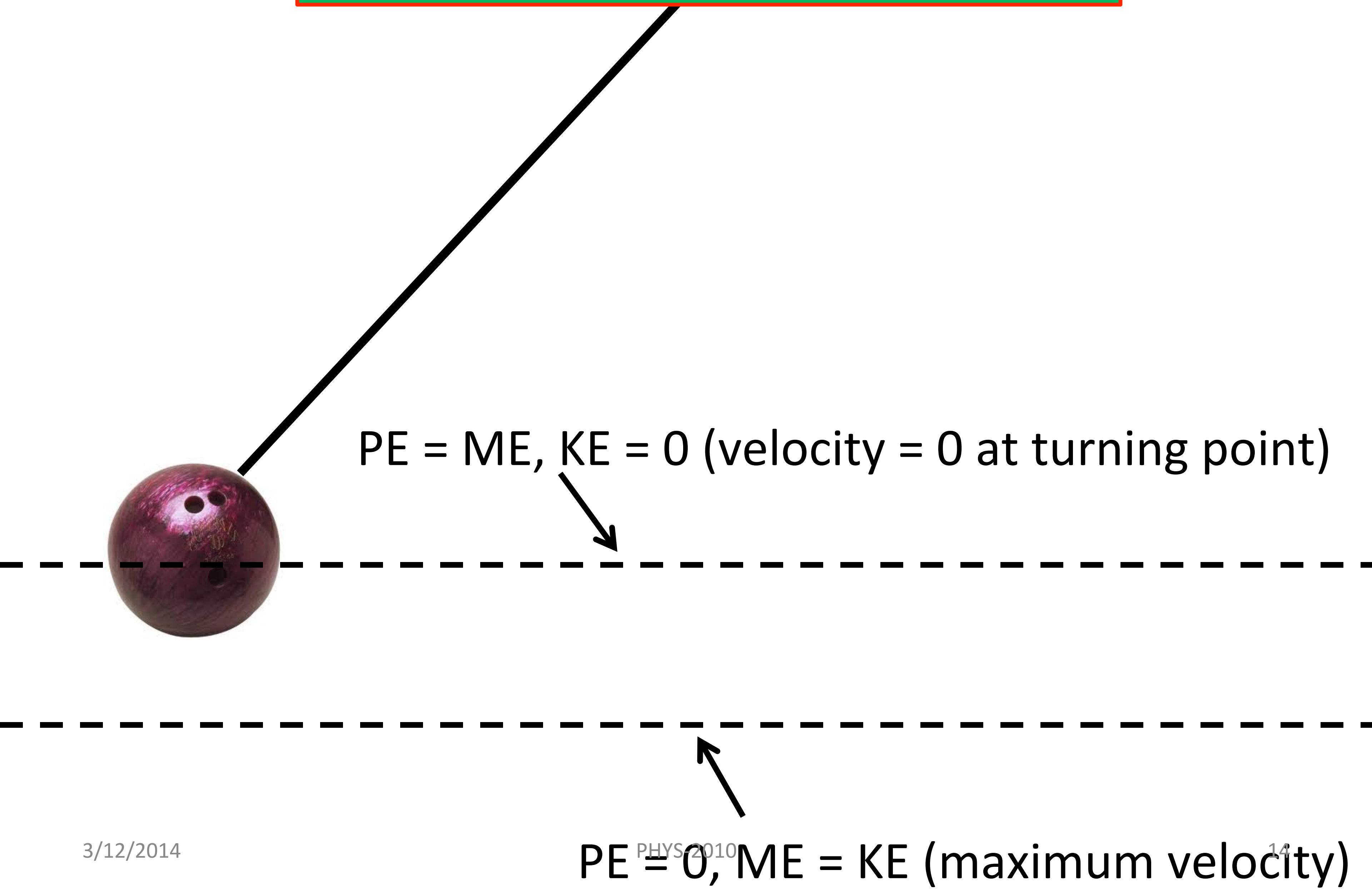
(E) Energy is not conserved.

External forces can do work on the system. Thus energy is transferred into or out of the system.

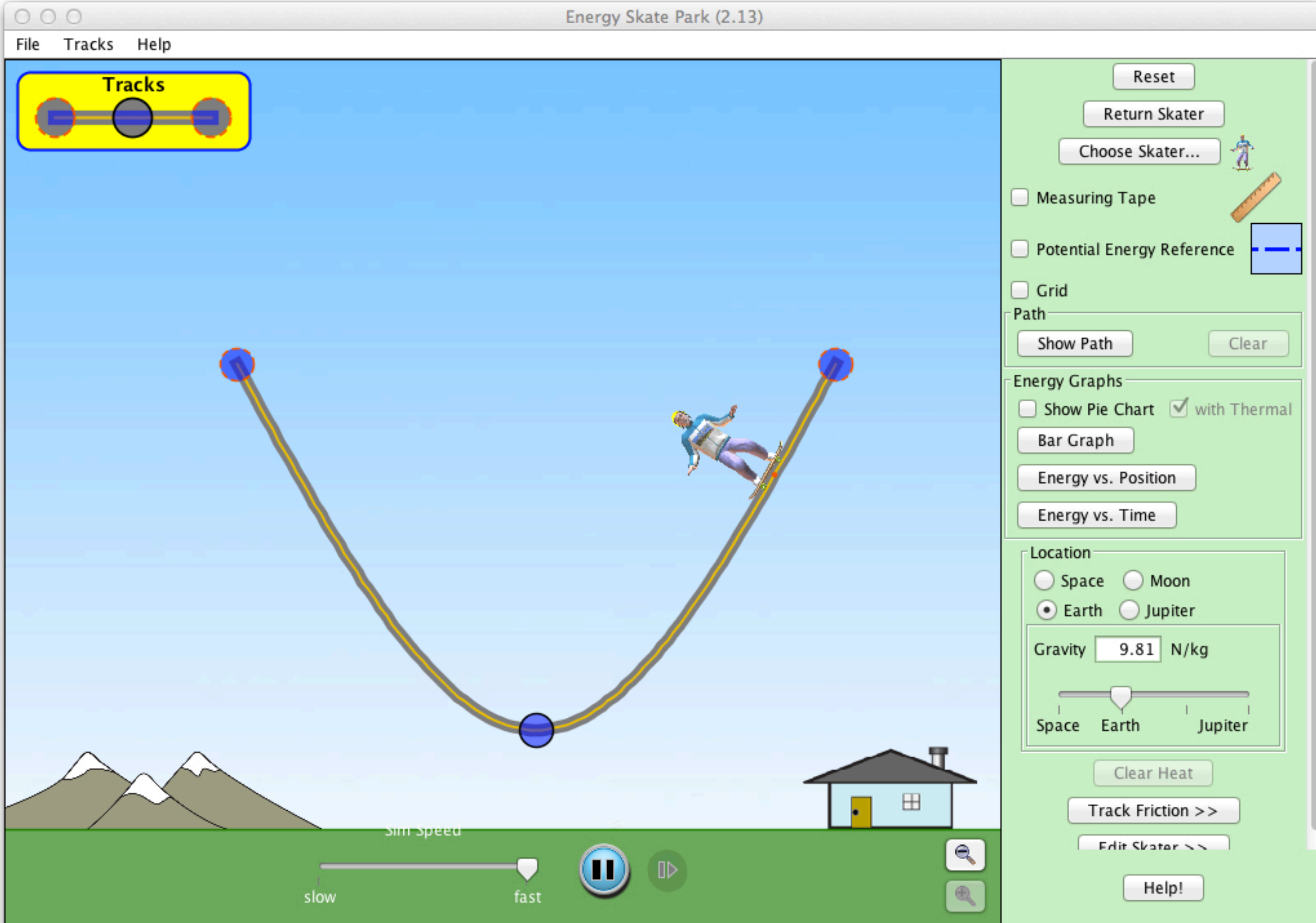
Applications of Energy Conservation:

- Pendulum
- Projectile motion
- Inclined Planes
- Roller-Coasters

PENDULUM



PE = ME, KE = 0 (velocity = 0 at turning point)
PE = 0, ME = KE (maximum velocity)

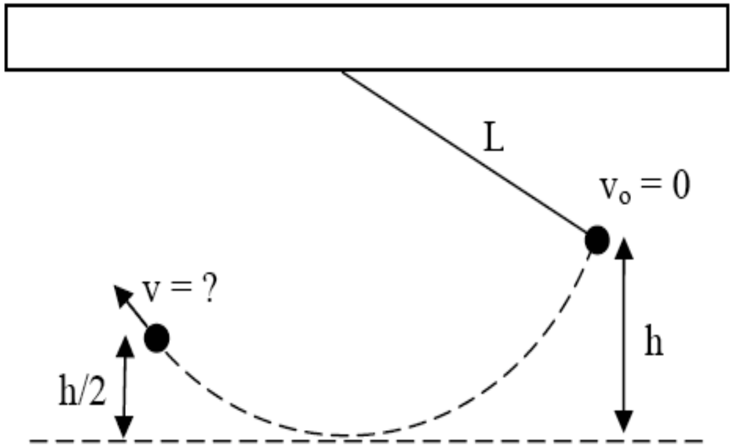


Energy Skate Park (2.13)
File
Tracks
Help
Tracks
Reset
Return Skater
Choose Skater...
Measuring Tape
Potential Energy Reference
Grid
Path
Show Path
Clear
Energy Graphs
Show Pie Chart
with Thermal
Bar Graph
Energy vs. Position
Energy vs. Time
Location
Space
Moon
Earth
Jupiter
Gravity
9.81
N/kg
Space
Earth
Jupiter
Clear Heat
Track Friction >>
Help!
Sim Speed
slow
fast

Conservation of Mechanical Energy

$E_{mechanical}$ = KE + PE = constant (isolated system, no dissipation)

Consider mass ***m*** swinging attached to a string of length ***L***.
The swing is released from rest at a height ***h***.
What is the speed ***v*** of the swing when it reaches height *h/2*?



$$ME_i = ME_f$$

$$KE_i + PE_i = KE_f + PE_f$$

$$\frac{1}{2}mv_i^2 + mgh = \frac{1}{2}mv_f^2 + mg\frac{h}{2}$$

0

$$\frac{1}{2}v_f^2 = \frac{1}{2}gh$$

$$v_f = \sqrt{gh}$$

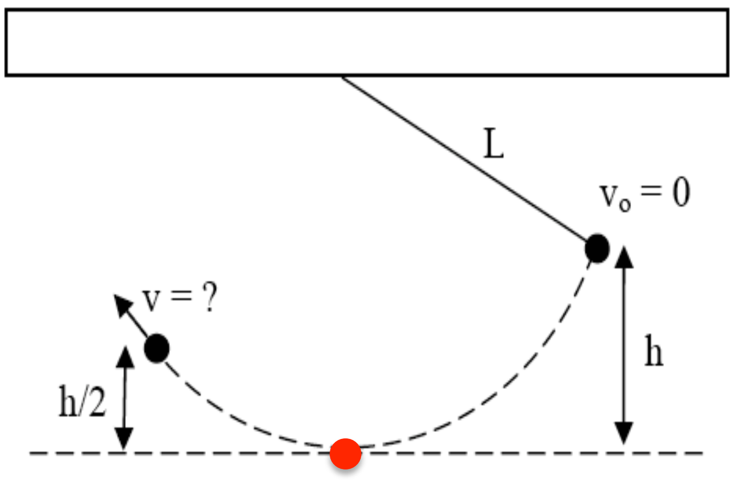
KE = ½ mv^2

PE_{grav} = mgy

Clicker Question | Room Frequency BA

Consider mass *m* swinging attached to a string of length *L*. The swing is released from rest at a height *h*.

What is the speed *v* of the swing when it reaches height ***h=0***?



$$A)\ \sqrt{gh}$$

$$B)\ 2\sqrt{gh}$$

$$C)\ \sqrt{\frac{g}{h}}$$

$$D)\ \sqrt{2gh}$$

$$KE_i + PE_i = KE_f + PE_f$$

$$0 \quad + mgh = \frac{1}{2}mv^2 + 0$$

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

KE = ½ mv^2

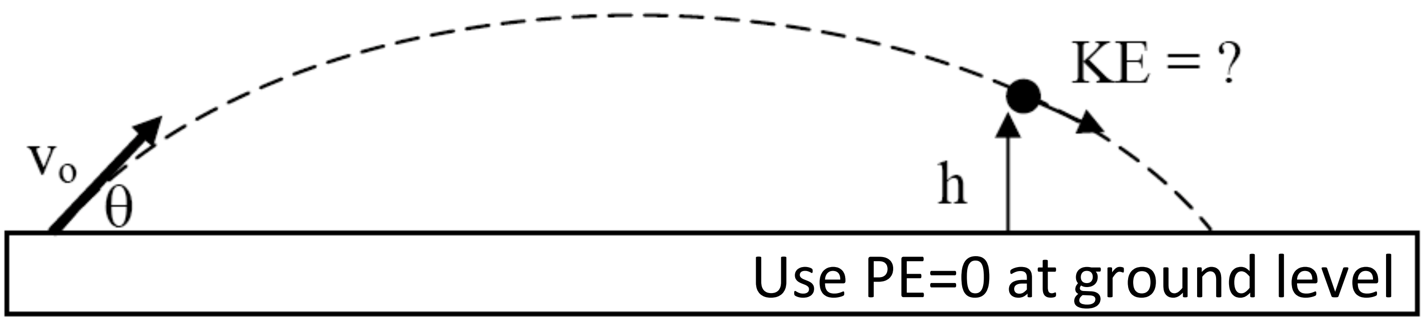
PE_{grav} = mgy

Projectile Motion

A projectile is fired with an initial speed $\mathbf{v_o}$ at an angle $\boldsymbol{\theta}$ from the horizontal.

What is the KE of the projectile when it is on the way down at a height **h** above the ground?

(Assume no air resistance)



A) ½ $mv_o^2 + mgh$

B) mgh

C) ½ $mv_o^2 - mgh$

D) Impossible to tell.

$$ME_i = ME_f$$

$$KE_i + PE_i = KE_f + PE_f$$

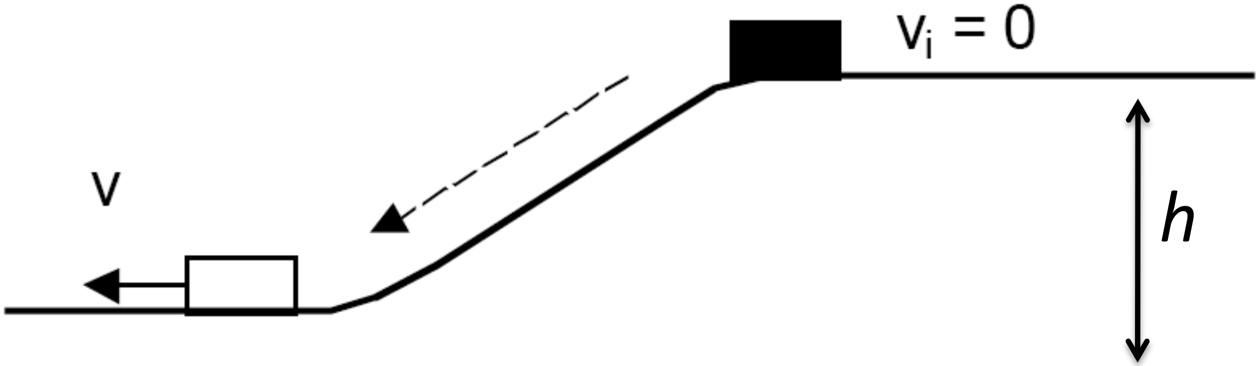
$$\frac{1}{2}mv_0^2 + 0 = KE_f + mgh$$

$$KE_f = \frac{1}{2}mv_0^2 - mgh$$

Clicker Question

Room Frequency BA

A mass slides down a **frictionless** ramp of height *h*.
Its initial speed is zero.
Its final speed at the bottom of the ramp is *v*.



As the mass descended, its KE
A) increased B) decreased C) remained constant

As the mass descended, its PE
A) increased B) decreased C) remained constant

As the mass descended, its (KE + PE) = total mechanical energy
A) increased B) decreased C) remained constant.

Clicker Question

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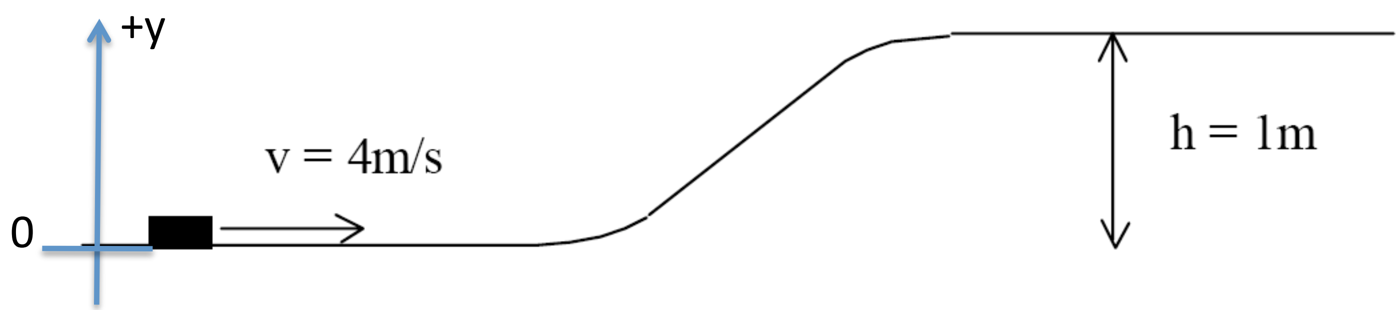
A hockey puck slides **without friction** along a frozen lake toward an ice ramp and plateau as shown. The speed of the puck is 4 m/s and the height of the plateau is 1 meter.



Will the puck make it all the way up the ramp?

A) Yes

B) No

C) Depends on the puck mass