Classical Mechanics
Lecture 8

Today's Concepts:

a) Potential Energy

b) Mechanical Energy

Stuff you asked about:

Gravity is the law. violators will be brought down.

How were these equations derived? I don't want to have to memorize, I would like a logical explanation of these equations.

Why is the potential energy of a spring hanging vertically $^1/_2ky^2$? I thought potential energy was always defined as mgh. What is the easiest way to understand these rates/ratios?

The whole thing with setting a point on a spring equal to h=0

the potential energy when the object is far from the surface of the earth. It is difficult, since the constant g is no longer the same as the one when the object is near the surface. How can I calculate the potential energy?

Too many letters and variables jumping around the screen

Show some examples of how to do a question, instead of giving all these notes and little experiment.

Summary

$$\Delta K \equiv W_{total}$$

Lecture 7

Work – Kinetic Energy theorem

Lecture 8

$$\Delta U \equiv -W$$

For springs & gravity (conservative forces)

$$E \equiv K + U$$

Total Mechanical Energy

E = Kinetic + Potential

$$\Delta E = W_{NC}$$

Work done by any force other than gravity and springs will change E

Relax. There is nothing new here

It's just re-writing the work-KE theorem:

everything except gravity and springs

$$\Delta K = W_{tot} = W_{gravity} + W_{springs} + W_{NC}$$

$$- \Delta U_{gravity} - \Delta U_{springs}$$

$$\Delta K + \Delta U_{gravity} + \Delta U_{springs} = W_{NC}$$

$$\Delta K + \Delta U = W_{NC}$$

$$\Delta E = W_{NC}$$

$\Delta E = 0$ If other forces aren't doing work

Finding the potential energy change:

Use formulas to find the magnitude

Check the sign by understanding the problem…

	Force $\vec{F}$	Work $W_{1\to 2}$	Change in P.E. $\Delta U = U_2 - U_1$	P.E. Function U
Gravity (Near Earth)	$m\vec{g}$	$-mg(h_2 - h_1)$	$mg(h_2 - h_1)$	$mgh + U_o$
Gravity (General Expression)	$-G\frac{m_1 m_2}{r^2}\hat{r}$	$Gm_1 m_2\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$	$-Gm_1 m_2\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$	$G\frac{m_1 m_2}{r} + U_o$
Spring	$-k\vec{x}$	$-\frac{1}{2}k(x_2^2 - x_1^2)$	$\frac{1}{2}k(x_2^2 - x_1^2)$	$\frac{1}{2}kx^2 + U_o$

CheckPoint

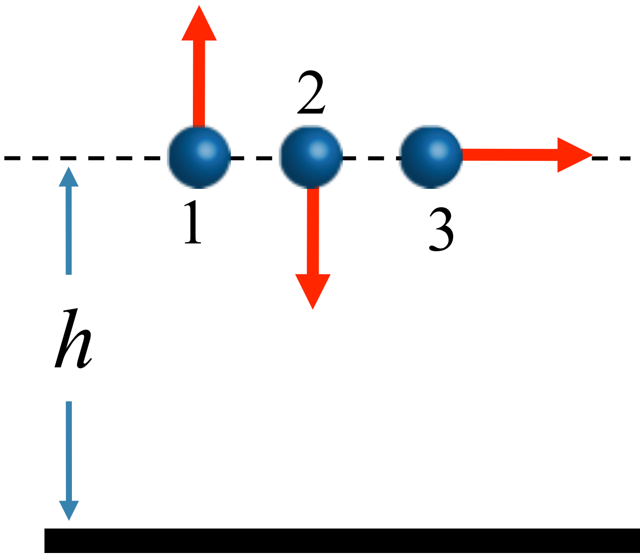
Three balls of equal mass are fired simultaneously with equal speeds from the same height h above the ground. Ball 1 is fired straight up, ball 2 is fired straight down, and ball 3 is fired horizontally. Rank in order from largest to smallest their speeds v_1, v_2, and v_3 just before each ball hits the ground.

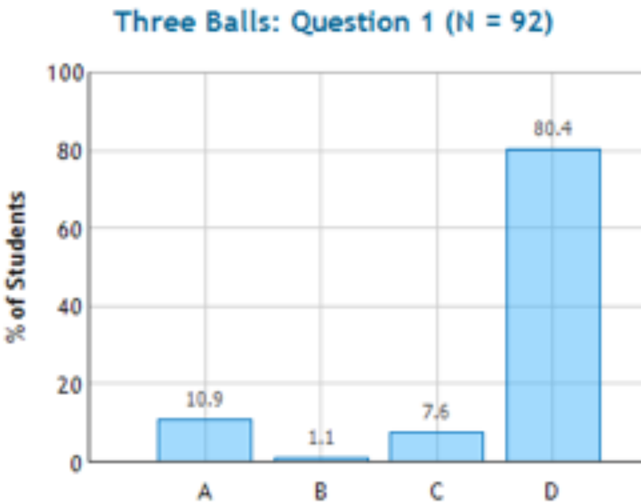
A) $v_1 > v_2 > v_3$

B) $v_3 > v_2 > v_1$

C) $v_2 > v_3 > v_1$

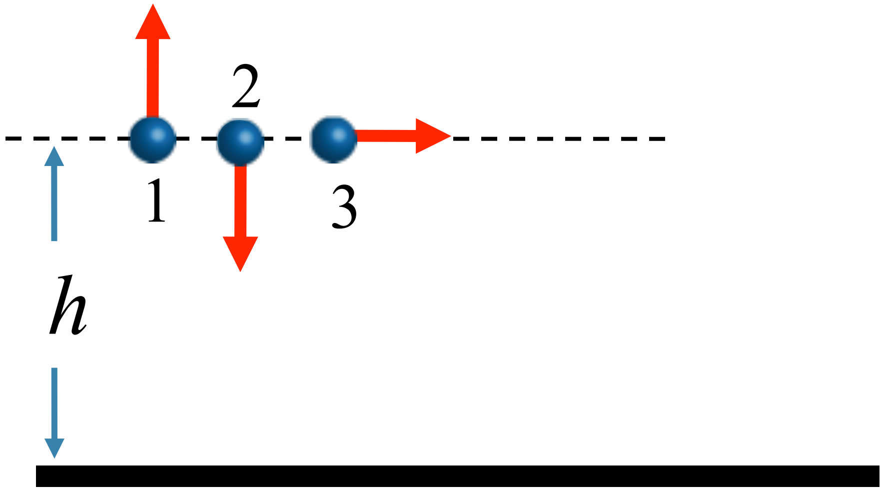
D) $v_1 = v_2 = v_3$





Clicker Question

Which of the following quantities are NOT the same for the three balls as they move from height *h* to the floor:



A) The change in their kinetic energies

B) The change in their potential energies

C) The time taken to hit the ground

Clicker Question

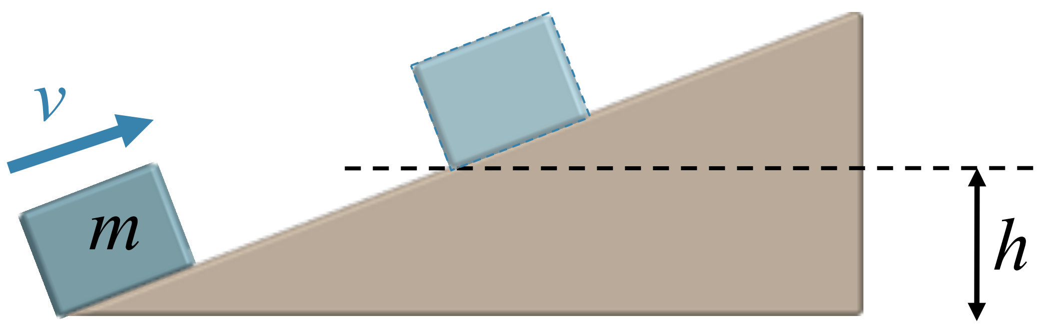
A block of mass m is launched up a frictionless ramp with an initial speed v and reaches a maximum vertical height h. A second block having twice the mass ($2m$) is launched up the same ramp with the same initial speed (v). What is the maximum vertical height reached by the second block?

A) h

B) $\sqrt{2}\,h$

C) $2h$

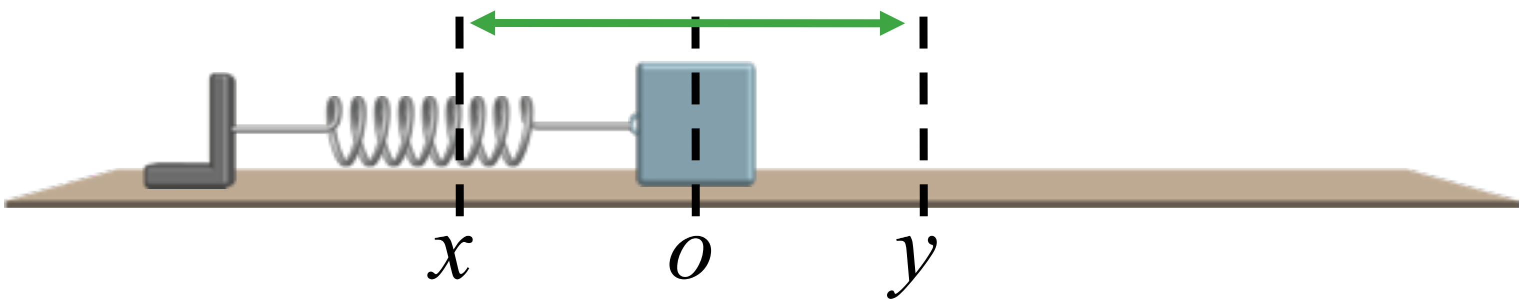
D) $4h$



$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2 \quad \Rightarrow \quad h = \frac{1}{2g}v^2$$

Clicker Question

A block attached to a spring is oscillating between point x (fully compressed) and point y (fully stretched). The spring is un-stretched at point o. At point o, which of the following quantities is at its maximum value?



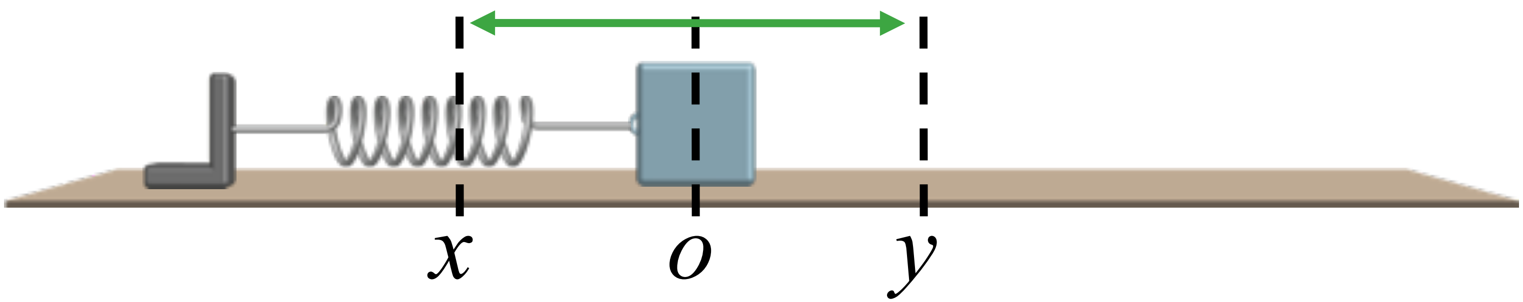
A) The block's kinetic energy

B) The spring potential energy

C) Both A and B

Clicker Question

A block attached to a spring is oscillating between point x (fully compressed) and point y (fully stretched). The spring is un-stretched at point o. At point x, which of the following quantities is at its maximum value?



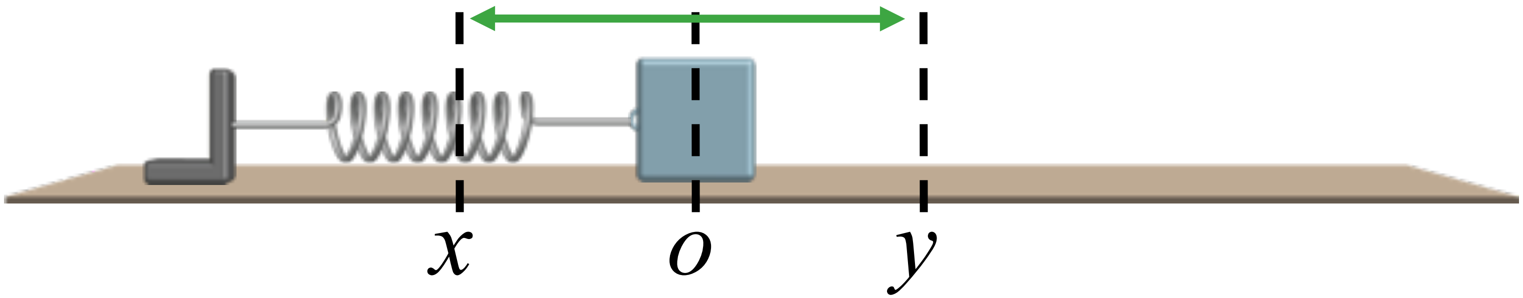
A) The block's kinetic energy

B) The spring potential energy

C) Both A and B

Clicker Question

A block attached to a spring is oscillating between point x (fully compressed) and point y (fully stretched). The spring is un-stretched at point o. At which point is the acceleration of the block zero?



A) At x

B) At o

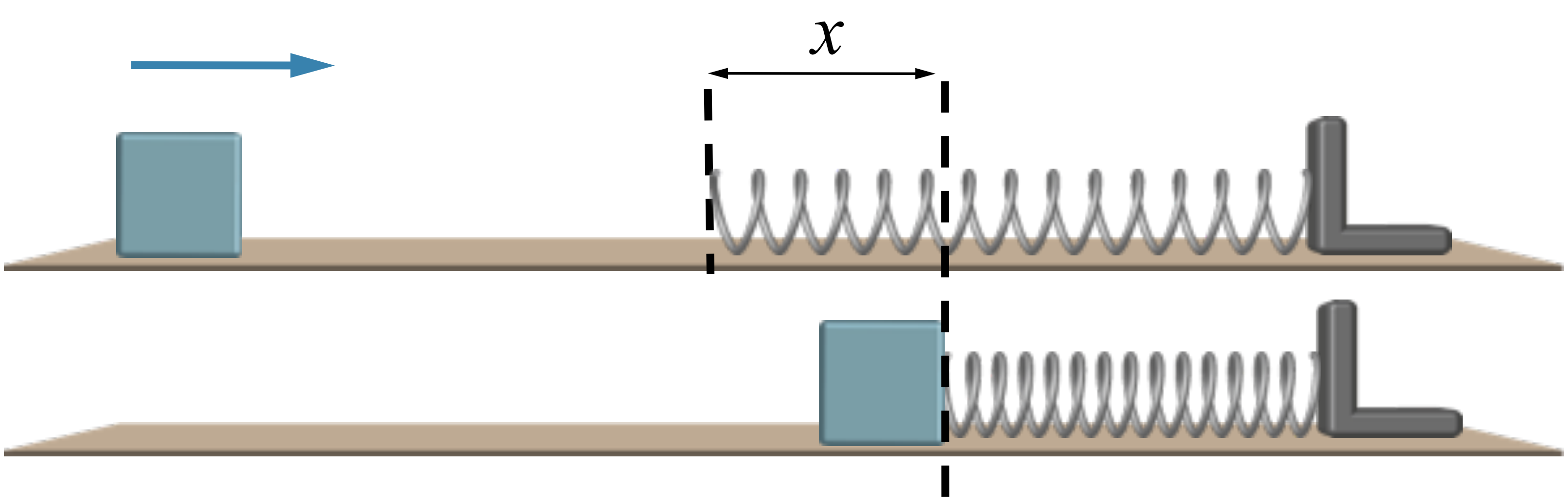
C) At y

CheckPoint

A box sliding on a horizontal frictionless surface runs into a fixed spring, compressing it a distance x_1 from its relaxed position while momentarily coming to rest.

If the initial speed of the box were doubled, how far x_2 would the spring compress?

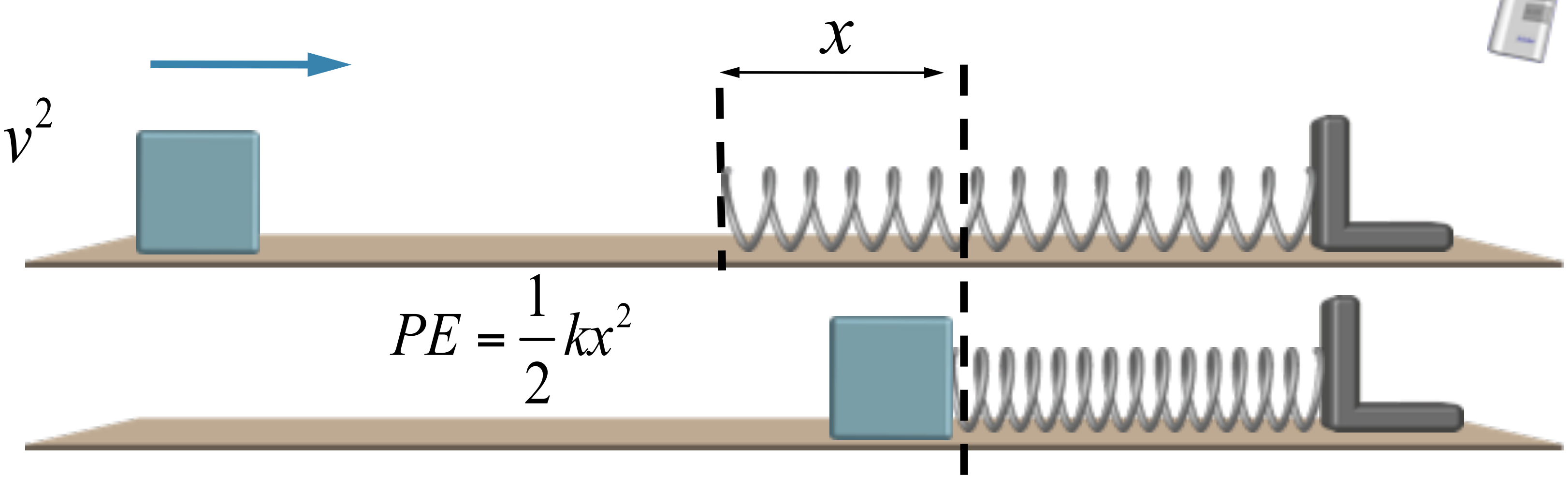
A) $x_2 = \sqrt{2}x_1$ B) $x_2 = 2x_1$ C) $x_2 = 4x_1$



CheckPoint

$$KE = \frac{1}{2}mv^2$$

$$PE = \frac{1}{2}kx^2$$

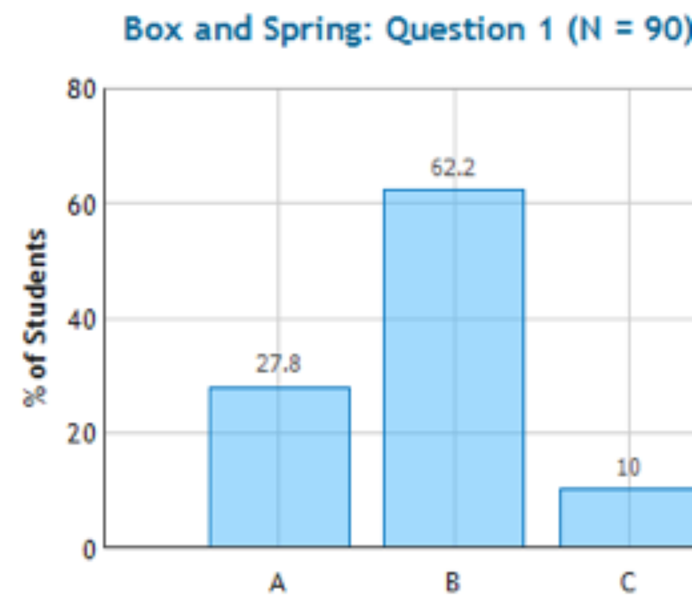


A) $x_2 = \sqrt{2}x_1$ B) $x_2 = 2x_1$ C) $x_2 = 4x_1$

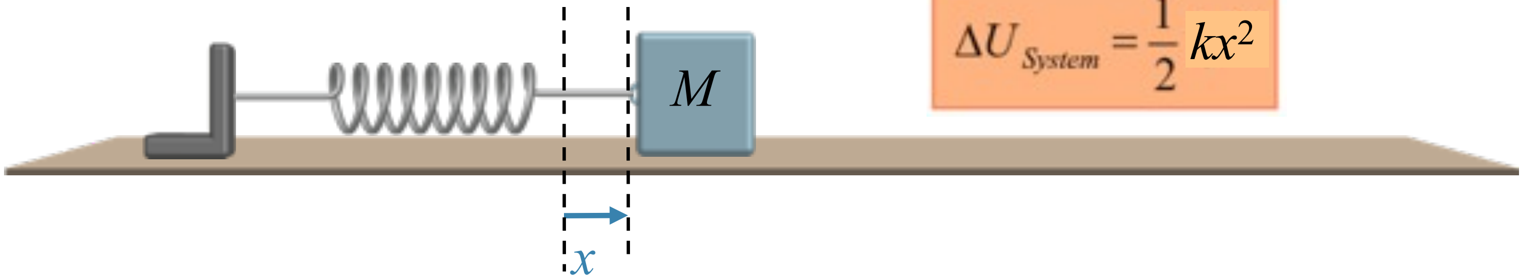
A) the formula is $1/2kX^2$ so it would be the square root two when the equation is rearranged

B) Since both the velocity and distance variables are squared in the kinetic energy and spring potential energy equation, double velocity also doubles extension.

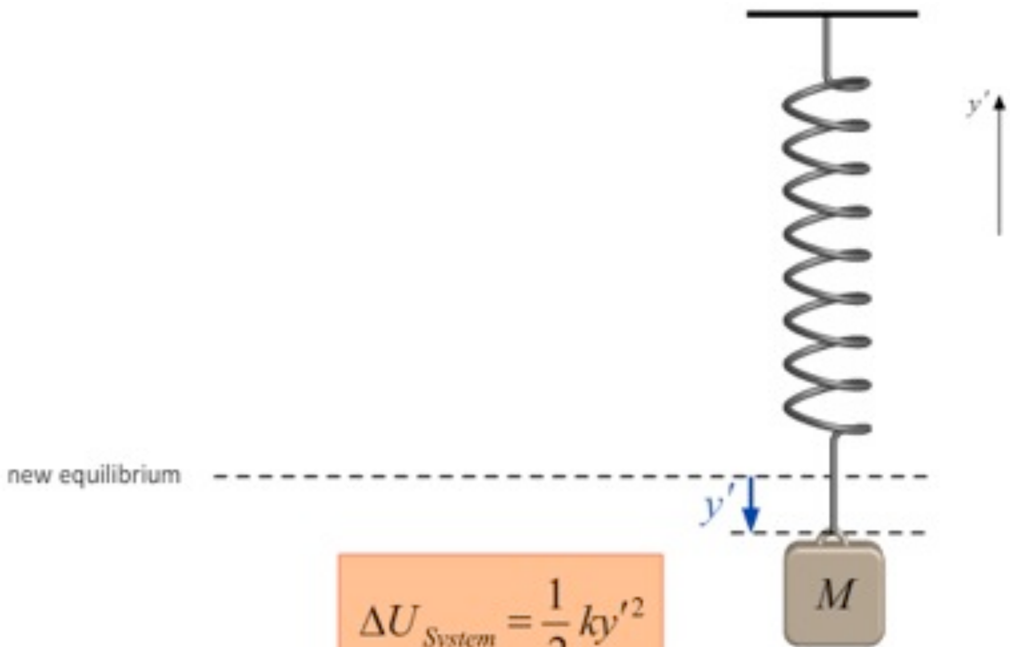
C) The velocity is squared so it will be 4 times more distance.



Spring Summary



$$\Delta U_{System} = \frac{1}{2}kx^2$$



$$\Delta U_{System} = \frac{1}{2}ky'^2$$

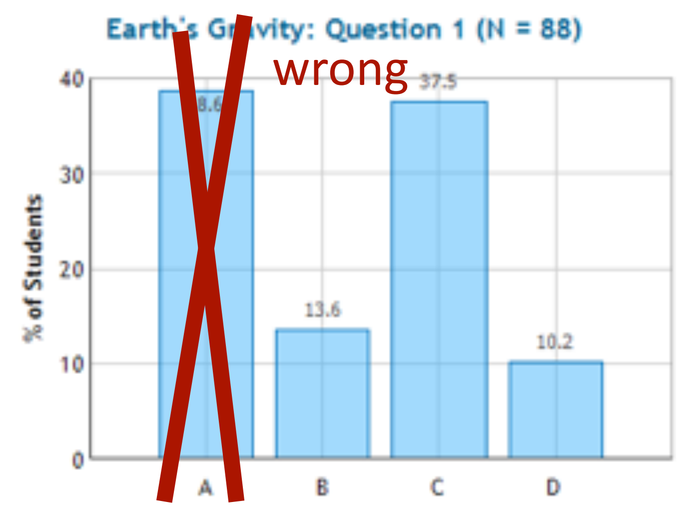
CheckPoint

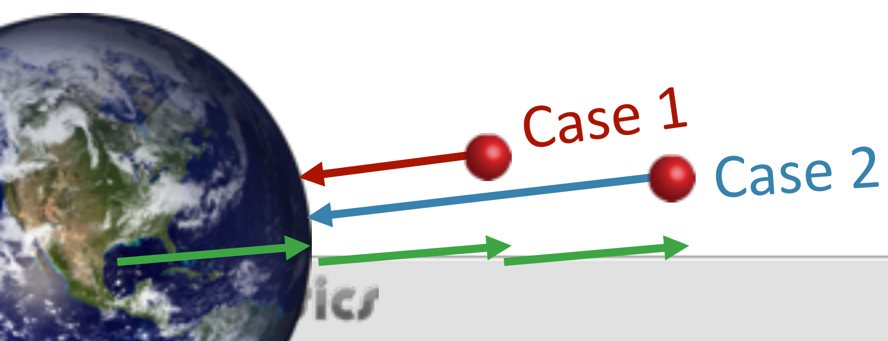
In Case 1 we release an object from a height above the surface of the earth equal to 1 earth radius, and we measure its kinetic energy just before it hits the earth to be K_1.

In Case 2 we release an object from a height above the surface of the earth equal to 2 earth radii, and we measure its kinetic energy just before it hits the earth to be K_2.

Compare K_1 and K_2.

A) $K_2 = 2K_1$
B) $K_2 = 4K_1$
C) $K_2 = 4K_1/3$
D) $K_2 = 3K_1/2$





Clicker Question

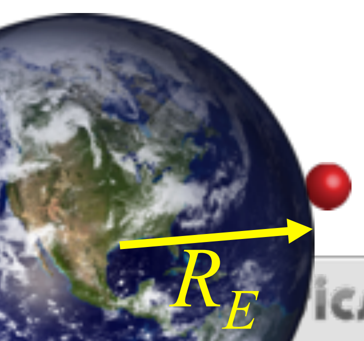
For gravity: $U(r) = -\frac{GM_e m}{r} \cancel{+U_0}$

What is the potential energy of an object of mass m on the earths surface:

A) $U_{surface} = -\frac{GM_e m}{0}$

B) $U_{surface} = -\frac{GM_e m}{R_E}$

C) $U_{surface} = -\frac{GM_e m}{2R_E}$



Clicker Question

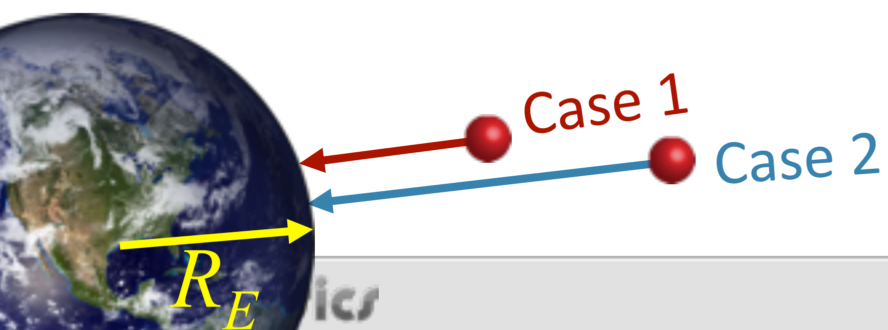
$$U(r) = -\frac{GM_e m}{r}$$

What is the potential energy of a object starting at the height of Case 1?

A) $U_1 = -\dfrac{GM_e m}{R_E}$

B) $U_1 = -\dfrac{GM_e m}{2R_E}$

C) $U_1 = -\dfrac{GM_e m}{3R_E}$



Clicker Question

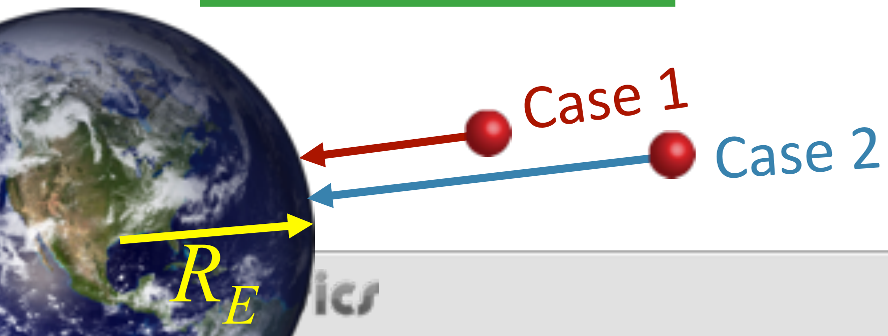
$$U(r) = -\frac{GM_e m}{r}$$

What is the potential energy of a object starting at the height of Case 2?

A) $U_2 = -\frac{GM_e m}{R_E}$

B) $U_2 = -\frac{GM_e m}{2R_E}$

C) $U_2 = -\frac{GM_e m}{3R_E}$

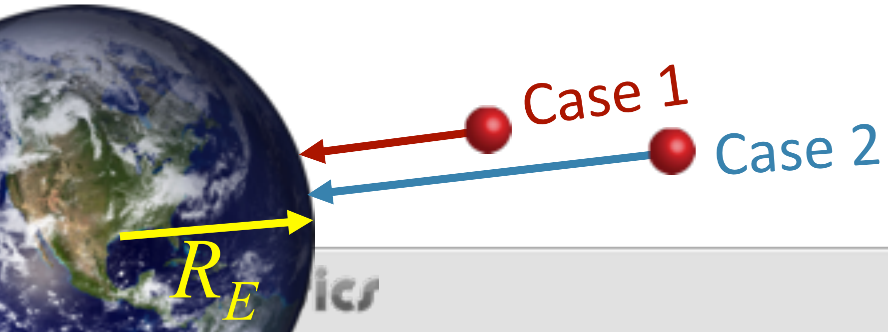


$$U_{surface} = -\frac{GM_e m}{R_E} \qquad U_1 = -\frac{GM_e m}{2R_E} \qquad U_2 = -\frac{GM_e m}{3R_E}$$

What is the change in potential in Case 1?

A) $$\Delta U_{case1} = -GM_e m\left(\frac{1}{2R_e} - \frac{1}{R_e}\right) = \frac{1}{2}\frac{GM_e m}{R_e}$$

B) $$\Delta U_{case1} = -GM_e m\left(\frac{1}{R_e} - \frac{1}{2R_e}\right) = \frac{-1}{2}\frac{GM_e m}{R_e}$$

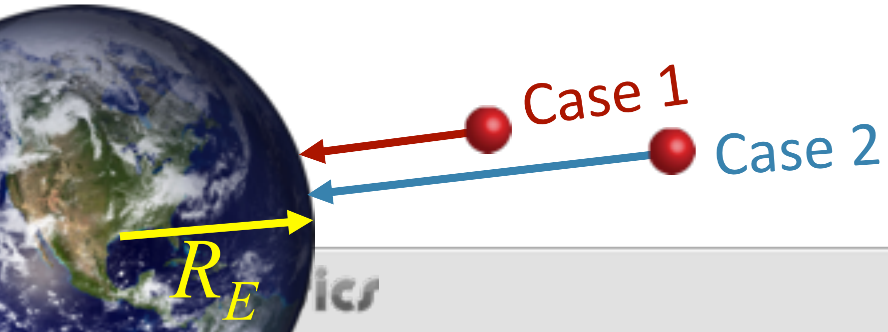


$$U_{surface} = -\frac{GM_e m}{R_E} \qquad U_1 = -\frac{GM_e m}{2R_E} \qquad U_2 = -\frac{GM_e m}{3R_E}$$

What is the change in potential in Case 2?

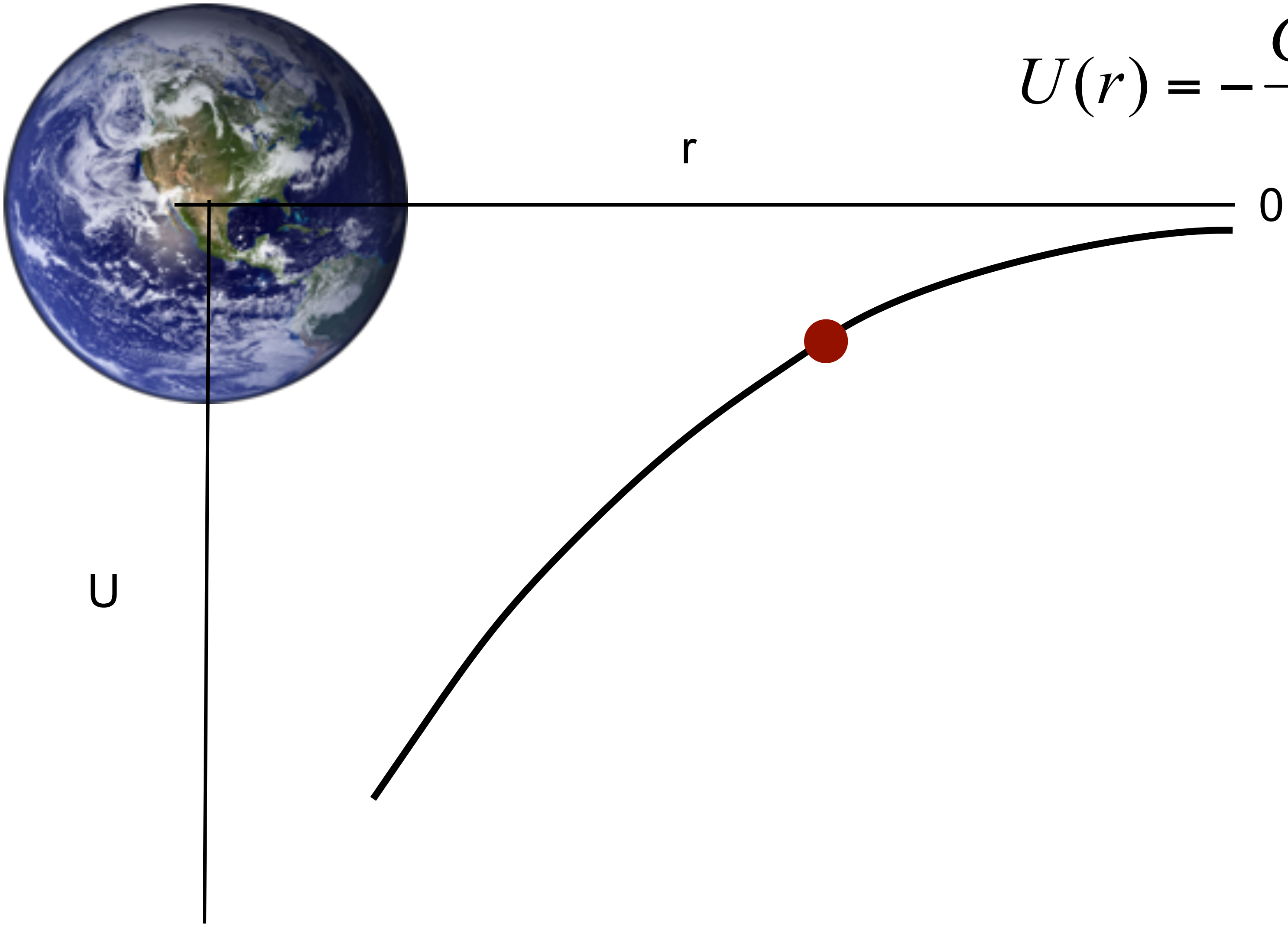
A) $$\Delta U_{case2} = -GM_e m\left(\frac{1}{3R_e} - \frac{1}{R_e}\right) = \frac{2}{3}\frac{GM_e m}{R_e}$$

B) $$\Delta U_{case2} = -GM_e m\left(\frac{1}{R_e} - \frac{1}{3R_e}\right) = \frac{-2}{3}\frac{GM_e m}{R_e}$$



Draw U

$$U(r) = -\frac{GM_e m}{r}$$



$$\Delta U_{case1} = -\frac{GM_e m}{2R_e} \qquad \Delta U_{case2} = -\frac{2GM_e m}{3R_e}$$

What is the ratio $\frac{\Delta K_2}{\Delta K_1} = \frac{\Delta U_2}{\Delta U_1}$

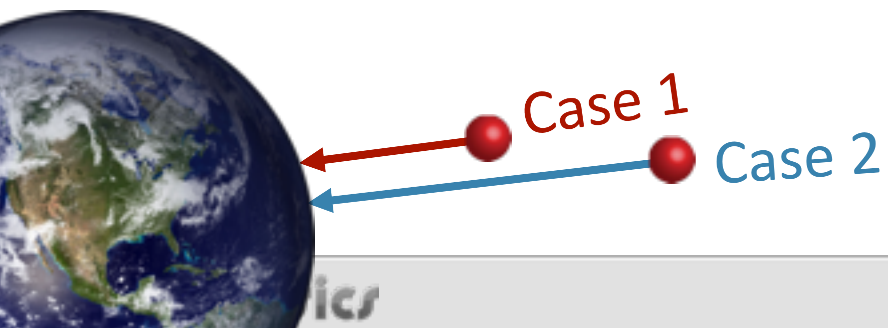
$$= \frac{-2/3}{-1/2} = \frac{4}{3}$$

A) 2

B) 4

C) 4/3

D) 3/2



CheckPoint

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Compare K_1 and K_2.

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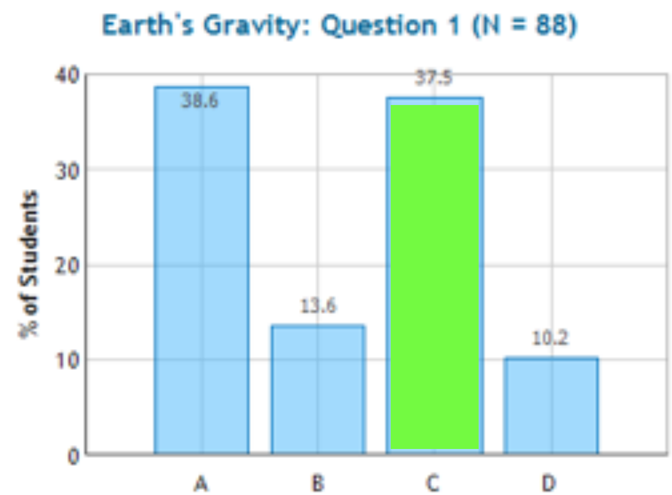
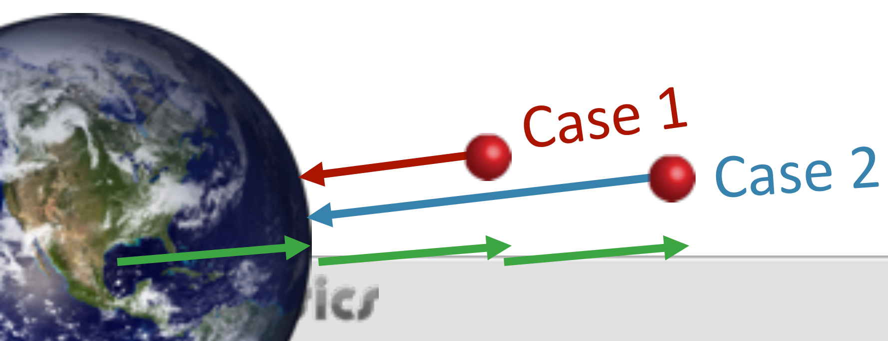
C) $K_2 = 4K_1/3$ D) $K_2 = 3K$





Jason's Explanation