Today: 7.1

$\boxed{L21}$

Today: 7.1

L21

Gravitational
Potential
Energy

Today: 7.1

Friday: 7.2

$\boxed{L21}$

Today: 7.1

Friday: 7.2

L21

Elastic

Potential

Energy

Bob lifts a box such that

$K_1 = K_2 = 0$

↑

Kinetic
energy

Bob lifts a box such that

$K_1 = K_2 = 0$

Since $W_{1 \to 2} = \Delta K$

Bob lifts a box such that

$K_1 = K_2 = 0$

Since $W_{1\to 2} = \Delta K = 0$

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$K_1 = K_2 = 0$

Since $W_{1\to2} = \Delta K = 0$

Then $W_{1\to2} = (W_{1\to2})_{Bob} + (W_{1\to2})_{gravity} = 0$

Bob lifts a box such that

$K_1 = K_2 = \emptyset$

Since $W_{1\to2} = \Delta K = \emptyset$

Then $W_{1\to2} = (W_{1\to2})_{Bob} + (W_{1\to2})_{gravity} = \emptyset$

so $(W_{1\to2})_{Bob} = -(W_{1\to2})_{gravity}$

Bob lifts a box such that

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A new point of view:

Bob lifts a box such that

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<u>A new point of view</u>: Let's say that Bob put energy into the box.

Bob lifts a box such that

$K_1 = K_2 = 0$

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<u>A new point of view</u>: Let's say that Bob put energy into the box. At point 2, the box has gained "Potential Energy"

Let $\left(\begin{matrix}\text{potential energy}\\ \text{at point } i\end{matrix}\right) \equiv U_i$

Let (potential energy at point i) $\equiv U_i$

Now $\underset{\text{Bob}}{W_{1\to 2}} = -\underset{\text{Gravity}}{W_{1\to 2}} = U_2 - U_1$

Let $\begin{pmatrix}\text{potential energy} \\ \text{at point } i\end{pmatrix} \equiv U_i$

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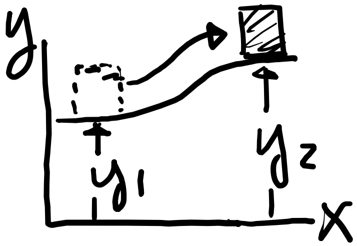
Please notice: The difference in potential energy is relatable to work put in.



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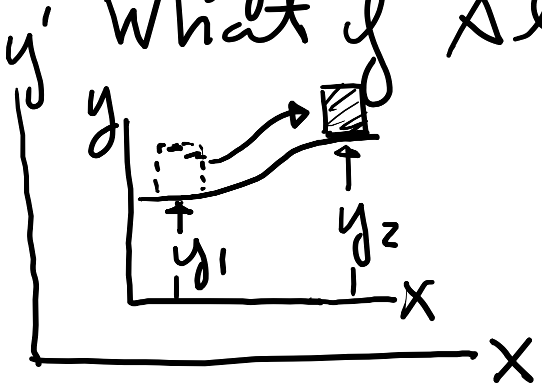
What if Alice had a coordinate system $x'y'$



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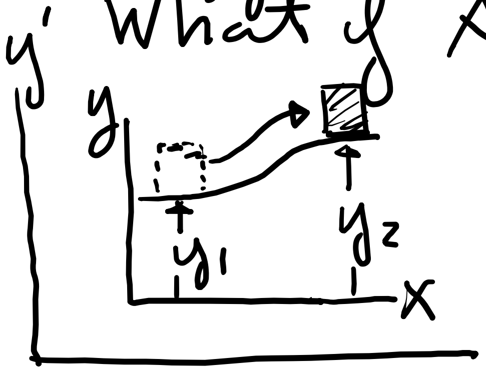

We, with coordinate system x, y could say $V_1 = mgy_1$ & $V_2 = mgy_2$

& $\underset{\text{Bob}}{W_{1\to 2}} = mg(y_2 - y_1)$

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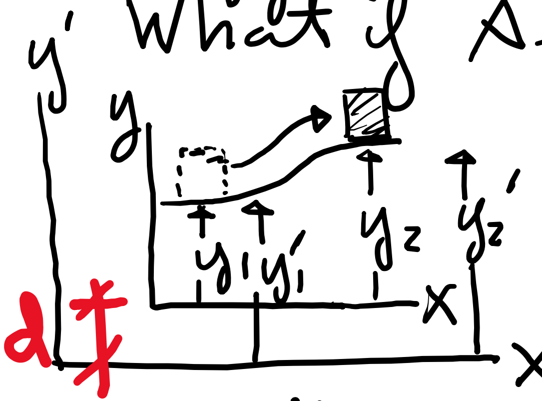

We, with coordinate system x,y could say $V_1 = mgy_1$ & $V_2 = mgy_2$ & $\underset{\text{Bob}}{W_{1\to 2}} = mg(y_2 - y_1)$ & Alice could say $U_1 = mgy_1'$ & $U_2 = mgy_2' \Rightarrow \underset{\text{Bob}}{W_{1\to 2}} = mg(y_2' - y_1')$

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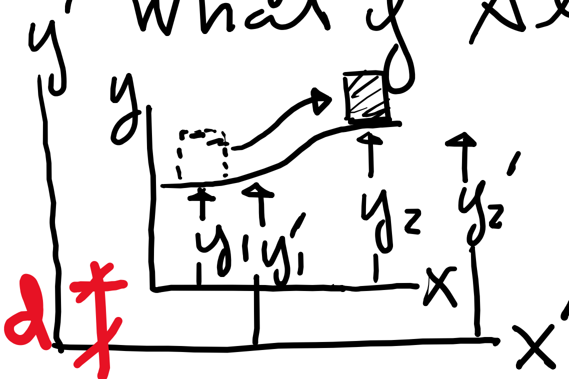

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But $y_1' = y_1 + d$ & $y_2' = y_2 + d$

So $W_{1\to 2 \atop \text{Bob}} = mg(y_2' - y_1') = mg(y_2 - y_1)$

So $W_{1\to 2}^{\text{Bob}} = mg(y_2' - y_1') = mg(y_2 - y_1)$

& we agree on the difference in potential energy

So $\underset{\text{Bob}}{W_{1\to 2}} = mg(y_2' - y_1') = mg(y_2 - y_1)$

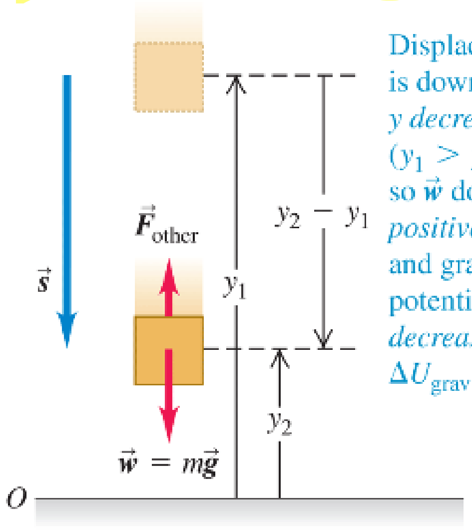
& we agree on the difference in potential energy but Not on the value at a given point.

So $\underset{\text{Bob}}{W_{1\to 2}} = mg(y_2' - y_1') = mg(y_2 - y_1)$

& we agree on the difference in potential energy but NOT on the value at a given point.

You can always add a constant to potential energy as long as it is the same constant for all points.

(a) An object moves downward



Displacement $\vec{s}$ is downward and *y decreases* ($y_1 > y_2$), so $\vec{w}$ does *positive* work and gravitational potential energy *decreases*: $\Delta U_{\text{grav}} < 0$.

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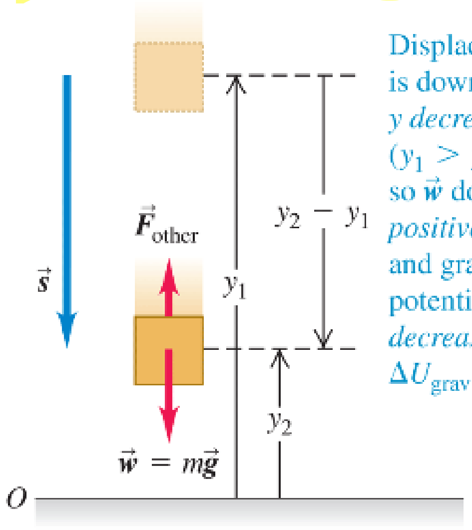

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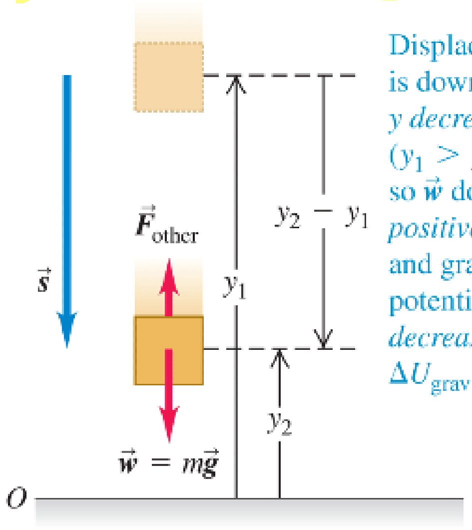

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$$(W_{1\to2})_{gravity} = mgy_1 - mgy_2$$

Here $y_1 > y_2$ so $(W_{1\to2})_g > 0$

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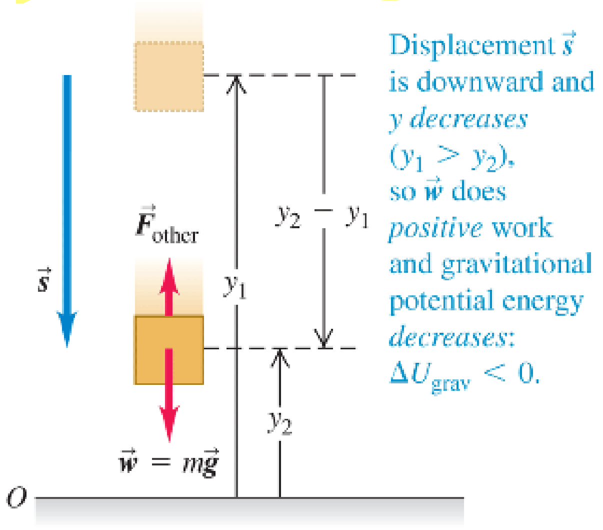
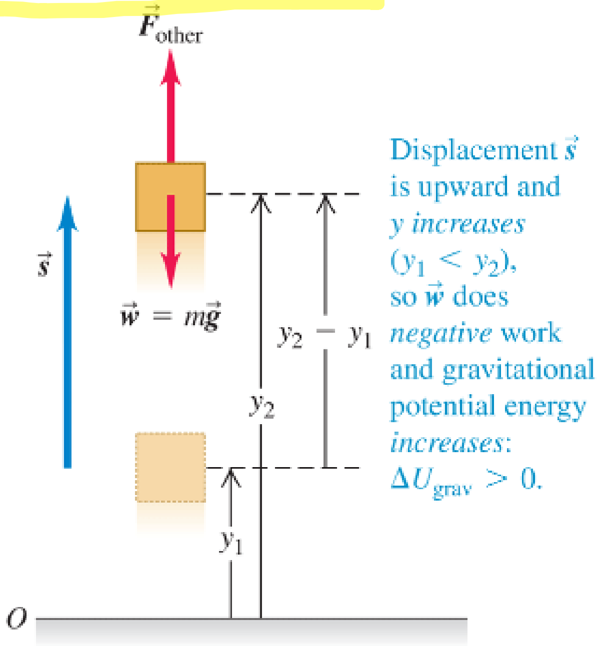


Displacement $\vec{s}$ is downward and *y decreases* ($y_1 > y_2$), so $\vec{w}$ does *positive* work and gravitational potential energy *decreases*: $\Delta U_{grav} < 0$.

(b) An object moves upward



Displacement $\vec{s}$ is upward and *y increases* ($y_1 < y_2$), so $\vec{w}$ does *negative* work and gravitational potential energy *increases*: $\Delta U_{grav} > 0$.

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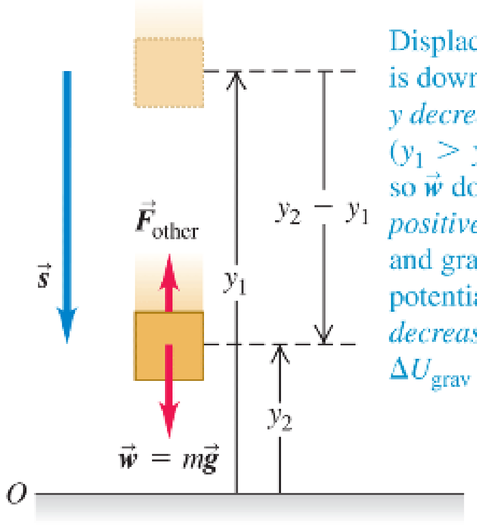

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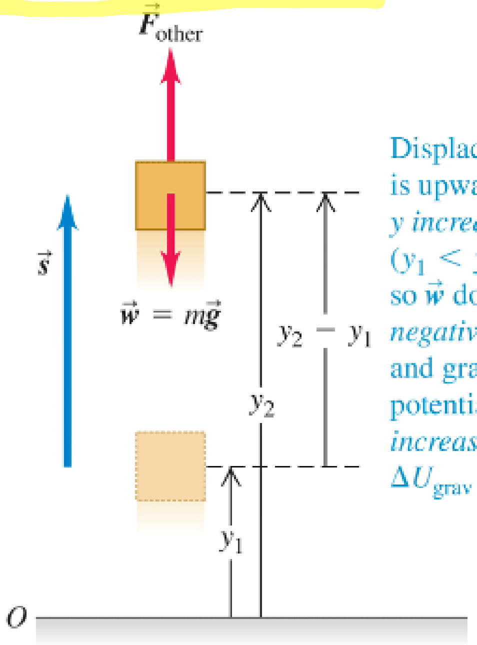

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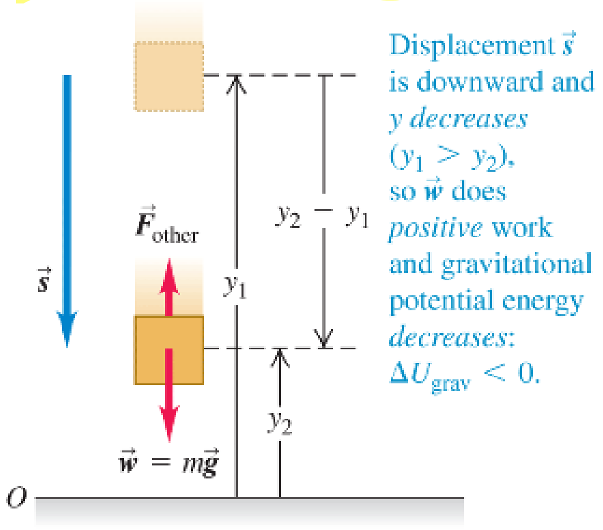

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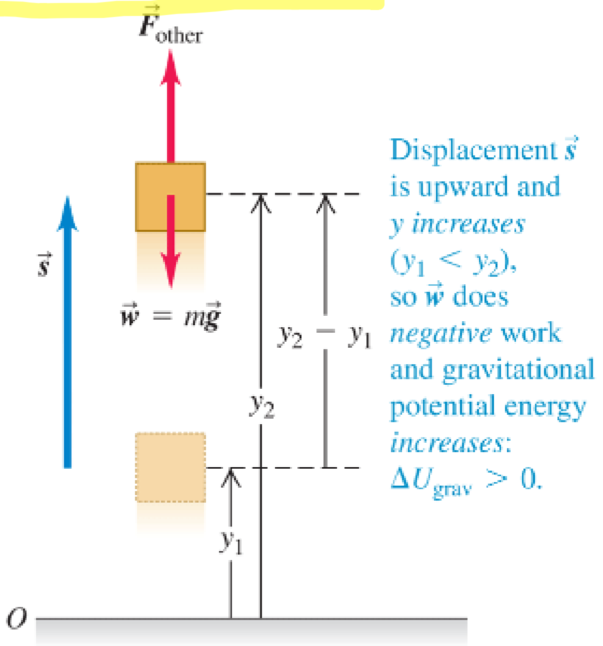

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& work was put into the box.

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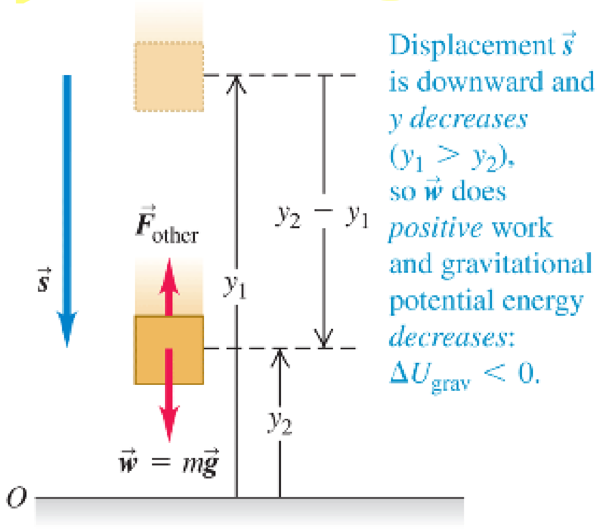

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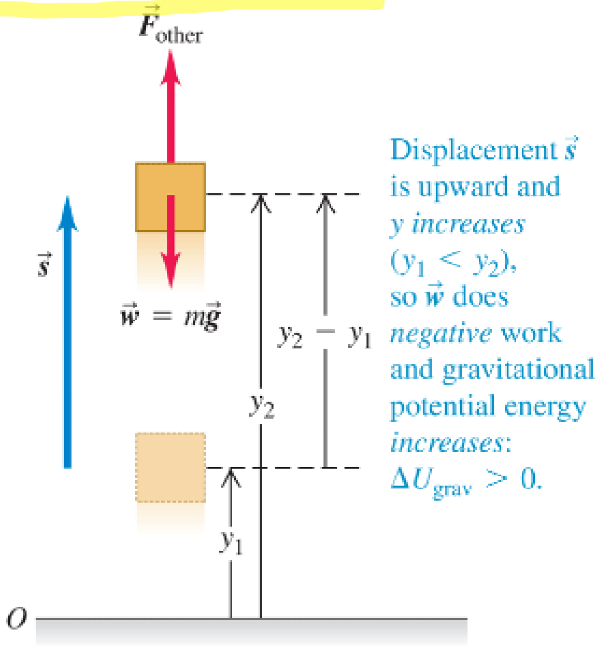

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Here $y_1 < y_2$ so $(W_{1\to 2})_g < 0$ & work was put <u>into</u> the box. The potential energy increased by $-(W_{1\to 2})_g$

$$U_{\text{grav}} = mgy$$

Gravitational potential energy
associated with a particle

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Mass of particle

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Mass of particle

Acceleration due to gravity

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Vertical coordinate of particle (y increases if particle moves upward)

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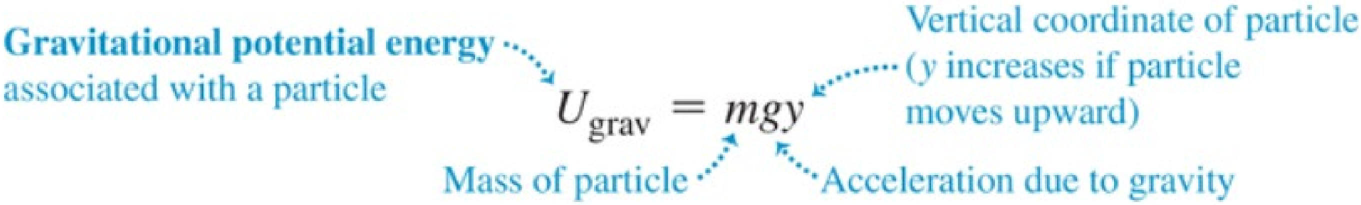

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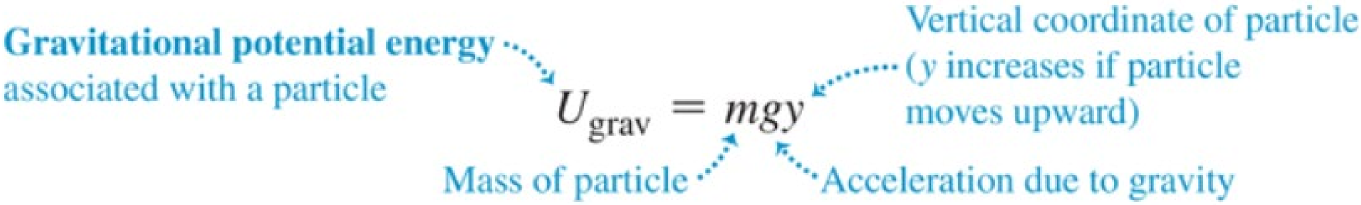

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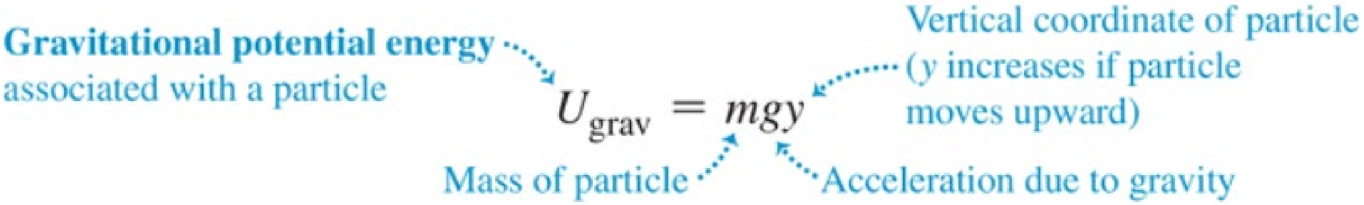

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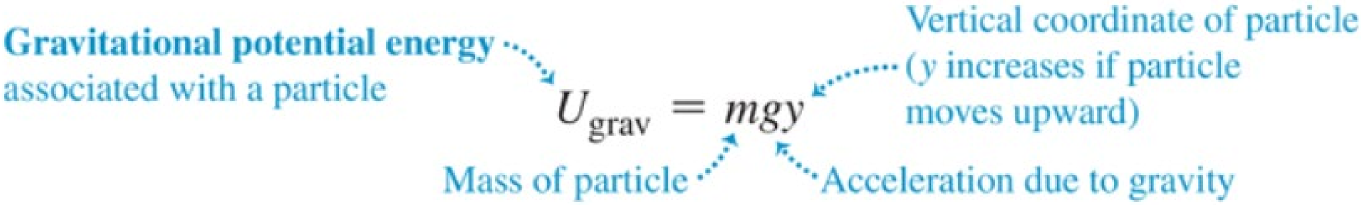
$$= -(U_{grav_2} - U_{grav_1})$$



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Vertical coordinate of particle (y increases if particle moves upward)

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$$= -(U_{grav_2} - U_{grav_1})$$

$$= -\Delta U_{grav}$$

Caution: Gravitational potential energy does NOT belong to an object. Instead, Gravitational potential energy is shared property of system

Conservation of Total mechanical energy [grav force only]

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$$K_1 + U_{g1} = K_2 + U_{g2}$$

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You throw a 0.145 kg baseball straight up, giving it an initial velocity of magnitude **20.0 m/s.** Find how high it goes, ignoring air resistance.

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Find y_{MAX} :

You throw a 0.145 kg baseball straight up, giving it an initial velocity of magnitude 20.0 m/s. Find how high it goes, ignoring air resistance.

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So $K_1 = U_2$ Convert all kinetic energy to potential energy

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$$\Rightarrow \frac{1}{2} m v_1^2 = m g y_{MAX}$$

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$$\Rightarrow \frac{1}{2} m v_1^2 = m g y_{MAX} \Rightarrow y_{MAX} = \frac{v_1^2}{2g}$$

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$$\Rightarrow \frac{1}{2} m v_1^2 = m g y_{MAX} \Rightarrow y_{MAX} = \frac{v_1^2}{2g} = \frac{400}{2 \times 9.8} \text{m}$$

You throw a 0.145 kg baseball straight up, giving it an initial velocity of magnitude 20.0 m/s. Find how high it goes, ignoring air resistance.

$m = 0.145\ \text{kg}\ ,\ v_1 = 20\ \text{m/s}$

Find y_{MAX}:

$$K_1 + \cancelto{0}{U_1} = \cancelto{0}{K_2} + U_2$$

I'll set coordinate system svc that $y_1 = 0 \Rightarrow U_1 = 0$. At $y_2 = y_{MAX}$, $v_2 = 0 \Rightarrow K_2 = 0$

So $K_1 = U_2$ Convert all kinetic energy to potential energy

$$\Rightarrow \frac{1}{2} m v_1^2 = m g y_{MAX} \Rightarrow \boxed{y_{MAX} = \frac{v_1^2}{2g} = 20.4\ \text{m}}$$

Plus other forces

Plus other forces

$$W_{other} + W_g = K_2 - K_1$$

Plus other forces

$$W_{other} + W_g = K_2 - K_1$$

But

$$W_g = -\Delta U_g = U_1 - U_2$$

Plus other forces

$W_{other} + W_g = K_2 - K_1$ so

$W_{other} + U_{g1} - U_{g2} = K_2 - K_1$

Plus other forces

$$W_{other} + W_g = K_2 - K_1 \quad \text{so}$$

$$W_{other} + U_{g1} - U_{g2} = K_2 - K_1 \quad \Rightarrow$$

$$K_1 + U_{g1} + W_{other} = K_2 + U_{g2}$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = \frac{m}{2}$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

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$s = {}^{m}/_{2}$, $V_1 = 20\,{}^{m}/_{s}$

$$K_1 + U_1 + W_{other} = K_2 + U_2$$

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$s = \frac{m}{2}$, $V_1 = 20 \,\text{m/s}$

$$\cancelto{0}{K_1} + U_1 + W_{other} = K_2 + U_2$$

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$s = {}^{m}/_{2}\ ,\ V_1 = 20\,{}^{m}/_{s}$

$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + U_2$

I am setting

$y_2 = 0$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$0 \quad s = m/2 \quad , \quad V_1 = 20\,m/s$

$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + U_2$$

I am setting

$y_2 = 0 \Rightarrow$

$y_1 = -s$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = {}^{m}/_{2}\ ,\ V_1 = 20\,{}^{m}/_{s}$

$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + U_2$

I am setting

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$s = {}^{m}/_{2}$, $V_1 = 20\,{}^{m}/_{s}$

$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + \overset{0}{\cancel{U_2}}$$

I am setting

$y_2 = 0 \Rightarrow$

$y_1 = -s$ & $U_2 = 0$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = {}^{m}\!/_{2}\ ,\ V_1 = 20\,{}^{m}\!/_{s}$

$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + \overset{0}{\cancel{U_2}}$$

$$\Rightarrow\ U_1 + W = K_2$$

I am setting $y_2 = 0 \Rightarrow$

$y_1 = -s$ & $U_2 = 0$

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$s = {}^{m}/_{2}\ ,\quad V_1 = 20\ {}^{m}/_{s}$

$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + \overset{0}{\cancel{U_2}}$$

I am setting $y_2 = 0 \Rightarrow$

$y_1 = -s$ & $U_2 = 0$

$$\Rightarrow U_1 + W = K_2 \Rightarrow W = K_2 - U_1$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = {}^{m}/_{2}$, $V_1 = 20\,{}^{m}/_{s}$

I am setting $y_2 = 0 \Rightarrow$

$y_1 = -s$ \& $U_2 = 0$

$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + \overset{0}{\cancel{U_2}}$$

$$\Rightarrow U_1 + W = K_2 \Rightarrow W = K_2 - U_1$$

$$\Rightarrow W = \frac{1}{2} m v_1^2 - mg(-s)$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = m/2 \ , \ V_1 = 20\,m/s$

I am setting $y_2 = 0 \Rightarrow$ $y_1 = -s$ & $U_2 = 0$

$$\cancelto{0}{K_1} + U_1 + W_{other} = K_2 + \cancelto{0}{U_2}$$

$$\Rightarrow U_1 + W = K_2 \Rightarrow W = K_2 - U_1$$

$$\Rightarrow W = \frac{1}{2} m V_1^2 - mg(-s) = m\left(\frac{V_1^2}{2} + gs\right)$$

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$s = \frac{m}{2}$, $v_1 = 20\, m/s$

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$y_1 = -s$ & $U_2 = 0$

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But $W = Fs$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

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$$\cancelto{0}{K_1} + U_1 + W_{other} = K_2 + \cancelto{0}{U_2}$$

I am setting $y_2 = 0 \Rightarrow$
$y_1 = -s$ & $U_2 = 0$

$$\Rightarrow U_1 + W = K_2 \Rightarrow W = K_2 - U_1$$

$$\Rightarrow W = \tfrac{1}{2} m v_1^2 - mg(-s) = m\left(\frac{v_1^2}{2} + gs\right)$$

$$\text{But } W = Fs \Rightarrow F = m\left(\frac{v_1^2}{2s} + g\right)$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = {}^{m}/_{2}\ ,\quad V_1 = 20\,{}^{m}/_{s}$

$\cancelto{0}{K_1} + U_1 + W_{other} = K_2 + \cancelto{0}{U_2}$

I am setting $y_2 = 0 \Rightarrow$
$y_1 = -s$ & $U_2 = 0$

$\Rightarrow U_1 + W = K_2 \Rightarrow W = K_2 - U_1$

$\Rightarrow W = \frac{1}{2} m V_1^2 - mg(-s) = m\left(\frac{V_1^2}{2} + gs\right)$

But $W = Fs \Rightarrow F = m\left(\frac{V_1^2}{2s} + g\right)$

$\Rightarrow F = 0.145\left(\frac{400}{1} + 9.8\right) N$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = {}^{m}/_{2}\ ,\ V_1 = 20\,{}^{m}/_{s}$

I am setting $y_2 = 0 \Rightarrow$

$y_1 = -s$ & $U_2 = 0$

$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + \overset{0}{\cancel{U_2}}$$

$$\Rightarrow U_1 + W = K_2 \Rightarrow W = K_2 - U_1$$

$$\Rightarrow W = \tfrac{1}{2}mV_1^2 - mg(-s) = m\left(\frac{V_1^2}{2} + gs\right)$$

$$\text{But } W = Fs \Rightarrow F = m\left(\frac{V_1^2}{2s} + g\right)$$

$$\Rightarrow F = 0.145\left(\frac{400}{1} + 9.8\right)N = 59.4\,N$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = {}^{m}/_{2}$, $V_1 = 20\,{}^{m}/_{s}$

$$K_2 + U_2 + (W_{2\to 3})_{other} = K_3 + U_3$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

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$$K_2 + \overset{0}{\cancel{U_2}} + (W_{2\to 3})_{other} = K_3 + U_3$$

setting $y_2 = 0$

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$s = m/2$, $V_1 = 20\,m/s$

$$K_2 + \overset{0}{\cancel{U_2}} + (\overset{0}{\cancel{W_{2\to3}}})_{other} = K_3 + U_3$$

Ball no longer in contact with hand

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = m/2$, $v_1 = 20\,m/s$

$$K_2 + \cancelto{0}{U_2} + \cancelto{0}{(W_{2\to 3})_{other}} = K_3 + U_3$$

$$\Rightarrow \quad K_2 = K_3 + U_3$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = m/2$, $v_1 = 20\,m/s$

$$K_2 + \cancelto{0}{U_2} + \cancelto{0}{(W_{2\to3})}_{other} = K_3 + U_3$$

$$\Rightarrow \quad K_2 = K_3 + U_3 \Rightarrow K_3 = K_2 - U_3$$

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$s = m/_2 \, , \quad V_1 = 20 \, m/s$

$$K_2 + \cancelto{0}{U_2} + \cancelto{0}{(W_{2\to3})}_{other} = K_3 + U_3$$

$$\Rightarrow \quad K_2 = K_3 + U_3 \Rightarrow K_3 = K_2 - U_3$$

$$\Rightarrow \frac{1}{2} m V_2^2 = \frac{1}{2} m V_1^2 - m g y_2$$

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$$\Rightarrow K_2 = K_3 + U_3 \Rightarrow K_3 = K_2 - U_3$$

$$\Rightarrow \frac{1}{2}mV_2^2 = \frac{1}{2}mV_1^2 - mgy_2 \Rightarrow$$

$$V_2^2 = V_1^2 - 2gy_2$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

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$$\Rightarrow \frac{1}{2} m V_2^2 = \frac{1}{2} m V_1^2 - m g y_2 \Rightarrow$$

$$V_2^2 = V_1^2 - 2 g y_2 \Rightarrow V_2 = \left[V_1^2 - 2 g y_2\right]^{1/2}$$

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$$V_2^2 = V_1^2 - 2gy_2 \Rightarrow V_2 = [V_1^2 - 2gy_2]^{1/2}$$

$$\Rightarrow \quad V_2 = [400 - 2*9.8*15]^{1/2}\ {}^{m}/_{s}$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

$s = m/2 \; , \; V_1 = 20\, m/s$

$$K_2 + \cancelto{0}{U_2} + \cancelto{0}{(W_{2\to3})_{other}} = K_3 + U_3$$

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$$\Rightarrow \frac{1}{2}mV_2^2 = \frac{1}{2}mV_1^2 - mgy_2 \Rightarrow$$

$$V_2^2 = V_1^2 - 2gy_2 \Rightarrow V_2 = [V_1^2 - 2gy_2]^{1/2}$$

$$\Rightarrow V_2 = [400 - 2*9.8*15]^{1/2}\, m/s = 10.3\, m/s$$

In Example 7.1 suppose your hand moves upward by 0.50 m while you are throwing the ball. The ball leaves your hand with an upward velocity of 20.0 m/s. (a) Find the magnitude of the force (assumed constant) that your hand exerts on the ball. (b) Find the speed of the ball at a point 15.0 m above the point where it leaves your hand. Ignore air resistance.

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$$\Rightarrow \frac{1}{2} m v_2^2 = \frac{1}{2} m v_1^2 - m g y_2 \Rightarrow$$

$$v_2^2 = v_1^2 - 2 g y_2 \Rightarrow v_2 = [v_1^2 - 2 g y_2]^{1/2}$$

$$\Rightarrow \quad v_2 = [400 - 2 * 9.8 * 15]^{1/2}\,m/s = 10.3\,m/s$$

$$= -10.3\,m/s \text{ if going down}$$

Gravitational potential energy for <u>motion along curved path</u>

Gravitational potential energy for motion along curved path

$W_g = m\vec{g} \cdot \Delta\vec{s}$

Gravitational potential energy for motion along curved path

$$W_g = m\vec{g} \cdot \Delta\vec{s} = -mg\hat{j} \cdot (\Delta x\hat{i} + \Delta y\hat{j})$$

Gravitational potential energy for motion along curved path

$$W_g = m\vec{g} \cdot \Delta\vec{s} = -mg\hat{j} \cdot (\Delta x\hat{i} + \Delta y\hat{j})$$

$$= -mg\Delta y$$

Gravitational potential energy for motion along curved path

$$W_g = m\vec{g}\cdot\Delta\vec{s} = -mg\hat{j}\cdot(\Delta x\hat{i}+\Delta y\hat{j})$$

$$\boxed{= -mg\Delta y}$$

Same as for non-curved path

Gravitational potential energy for motion along curved path

$$W_g = m\vec{g}\cdot\Delta\vec{s} = -mg\hat{j}\cdot(\Delta x\,\hat{i} + \Delta y\,\hat{j})$$

$$\boxed{= -mg\,\Delta y}$$

Same as for non-curved path

W_g is path independent

Gravitational potential energy for motion along curved path

$$W_g = m\vec{g}\cdot\Delta\vec{s} = -mg\hat{j}\cdot(\Delta x\hat{i} + \Delta y\hat{j})$$

$$\boxed{= -mg\Delta y}$$

Same as for non-curved path

W_g is path independent ONLY

THE END POINTS MATTER

Your cousin Throckmorton skateboards from rest down a curved, frictionless ramp. If we treat Throcky and his skateboard as a particle, he moves through a quarter-circle with radius $R = 3.00\ \mathrm{m}$ (Fig. 7.9, next page). Throcky and his skateboard have a total mass of 25.0 kg. (a) Find his speed at the bottom of the ramp. (b) Find the normal force that acts on him at the bottom of the curve.

Your cousin Throckmorton skateboards from rest down a curved, frictionless ramp. If we treat Throcky and his skateboard as a particle, he moves through a quarter-circle with radius $R = 3.00$ m (Fig. 7.9, next page). Throcky and his skateboard have a total mass of 25.0 kg. (a) Find his speed at the bottom of the ramp. (b) Find the normal force that acts on him at the bottom of the curve.

$R = 3m$, $m = 25kg$

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Find V_2:

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Find v_2: $K_1 + U_1 = K_2 + U_2$

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$R = 3\,m$, $m = 25\,kg$

Find v_2:

$$K_1 + U_1 = K_2 + \cancel{U_2}$$

setting $y_2 = 0$

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Find V_2 :

$$\cancelto{0}{K_1} + U_1 = K_2 + \cancel{U_2}$$

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$R=3m$, $m=25kg$

Find V_2:

$$\overset{0}{\cancel{K_1}}+U_1=K_2+\cancel{U_2} \Rightarrow$$

$$U_1=K_2$$

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Find v_2:

$$\cancelto{0}{K_1} + U_1 = K_2 + \cancel{U_2} \Rightarrow$$

$$U_1 = K_2 \Rightarrow mgy_1 = \frac{1}{2} m v_2^2$$

Your cousin Throckmorton skateboards from rest down a curved, frictionless ramp. If we treat Throcky and his skateboard as a particle, he moves through a quarter-circle with radius $R = 3.00$ m (Fig. 7.9, next page). Throcky and his skateboard have a total mass of 25.0 kg. (a) Find his speed at the bottom of the ramp. (b) Find the normal force that acts on him at the bottom of the curve.

$R = 3m$, $m = 25kg$

Find V_2:

$$\cancelto{0}{K_1} + U_1 = K_2 + \cancelto{0}{U_2} \Rightarrow$$

$$U_1 = K_2 \Rightarrow mgy_1 = \frac{1}{2} m V_2^2 \Rightarrow$$

$$V_2 = \sqrt{2gy_1}$$

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$$V_2 = \sqrt{2gy_1} \quad \text{But } y_1 = R$$

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$R = 3\,m \quad , \quad m = 25\,kg$

Find V_2:

$$\cancelto{0}{K_1} + U_1 = K_2 + \cancelto{0}{U_2} \Rightarrow$$

$$U_1 = K_2 \Rightarrow mgy_1 = \frac{1}{2} m V_2^2 \Rightarrow$$

$$V_2 = \sqrt{2gy_1} \qquad \text{But } y_1 = R$$

$$\text{so } V_2 = \sqrt{2gR} = \sqrt{2 * 9.8 * 3} \left(\frac{m}{s}\right)$$

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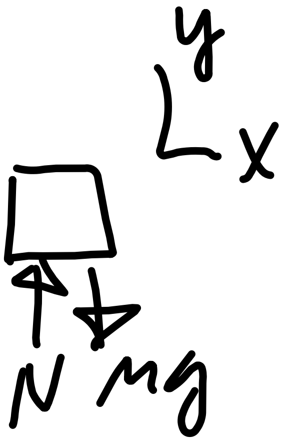

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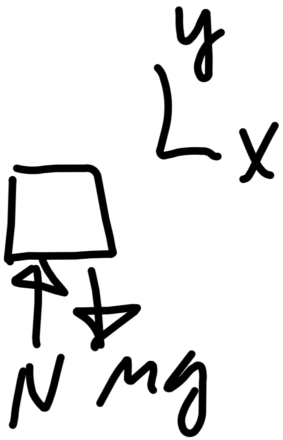

$$\Sigma F_y = ma$$

Your cousin Throckmorton skateboards from rest down a curved, frictionless ramp. If we treat Throcky and his skateboard as a particle, he moves through a quarter-circle with radius $R = 3.00$ m (Fig. 7.9, next page). Throcky and his skateboard have a total mass of 25.0 kg. (a) Find his speed at the bottom of the ramp. (b) Find the normal force that acts on him at the bottom of the curve.

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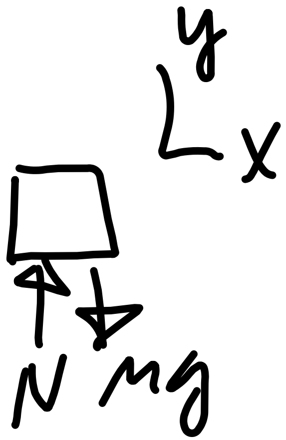
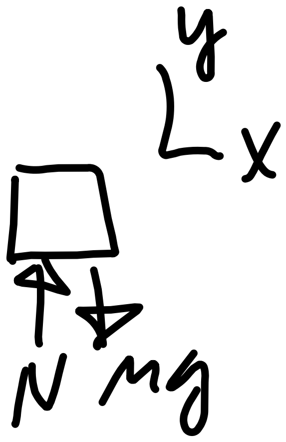


$$\Sigma F_y = ma$$

$$\Rightarrow N - mg = m\frac{v^2}{R}$$

Your cousin Throckmorton skateboards from rest down a curved, frictionless ramp. If we treat Throcky and his skateboard as a particle, he moves through a quarter-circle with radius $R = 3.00$ m (Fig. 7.9, next page). Throcky and his skateboard have a total mass of 25.0 kg. (a) Find his speed at the bottom of the ramp. (b) Find the normal force that acts on him at the bottom of the curve.

$R = 3\text{m}$, $m = 25\text{kg}$



$$\Sigma F_y = ma$$

$$\Rightarrow N - mg = m\frac{v^2}{R}$$

$$\Rightarrow N = m(g + v^2/R)$$

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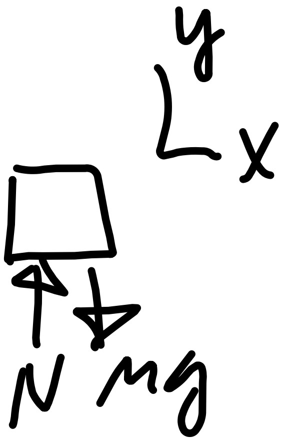


$$\Sigma F_y = ma$$

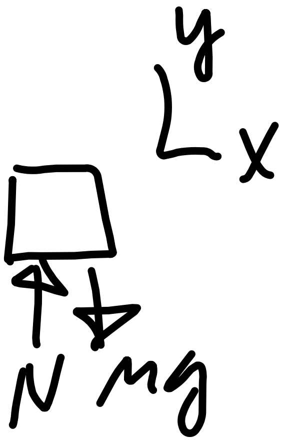
$$\Rightarrow N - mg = m\frac{v^2}{R}$$

$$\Rightarrow N = m(g + v^2/R)$$

$$\Rightarrow N = (25)(9.8 + \frac{7.67^2}{3})$$

Your cousin Throckmorton skateboards from rest down a curved, frictionless ramp. If we treat Throcky and his skateboard as a particle, he moves through a quarter-circle with radius $R = 3.00\ \mathrm{m}$ (Fig. 7.9, next page). Throcky and his skateboard have a total mass of 25.0 kg. (a) Find his speed at the bottom of the ramp. (b) Find the normal force that acts on him at the bottom of the curve.

$R = 3\,m \;,\; m = 25\,kg$



$$\Sigma F_y = ma$$

$$\Rightarrow N - mg = m\frac{v^2}{R}$$

$$\Rightarrow N = m(g + v^2/R)$$

$$\Rightarrow \boxed{N = (25)(9.8 + \frac{7.67^2}{3}) = 735\,N}$$

Suppose that the ramp of Example 7.4 is not frictionless and that Throcky's speed at the bottom is only $6.00\ \mathrm{m/s}$, not the $7.67\ m/s$ we found there. What work was done on him by the friction force?

Suppose that the ramp of Example 7.4 is not frictionless and that Throcky's speed at the bottom is only 6.00 m/s, not the 7.67 m/s we found there. What work was done on him by the friction force?

$$K_1 + U_1 + W_{other} = K_2 + U_2$$

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$$\Rightarrow \quad W_{other} = K_2 - U_1$$

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$$\overset{0}{\cancel{K_1}} + U_1 + W_{other} = K_2 + \overset{0}{\cancel{U_2}}$$

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$$\Rightarrow \quad \boxed{W_{Friction} = -285 J}$$

We want to slide a 12 kg crate up a 2.5-m-long ramp inclined at 30°. A worker, ignoring friction, calculates that he can do this by giving it an initial speed of $5.0\ \mathrm{m}/s$ at the bottom and letting it go. But friction is *not* negligible; the crate slides only 1.6 m up the ramp, stops, and slides back down (Fig. 7.11a). (a) Find the magnitude of the friction force acting on the crate, assuming that it is constant. (b) How fast is the crate moving when it reaches the bottom of the ramp?

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$m = 12\,kg$, $L = 2.5\,m$, $\theta = 30°$

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$m = 12\,\text{Kg}$, $L = 2.5\,\text{m}$, $\theta = 30^\circ$, $V_1 = 5\,\text{m/s}$

$L_2 = 1.6\,\text{m}$

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Find F_F:

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Find F_F:

$$K_1 + U_1 + W_F = K_2 + U_2$$

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$\underline{\text{Find } F_F}$:

$$K_1 + \overset{0}{\cancel{U_1}} + W_F = \overset{0}{\cancel{K_2}} + U_2$$

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$L_2 = 1.6\,m$

Find F_F:

$K_1 = \frac{1}{2} m V_1^2$

$$K_1 + \cancelto{0}{U_1} + W_F = \cancelto{0}{K_2} + U_2$$

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$U_2 = mg L_2 \sin\theta$

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$K_1 = \frac{1}{2} m V_1^2,\ W_F = F_F L_2$

$K_1 + \cancel{U_1} + W_F = \cancel{K_2} + U_2$

$U_2 = mg L_2 \sin\theta$

so $W_F = U_2 - K_1$

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$$K_1 + \overset{0}{\cancel{U_1}} + W_F = \overset{0}{\cancel{K_2}} + U_2$$

$U_2 = mgL_2 \sin\theta$

so $W_F = U_2 - K_1 \Rightarrow$

$$F_F L_2 = mgL_2 \sin\theta - \frac{1}{2} m V_1^2$$

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$K_1 = \frac{1}{2} m V_1^2,\ W_F = F_F L_2$

$K_1 + \cancelto{0}{U_1} + W_F = \cancelto{0}{K_2} + U_2$

$U_2 = m g L_2 \sin\theta$

so $W_F = U_2 - K_1 \Rightarrow$

$F_F L_2 = m g L_2 \sin\theta - \frac{1}{2} m V_1^2$

$\Rightarrow F_F = m(g \sin\theta - V_1^2/2)$

We want to slide a 12 kg crate up a 2.5-m-long ramp inclined at 30°. A worker, ignoring friction, calculates that he can do this by giving it an initial speed of 5.0 m/*s* at the bottom and letting it go. But friction is *not* negligible; the crate slides only 1.6 m up the ramp, stops, and slides back down (Fig. 7.11a). (a) Find the magnitude of the friction force acting on the crate, assuming that it is constant. (b) How fast is the crate moving when it reaches the bottom of the ramp?

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$L_2 = 1.6m$

Find F_F:

$K_1 = \frac{1}{2} m V_1^2,\ W_F = F_F L_2$

$K_1 + \overset{0}{\cancel{U_1}} + W_F = \overset{0}{\cancel{K_2}} + U_2$

$U_2 = mg L_2 \sin\theta$

so $W_F = U_2 - K_1 \Rightarrow$

$F_F L_2 = mg L_2 \sin\theta - \frac{1}{2} m V_1^2$

$\Rightarrow F_F = m\left(g \sin\theta - V_1^2/2L_2\right) = 12\left(9.8 \sin 30° - \frac{25}{3.2}\right) N$

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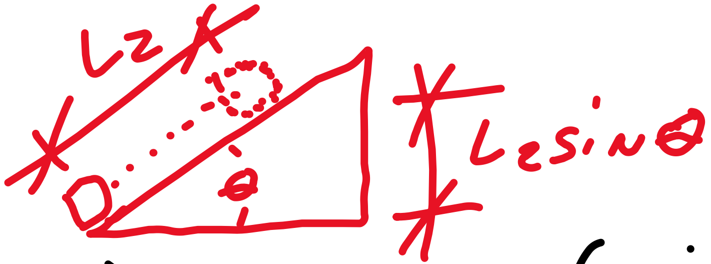
$U_2 = m g L_2 \sin\theta$



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$$F_F L_2 = m g L_2 \sin\theta - \frac{1}{2} m V_1^2$$

$$\Rightarrow F_F = m\left(g\sin\theta - V_1^2/2L_2\right) = 12\left(9.8\sin 30° - \frac{25}{3.2}\right) N$$

$$\Rightarrow F_F = 35\,N$$

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$L_2 = 1.6\,m$ Find V_3 [at bottom] :

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$L_2 = 1.6\,m$ Find V_3 [at bottom]:

$$\cancelto{0}{K_2} + U_2 + W_F = K_3 + \cancelto{0}{U_3} \qquad U_2 = mgy_2$$

We want to slide a 12 kg crate up a 2.5-m-long ramp inclined at 30°. A worker, ignoring friction, calculates that he can do this by giving it an initial speed of 5.0 m/*s* at the bottom and letting it go. But friction is *not* negligible; the crate slides only 1.6 m up the ramp, stops, and slides back down (Fig. 7.11a). (a) Find the magnitude of the friction force acting on the crate, assuming that it is constant. (b) How fast is the crate moving when it reaches the bottom of the ramp?

$m = 12\,\text{Kg}$, $L = 2.5\,\text{m}$, $\theta = 30°$, $V_1 = 5\,\text{m/s}$

$L_2 = 1.6\,\text{m}$ Find V_3 [at bottom]:

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$$= \left[3.2\left(9.8\sin 30° - \frac{35}{25}\right)\right]^{1/2}$$

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$= \left[3.2\left(9.8\sin 30^\circ - \frac{35}{12}\right)\right]^{1/2} = \boxed{2.5\,\text{m/s}}$