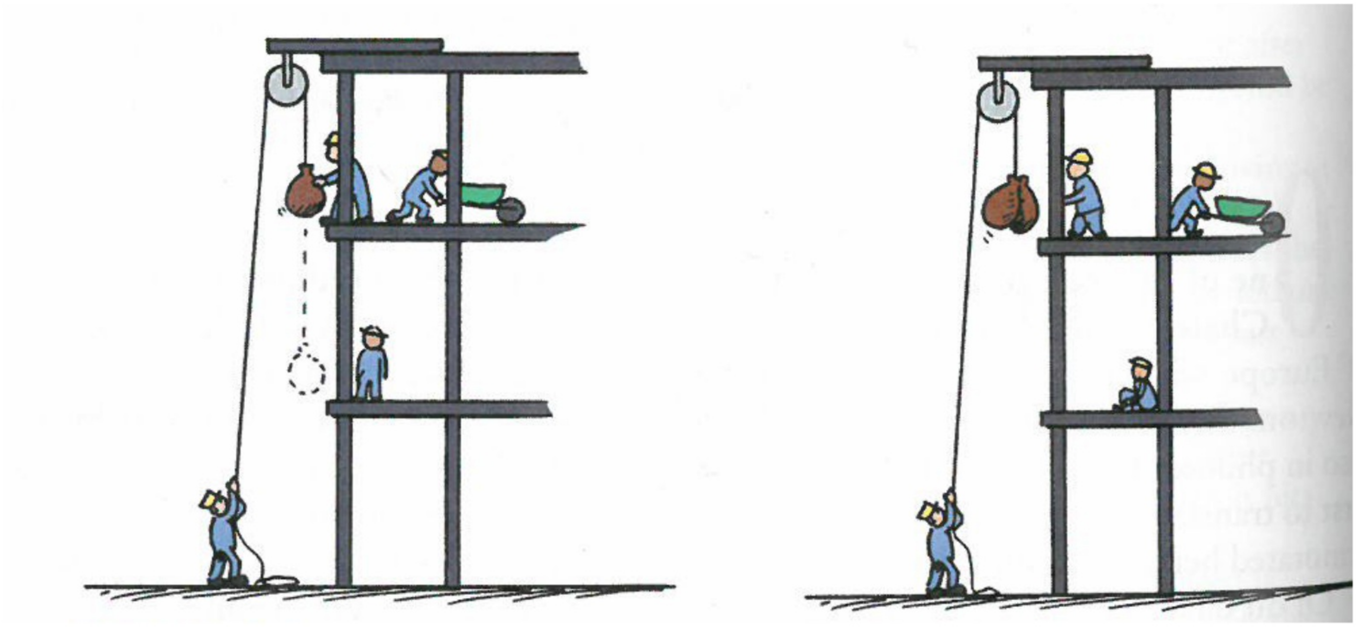
Work and energy, Power

Which takes more effort?



Work =F*d

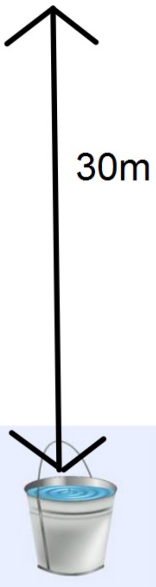
$[N][m] = [J]$

$J \equiv N \cdot m$

History: Originally used to figure out how hard it would be to life buckets of water out of flooder ore mines

<u>Example</u>: How much work is it to lift 10N of water 30 meters out of an ore mine?

$$W = F \cdot d$$
$$= 10N \cdot 30m$$
$$= 300 N \cdot m$$



Example: How much work is it to lift 10**kg** of water 30 meters out of an ore mine?

$$F_g = mg$$

$$F_g = 10kg \cdot 9.8\frac{m}{s^2}$$

$$= 98N$$

$$W = F \cdot d$$

$$= 98N \cdot 30m = 2940N \cdot m$$

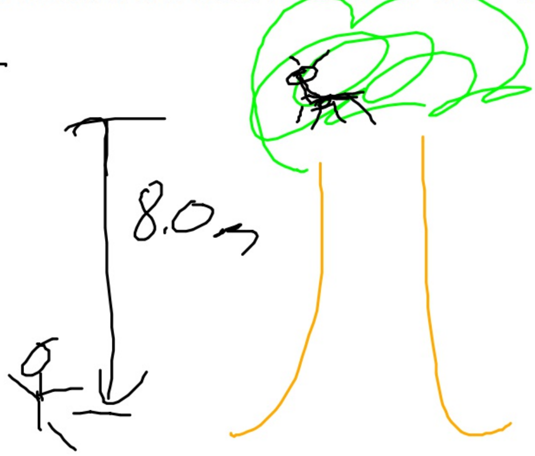
$$= 2940J$$

Example: Katie, a 30.0-kg child, climbs a tree to rescue her cat who is afraid to jump 8.0 m to the ground. How much work does Katie do in order to reach the cat?

$30 kg \cdot 9.8 \frac{m}{s^2}$

$F_g = mg$

$\approx 300 N$



$W = F \cdot d$

$= 300 N \; 8 m = 2400 J$

$= 2352 J$

Example: Aki can do 200J of work. How **high** can Aki lift his 2.0-kg textbook?

$F_g = 2kg \cdot 9.8\frac{m}{s^2} = 19.6N$

$W = F \cdot d$

$[200J = 19.6N \cdot d] \div 19.6N$

$\frac{200J}{19.6N} = d$

$10.2m = d$

Power

(a) I bike up a hill that is 100m tall, how much work do I do if $m_{me+bike}$=80kg in 420 seconds?

$$W = F \cdot d = 800N \cdot 100m$$

$$F_g = mg = 80kg \cdot 9.8\frac{m}{s^2}$$

$$\simeq 800N$$

$$= 80{,}000\ N \cdot m$$

$$= 80{,}000\ J$$

(b) My dad bikes up a hill that is 100m tall, how much work does he do if $m_{dad+bike}$=80kg in 1200 seconds?

$$80kg \cdot 10\frac{m}{s^2} = 800N$$

$$W = F \cdot d = 800N \cdot 100m$$

$$= 80{,}000J$$

Power: the rate of work done

Measured in *watts* (1W ≡ 1J/s)

$$P \equiv \frac{\text{work}}{\text{time}} = \frac{F d}{\text{time}} = F\frac{x}{t} = F \cdot V$$

In the previous example: who applies more power?

$$P_{we} = \frac{80{,}000\,J}{420\,s} = 190\,J/s = 190\,W$$

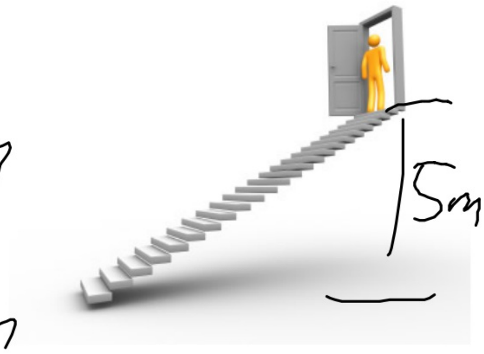
$$P_{Dad} = \frac{80{,}000\,J}{1200\,s} = 66.7\,W$$

Curious about bicycle power?

https://en.wikipedia.org/wiki/Bicycle_performance#Power_required

__Example__: After finishing her physics homework, Sherita pulls her 50.0-kg body out of the living room chair and climbs up the 5.0-m-high flight of stairs to her bedroom. How much work does Sherita do in ascending the stairs?

$$W = F \cdot d$$
$$= 50\,kg \cdot 10\,\frac{m}{s^2} \cdot 5\,m$$
$$= 500\,N \cdot 5\,m$$
$$= 2500\,J$$



Example continued: In the previous example, Sherita slowly ascends the stairs taking 10.0 s to go from bottom to top. The next evening, in a rush to catch her favorite TV show, she runs up the stairs in 3.0 s (a) On which night does Sherita more **work**?

Same

(b) On which night does Sherita generate more **power**?

$$\frac{W}{t} = P_{lazy} = \frac{2500\,J}{10\,s} = 250\,W$$

$$P_{fast} = \frac{2500\,J}{3\,s} = 833\,W$$

Homework answer: how did we do?

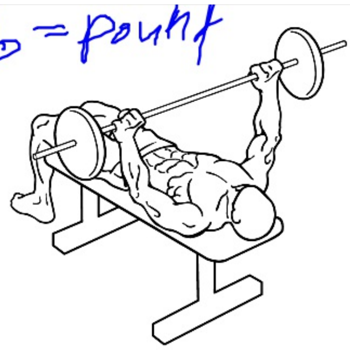
http://en.wikipedia.org/wiki/Joule#Multiples

$F_g = mg$

Example: At the gym

$1\,lb$ = pound

$1\,kg = 2.2\,lb$



I bench press 155 lb (pounds) at the gym by lifting the weight 40cm.

(a) What is the work done for each repetition (called a "rep")?

$\frac{155}{2.2} = 70.45\,kg$

$W = F \cdot d =$

$F_g = 70.45\,kg \cdot 9.8\,\frac{m}{s^2} \approx 700\,N$

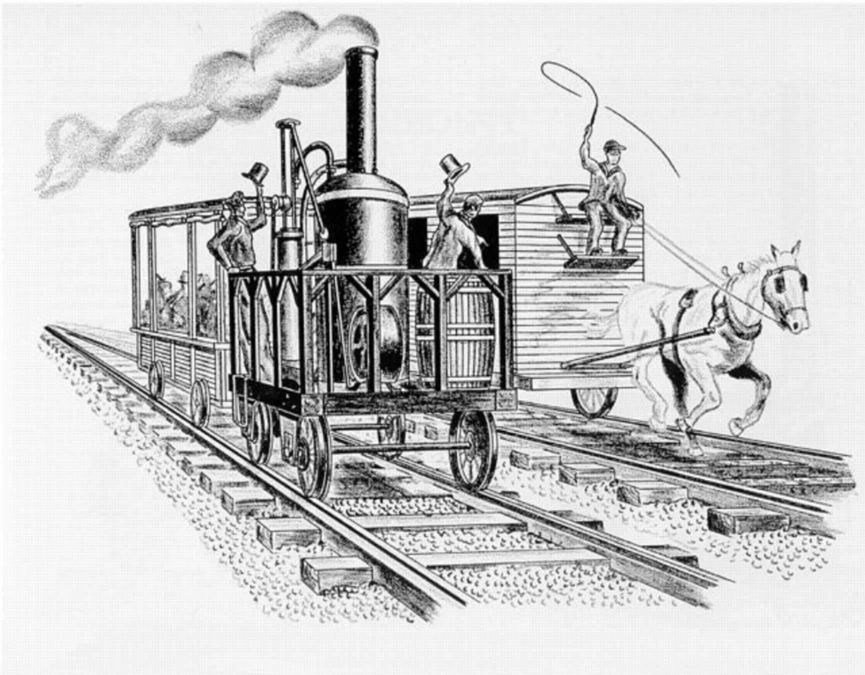
$W_1 = 700\,N \cdot 0.40\,m = 280\,N \cdot m = 282\,J$

(b) If I do 12 reps in 20 seconds, what is my power output?

$W_{12} = 12 \cdot W_1 = 12 \cdot 282\,J = 3380\,J$

$P = \frac{3380\,J}{20\,s} = 170\,W$

Compare my power output to the power of a horse (746W).



Power: Who will win? Motorcycle vs. car vs. plane:

http://www.youtube.com/watch?v=5sj9MIoG
O6c

Everything that's moving has *energy*.

Energy: The ability to do work

$N = kg \cdot \frac{m}{s^2}$

Kinetic energy: the energy something has because it's *moving*

$p = mv = [kg \cdot \frac{m}{s}]$ $\rightarrow m\,v$

Momentum depends on **m** and **v**. What do you think kinetic energy depends on?

$W = \frac{J}{s}$

Let's figure it out with units:

$p = kg \cdot \frac{m}{s} \cdot \frac{m}{s} = kg\frac{m^2}{s^2}$

Work = Energy

$J = N \cdot m = kg\frac{m}{s^2} \cdot m$

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

$J = \frac{1}{2} m \cdot v^2$ — KE

$m = 70kg$

Example: What is the kinetic energy of Bora running at 6 m/s?

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

$$= \frac{1}{2} 70kg \cdot \left(6 \frac{m}{s}\right)^2$$

$$= \frac{1}{2} \cdot 70kg \cdot 36 \frac{m^2}{s^2}$$

$$= 1260 J$$

Example: What is the kinetic energy of a 1000-kg car moving at highway speed (28m/s)?

$$KE = \frac{1}{2} \cdot 1000kg \left(28 \frac{m}{s}\right)^2$$

$$= 392000 J$$

Example: A 10-gram bullet travels at 250m/s.

(a) What is its **momentum**?

$p = mv = 0.01\,kg \cdot 250\,\frac{m}{s}$
$= 2.5\,kg\,\frac{m}{s}$

Which has more momentum?

(b) What is its **kinetic energy?**

$KE = \frac{1}{2}mv^2 = \frac{1}{2}0.01\,kg\,(250\,\frac{m}{s})^2$
$= 312.5\,J$

Compare: A 2-kg 2-liter bottle of soda rolls on the floor at [redacted]/s. $1.25\,m/s$

Which has more kinetic energy?

(c) What is its **momentum**?

$p = mv = 1.25\,\frac{m}{s} \cdot 2\,kg = 2.5\,kg\,\frac{m}{s}$

(d) What is its **kinetic energy**?

$KE = \frac{1}{2} \cdot mv^2 = \frac{1}{2} \cdot 2\,kg\,(1.25\,\frac{m}{s})^2$
$= 1.56\,J$

What about things that are not moving, but might move *soon*?

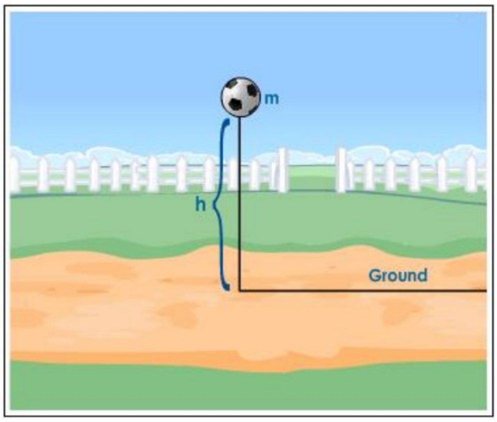
If an object is in a situation so that it could *soon* have kinetic energy, we say that the object has ***potential energy***.

Potential energy: energy something has because it has height

How to calculate potential energy:

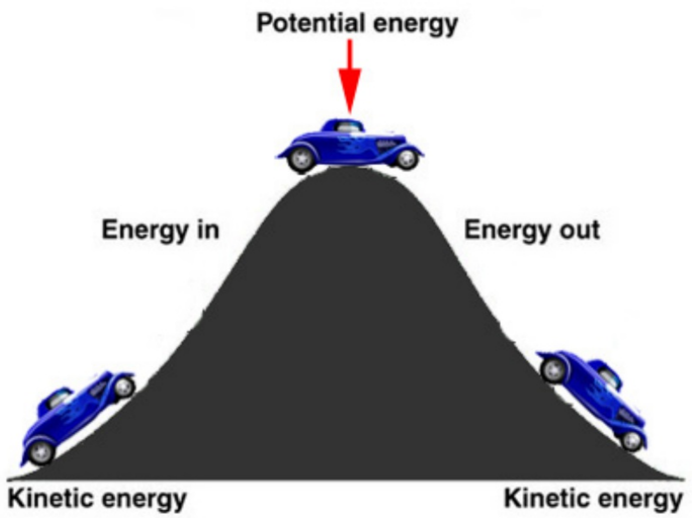
$F_g \cdot d$ $M_{ball} = 1kg$

PE = $m \cdot g \cdot h$



Example: Estimate the potential energy of a soccer ball 1 meter above the ground

$PE = 1kg \cdot 9.8\frac{m}{s^2} \cdot 1m = 9.8J$


Potential energy
Energy in
Energy out
Kinetic energy
Kinetic energy

Total energy is conserved, constant, does not change!

http://www.youtube.com/watch?v=BVxEEn3w688

Conservation of mechanical energy

Initial total energy = final total energy

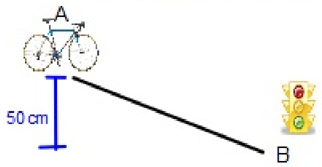
$KE_f + PE_f = KE_i + PE_i = \text{constant}$

or

$KE_f - KE_i = PE_f - PE_i \Rightarrow \Delta KE = \Delta PE$

Example: biker on a hill

I ride my bicycle to a traffic light. The traffic light is at the bottom of the hill. If I stop up the hill so that I am 50cm higher than the ground height at the traffic light, how much speed will I have when it is time to roll through the intersection?



What is my potential energy at A if m=65kg?

$$PE = m g h = 65kg \cdot 9.8\frac{m}{s^2} \cdot .50m = 318.5J$$

What is my kinetic energy at A if m=65kg?

$$KE = \frac{1}{2} m v^2 = \frac{1}{2} \cdot 65 \cdot 0 = 0$$

What is my potential energy at B if m=65kg?

$$PE = mgh = 0$$

What is my kinetic energy at B if m=65kg?

$$KE = \frac{1}{2} \cdot 65kg\, V^2$$

$$E_{TOT\,i} = E_{TOT\,F}$$

$$KE_i + PE_i = KE_F + PE_F$$

$$0 + 318.5J = \frac{1}{2} \cdot 65kg \cdot V^2 + 0$$

$$\left[318.5J = \frac{1}{2} 65kg\, V^2\right] \div 32.5kg$$

$$\frac{318.5J}{32.5kg} = V^2$$

$$\sqrt{9.8\frac{m^2}{s^2} = V^2} \quad \neq V \cdot 2$$

$$\sqrt{9.8\frac{m^2}{s^2}} = V$$

$$3.1\frac{m}{s} = V$$

Example: Roller coaster

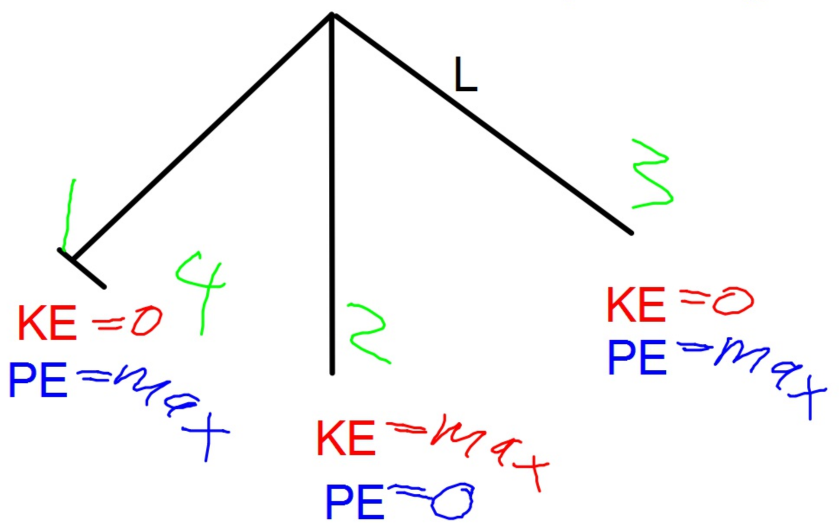
Build your own roller coaster:

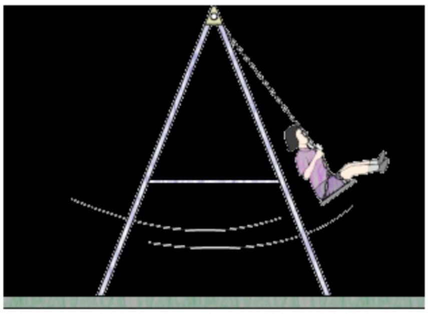
http://www.brainpop.com/games/coastercreator/

Conservation of energy

Example: child on a swing

$PE = mgh$





Example: Snowboarding

Dr. T snowboards down a hill that is 20m high. What is his speed at the bottom of the hill?

Example: astronauts on the moon:

While on the moon, the Apollo astronauts enjoyed the effects of a gravity much smaller than that on Earth. If Neil Armstrong jumped on up on the moon with an initial speed of 1.51m/s to a height of 0.700m, what amount of gravitation acceleration did he experience?

Example: The Matrix

The 10,000kg helicopter that crashes in The Matrix goes from the top of a 100-m tall building to the side of a nearby building. It crashes at a height of 60 meters. If the helicopter had a speed of 10m/s at the top of the first building, what speed did the helicopter have when it crashed?

Energy = the ability to do work
Work = Change in energy

Example: A 12-kg crate is ~~at rest~~. I push on the crate with a force of 20N for 3 m. Do I get tired? Where my energy go?

(a) What is the work done?

$$W = F \cdot d$$
$$= 20N \cdot 3m$$
$$= 60 Nm = 60J$$

(b) What is the crate's final velocity?

$$60J = \frac{1}{2} m v^2$$
$$60J = \frac{1}{2} 12kg\, v^2$$
$$[60J = 6kg\, v^2] \div 6$$
$$10 \frac{m^2}{s^2} = v^2$$

$$[120J = 12kg \cdot v^2] \div 12$$
$$10J = v^2$$
$$\sqrt{10 \frac{m}{s}} = v$$
$$3.16 \frac{m}{s} = v$$

$V_0 = 2\frac{m}{s}$

moving at $2\frac{m}{s}$ before I pushed it.

$W = 60J$ $\frac{1}{2} \cdot m \cdot v^2$

$KE_0 = \frac{1}{2} \cdot 12kg \cdot (2\frac{m}{s})^2$

$= 24J$ $V_f =$

$KE_f = KE_0 + W$

$84J = 24J + 60J$

$84J = KE_f = \frac{1}{2} m v^2$

$84J = \frac{1}{2} \cdot 12kg \cdot v^2$

$[84J = 6kg \cdot v^2] \div 6$

$14\frac{m^2}{s^2} = v^2$

$\sqrt{14}\frac{m}{s} = v$

$3.74\frac{m}{s} =$

Example: accelerating car

1hp=746W

A Honda Civic's engine produces 140hp (1.044×10^5 W) and a Honda civic has a mass of 2815lbs (1277kg). How long (how much *time*) does it take to accelerate to 60mph (26.8m/s) from rest?

$$P = \frac{Work}{time} = \frac{\frac{1}{2}mv^2}{t}$$

$$1.044 \times 10^5 W = \frac{\frac{1}{2} 1277kg (26.8\frac{m}{s})^2}{t} \quad \times t$$

$$1.044 \times 10^5 W \cdot t = \frac{1}{2} \cdot 1277kg (26.8\frac{m}{s})^2 \quad \div 1.044 \times 10^5$$

$$t = \frac{\frac{1}{2} \cdot 1277kg (26.8\frac{m}{s})^2}{1.044 \times 10^5 W}$$

$$= 4.4s$$

4.4s
9.2s