Unit Three: Energy

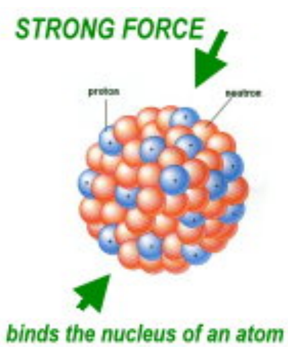
Lesson 1: Forces

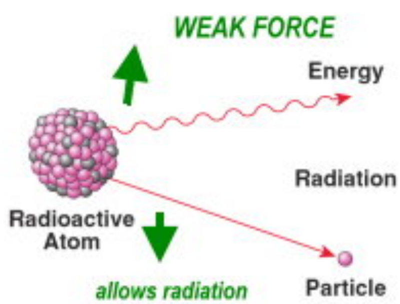
What is a Force?

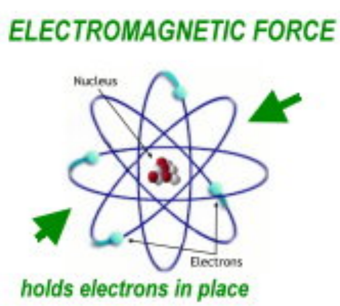
A force is any interaction that, when unopposed, will change the motion of an object.

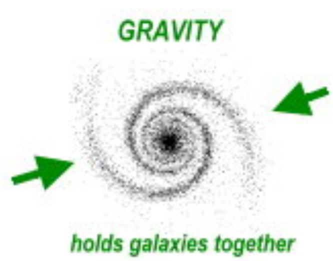
Forces can be measured in Newtons (N).

Physicists think that there are only four fundamental forces in the universe. All of the forces you can think of can be classified into one of the four fundamental forces.









The four fundamental forces are:

1) Gravity

2) Electromagnetic force

3) Strong nuclear force

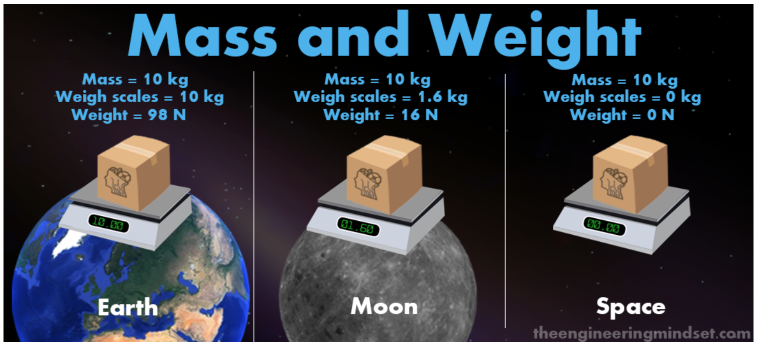
4) Weak nuclear force

1) Gravity

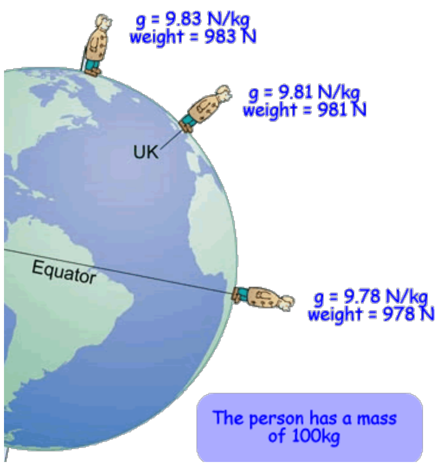
Gravity is a natural phenomenon by which all things with mass are brought together. This includes all objects smaller than electrons and larger than stars and galaxies.

Your weight is the result of the force due to gravity on your body. Your mass is a measure of the amount of material in an object and is measured in kilograms.

Here on the surface of the Earth there is a mutual force of attraction between any mass and the mass of the Earth. The amount of force is 9.8N of force for every kilogram of mass or 9.8N/kg.



The 9.8N/kg value is known as the gravitational field strength g.



The gravitational field strength results in you having a weight and can be calculated by:

$$F_g = mg$$

Or

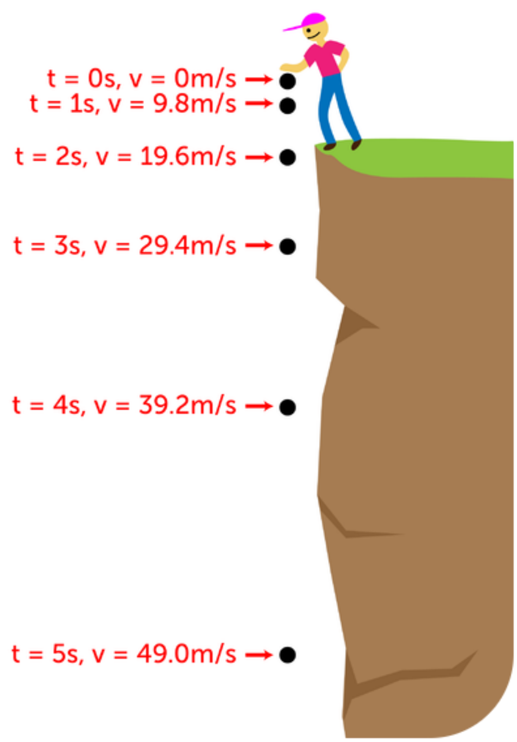
$$w = gm$$

F_g or w, is the force due to gravity or weight (w) measured in Newtons

m is the mass of the object in kilograms (kg)

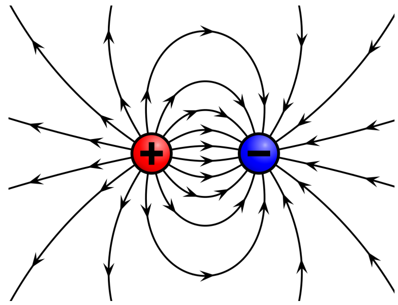
g is the gravitational field strength in N/kg

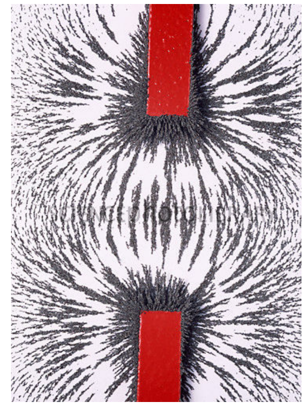
In addition to producing your weight, the gravitational field strength accelerates objects at a predictable rate of 9.8m/s^2 close to the surface of the Earth.



2) Electromagnetic Force

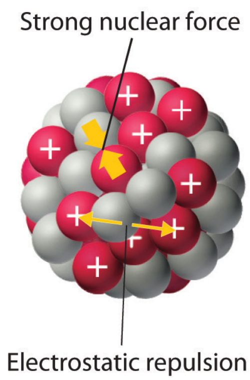
Electromagnetic force is the force of attraction or repulsion between two charged particles or two magnetic poles.





3) The Strong Nuclear Force

The Strong Nuclear force is the strongest force of the four fundamental forces. It is responsible for binding together the fundamental particles of matter to form larger particles like atoms.

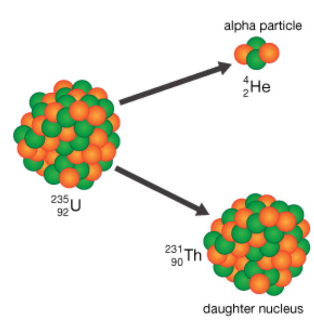


This force is strong enough that it overcomes the repulsive force between the two positively charged protons, allowing protons and neutrons to stick together in an unimaginably small space. The strong force dies off with distance much faster than gravity or the electromagnetic force, so fast that it's almost impossible to detect the strong force outside of a nucleus.

4) The Weak Nuclear Force

While the other three forces hold things together, the weak force plays a greater role in things falling apart, or decaying.

The weak force, or weak interaction, is stronger than gravity, but it is only effective at very short distances. It acts on the subatomic level and plays a crucial role in powering stars and creating elements. It is also responsible for much of the natural radiation present in the universe,



Additional Practice

1. Complete the following table.

	Variable used	Units measure in	Unit symbol
Force			
Mass			
Gravitational Field Strength			

2. What is the force of gravity on a 1050 kg cow?

3. The gravitational field on the surface of Mars is 3.7 N/kg. What is the weight of a 12 kg chunk of ice on the Mars?

4. A 450 kg probe travels from the surface of the Earth to the surface of the Moon. What is the difference in the force of gravity on the probe between these two locations?

5. A 5.4 kg space probe is moved to different parts of the solar system.
   a) What is the force of gravity on the probe on the surface of the Earth?

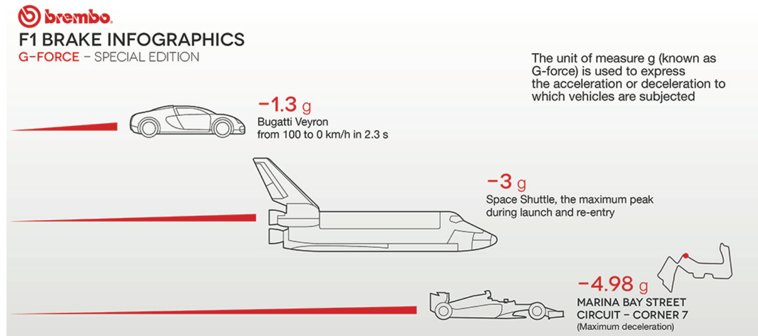
   b) What is the weight of the probe on the surface of the Moon?

   c) What is the mass of the probe on the surface of Mars?

6. A dog has a weight of 230 N. What is its weight?

7. A space probe lands on the surface of a small asteroid. The force of gravity pulling down on the probe is 150 N and its mass is 102 kg. What is the gravitational field strength on the surface of the asteroid?

Lesson 2: Work and Power



What is work?

Work is done whenever a force makes something move. Work is measured in joules (J).

Work (J) is calculated by finding the product between the applied force (N) and the distance moved (m).

Work = force (N) x distance (m)

W = F x d

The force must be parallel to the distance moved otherwise no work is done.

If no distance is moved then no work is done.

Example: How much work is done by a boy pushing a car with a force of 800N for a distance of 200m?

W = F x d
W = 800 N x 200m
W = 160000 Nm
160000 J

Additional Practice

1. Work is done whenever a __________ makes an object __________.

2. Calculate the work done by a 100N force applied to a 10kg object and the object moves a distance of 10 m.

3. If 20J of work is done on a 5 kg object moving it a distance of 20m, what is the applied force on the object?

4. A 200N force moves a 15kg object and as a result does 5000J of work on the object. What distance does the object move as a result of the work done on it?

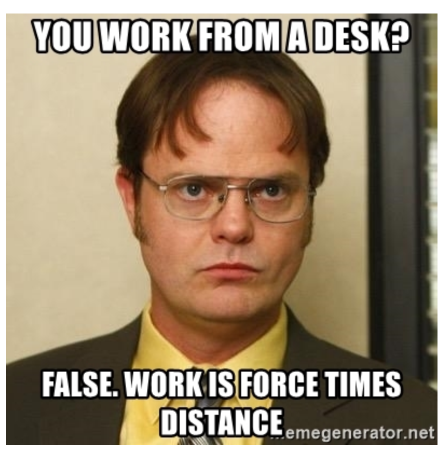
5. A 10kg object is lifted a distance of 3 m. How much work was done on the object? (the acceleration due to gravity is $9.8m/s^{2}{}_{2}$)

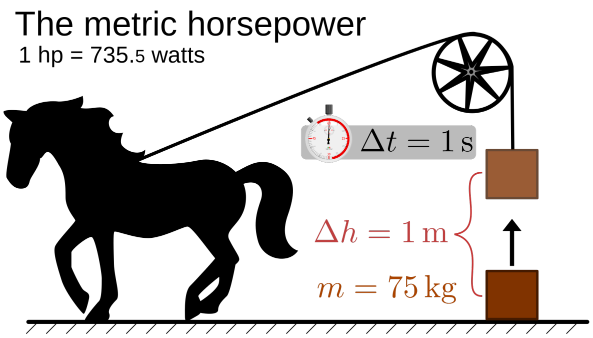
6. How much energy did the object gain?

7. Calculate the work done when a student exerts a force of 400N to push a stalled motorcycle from a busy highway to a quiet street, a distance of 500m. There is a 200N friction force acting on the motorcycle.

8. A Physiotherapist exerts 18N of force to move a patient's arm a distance of 0.6m. Calculate the work done on the arm.

9. A 100W immersion heater is used to warm water in a beaker for 3.0 minutes. How much energy is transferred to the water?





What is Power?

Power is the rate at which work is done.

Power = work/time

P = W / t

Power is measured in watts (W), which is a joule per second.

Example: What is the power of a bulldozer that does 5.5 x 10^4 J of work in 1.1s?

P = W / t

P = 5.5 x 10^4 J / 1.1s

P= 5.0 x 10^4 W

1. Complete the following table.

	Variable used	Units measure in	Unit symbol
Power			
Work			
Time			

2. A water pump does 250 000 Joules of work to remove water from a swimming pool in one hour (3600 seconds). Determine the power rating of the pump.

3. A winch lifts a 12 kg rock vertically upward from a height of 1.0 metre to 12 metres in 15 seconds.

a) Determine the work done by the winch.

b) Determine the power rating of the winch.

4. A 1200 Watt blow-dryer for 10 minutes (600 seconds). Determine the amount of energy that is used.

5. An alkaline AA 1.5 V battery holds around 13 000 Joules. A small toy car is rated at 0.50 W. How many seconds will the toy car be able to operate continuously?

6. Determine the power for each of the following electrical appliances:

   a) The output of a laser is 0.05J every second.

   b) A curling iron uses 48000 J of energy per minute.

   c) An electric light bulb uses 2.16×10^5 J of energy in one hour.

7. Determine the amount of energy transformed or used in each case:

   a) A 2000W electric pencil sharpener operates for 3.0s

   b) A 1200W kettle heats water for 5 minutes.

   c) A 100W stereo is operated for one hour.

Lab: Stair Power

Purpose: To determine the power produced when climbing a flight of stairs.

Procedure:

1. Measure the vertical height of the set of stairs (or a portion that's easily measured), in metres (m). The vertical height refers to the height from the bottom to the top (straight down), not the slope.
2. Record all values in the provided table.
3. Determine your body mass, in kilograms (kg) by getting on the scale.
4. Time the number of seconds (s) it takes you to run up the stairs.
5. The amount of **power** used is equal to the amount of **work** done divided by a given amount of **time** (P = W/t). To determine the amount of work done, you calculate the amount of force that is exerted over a given distance (W = F x d). The force in this case is calculated by multiplying the downward acceleration due to gravity (9.8 m/s^2) by your mass (in kg).
6. **Keep quiet in the hallway and stay on task.**

Trial	Time (s)	Mass (kg)	Vertical distance (m)
1			
2			
3			
Average values			

Questions:

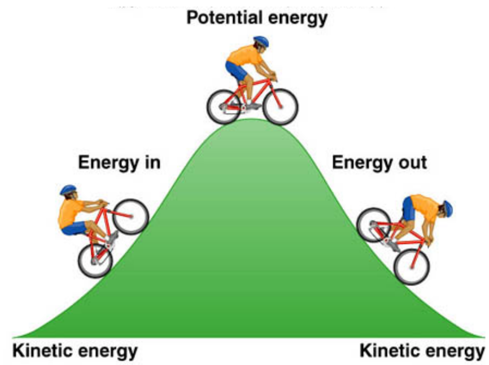
1. Using the above average values, how much work does it take to get up the stairs?
W= F x d = (mass (kg) x (9.8 m/s^2) x (height of the stairs))

2. Calculate the power required to climb the staircase.
Power= W/t

3. Compare the power the person developed going up the stairs to a 100W lightbulb. Could the person sustain the power output they exerted in this experiment?

4. The CN tower has 1776 steps and the record time to climb is 7:52. Assume the height of one stair is the same as the stairs you climbed. Determine the power developed by the person who holds the record. Assume their mass is the same as yours.

Lesson 3: Work and Types of Energy



What is Energy?

Energy is the ability to do work. Each time work is done energy is transferred from the object doing work to the object being worked on.

Work done on an object is equal to the change in energy of the object.

$$W = \Delta E$$

Work and Energy are both measured in Joules.

There are many different types of energy. All of the types can be classified into two categories, **potential or kinetic.**

Types of energy can be further classified into: gravitational potential, kinetic, heat, chemical potential, elastic, light, electrical and nuclear energy.

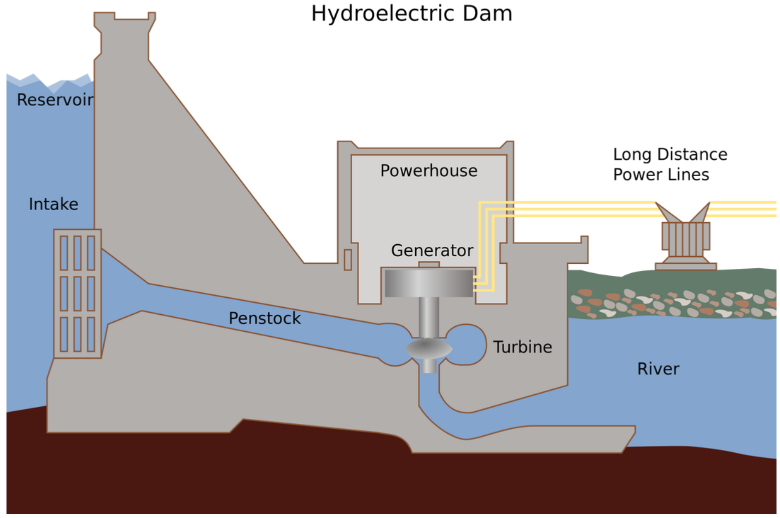
Gravitational Potential Energy

Gravitational potential energy is energy due to its position above the earth.

A paratrooper prior to jumping has considerable gravitational potential energy. Once they jump they have considerable gravitational kinetic energy.

Another example to consider is that of a hydroelectric dam. Prior to the water being released to flow through the dam it has gravitational potential energy.

Once the water flows through the dam because of gravity it has considerable gravitational kinetic energy. This kinetic energy is converted to electrical energy.

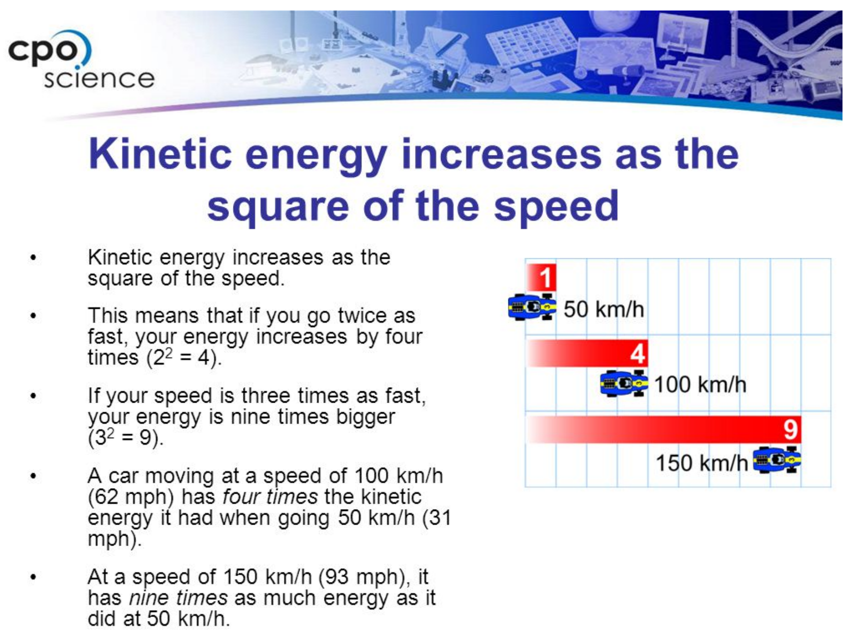


Kinetic Energy

Kinetic Energy is the energy of a moving object.

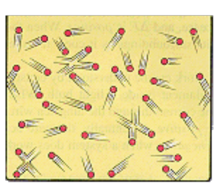
Kinetic energy is calculated by:

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

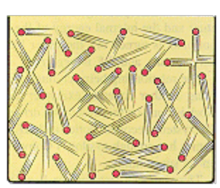


Heat Energy

Heat energy is the kinetic energy of the molecules in an object or a system.



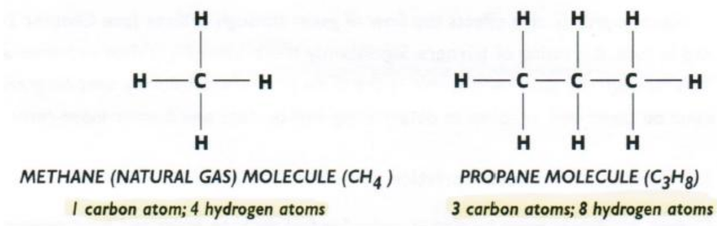
Low Temperature



High Temperature

Chemical Potential Energy

Chemical potential energy is stored energy within the chemical bonds of a compound.



Elastic Potential Energy

Elastic energy is stored (potential) energy that can do work once it is released.

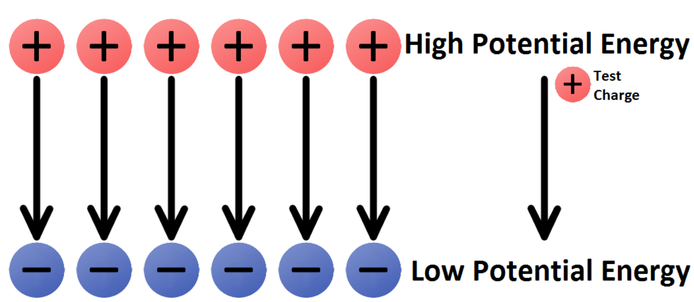
	standard incandescent	CFL compact fluorescent lamp	LED
watts >>	60	18	10
lumens >>	840	825	800
life (years) >>	0.9	9.1	22.8
estimated annual energy cost* >>	$7.23	$5.18	$1.56
initial cost per bulb >>	$2.00	$8.00	$12.00

Light Energy

Light energy is energy that the photons have as they move through space.

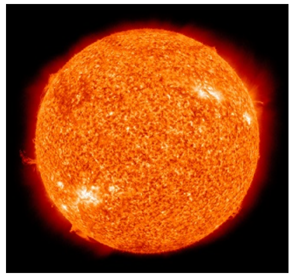
Electrical Potential Energy

Electrical energy is electric potential energy of the charge (electron) due to its position away from its paired proton. Electric potential energy is measured in Volts.



Nuclear Energy

Nuclear energy is energy stored in the nucleus of every atom. Nuclear fission and fusion release huge amounts of energy as a result of a very small mass loss according to Einstein's equation.

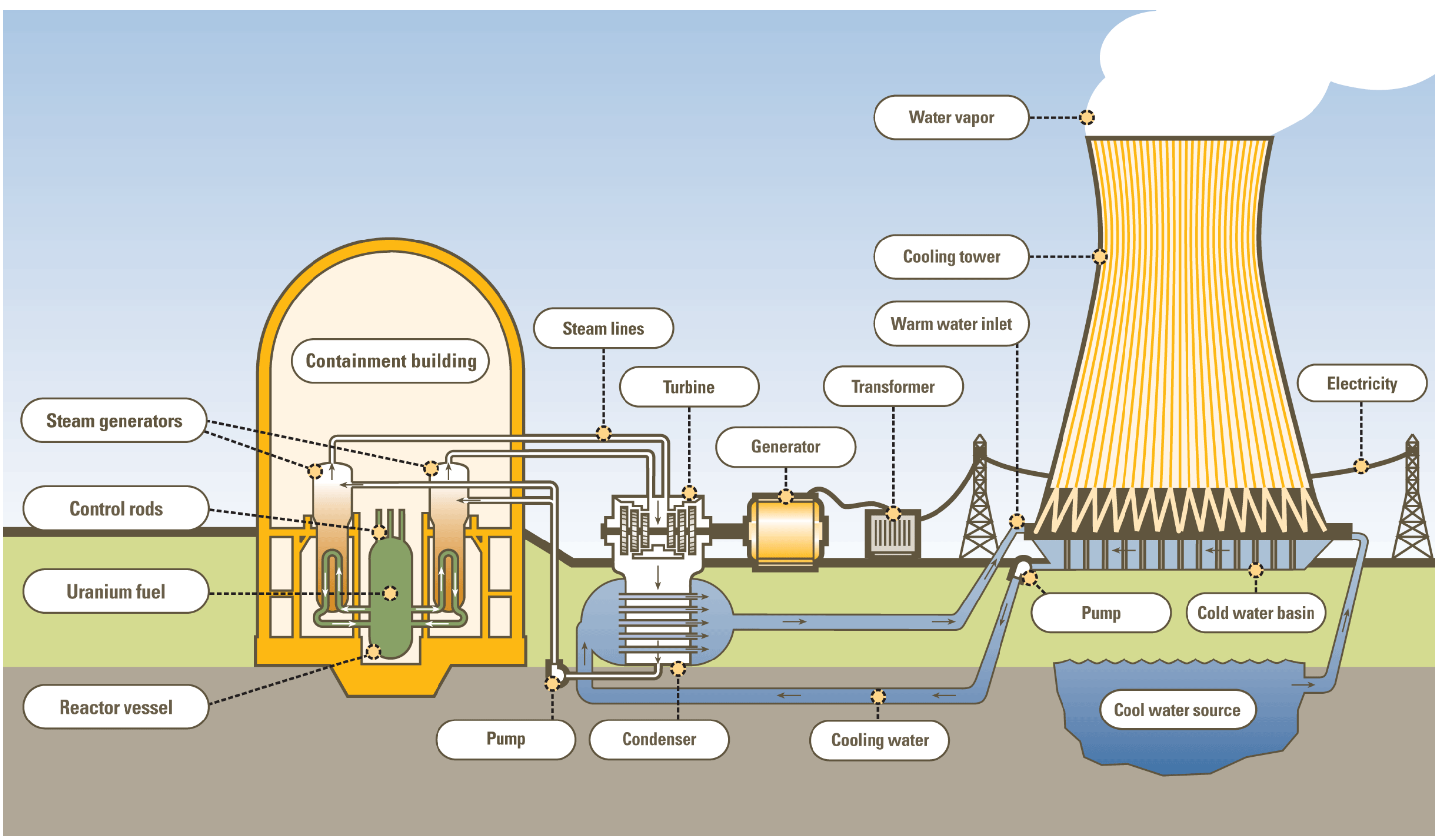


$$E = mc^2$$

Nuclear power plant

Nuclear energy originates from the splitting of uranium atoms – a process called fission. This generates heat to produce steam, which is used by a turbine generator to generate electricity. Because nuclear power plants do not burn fuel, they do not produce greenhouse gas emissions.

By reliably providing power 24 hours a day, nuclear energy is an important part of the energy mix necessary to meet electricity demand. And, with no carbon emissions, it will remain an important clean energy resource for the future.



Additional Practice

Force Practice Problems: (hint: try writing out the equations here first)

1. A force of 20 N acts upon a 5 kg block. Calculate the acceleration of the object.

2. An object of mass 300 kg is observed to accelerate at the rate of 4 m/s^2. Calculate the force required to produce this acceleration.

3. An object of mass 30 kg is in freefall in a vacuum on earth where there is no air resistance. Determine the acceleration of the object.

4. A force of 200 N is exerted on an object of mass 40 kg that is located on a sheet of perfectly smooth ice.

   a. Calculate the acceleration of the object.

   b. If a second object identical to the first object is placed on top of the first object, what acceleration would the 200 N force produce?

5. An object of mass 10 kg is accelerated upward at 2 m/s^2. What force is required?

6. A 5 kg block is pulled across a table by a horizontal force of 40 N with a frictional force of 8 N opposing the motion. Calculate the acceleration of the object. **Hint**: **Try drawing what this would look like first** (We will do this one as a class)

Work Practice Problems: (hint: try writing out the equations here first)

1. Mr. Ewan uses 20N of force to push a lawn mower 10 meters. How much work does he do?

2. How much work does an elephant do while moving a circus wagon 20 meters with a pulling force of 200N?

3. How much work is done when a force of 33N pulls a wagon 13 meters?

4. Taylor does 15 Joules of work to push Cody 6 meters. How much force did he use?

5. Matthew uses a force of 25 Newtons to lift Leo while doing 50 Joules of work. How far did he lift Leo?

6. Maddy throws a ball with 1237 Joules of work and the ball landed 40m away, how much force did she use to throw the ball?

7. A 30kg mass is lifted and accelerates at $4m/s^2$. What are the total amount of Joules gained by this mass if it travels a distance of 36m?

Power Practice Problems: (hint: write out the equations first)

Watt are the units for Power? __________

1. If 4500 joules of work are done to lift an object in 5 seconds, what is the power?

2. How much work does a 30W engine do if it operates for 40 seconds?

3. During the staircase lab, Tigger runs up the stairs, elevating his 102 kg body a vertical distance of 2.29 meters in a time of 1.32 seconds at a constant speed.

   a**.** Determine the work done by Tigger in climbing the staircase.

   b**.** Determine the power generated by Tigger.

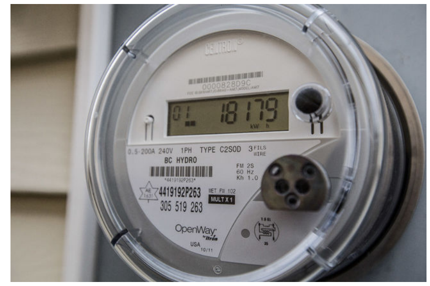
4. Hannah pushes a box across the floor a distance of 50 meters. Pushing the box required a force of 20 N and took the person 40 seconds.

   a. What is the work?

   b. What is the power?

5. A new conveyor system at the local packaging plan will utilize a motor-powered mechanical arm to exert an average force of 890 N to push large crates a distance of 12 meters in 22 seconds. Determine the power output required of such a motor.

Lesson 4: The Kwh, Another Measure of Energy



How do we measure Energy?

Energy can be measured in Joules (J) or the kilowatt-hour. The relationship between the kwh and J is shown below through an example.

The scenario is that a 1000 W light bulb is on for an hour. How much energy does it use in that time? Two separate calculations will be done below

1000 W = 1kw

3600 seconds in one hour

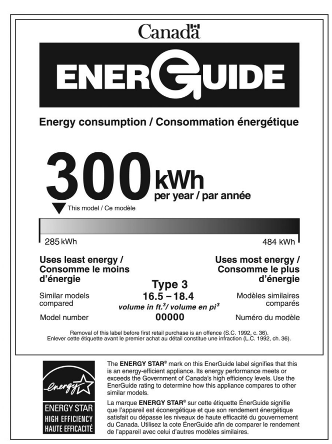
P = W/t

Or

W = P x t

W = P x t	**W = P x t**
W = 1000W x 3600s	**W = 1Kw x 1h**
Work (energy) = 3.6 x 10^6 J	**Work (energy) = 1kwh**

3.6 x 10^6 J = 1kwh



Additional Practice

1. Convert the following into kilowatts:

    a) 1500 W

    b) 25.0 W

    c) 1670000 W

2. Determine the total kilowatt hours for the following:

    a) 3000W heater on for 3 hours.

    b) 1500W water pump on for 5 hours a day 7 days a week for 2 weeks.

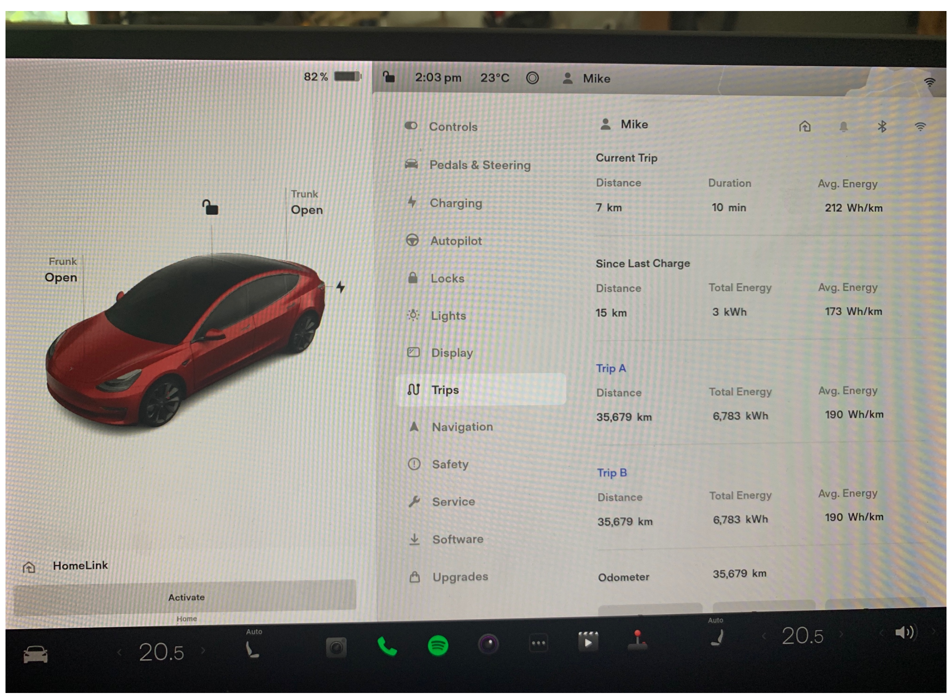
3. Determine the total cost of operating a 2000W heater for 4 hours a day, 5 days a week for 8 weeks. The cost of one kilowatt hour is $0.14.

4. If operating a 2000W stove for 2 months is $10.50 and the cost per kwh is $0.14, how long was the stove on during those 2 months?

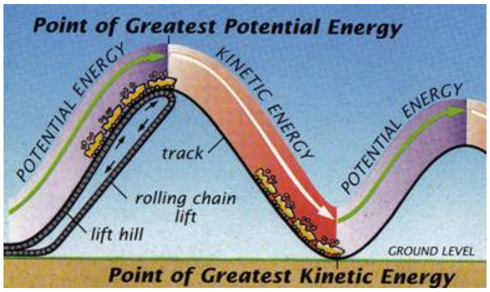
5. An LED lightbulb is rated at 14 Watts and is left on for eight hours in a day. Determine how much it would cost to keep the light on for one month (30 days) if the cost of electricity is 14 cents per kiloWatt hour.

6. An electric car charger is rated for 7,700W and runs for 90 minutes each night after a typical day of driving. If electricity costs $0.14 per Kwhr what is the cost of charging nightly?

7. (**BONUS**) Compare the cost for driving my car over the course of two years (35,679 km and 6,783 Kwhr) given that electricity costs $0.14 per Kwhr and my previous car averaged 12L/100 km on premium gas. Use the average price for premium gas today in your calculations.



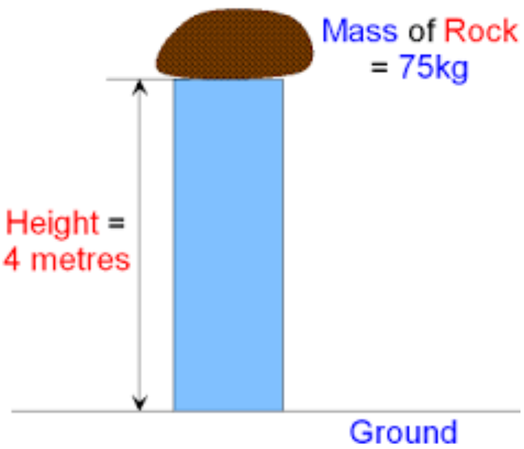
Lesson 5: Gravitational Potential Energy



Does Height affect Potential Energy?

The gravitational potential energy of an object is the energy an object has due to its position. Gravitational potential energy has the symbol PE and is measured in joules.

The equation for the gravitational potential energy is PE = mgh, where m is the mass of the object in kg, h is the height of the object in meters and g is the acceleration due to gravity $9.8 m/s^2$.



Example: How much gravitational potential energy does a 75kg rock have if it is lifted 4m?

PE = mgh

PE = 75kg x 9.8N/kg x 4m

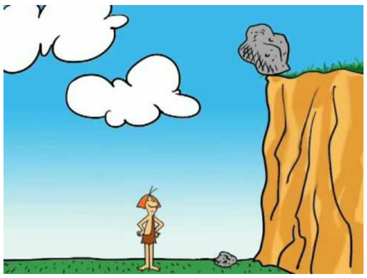
PE = 2940J

Relative potential energy assumes the lowest point in a scenario to have a zero height value. It can be calculated by:

PE = mgh, where h is the the height above a certain point.

Eg. 1: A 10.0kg rock is on top of a house 3.00m high. What is the gravitational potential energy of the rock:

PE = mgh
PE = 10.0kg x 9.80N/kg x 3.0 m
PE = 294J



Eg. 2: A 1500Kg car is lifted on a hoist until it gains 37,000J of potential energy. How high was the car lifted?

$$PE = mgh$$
$$PE/mg = h$$
$$h = 37{,}000J / (1500\ kg \times 9.80N/kg)$$
$$h = 2.6\ m$$

Eg. 3: A bird flying at a height of 120m has 4600J of GPE. What is its mass?

$$PE = mgh$$
$$PE/gh = m$$
$$m = 4600J / (9.8N/kg \times 120\ m)$$
$$m = 3.9\ Kg$$

Additional Practice:

Write the formula for potential energy here: ___________

1. Determine the gain in the potential energy when a 4.0 kg rock is raised 18.000 m.

2. A leopard with a mass of 55.00 kg climbs 12.0 m up a tree. What is its gain in PE?

3. An aircraft is taking a group of skydivers up into the air. Mr. Vucko is dressed in his parachuting outfit, which brings his mass to a total of 120.0 kg. The aircraft takes the group to a height of 5000.00 m before the jump. How much PE does Mr. Vucko gain before jumping?

4. An owl has a mass of 4.00 kg. It dives to catch a mouse, losing 800.00 J of its GPE. What was the starting height of the owl, in meters?

5. An astronaut with a mass of 110.0 kg visits the moon (which has a different gravitational force than Earth). The astronaut climbs 5.0 m up the ladder into his spacecraft and gains 880.0 J in GPE. What is the strength of gravity on the moon?

6. One of the tallest radio towers on Victoria island is 629.9 m tall. If a bird lands on top of the tower, so that the gravitational potential energy associated with the bird is 2033.76 J, what is its mass, in kilograms?

7. The largest sea turtle found in North America had a mass of 860.24 kg. If the gravitational potential energy associated with the turtle as it was being lifted onto a ship was 20,320.7 J, how high above the water was the turtle when it was lifted?

8. Which of the following has the most potential energy?

a. car at the top of a hill

b. A car speeding down the hill

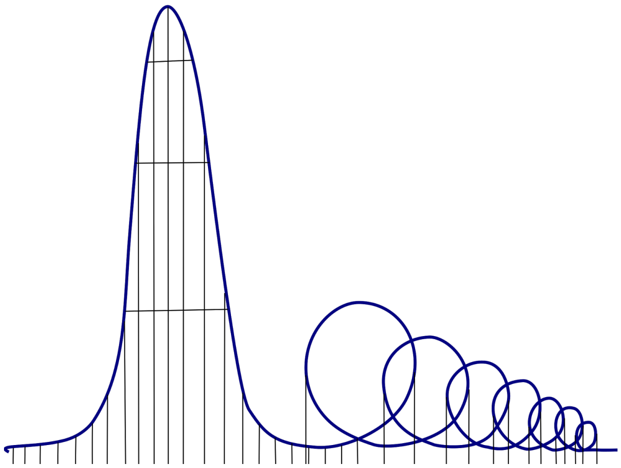
c. A person at the top of a hill

9. One of Mr. Ewan's students went bungee jumping off of a building in China last summer. After several heart-pounding seconds, he leapt from a height of 233 meters. If his weight is 104 kilograms, what would his potential energy be just prior to jumping?

10. He almost hit the ground but luckily he snapped back up towards the top of the building. What was his potential energy just before hitting the ground?

11. An owl has a mass of 4 kg. It dives to catch a mouse losing 800 J of PE. How high was the bird to begin with?

12. In the following image of a roller coaster. Label the point where you would have the highest amount of potential energy. Using the formula PE= mgh, explain how you came to that conclusion.

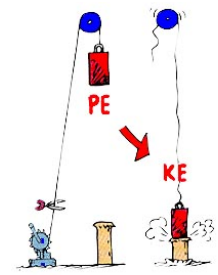


13. A marble is on a table 2.4 m above the ground. What is the mass of the marble if it has a GPE of 568 J.

14. A cart at the top of a 300 m hill has a mass of 40 kg. What is the cart's gravitational potential energy?

15. Find the gravitational potential energy of a light that has a mass of 13.0 kg and is 4.8 m above the ground.

Lesson 6: Kinetic Energy



What is Kinetic Energy?

Kinetic energy is the energy of motion. KE is the symbol for kinetic energy.

Kinetic energy can be calculated by:

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

Where m is the mass of an object measured in kg

v is the velocity of the object measured in m/s

KE has the unit of measure of Joules (J)

Example: What is the kinetic energy of a 6.0kg curling stone sliding at 4.0m/s?

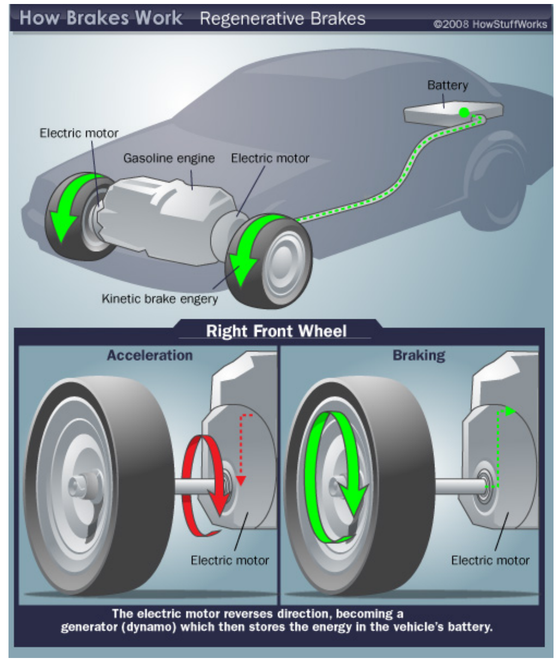
$$E_k = \frac{1}{2} mv^2$$

$$E_k = \frac{1}{2}\ 6.0kg \times (4.0m/s)^2$$

$$Ek = 48J$$

Example: The kinetic energy of a boat is calculated at 52,000 J. If the boat has a mass of 39,000 kg, with what velocity is it moving?

Looking at the kinetic energy equations reveals the dominance of velocity on the kinetic energy. If the velocity is doubled or tripled then the kinetic energy increases four or nine times, respectively.

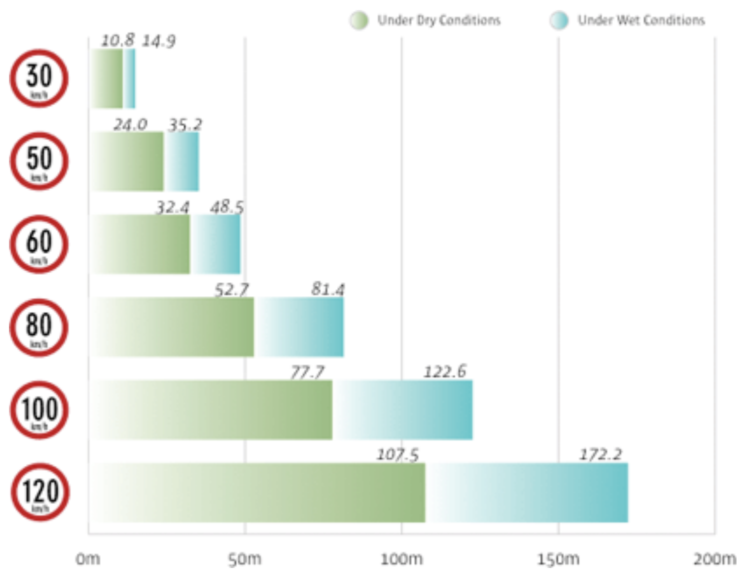


The total mechanical energy (TME) of a system is KE + PE. When energy is transferred or transformed in our Universe, TME remains constant.

Additional Practice

Write the formula for Kinetic energy here:

1. What is the Kinetic Energy of a 150 kg object that is moving with a speed of 15 m/s?



2. An object has a kinetic energy of 25 J and a mass of 34 kg , how fast is the object moving?

3. An object moving with a speed of 35 m/s and has a kinetic energy of 1500 J, what is the mass of the object.

4. What is the Kinetic Energy of a 1200 kg object that is moving with a speed of 24 m/s?

5. An object has a kinetic energy of 14 J and a mass of 17 kg , how fast is the object moving?

6. An object moving with a speed of 67 m/s and has a kinetic energy of 500 J, what is the mass of the object.

7. What is the Kinetic Energy of a 478 kg object that is moving with a speed of 15 m/s?

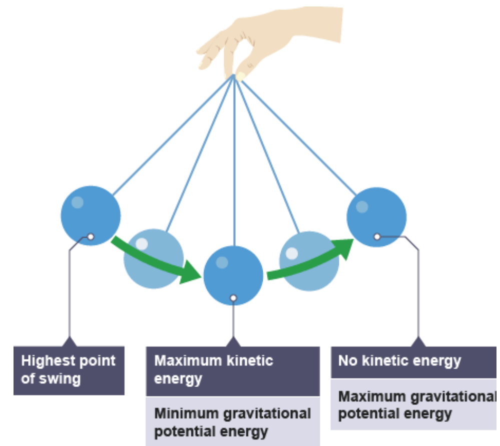
8. An object has a kinetic energy of 88 J and a mass of 45 kg , how fast is the object moving?

9. An object moving with a speed of 21 m/s and has a kinetic energy of 140 J, what is the mass of the object.

10. What is the Kinetic Energy of a 100 kg object that is moving with a speed of 12.5 m/s?

Lesson 7: Conservation of Energy

In any closed system the TME (Total Mechanical Energy) remains constant. When energy is transferred or transformed the TME remains constant. This is the law of conservation of energy.



The Law of conservation of energy can also be stated as $\Delta KE + \Delta PE = 0$. Where ΔKE means change in kinetic energy, $KE_{final} - KE_{initial}$. ΔPE means change in potential energy, $PE_{final} - PE_{initial}$.

Example: As 10 kg rock falls from a height of 10m to the ground it loses gravitational potential energy. Determine the change in gravitational potential energy.

$$\Delta PE = PE_{final} - PE_{initial}$$

$$mgh_{final} - mgh_{initial}$$

$$10kg \times 9.8m/s^2 \times 0m - 10kg \times 9.8m/s^2 \times 10m$$

$$-980\ J$$

Note the negative sign indicates a loss in energy.

What is the gain in kinetic energy of this rock? The rock must gain 980J of kinetic energy.

The final velocity of the falling rock can now be found using $\Delta KE = 980$ J.

$$KE_{final} - KE_{initial} = 980$$

$$1/2mv^2_{final} = 980$$

$$mv^2_{final} = 2 \times 980$$

$$10 \times v^2_{final} = 1960$$

$$v^2_{final} = 196$$

$$V_{final} = 14m/s$$

1. Complete the following table.

	Variable used	Units measure in	Unit symbol
Kinetic Energy			
Potential Energy			
Mass			
Gravitational Field Strength			
Velocity			
Height			

Remember…
PE=KE

$mgh=1/2mv^2$

$\cancel{m}gh=1/2\cancel{m}v^2$

$gh=1/2v^2$

$2gh= v^2$

$\sqrt{2gh} = v$

2. A 20.0 kg boulder is at a height of 152 metres above the ground.

a) Determine its potential energy.

b) Determine its kinetic energy.

c) It releases from the cliff and falls to the ground. What is the boulder's impact velocity (how fast it hits the ground)?

3. A 180 kg boulder falls off a cliff and hits the ground at 45 m/s.
What height is the cliff?

4. What is the initial potential energy of the boulder?

5. What is the final potential energy of the boulder?

6. A cannon launches a 3.5 kg cannonball vertically upwards at 89 m/s.
What maximum height will the cannonball reach?

7. What is the initial kinetic energy of the cannonball?

8. What is the final kinetic energy of the cannonball?

Additional Practice:

1. According to the Law of Conservation of Energy, the total amount of energy in the universe _________.
   a) Remains constant
   b) Decreases
   c) Increases
   d) Changes constantly

2. A basketball is dropped outside of the school. If it reaches the floor at a speed of 3.2 m/s, from what height did it fall?

3. A safe is hurled down from the top of a 130 m building. What is its velocity as it hits the ground?

4. A 2.5 kg object is dropped from a height of 10.0 m above the ground. Calculate the speed of the object as it hits the ground.

5. A 200-kg boulder is 1000-m above the ground.
   a) What is its potential energy when it is 1000-m above the ground?

   b) What is its kinetic energy when it is 1000-m above the ground?

c) The boulder begins to fall. What is its potential energy when it is 500-m above the ground? Where did the "lost" potential energy go?

d) What is the kinetic energy of the boulder when it has fallen 500-m?

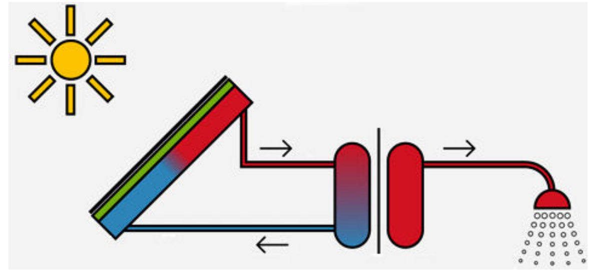
e) What is the kinetic energy of the boulder just before it hits the ground?

6. A boulder sits atop a steep cliff and someone pushes it off the edge. If the cliff is 45 metres high and the boulder is 200kg, what speed will the boulder hit the ground with? Ignore air friction in this case.

7. A child with a mass of 25.5 kg starts at rest and goes down a slide with a height of 3.50 m

8. **Challenge**… Silverstar, a Roller Coaster in Germany is 78m high at its tallest point. The total mass of the carts is 537 kg. With what speed would the cart be travelling at the bottom of the roller coaster if the cart had a speed of 5 m/s at the top of the roller coaster?

Lesson 8: Heat Energy

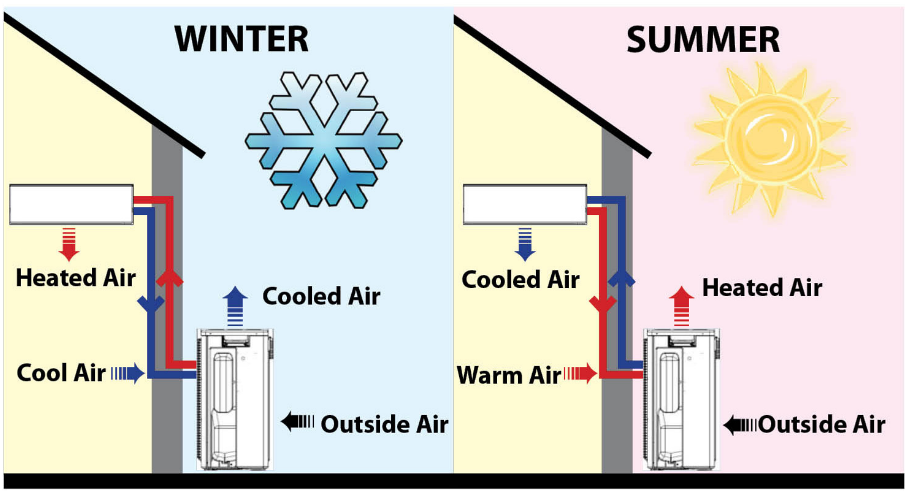


What is Thermal Energy?

Thermal energy is the total energy stored in an object. It is the sum total of all the kinetic and potential energy of the molecules within an object.

Heat energy is the energy that is transferred from one object to another because of a difference in temperature.

How Heat Pumps Work



Heat pumps do not generate heat but extract it from one body of air and transfer it to another. They use the same principle as your fridge, compressing gas and then allowing it to expand, extracting heat as it does so.
Even if the air outside is freezing, heat pumps can extract heat energy and transfer it inside to keep you warm. In summer the system works in reverse, extracting heat from indoors and transferring it outside leaving you comfortable and cool.
During The Summer, a heat pump pulls heat from inside your home and moves it outside, just like an air conditioner. During Winter, a heat pump pulls heat from outside and moves it into your home. During extreme cold weather, the heat pump will use a backup heat source.

Which contains more thermal energy?

Temperature is a measure of the average energy per molecule.

A teaspoon of boiling water or a bathtub full of lukewarm water

Which has a higher temp?

The total amount of heat needed to raise the temperature of an object depends on three quantities:

1. mass of the object
2. desired temperature change
3. the specific heat capacity.

The specific heat capacity (c) is a measure of how much energy (J) is needed to change the temperature of 1kg of mass by one °C. The specific heat capacity for water is 4200J/kg°C.

The total amount of heat energy needed to raise the temperature of an object can be calculated using:

$$\Delta E_h = mc\Delta T$$

ΔE_h is the heat energy added or lost in joules (J)
m is the mass of the object (kg)
c is the specific heat capacity (J/kg°C)
ΔT is the change in temperature (°C)

Example: How much heat energy does it take to raise the temperature of 100g of lead shot from 20°C to 33°C? The specific heat capacity of lead is 130J/kg°C.

$$\Delta E_h = mc\Delta T$$

$$\Delta E_h = 0.100\text{kg} \times 130\ \text{J/kg°C} \times (33 - 20)\text{°C}$$

$$\Delta E_h = 1.7 \times 10^2\text{J}$$

Additional Practice:
Use the following table to help you answer questions 1-8

Substance	Specific heat capacity (J/kg°C)
Water	4200
Air	990
Copper	390
Iron	450
Concrete	3400
Cotton	1400

1. What are the units for specific heat capacity?

2. What is the unit for energy?

3. How much energy is needed to heat up 1kg of water by 15°C?

4. How much energy would be needed to raise the temperature of a 5kg block of concrete by 10°C?

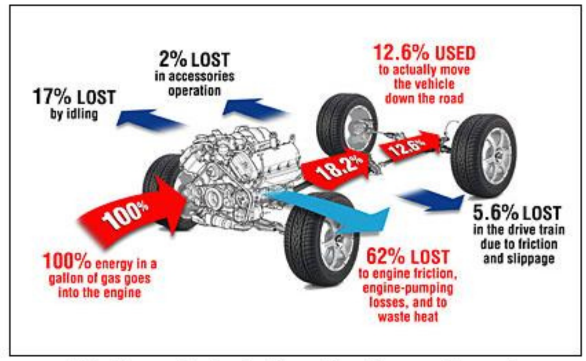
5. Can you calculate the energy needed to increase the temperature of 100kg of iron by 40°C?

6. A 20kg concrete block is at 20°C and is heated to 65°C. What is the energy used to heat this block?

7. A 250g copper pipe is heated from 10°C to 31°C. What is the energy needed to heat the pipe?

8. Can you rearrange the equation to calculate the temperature difference?

Lesson 9: Efficiency

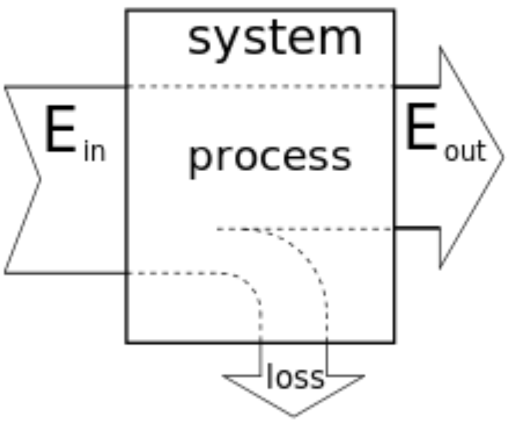


This diagram illustrates the paths of energy through a typical gas-powered vehicle in city driving.

What is Thermal Energy?

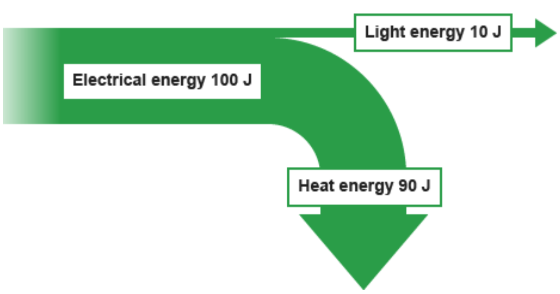
The law of conservation of Energy states that in any transfer or transformation of energy, the total amount of energy remains constant. Unfortunately the energy may not be in the form that we desired.

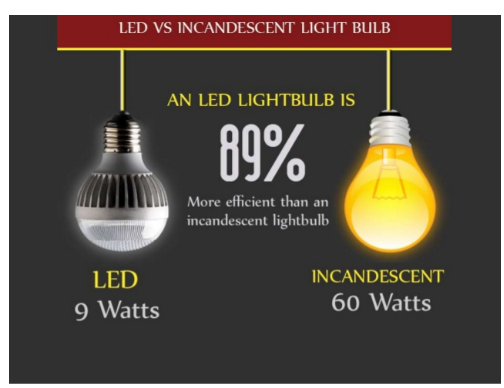
People use machines to transform or transfer energy. Unfortunately they will never be 100% efficient. The efficiency of any machine can be determined by the following:



$$\textbf{Efficiency} = \frac{\textbf{useful energy output}}{\textbf{energy input}} \times 100\%$$

A typical light bulb is very inefficient





Example: A 1500W kettle heats 1.5kg of water from 18°C to 59°C in 3.0 minutes.

A) How much electrical energy did the kettle use?

$P = W/t$ or $W = P \times t$

$W = 1500W \times 180s$

Work done by kettle = $2.7 \times 10^5 J$

B) How much heat energy was delivered to the water?

$\Delta E_h = mc\Delta T$

$\Delta E_h = 1.5kg \times 4200 J/kg^{\circ}C \times (59 - 18)^{\circ}C$

$\Delta E_h = 2.6 \times 10^5 J$

C) What is the efficiency of the kettle?

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

$$\text{Efficiency} = \frac{2.6 \times 10^5 J}{2.7 \times 10^5 J} \times 100\%$$

Efficiency = 96%

Example: A rocket engine takes in 800J of chemical energy and changes this into 480J of kinetic energy and 320J of heat energy.

Example: A jet engine gas turbine takes in 1200J of chemical energy and gives out 960J of kinetic, 180J of heat and 60J of sound energy.

Example: A TV takes in 600J of electrical energy and gives out 300J of light, 240J of sound and 60J of heat energy

Additional Practice:

1. What is the law of conservation of energy?

2. What is the formula for calculating the efficiency of a system?

3. What does most of the energy of a system usually transform into?

4. What is the efficiency of a car if the car uses 1000 J of chemical potential energy and only 100J of kinetic energy is produced?

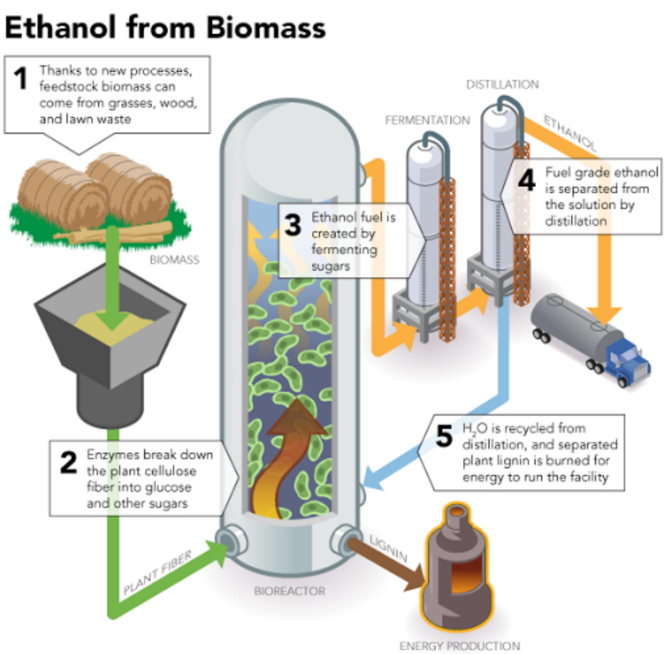
5. If an electric car is 80% efficient then how much electric potential energy is used by the car when 333 J of kinetic energy is produced?

Lesson 10: Alternate Energy Sources

In the early 1970's the realisation that fossil fuels were not going to last forever resulted in the search for alternate energy sources.

Some of the alternate energy sources are: **biomass fuels, wind turbine, hydroelectric, solar, tidal, geothermal, nuclear fission and nuclear fusion.**

1. Biofuels



Biofuels use a process called pyrolysis. Pyrolysis occurs when certain materials are heated strongly in an air-free environment to form burnable methane gas.

Fermentation is also used to extract combustible methane and ethanol. Fermentation uses microscopic organisms to break down the biomass.

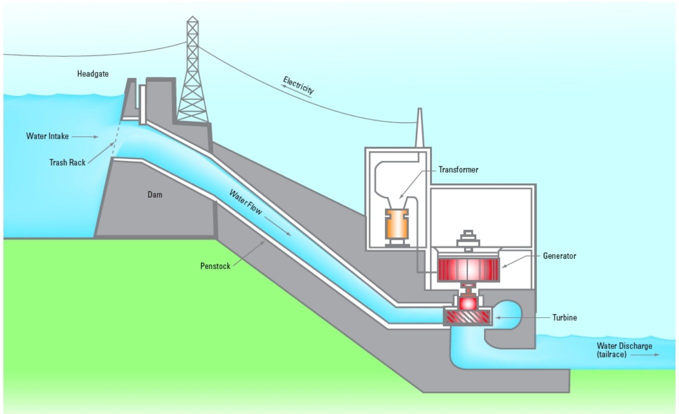
2. Wind Turbines

Wind turbines use the air passing over the blades to create lift. The blades turn which in turn powers an electric generator.

The generator produces the electricity.

3. Hydroelectric

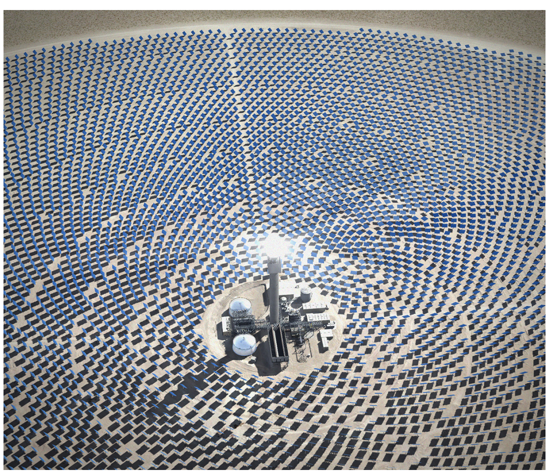
Hydroelectric is very similar to wind turbine in the sense that instead of air moving a turbine, water turns the turbine which in turn turns an electric generator.



4. Solar Water Heating

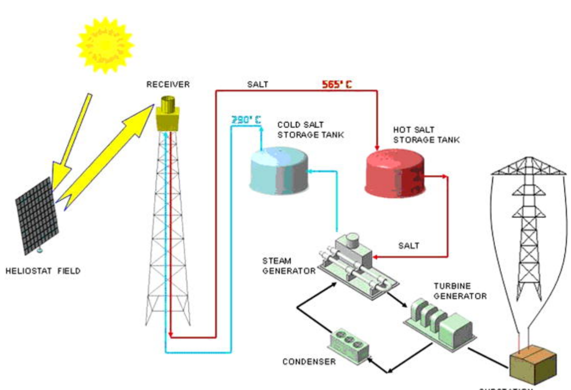
Solar energy can be captured using two methods, one is passive capture and the other is active.

The passive capture simply uses the sun's energy to heat water and the water is then used directly or turns into steam, which turns a turbine to produce electricity.

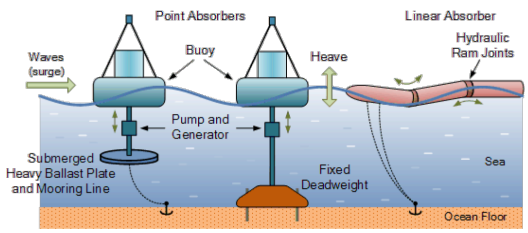


5. Photovoltaics

Active solar capture uses the light energy of the sun when the photons in the sunlight produce a charge separation in the materials that make up the solar panel. This produces electricity directly.

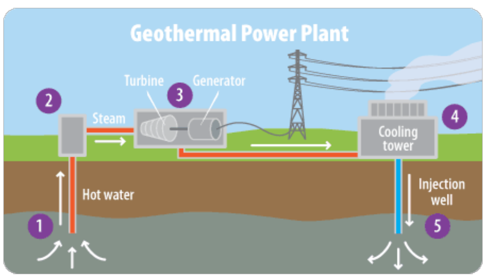


6. Tidal and Wave Energy



Tidal and wave energy are captured through the repeated motion of waves or tidal movement of water.

The motion is used to turn a turbine, which in turn produces the electric energy.



7. Geothermal Energy

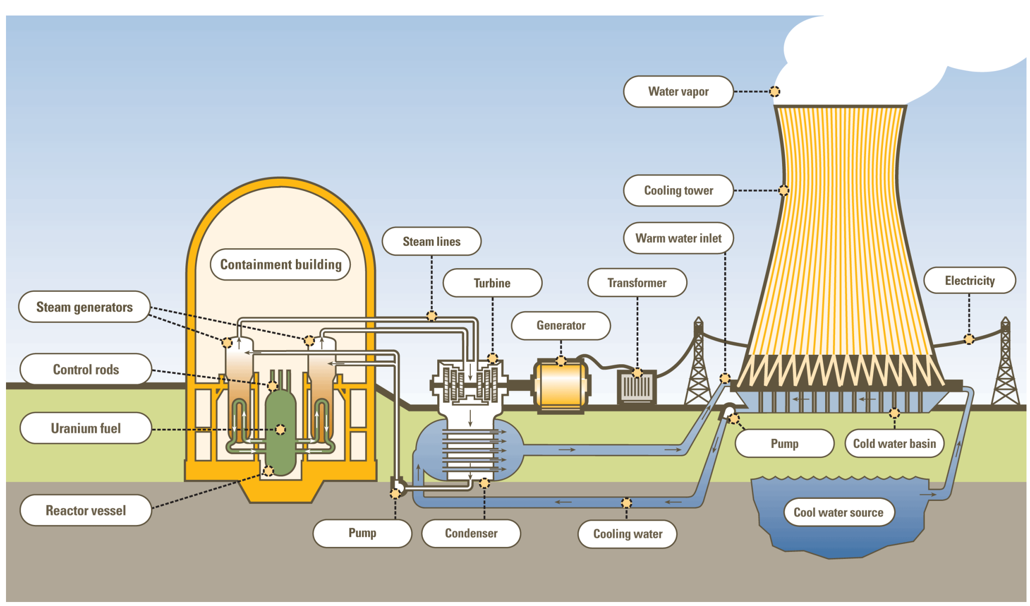
Geothermal energy can be harnessed to produce electricity. The thermal energy of the Earth can be captured for direct heating or for steam production that turns a turbine that in turn turns an electric generator.

8. Nuclear Energy

In a nuclear reaction there is a small amount of mass lost in the form of energy based on Einstein's famous equation:

$E = mc^2$

E is the energy produced in joules (J)
m is the mass loss measured in kg
C is the speed of light 3×10^8 m/s



THE TIMES

No 62,443 TUESDAY APRIL 29 1986

Alert 1,000 miles away in Sweden after Moscow admits casualties

Huge nuclear leak at Soviet plant

By Thomson Prentice, Science Correspondent, and Christopher Mosey, Stockholm

A massive radioactive leak at a Soviet nuclear power station has caused casualties in what may be the world's worst nuclear accident. The leak was so large that it prompted a full-scale alert nearly 1,000 miles away in Sweden, including the evacuation of 600 workers from a Swedish power station on the Baltic coast.

Finland reported radiation levels six times higher than normal, Denmark five times higher than normal, and Norway 50% up as a result of the accident. "We have registered radiation just about everywhere we have looked," said Mr. Ragnar Boge, of the Swedish Radiation Institute.

Soviet atomic energy authorities at first told the Swedish Embassy in Moscow they were unaware of any nuclear accident on Soviet territory that could cause a leak to reach Sweden.

But later Tass reported that an accident had taken place at a nuclear power station at Chernobyl, north of Kiev, and there were some casualties.

It said measures were being undertaken "to eliminate the consequences of the accident" at the plant, where a reactor had been damaged. Aid was being given to those affected by the leak, it added.

Swedish scientists at first believed a leak had occurred at their own nuclear plant at Forsmark, on the Baltic coast about 60 miles north of Stockholm, and evacuated the 600 workers there. After the evacuation radiation levels were checked at other areas of the country, including the capital.

These all confirmed a higher degree of radioactivity than normal, and further tests at Forsmark led the Swedish authorities to conclude that the discharge had come from the Soviet Union.

Some Swedish nuclear experts said they believed the Soviet accident was caused by the overheatinng of nuclear fuel. A "considerable explosion" would be the result of such overheating and could have led to a "meltdown" of the nuclear core of the reactor, they said.

The Swedish Energy Minister, Mrs Birgitta Dahl, said all Russian nuclear reactors should be placed under international control.

"We must demand that Soviet Union improve their security, and inform the rest of the world of such accidents in good time," she said.

The first stage of the Chernobyl nuclear plant was put into service in September 1977, followed by two more stages in 1980.

A government committee of inquiry had been set up by the Soviet Union into the accident, Tass said.

The Swedish Defence Ministry said an abnormally high level of radioactivity had been recorded on Monday afternoon by several monitoring stations in Finland, Sweden, Denmark and Norway.

The ministry said that at a rate of "a few millirems an hour" the level was not thought high enough to warrant the evacuation of the local population at Forsmark. It would not be a danger to human beings, although regional specialists said the level was twice as high in Finland as in Sweden and Norway.

A millirem is a unit of ionizing radiation that gives the same biological effect as one thousandth of a standard unit of X-rays.

● MOSCOW: Tass said the accident was the first of its kind in the USSR. (Christopher Walker writes).

Since Mr Mikhail Gorbachov came to power in March 1985 there have been repeated calls in the Soviet press for more open reporting of disasters inside the Soviet Union.

The Tass statement was seen as a quick propaganda move ordered by the Kremlin to counter any international criticism of safety measures taken inside the Soviet Union, which has traditionally surrounded details of its nuclear programme with secrecy.

● **Abandoned villages:** There was a serious nuclear accident in the Soviet Union during winter of 1957-58, according to a report published in February 1980 by the Oak Ridge National Laboratory in Tennessee (UPI reports).

The report said the contamination covered between 40 to 400 square miles. It said there was "some loss of life", and at least 30 villages were abandoned, their names subsequently deleted from Soviet maps.

Before the leak: workers in a reactor room of the Chernobyl nuclear plant near Kiev.

Which form of alternate energy is safest?

Which is most cost effective?

Which is the 'cleanest'?