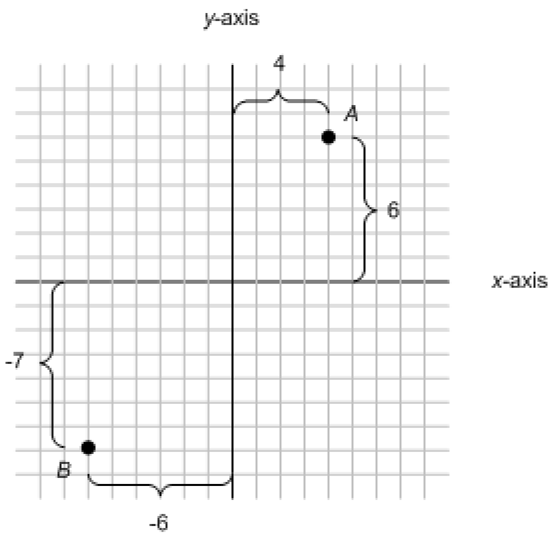
Activities/ Resources for Outcomes

Outcome #1

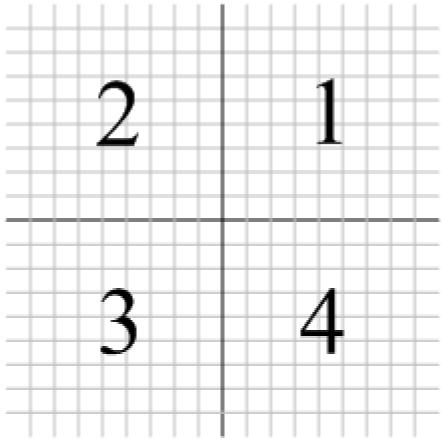
Please note the textbook, *Liberal Arts Physics,* Is used for the curriculum activities/resources. Provided here are some easily accessible substitutes in the event the book is not available.

Graphing in Two Dimensions



Graphing in two dimensions is a simple extension of the graphing that you do in one dimension, i.e. on a number line. To work in two dimensions, we'll need two number lines that cross at right angles. So we can tell them apart, we'll call the horizontal one the x-axis and the vertical one the y-axis. Now we can specify the location of a point, called its **coordinates**, by counting the number of units that we have to go over and the number of units we have to go up to get to the point.

If you look at the graph to the right, the coordinates of point *A*, are (4, 6) because you have to go four units over and 6 units up to get to it. Negative values work exactly the same in two dimensions as they did on a number line. Point *B* is located at coordinates (-6, -7) because you have to go six units *to the left* and 7 units *down* to get to it.



Notice that the two axes create four equal sections. To make the four parts, called **quadrants**, easier to talk about, each one is given a number like the ones in the diagram on the right.

Source: *http://www.whitecraneeducation.com/reference/algebra/index.php?id1=10*

Website for plotting practice:
http://www.teacherschoice.com.au/maths_library/coordinates/plotting_ordered_pairs.htm

Interpreting Graphs

Use the chart below to allow students to practice graphing two-dimensionally and to interpret the data: average vacation weeks by years experience for CNC Machinist.

Job: Computer Numerically Controlled (CNC) Machinist
Average Vacation Weeks by Years Experience

Years Experience	National Vacation Data
Less than 1 year	1.0 weeks
1-4 years	1.5 weeks
5-9 years	1.7 weeks
10-19 years	2.1 weeks
20 years or more	2.7 weeks

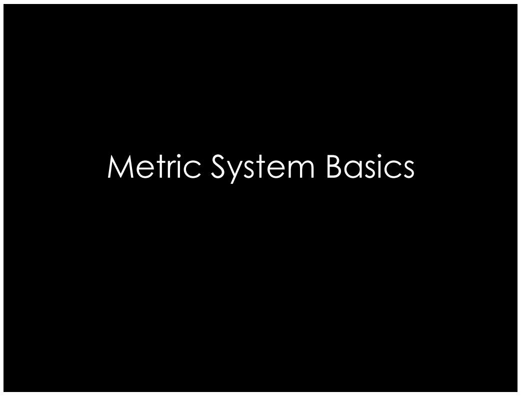
PayScale
Country: United States | Updated: 7 Jul 2011 | Individuals Reporting: 245

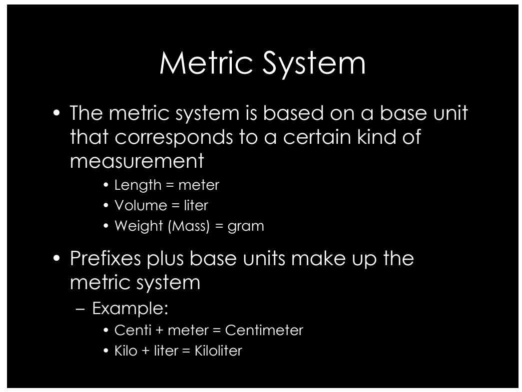
http://www.payscale.com/research/US/Job=Computer_Numerically_Controlled_%28CNC%29_Machinist/Vacation_Weeks

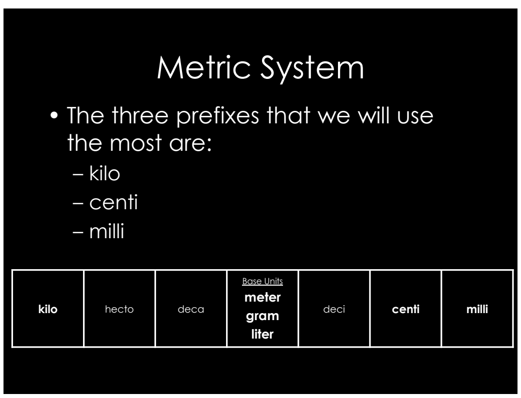
Outcome #2

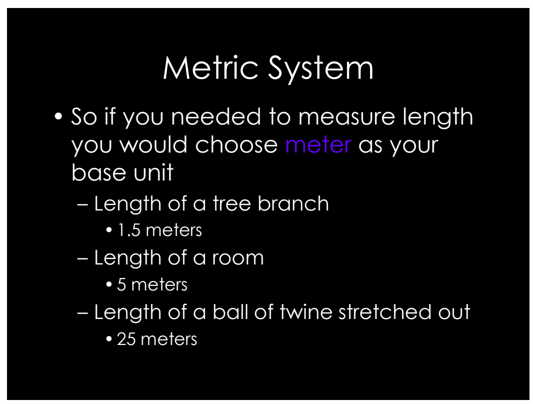
Please note the textbook, *Liberal Arts Physics,* Is used for the curriculum activities/resources. Provided here are some easily accessible substitutes in the event the book is not available.

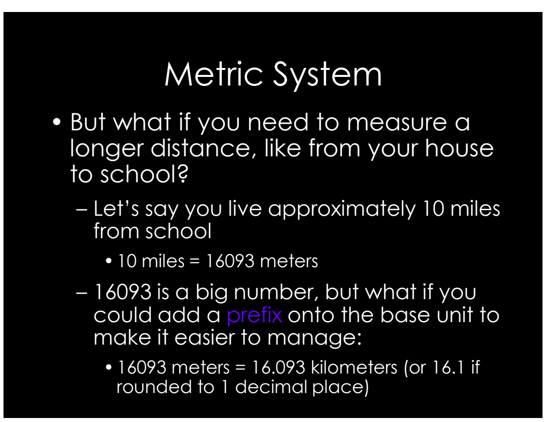
http://math.pppst.com/metrics.html

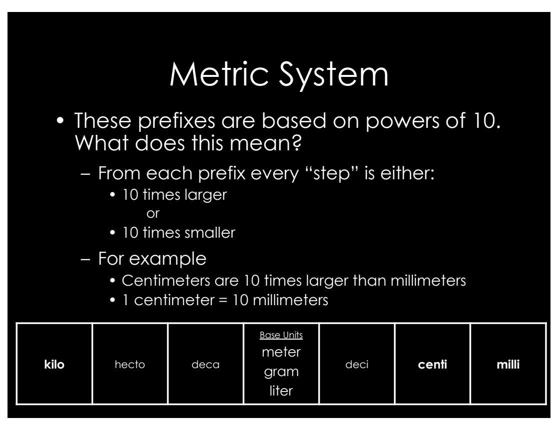










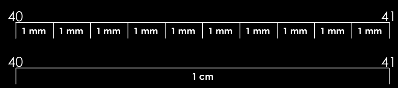


Metric System

– Centimeters are 10 times larger than millimeters so it takes more millimeters for the same length

1 centimeter = 10 millimeters

Example not to scale



Metric System

- For each "step" to right, you are multiplying by 10
- For example, let's go from a base unit to centi

1 liter = 10 deciliters = 100 centiliters
(1 x 10 = 10) = (10 x 10 = 100)

2 grams = 20 decigrams = 200 centigrams
(2 x 10 = 20) = (20 x 10 = 200)

kilo	hecto	deca	meter liter gram	deci	**centi**	**milli**

Metric System

- An easy way to move within the metric system is by moving the decimal point one place for each "step" desired

Example: change meters to centimeters

1 meter = 10 decimeters = 100 centimeters
or
1.00 meter = 10.0 decimeters = 100. centimeters

kilo	hecto	deca	meter liter gram →	deci →	**centi**	**milli**

Metric System

- Now let's try our previous example from meters to kilometers:

  16093 meters = 1609.3 decameters = 160.93 hectometers = 16.093 kilometers

- So for every "step" from the base unit to kilo, we moved the decimal 1 place to the left (the same direction as in the diagram below)

kilo ←	hecto ←	deca ←	meter liter gram	deci	**centi**	**milli**

Metric System

- If you move to the left in the diagram, move the decimal to the left
- If you move to the right in the diagram, move the decimal to the right

kilo ⇄	hecto ⇄	deca ⇄	meter liter gram ⇄	deci ⇄	**centi** ⇄	**milli**

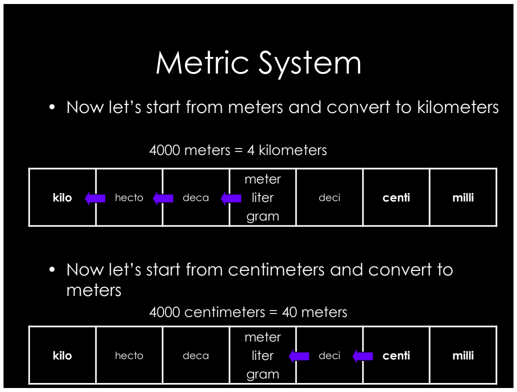
Metric System

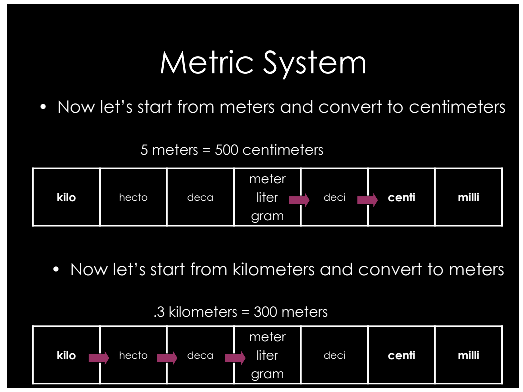
- Now let's start from centimeters and convert to kilometers

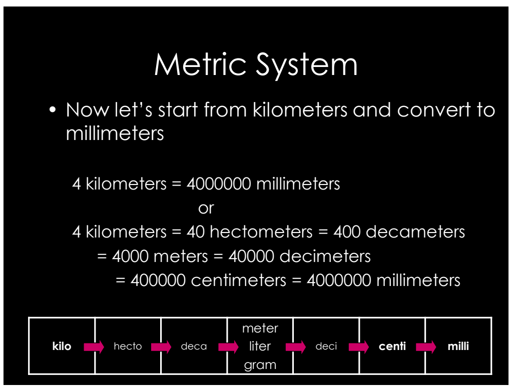
400000 centimeters = 4 kilometers

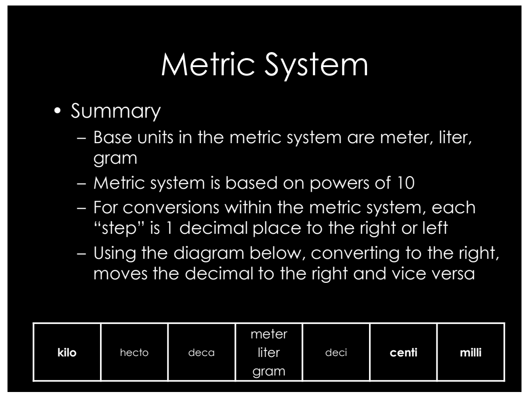
400000 centimeters = 4.00000 kilometers

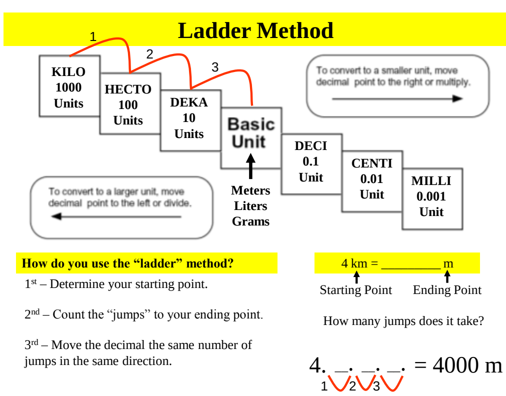
kilo ←	hecto ←	deca ←	meter liter gram ←	deci ←	**centi**	**milli**

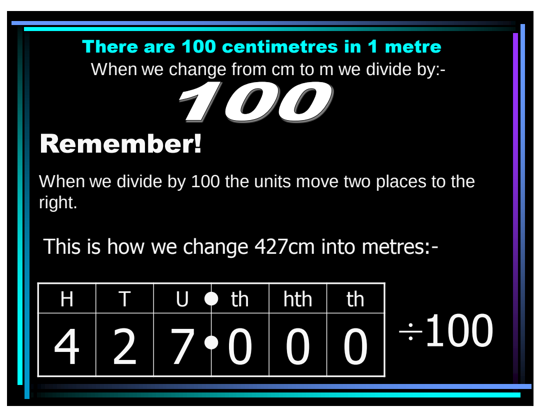

Metric System
• Now let's start from meters and convert to kilometers
4000 meters = 4 kilometers
kilo
hecto
deca
meter
liter
gram
deci
centi
milli
• Now let's start from centimeters and convert to meters
4000 centimeters = 40 meters
kilo
hecto
deca
meter
liter
gram
deci
centi
milli

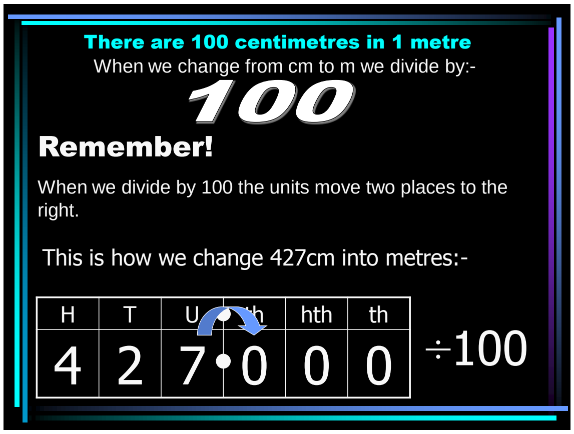

Metric System
• Now let's start from meters and convert to centimeters
5 meters = 500 centimeters
kilo
hecto
deca
meter
liter
gram
deci
centi
milli
• Now let's start from kilometers and convert to meters
.3 kilometers = 300 meters
kilo
hecto
deca
meter
liter
gram
deci
centi
milli


Metric System
• Now let's start from kilometers and convert to millimeters
4 kilometers = 4000000 millimeters
or
4 kilometers = 40 hectometers = 400 decameters
= 4000 meters = 40000 decimeters
= 400000 centimeters = 4000000 millimeters
kilo
hecto
deca
meter
liter
gram
deci
centi
milli


Metric System
• Summary
– Base units in the metric system are meter, liter, gram
– Metric system is based on powers of 10
– For conversions within the metric system, each "step" is 1 decimal place to the right or left
– Using the diagram below, converting to the right, moves the decimal to the right and vice versa
kilo
hecto
deca
meter
liter
gram
deci
centi
milli


Ladder Method
1
2
3
KILO 1000 Units
HECTO 100 Units
DEKA 10 Units
Basic Unit
Meters Liters Grams
DECI 0.1 Unit
CENTI 0.01 Unit
MILLI 0.001 Unit
To convert to a smaller unit, move decimal point to the right or multiply.
To convert to a larger unit, move decimal point to the left or divide.
How do you use the "ladder" method?
1st – Determine your starting point.
2nd – Count the "jumps" to your ending point.
3rd – Move the decimal the same number of jumps in the same direction.
4 km = _________ m
Starting Point
Ending Point
How many jumps does it take?
4. __. __. __. = 4000 m
1
2
3


There are 100 centimetres in 1 metre
When we change from cm to m we divide by:-
100
Remember!
When we divide by 100 the units move two places to the right.
This is how we change 427cm into metres:-
H
T
U
th
hth
th
4
2
7
0
0
0
÷100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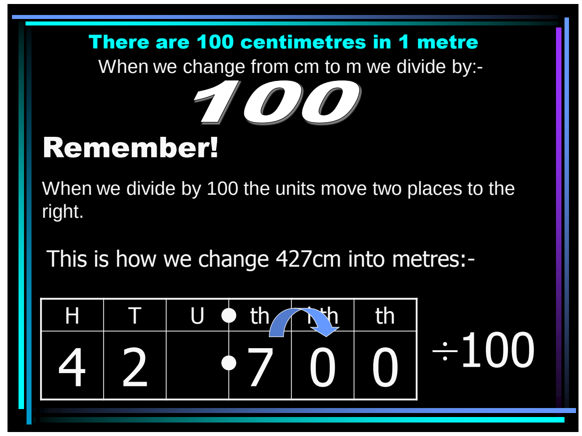
H T U th hth th
4 2 7 • 0 0 0
÷100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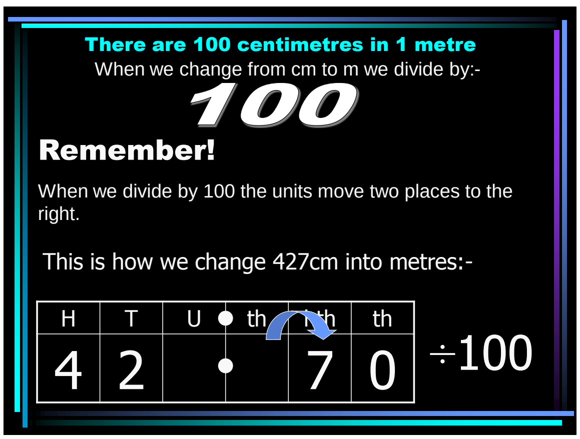
4 2 • 7 0 0
÷100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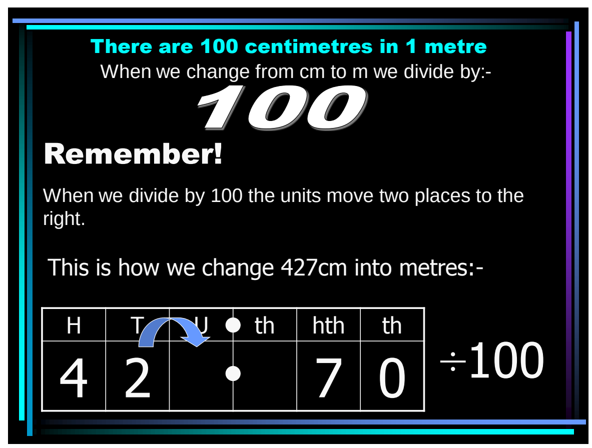
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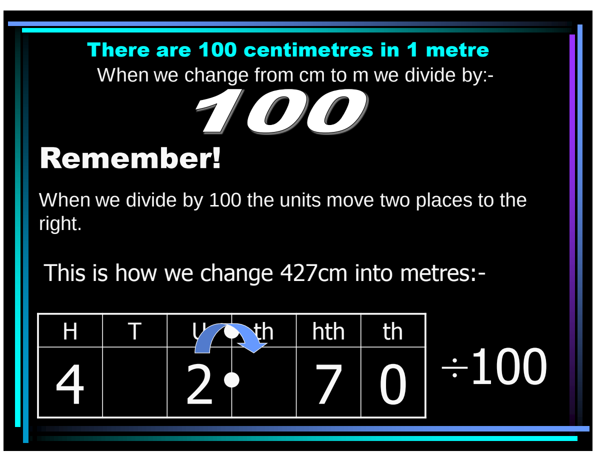
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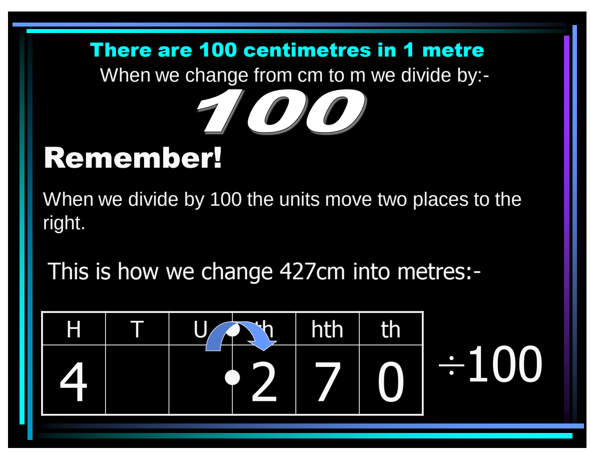
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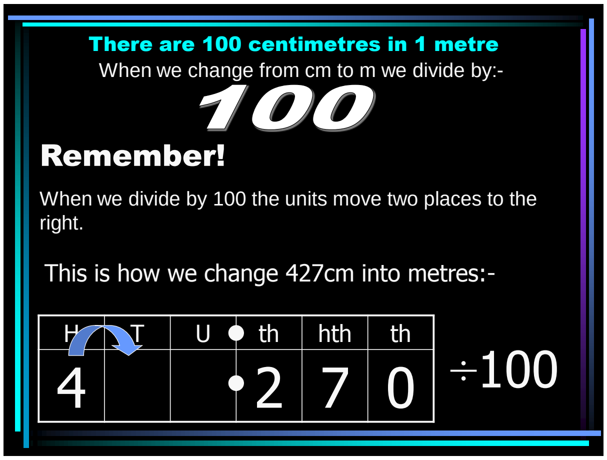
H T U th hth th
4 • 2 7 0
÷100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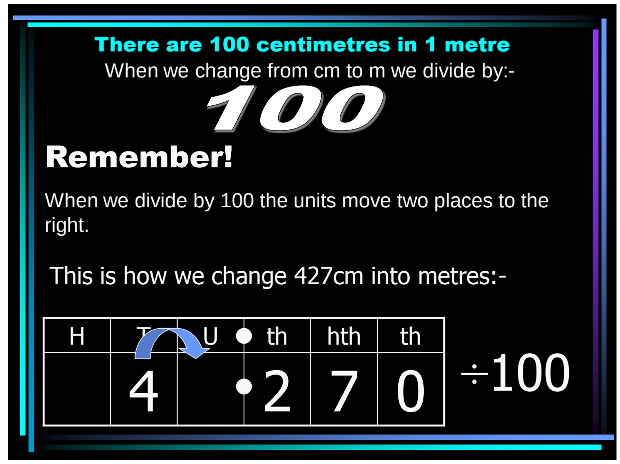
H T U • th hth th
4 • 2 7 0
÷100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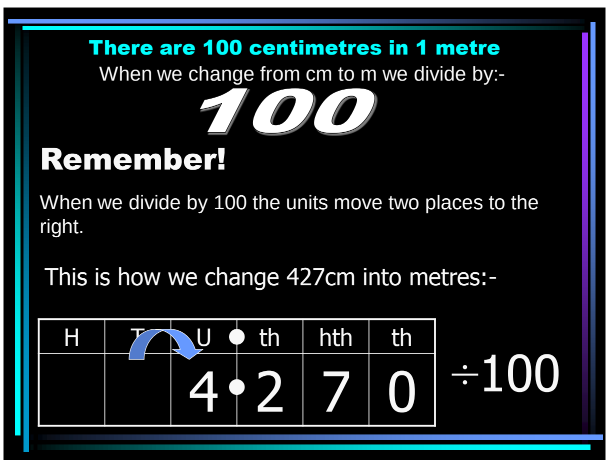
4 • 2 7 0
÷100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Remember!
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This is how we change 427cm into metres:-
H T U • th hth th
4 • 2 7 0
÷100

Outcome #3

Visit the following website for a rap video explaining Newton's Laws.

http://www.youtube.com/watch?v=UDThbykD6P0&feature=related

Newton's Laws of Motion (F=ma)

September 30, 2010 By Science Teacher

http://www.pfscience.com/2010/09/newtons-laws-of-motion-fma/

Newton's Second Law is one that everyone seems to understand without having been taught it because it is intuitive. We all know that when something is heavier, that thing is harder to push around, compared to something that is lighter. It takes more force to push a 100 lb boulder than to push a 1 lb rock. In other words, it takes more force to push something with more mass than something with less mass.

Newton figured out that there is a relationship between an object's mass, acceleration, and force. Knowing any two parts of this will help you figure out the third piece of the puzzle.

THE EQUATION:
Force = mass x acceleration

F=ma

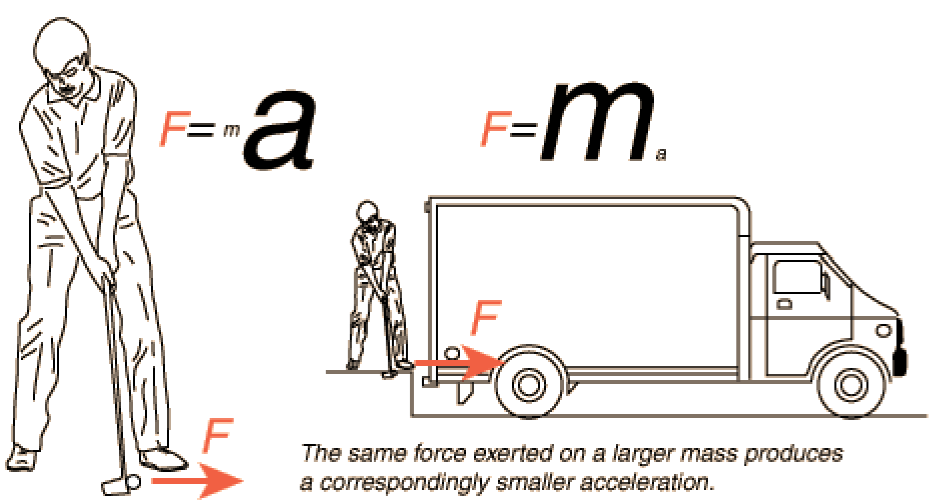


image credit: George State University

Let's quickly review acceleration. Acceleration is when an object speeds up, slows down, or changes direction. If the man in this picture applies a very large force on a tiny object with little mass like the golf ball, than we would expect the golf ball's acceleration to be great. The golf ball would go flying somewhere, right?

Let's say this man applies the same force on a huge object with a huge mass. The huge object might budge just a tiny bit, so very little acceleration.

What would the man have to do to get the huge object to accelerate more? He would have to apply a much greater force.

The trick to solving any equations that deal with Newton's Second Law is to look at the scenario that you are given. Use pictures and the descriptions to help you figure out if you are given force, mass, or acceleration. Once you have it, you just plug the numbers in the equation F=ma to solve the problem.

To solve for force:

- F= ma

To solve for acceleration:

- a = F/m

To solve for mass:

- m = F/a

Outcome #4

http://www.studyphysics.ca/newnotes/20/unit01_kinematicsdynamics/chp05_forces/lesson20.htm

Static and Kinetic Friction

There are two kinds of friction, based on how the two surfaces are moving relative to each other:

1. **Static friction**
   The friction that exists between two surfaces that are ***not*** moving relative to each other.
2. **Kinetic friction**
   The friction that exists between two surfaces that ***are*** moving relative to each other.

In any situation, the **static friction** is greater than the **kinetic friction**.

- Have you ever tried to push a really big object? Did you notice that you were pushing harder, and harder, and HARDER, until suddenly it was like glue that was holding it to the floor snapped? Then, it felt easier to push the object than it did just to get it started.
  - When it was still, you were trying to overcome the **static friction** (bigger force).
  - When it finally started to move, you were now pushing against the **kinetic friction** (smaller force).

Visit youtube to watch Mythbusters and a phonebook experiment.

http://www.youtube.com/wathc?v=jSu0Tvlm6LY&feature=related

http://tristanmac.tripod.com/id13.html

Friction Between Car Tires and the Road

What is Friction?

- Friction is the force between two objects as they move over one another such as a car's tire and the surface which it is travelling on.
- There are two types of friction, only one which with we will be dealing with. These types are known as static friction and kinetic friction. Static friction is the frictional force required to start an object moving on another surface. Kinetic frictional force is the force to keep the object in motion.
- The force to get something moving is always greater than the force to get it moving due to the "stickiness" between the two objects while trying to move one. Once you get your car moving the tires do not need as great of a force to keep moving.
- A value known as the coefficient of friction is the value which tells how much "stickiness" is between the two objects.
- The force of friction is measured as the coefficient of friction multiplied by the normal force.
- The normal force is the force of the bottom surface (such as a road) pushing up on the other object (such as a car) as the first object (car tires) pushes down on it.
- One thing that you may not have realized is the sound caused by running one surface over another is caused by friction. The sound made by car tires is caused by the frictional force between the rubber and the pavement.
- This sound is caused when the two objects form and break new bonds as one object moves across the other.

Friction and weather conditions
SNOW
As snow becomes hard and packed it can be very slippery. The coefficient of friction is then less then when the tires are on pavement which means that the "sticky" force is not as great holding the tires and the snow covered road together. In these conditions the car tires begin to slip as they try to grip onto the road but the static frictional force to get the car going is not there and as a result the car tires spin in the snow.
RAIN
When there is too much water on the road cars will hydroplane if they are going too fast. What happens when a car hydroplanes is that the water gets between the tires and the road leaving an nonexistent frictional force. The tires are not in contact with the road so the frictional force is gone causing the car to slide until the tires make contact with something that will cause there to be a frictional force.

Source:
http://auto.howstuffworks.com/tire5.htm

This tire is an example of a tire that is made for rainy conditions. The design allows water to go from under the wheels thereby permitting the tire to stay in contact with the road and providing the traction needed to stay on the road.

Outcome #5

Hydrostatic Pressure

Hydrostatic pressure is the driving force behind various important aspects of our lives, important for everything from energy creation to water dispersal. The more that you learn about this pressure, the better you can understand some of the important tools in our lives.

Simply put, hydrostatic pressure is the amount of pressure that fluid has, when at equilibrium, due to the gravitational pull of the earth. This is the force that the water is pushing with, whether it be sitting in the earth or pushed up against a wall. The pressure builds on itself when there is a higher level of fluid in one location, just as the weight of an object builds if you add more and more to that object.

Hydrostatic Pressure and Energy

One of the most visible uses of hydrostatic pressures comes from one of our main sources of renewable energy – dams. The dam works to hold back water that would otherwise be flowing freely through an area. The dam only allows a small amount of water to go through at any given time. The hydrostatic pressure pushes the water through the turbines at a faster rate, providing more power that can be converted into energy. If the turbines were simply placed in the water without a true dam, they would not generate this high level of energy.

Hydrostatic Pressure and Water Tanks

One of the most iconic structures of many of the small towns in the United States is the water tower. For many cities, the water tower is the highest structure in the town, and for good reason. The hydrostatic pressure works to force the water through the system. The higher the tank is and the larger the tank is, the more pressure and force that the water will have. It will drop and push itself through the pipe system. The idea is that when the water is high, the water is pushed at a faster rate because of the hydrostatic pressure. This reduces the need for electric pumps through the system, as the pressure is responsible for moving the water through the pipes.

Hydrostatic pressure is a simple scientific concept that we have come to rely on. We work to control liquid and make that liquid work for us. We get it to create energy for us by holding it back, and we get it to push itself through pipes by holding it as high as possible. The next time that you go by a dam or drive past a water tower, you can understand the science and technology behind the design.

http://hydrostaticpressure.net/

Hydro pressure testing helps locate leaks or verify performance durability in pressure vessels such as pipe, tubing, and coils.

Understanding Air Pressure

http://www.usatoday.com/weather/wbarocx.htm

The weight of the air pressing down on the Earth, the ocean and on the air below causes air pressure. Earth's gravity, of course, causes the downward force that we know as "weight." Since the pressure depends upon the amount of air above the point where you're measuring the pressure, the pressure decreases as you go higher.

Air pressure is related to its density, which is related to the air's temperature and height above the Earth's surface.

Air pressure changes with the weather. In fact, it's one of the most important factors that determines what the weather is like. You can do some basic weather forecasting by using the wind and barometric pressure.

Air pressure is also called barometric pressure because barometers are used to measure it.

The use of direct pressure measurements goes back to the late 19th century. This was when the Norwegian meteorologist Vilhelm Bjerknes, a leader in making meteorology a mathematical science, urged weather services to use direct pressure measurements because they can be used in the formulas that describe the weather, unlike measures of the height of the mercury in a barometer.

Air pressure and your body

Changes in air pressure, especially rather quick changes, can affect your body. The most obvious of these are the discomfort or even pain you feel in your ears when your gain or lose altitude rather quickly, such as in an aircraft, or even a fast elevator that goes up or down several floors.

Air pressure corrections

When you read a barometer the reading directly from it is the "**station pressure**."

Two things affect the barometer's reading, the high or low air pressure caused by weather, and the air pressure caused by the station's elevation, or how high it is above sea level.

No matter what weather systems are doing, the air's pressure decreases with height. If you're trying to draw a weather map of air pressure patterns, you need a way to remove the effects of the station's elevation. That is, you want to see what the pressure would be at the station if it were at sea level. Otherwise, all high-elevation locations would be mapped as having low pressure.

You need to calculate, **sea-level pressure**, which is defined as: "A pressure value obtained by the theoretical reduction of barometric pressure to sea level. Where the Earth's surface is above sea level, it is assumed that the atmosphere extends to sea level below the station and that the properties of that hypothetical atmosphere are related to conditions observed at the station."

To do this, you have to take into account the barometric reading at the station, the elevation above sea level, and the temperature.

Another kind of barometric reading is the **altimeter setting**, which aircraft use. It's defined as: "The pressure value to which an aircraft altimeter scale is set so that it will indicate the altitude above mean sea level of an aircraft on the ground at the location for which the value was determined." For it, all you need is the station pressure and the elevation, you can ignore the temperature.

How pressure decreases with altitude

As you go higher in the air, the atmospheric pressure decreases.

The exact pressure at a particular altitude depends of weather conditions, but a couple of approximations and a formula can give you a general idea of how pressure decreases with altitude.

A rule of thumb for the altimeter correction is that the pressure drops about 1 inch of mercury for each 1,000 foot altitude gain. If you're using millibars, the correction is 1 millibar for each 8 meters of altitude gain. These rules work quite well for elevations or altitudes of less than two or three thousand feet.

The standard atmosphere is a table giving values of air pressure, temperature and air density for various altitudes from the ground up. You can think of these values as averages for the entire Earth over the course of a year.

Air Pressure – Application to Work

To show the power of air pressure and the importance in work and safety, show this youtube video. This happens when you don't properly vent a sealed storage tank before emptying it. Hot gas/air in the sealed container is left to cool. The air pressure difference inside is so great that the structure is instantly crushed.

http://youtube.com/watch?v=2WJVHtF8Gwl&feature=related

Air Pressure Experiment

http://www.thehomeschoolmom.com/teacherslounge/articles/air_pressure_experiments.php

There's air surrounding us everywhere, all at the same pressure of 14.7 psi (pounds per square inch). It's the same force you feel on your skin whether you're on the ceiling or the floor, under the bed or in the shower.

An interesting thing happens when you change a pocket of air pressure - things start to move. This difference in pressure that causes movement is what creates winds, tornadoes, airplanes to fly, and some of the experiments we're about to do right now.

An important thing to remember is that higher pressure always pushes things around. (Meaning lower pressure does not "pull", but rather that we think of higher pressure as a "push".)

Another interesting phenomenon occurs with fast-moving air particles. When air moves fast, it doesn't have time to push on a nearby surface, like an airplane wing. It just zooms by, barely having time to touch the surface. The air particles are really in a rush.

Think of really busy people driving fast in their cars. They are so busy doing other things and driving fast to get somewhere that they don't have time to just sit and relax.

Air pressure works the same way. When the air zooms by a surface (like an airplane wing) like fast cars, the fast air has no time to push on the surface and just sit there, so not as much air weight gets put on the surface.

Less weight means less force on the area. (Think of "pressure" as force on a given area or surface.) This causes a less (or lower) pressure region wherever there is faster air movement.

Confused? Great! Let's try an experiment to straighten out these concepts so they make sense to you.

Magic Water Glass Trick
Fill a glass one-third with water. Cover the mouth with an index card and invert (holding

the card in place) over a sink. Remove your hand from the card. Voila! The card stays in place because air is heavier than water, and the card experiences about 15 pounds of force pushing upward by the air and only about one pound of force pushing downward from the water - hence the card stays in place.

Outcome #6

First Law of Thermodynamics

The first law of thermodynamics is the application of the conservation of energy principle to heat and thermodynamic processes:

The change in internal energy of a system is equal to the heat added to the system minus the work done by the system.

$$\Delta U = Q - W$$

Change in internal energy — Heat added to the system — Work done by the system

The first law makes use of the key concepts of internal energy, heat, and system work. It is used extensively in the discussion of heat engines. The standard unit for all these quantities would be the joule, although they are sometimes expressed in calories or BTU.

http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/firlaw.html

The First and Second Law of Thermodynamics in Lyrics

If you are inclined to sing a song (or if your students are), try these lyrics that drive home the basic points of the first and second laws of thermodynamics.

http://lyricsplayground.com/alpha/songs/f/firstandsecondlaw.shtml

(Flanders / Swann)
Flanders & Swann

The first law of thermodynamics
Heat is work and work is heat (x 2)
Very good

The second law of thermodynamics
Heat cannot of itself pass from one body to a hotter body (x 2)
Heat won't pass from a cooler to a hotter (x 2)
You can try it if you like but you far better notter (x 2)
'Cause the cold in the cooler will be hotter as a ruler (x 2)
Because the hotter body's heat will pass through the cooler

Heat is work and work is heat
And work is heat and heat is work
Heat will pass by conduction (x 2)
And heat will pass by convection (x 2)
And heat will pass by radiation (x 2)
And that's a physical law

Heat is work and work's a curse
And all the heat in the universe
It's gonna cool down as it can't increase
Then there'll be no more work
And they'll be perfect peace
Really?
Yeah, that's entropy, man!
And all because of the second law of thermodynamics, which lays down

That you can't pass heat from the cooler to the hotter
Try it if you like but you far better notter
'Cause the cold in the cooler will get hotter as a ruler
'Cause the hotter body's heat will pass through the cooler

Oh, you can't pass heat from the cooler to the hotter
You can try it if you like but you far better notter
'Cause the cold in the cooler will get hotter as a ruler
That's the physical law

Ooh, I'm hot!

What? That's because you've been working

Oh, Beatles? Nothing!

That's the first and second law of thermodynamics

Outcome #7

Measuring Heat Capacity

While electrical batteries store electricity, all matter is capable of storing heat. All you have to do is heat it to get the atoms and molecules vibrating (note 1), and it will stay hot for awhile. During that time you can use that hot thing to heat other things (note 2) - such as that old camping trick of dropping hot rocks from the campfire into a pot of water and soon the water boils! However, different kinds of matter can store different amounts of heat. And it is just that which you will determine on this page. You probably have heard the child's riddle: "Which is heavier - an ounce of silver or an ounce of feathers?"* Well, here we can ask the question: "Which has the higher heat capacity - a pound of silver or a pound of feathers?"

If you are a glutton for equations, well-, here is one devised by - of all persons - Albert Einstein, who posited that each substance has a characteristic frequency of vibration "v", and that the absorption of energy by oscillators does not obey continuous classical mechanics, but rather follows discontinuous quantum theory *a la* Planck. Here is an Einstein equation that is a bit more difficult to remember than E = mc^2:

$$\boxed{\text{Heat capacity per mole at constant volume}} = C_v = 3\,kN\left(\frac{hv}{kT}\right)^2 \frac{e^{hv/kT}}{(e^{hv/kT}-1)^2}$$

*where: T =absolute temperature; v = characteristic frequency; N = Avogadro's number k = R/N = 1.380x10^{-15} erg/degree; and h = Planck's constant = 6.625 x 10^{-27} erg seconds***

Happily - no - Joyously! we can escape Einstein because there is another way to define heat capacity! That is to measure how much heat (calories) it takes to heat up a gram of the specified material. By definition, a calorie is almost precisely the amount of heat needed to increase the temperature of a gram of water by one degree centigrade. ('Almost precisely' because it differs slightly depending on the temperature of the water.)

How one can do this is usually done in an easily made calorimeter - a well insulated container of low heat capacity (note 3) holding some water. You place a known volume of water into the container, and then measure its temperature. Into that water you introduce something of known mass that has a far different temperature. Then you look to see how much the whole system changes in its temperature by measuring the water after thermal equilibrium is attained.

Let's take an obvious example. Were you to add 100 gm of water at 10°C to 100 gm of water at 30°C, you would expect to end up with 200 gm of water at 20°C. To discuss this ad nauseum would be to explain that every gram of 30°C water would give off the same amount of its stored heat per degree drop that it would take to warm a gram of 10°C water one degree - an example of the "conservation of energy" equation.

It would be less obvious if we were to take 100 gm of water at 30°C and add to it a 100 gm piece of iron at 10°C. Here, however, things are different. Perhaps the amount of stored heat in the water (1 cal/gm/degree) is sufficient to raise the iron's temperature more than a degree/gram. Let's pretend that water's can store twice as much heat as can iron. Then water's temperature would drop on half as much as the iron's temperature would rise. The final temperature would be 23.33°C (the water's temperature dropped 6.67°C, while the iron's went up 13.33°C. Qualitatively: water's heat capacity is greater than that of iron (in this pretend case); and quantitatively, water's heat capacity would be 2.00 times that of iron - in this pretend case.

PROCEDURE

Preparations:

- The day before, place two full buckets to stand overnight to attain room temperature.
- Just before doing the experiments, fill a third bucket with water and ice, and into the ice water add all the other components the instructor provides (any liquids in their bottles of course!). Allow all to come to thermal equilibrium in the ice/water, which has what temperature?

The First "Run"

1. Using water from one of the room temperature buckets, half fill a preweighed Styrofoam cup. Carefully measure the temperature of the water in the cup (be as precise as you can since this is the "weak link" in the experiment).
2. Place the cup on a balance, and note the weight (and determine the weight of water in it)
3. With a minimum of contact remove a little of the ice-water (no ice chunks, please!), and pour it into the cup of water, and stir.
4. Note the weight, and determine the mass of the cold water added.
5. Measure the temperature of the water after it is come to thermal equilibrium.
6. Using this calculate: $|(\Delta temp_{original\ water} \text{ x } mass_{original\ water})/(\Delta temp_{ice\ water} \text{ x } mass_{ice\ water})|$ = the RELATIVE heat capacity of the cold water you added. ((You, of course, know what this "|" means in that equation! It means that you take the "absolute" value, which in turn means that if you get a negative number, you make it positive.)) Anyway, this is your control. If your answer is close to 1.0, you are doing the procedure correctly.

$$\text{RELATIVE heat capacity} = |(\Delta temp_{water} \text{ x } mass_{water})/(\Delta temp_{x} \text{ x } mass_{x})|$$

The SPECIFIC heat capacity, C_s, is the heat capacity for a specified standard mass of material versus the heat capacity of that same mass of water. This will work for grams, tons, kilograms, or even those peculiar British weights called "stones" or jeweler's pennyweights - just so long as the units are the same for the thing added and for the water. It should thus be happily noted that the relative heat capacity is unit-less.

Subsequent "Runs"

- Suggested things to test: lead (fishing or drapery weights), iron (nails, screws, bolts, wire, hammerheads), aluminum (spool of wire), copper (spool of wire), brass (copper/zinc: bells, spool of wire, screws), bronze (copper/tin: pennies), glass (marbles, small bottles), water ice, ethanol, plastic, piece of wax (candle), and, if you want, a pound of feathers!

1. Test the various other solids available to you.
2. Test the liquids in the bottles (just pour some out of the chilled bottles into the water in the cups. And don't forget to test the cold water itself!
3. Test an ice cube, while you have some in the ice-bath.

---

* An ounce of silver, which being a precious metal, is commonly weighed in Troy ounces, which are 1/12 of a pound, while feathers are commonly weighed in ounces Avoirdupois (1/16 of a pound).

Note 1: A corollary of the 3rd Law of Thermodynamics
Note 2: Another Law of Thermodynamics! Which one?
Note 3: Textbook authors generally persist in reproducing diagrams of antique devices designed before the invention of Styrofoam. So we shall simply be using a Styrofoam cup!)

** Interestingly, this heat capacity equation is so filled with constants that if they are all combined into a term we'll call "K", then $C_p=Kv^2$. Since Newton's equation $F=½mv^2$, v at any given T is thus defined by the constant mass of the atom in question. Thus, at the very fundamental level, Einstein's heat capacity equation is little more than a corollary of Newton's equation. Indeed, Einstein's most famous equation, $E=mc^2$, is merely Isaac Newton's equation taken to the extreme velocity of the speed of light! Like Einstein once said: "I am merely standing on the shoulders of a giant [Newton], so that I can reach higher still." In any event, this all means that heat capacity ought to be inversely related to the atomic mass - which you might check out for yourself by looking at the Table of Specific Heat Capacities of the Elements, in the links below.

Two interesting points about this heat capacity equation: (1) Einstein considered it his life's best piece of work, and (2) the reason Einstein could come up with his famous $E=mc^2$ formula and no one before him, was that previously it was not known that the speed of light was constant.

Source: http://www.science-projects.com/HeatCapacity.htm#one

Outcome #8

Energy Conversion

http://www.uwsp.edu/cnr/wcee/keep/Mod1/Rules/EnConversion.htm

Most of us don't realize how important energy is in our lives. Every facet of our life involves energy. One of the reasons energy is hard to conceptualize is that it is constantly changing from one form to another. When this happens it is called an ***energy conversion*.**

During these conversions, energy is changing between potential and kinetic forms of energy. **Potential energy** is the energy in matter because of its position or the arrangement of its parts. **Kinetic energy** is the energy of motion. For example, to operate a wind-up toy, kinetic energy from

winding the toy is converted to elastic potential energy in the toy's spring mechanism. After the spring is released, the elastic potential energy is converted back to kinetic energy when the toy moves.

Heat is transferred to the surrounding environment during all energy conversions. Examples include:

- The chemical energy in food that is converted to mechanical energy (moving our muscles) by a process similar to burning called respiration. Energy is needed to break apart the food molecules, and during the process, thermal (heat) energy is generated. Feel your arm; this warmth is the energy that is released by respiration within your cells.

- Let's say you are using the energy you gained from food to operate a pair of scissors. Heat is transferred (lost) during this activity, too. There is friction when the blades of the scissors slide against each other to cut paper. Friction, the resistance to sliding, rubbing, or rolling of one material against another, requires extra work to overcome and results in energy loss through heat. This **thermal (heat) energy** escapes into the environment.

With each energy conversion, transferred heat leads to a slight increase in the thermal energy in the environment. In other words, this thermal energy is "lost" in to environment (eventually lost in space!) and not useable.

Energy Conversions and the Laws of Thermodynamics
To elaborate more on energy conversions suppose you paid $100 a year to light your home. What if you found out that only five dollars of this payment went toward paying for the light? Would you feel shortchanged? What about the other $95 of energy you paid for? Where did it go?

If you light your home with incandescent light bulbs, most of your $100 paid for the heat the light bulb generated rather than the light. A light bulb is one of many types of conversion devices. Its purpose is to convert electrical energy to light energy. **NOTE:** The efficiency of incandescent light bulbs can range from five to ten percent.

During the conversion process, all the energy that enters a conversion device is turned into other forms of energy. That is, you end up with an equal quantity of energy before and after the conversion. This is another way of stating the ***first law of thermodynamics*** **that energy can be neither created nor destroyed.**

However, not all the energy is converted into the desired form of energy (such as light). **Although the *quantity* of energy is the same before and after conversion, the *quality* is different.** An incandescent light bulb has a thin wire filament mounted inside it. When the bulb is turned on, an electrical current passes through the filament, heating it up so much that it emits light. The thermal energy that is produced by the light bulb is often called wasted heat, because it is difficult to use this form of energy to do work.

The energy that is wasted when a light bulb shines exemplifies the ***second law of thermodynamics*** **that states that with each energy conversion from one form to another, some of the energy becomes unavailable for further use**. Applied to the light bulb, the second law of thermodynamics says that 100 units of electrical energy cannot be converted to 100 units of light energy. Instead, of the 100 units that are used to generate light, 95 are needed to heat the filament. **NOTE:** There are other considerations with developing and using efficient conversion devices, such as costs and government subsidies.

Click on thumbnail to enlarge.

Second Law of Thermodynamics and Energy Efficiency
In terms of energy, efficiency means how much of a given amount of energy can be converted from one form to another useful form. That is, how much of the energy is used to do what is intended (e.g., produce light) compared to how much is lost or "wasted" as heat.

A formula for energy efficiency is the amount of useful energy obtained from a conversion divided by the energy that went into the conversion (efficiency = useful energy output / energy input). For example most incandescent light bulbs are only 5 percent efficient (.05 efficiency = f units of light out / 100 units of electricity in).

Because of unavoidable compliance with the second law of thermodynamics, no energy conversion devise is 100 percent efficient. Even natural systems must comply to this law.

Most modern conversion devices -- such as light bulbs and engines -- are inefficient. The amount of usable energy that results from the conversion process (electricity generation, lighting, heating, movement, etc.) is significantly less than the initial amount of energy. In fact, of all the energy that is incorporated into technologies such as power plants, furnaces, and motors, on average only about *16 percent* is converted into practical energy forms or used to create products. Where did the other 84 percent go? Most of this energy is lost as heat to the surrounding atmosphere.

You might be wondering why improvements have not occurred if there is so much room for increasing efficiency? 	One reason is when light bulbs and other conversion devices were first invented, energy supplies seemed abundant and there was not much concern for the waste heat they generated as long as their primary purpose (light, movement, and electricity) was accomplished. However, as it is becoming apparent that the energy supplies -- primarily fossil fuels -- that we use are indeed limited, one goal of technology has been to make conversion devices and systems more efficient.

The light bulb is one example of a conversion device for which a more efficient alternative has been developed. This alternative, the compact fluorescent light bulb (CFL), was commercially introduced in the 1980's. Instead of using an electric current to heat thin filaments, the CFLs use tubes coated with fluorescent materials (called phosphors) that emit light when electrically stimulated. Even though they emit the same amount of light, a 20-watt compact fluorescent light bulb feels cooler than a 75-watt incandescent light bulb. The CFL converts more electrical energy into light, and less into waste heat. CFLs have efficiencies between 15 and 20 percent, making them three to four times more efficient than incandescent bulbs.

A single 20-watt compact fluorescent bulb, compared to a 75-watt incandescent light bulb, saves about 550kWh of electricity over its lifetime. If the electricity is produced from a coal-fired power plant, that savings represents about 500 pounds of coal. If every household in Wisconsin replaced one 75-watt incandescent light bulb with a 20-watt compact fluorescent bulb, enough electricity would be saved that a 500-megawatt coal-fired plant could be retired.

Installing efficient light bulbs is just one action people can take to improve system efficiency. Other efficient electrical appliances, such as water heaters, air conditioners, and refrigerators, are available and are becoming more affordable. Turning off lights and other devices when not in use also creates less demand on the system. Therefore, individuals -- whether they are engineers improving an energy conversion device or children turning off lights around the home -- can make significant contributions to energy conservation.

Specific Heat Capacity

For directions to experiments to measure specific heat capacities visit:

http://tap.iop.org/energy/thermal/607/file_47502.pdf

Outcome #9

Sound waves: interference, wavelength, and velocity

The purpose in this lab exercise is to become familiar with the properties of waves: frequency, wavelength, phase and velocity. We use ultrasound waves because the wavelength is easily measured with an ordinary meter stick. The frequency of ultrasound is above the range of human hearing, so the experiment does not create an audible sound. The experiment also illustrates the interference of waves

Sound is a pressure wave in air. When we hear a sound, we are sensing a small variation in the pressure of the air near our ear. The speed of a sound wave in air is about 340 m/s or about 5 seconds to travel one mile, and this speed depends only on the properties of the air (temperature, composition, etc.) and not on the frequency or wavelength of the wave.

Consider a sinusoidal sound wave in air with frequency f and wavelength λ . The speed v is related to f and λ by

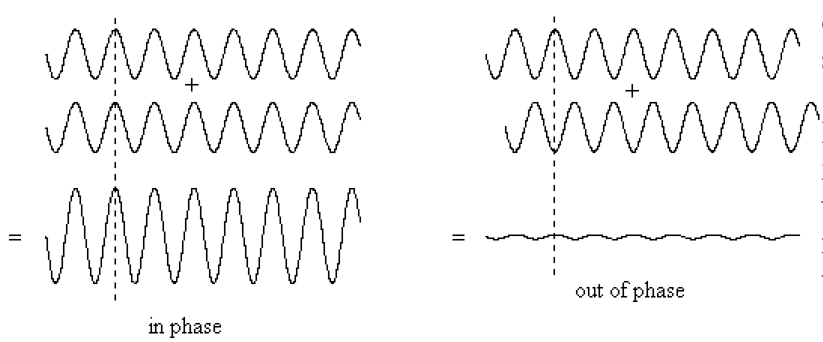
$$(1) \qquad v = f\,\lambda.$$

To see where this relation comes from, think:

$$\text{speed} = \frac{\text{change in distance}}{\text{change in time}}.$$

The time it takes for one wavelength of the sound to go by is the period T, so $v = \lambda / T$. But $f = 1/T$ so $v = f\,\lambda$. Note that as f increases, λ goes down, but the speed v stays the same. The frequency range of human hearing is about 20 Hz to 20,000 Hz. (The upper end drops as we age; for people over 60, it is about 15 kHz, while dogs can hear up to about 35 kHz.)

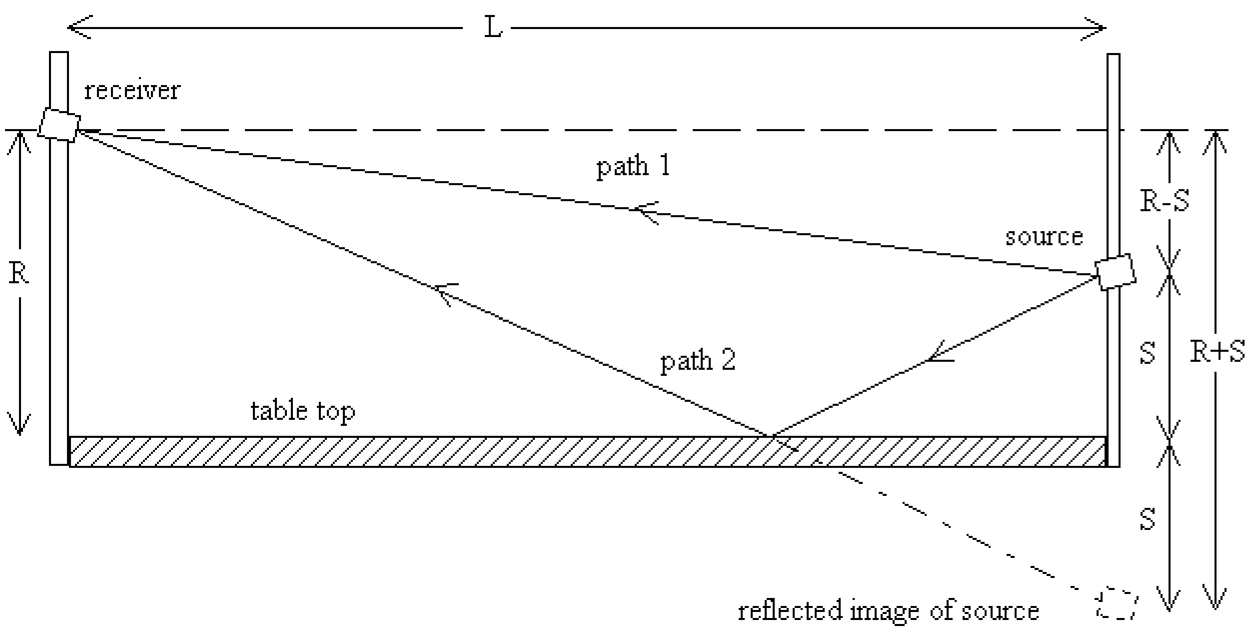
Consider two sound waves of equal f , equal λ , and nearly equal amplitude, both approaching a detector, such as the human ear. If the two waves arrive at the ear in phase, that is with successive maxima arriving at the same time and successive minima arriving at the same time, then the waves interfere constructively, their amplitudes add, and the ear hears a loud sound. But if the waves arrive at the ear exactly out of phase, that is, with the maxima of one wave arriving at the same time as the minima of the other wave, then the waves interfere destructively; they cancel and the ear hears little or no sound.



Now, in order to observe the interference of sound waves in the way just described, the two waves must have the same frequency and their phase difference should not change with time. A clever observation makes it unnecessary for experimenters to build two identical sources: *The reflection of a source of waves is a new source with the same frequency and phase as the source being reflected.*

In our experiment, a source of sound (a speaker emitting a pure tone with known frequency f) sits a height S above a flat table. A receiver sits a distance R above the table, a distance L along the table away from the source. Sound from the source can travel to the receiver along two different paths: the sound can travel directly from the source to the receiver (path 1 - total length D_1) or the sound can reflect from the surface of the table to the receiver (path 2 - total length D_2). (Sound, like light, can reflect from a smooth flat surface with the angle of incidence equal to the angle of reflection.) The receiver "sees" a reflection of the speaker in the table top which appears to be at a distance D_2 .

Whether the two waves arrive at the receiver in phase or out of phase depends on the path difference (D_2 - D_1). If the path difference is an integral number of wavelengths ($D_2 - D_1 = n\lambda$) then the waves arrive in phase. If $D_2 - D_1 = (n + \frac{1}{2})\lambda$ then the waves arrive out of phase and the detector receives a small amplitude total wave. In this lab, you will measure the heights R and S at which interference maxima and minima occur. From this information, you will compute the wavelength λ of the sound. Finally, from the wavelength and the known frequency f, you will compute the speed of sound $v = \lambda f$.

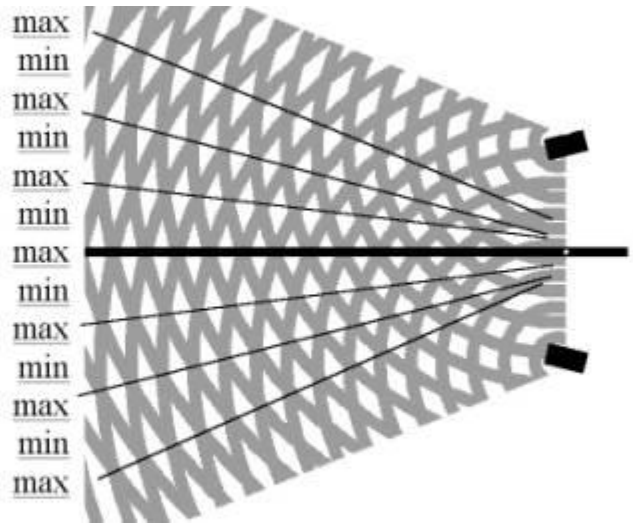


From the diagram above, we see that the two path lengths are

(2) $$D_1 = \sqrt{L^2 + (R-S)^2} \text{ and } D_2 = \sqrt{L^2 + (R+S)^2} .$$

Interference minima occur at the receiver when

(3) $$D_2 - D_1 = \sqrt{L^2 + (R+S)^2} - \sqrt{L^2 + (R-S)^2} = (n + \tfrac{1}{2})\,\lambda, \qquad n = 0,1,2,3,\ldots$$

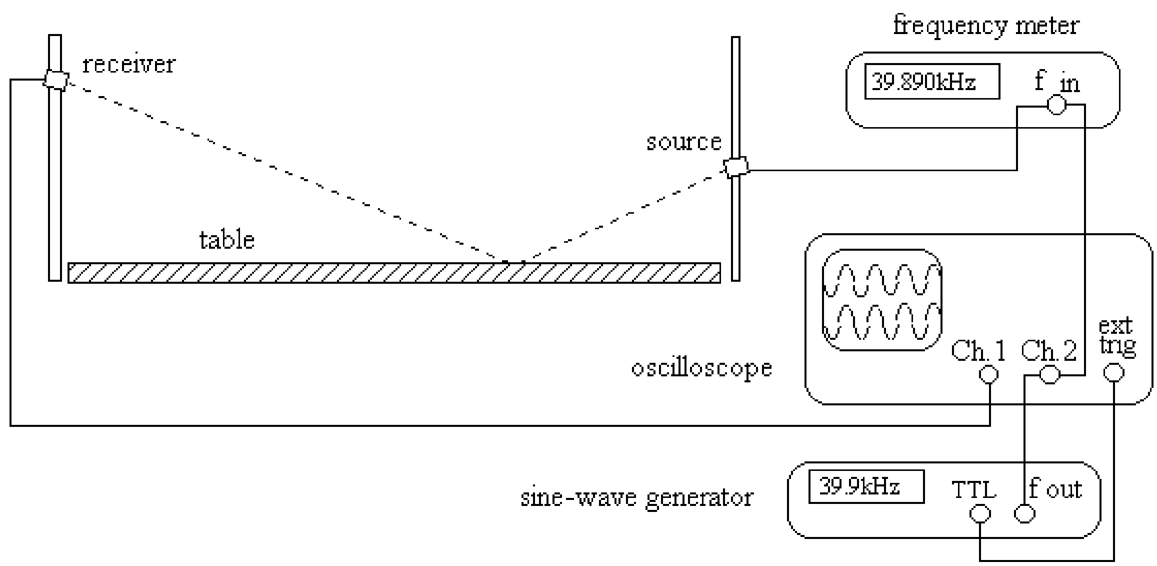


Hence, if n is known, then one can compute λ from measurements of R, S, and L.

The interference pattern you will investigate is shown at left. The gray arcs are the crests of the waves from the real source (upper black rectangle) *and* the crests of the waves from the imaginary source below the tabletop (lower black rectangle). The lower source is the reflection of the real source. Imagine that the tabletop is a glass mirror. The reflection of the real source that your eyes would see in the mirror would be the source shown here below the tabletop. There is a maximum in the combined signals where the wave crests of the two waves lie on top of one another. There is a minimum where the dark wave crests from one wave are on the light wave troughs from the other wave. There are narrow lines in the figure tracing the locations of the maxima. There is a maximum on the tabletop because the distances from the two sources are equal.

Experiment

A schematic of the apparatus is shown below. The sound source and receiver are ultrasonic transducers which are tuned to operate at about 40 kHz, well above the range of human hearing. The receiver signal is displayed on an oscilloscope, allowing the user to see when the signal is maximum or minimum.



Begin by turning everything on and allowing the sine-wave generator and the frequency meter to warm up for several minutes and stabilize. Aim the source directly at the receiver and tune the frequency for a maximum signal around 40 kHz. The source and receiver are tuned transducers and do not work well if only slightly away from the optimum frequency. Record this frequency f and, from time to time during the experiment, check whether f has drifted at all. Retune to the original frequency if necessary.

Part I. Wavelength

Set the source at some height around 20 cm above the table, aiming it approximately at the opposite edge of the table. Measure the distance S from the table top to the center of the source. Now move the receiver up and down along its support. You should see the output on the oscilloscope go through several maxima and minima as you move the receiver.

Place the receiver level with the top surface of the table and slowly raise it until you encounter the 1st minimum. This should be the n=0 minimum, corresponding to a path difference of $\frac{1}{2}\lambda$. Record the height $R = h_o$ of the n=0 minimum. Continue slowly raising the receiver, recording the heights h_1, h_2, h_3, .. of the subsequent minima. Record as many minima as possible and then make a plot of h_n vs. n. Recall that, in Mathcad, the index i of an array variable x_i must begin with 1, $i = 1,2,3,\ldots$, so you shouldn't define an array variable h_n , since you want the first n to be n=0. Instead, you could define

$$i := 1,2..N \qquad \text{(N is the number of data points.)}$$

$$n_i := i - 1 \qquad h_i := \blacksquare \qquad \text{(Enter your values for h.)}$$

This way, you have n = 0, 1, 2, ... with corresponding h's.

Looking at eq'n (3) for inspiration, define a Mathcad function or array for λ , which is the wavelength computed from the height h at which the n^{th} minimum occurs. Make a plot of λ vs. n . To define λ in Mathcad, you can either define an array variable λ_i in terms of n_i and h_i, or you can define a function λ (h,n).

If there are no systematic errors, the computed wavelength λ should be independent of n. If you see a λ gradually decreasing with n, it is a sure sign of a systematic error. **You may have missed the minimum nearest the tabletop** and are calling the second minimum the first minimum. You can fix this without taking more data by changing $n_i = i - 1$ to $n_i = i$. The first few λ 's are the most troublesome because when h is small, the two paths D_1 and D_2 are almost the same and there is a large fractional uncertainty in the difference ($D_2 - D_1$). From your plot of λ vs. n, decide which data points, if any, should be eliminated from further analysis. It may simplify analysis to copy the good values into a new list. Compute the mean, standard deviation, and standard deviation of the mean of λ .

$$\bar{\lambda} = \frac{1}{N}\sum_i \lambda_i \quad , \quad \sigma = \sqrt{\frac{\sum_i (\lambda_i - \bar{\lambda})^2}{N-1}} \quad , \quad \sigma_{mean} = \frac{\sigma}{\sqrt{N}} \; .$$

Part II. Speed of sound

Using the known frequency f, and your measured value for λ , compute the speed of sound v. Also compute the uncertainty δv, from the uncertainties in λ and f.

The speed of sound in air depends on the temperature according to

$$v(m/s) = 331.5 + 0.607 \cdot T \qquad (4)$$

where the temperature T is in degrees Celsius (there is a big dial thermometer on the wall in the lab). Compare this known v with your measured v .

Related exercises: If you want to explore more about sound see Lab M6, The Doppler Effect and if you want to explore interference of light waves see Lab O4, Single and Multiple Slit Diffraction.

Questions:

1. If the speed of sound is v = 345 m/s, what is the range of wavelengths of sound which the human ear can detect?

2. (Counts as two questions.) Show how you will define the wavelength λ in your Mathcad document. [Just write the Mathcad definition like it will appear on the computer screen, except write it on paper with your pen.] Also show how you will make a Mathcad graph of λ vs. n . For instance, if I want to show how to define a function $y(x,t) = x\, t^2$,where $x = 3\, t^{1/2}$, and how to graph y vs. t in Mathcad, I could write either the Mathcads commands below on the left or the commands on the right.

$t_i :=$ ▮ (Enter values for t.)

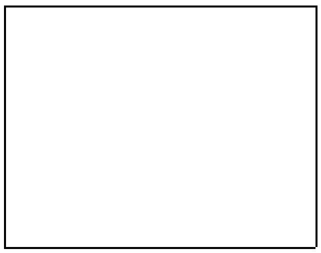
$x_i := 3 \cdot \sqrt{t_i}$

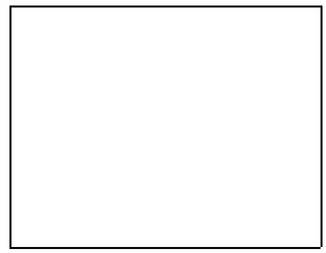
$y(x,t) := x \cdot t^2$

$t_i :=$ ▮ (Enter values for t.)

$x_i := 3 \cdot \sqrt{t_i}$

$y_i := x_i \cdot \left(t_i\right)^2$





3. What conditions (at least three) must be satisfied in order to have <u>complete</u> destructive interference of two sound waves?

4. Explain with a diagram and a few words why equations (2) are the correct expressions for the two paths D_1 and D_2.

5. Sketch the graph h vs. n. [No numbers on this graph! And no calculations. Just think a minute and make a qualitative sketch, showing what the graph should look like. Ask yourself, should h increase, decrease, or stay constant as n increases.]

6. Sketch the graph λ vs. n . [No numbers! Just a qualitative sketch, showing what the graph should look like.]

7. Ultrasound is used as a tool in obstetric medicine to "see" inside the body objects larger than about a wavelength. The speed of sound in humans is about 1500 m/s, the same as in water. What would be the wavelength of 5 MHz medical ultrasound waves in humans?

8. (Counts as two questions) How do you compute δ v, the uncertainty in v, from measurements of f, δ f, λ , and δ λ ? In this experiment, how is δ λ determined?

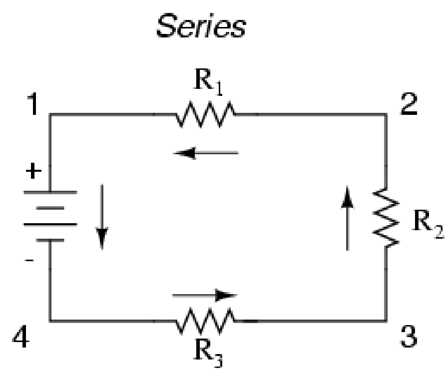
Source: http://www.colorado.edu/physics/phys1140/phys1140_fa01/Experiments/M2/M2.html

Outcome #10

What are "series" and "parallel" circuits?

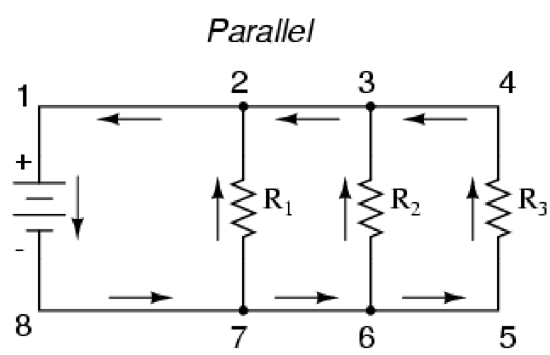
Circuits consisting of just one battery and one load resistance are very simple to analyze, but they are not often found in practical applications. Usually, we find circuits where more than two components are connected together.

There are two basic ways in which to connect more than two circuit components: *series* and *parallel*. First, an example of a series circuit:



Here, we have three resistors (labeled R1, R2, and R3), connected in a long chain from one terminal of the battery to the other. (It should be noted that the subscript labeling – those little numbers to the lower-right of the letter "R" – are unrelated to the resistor values in ohms. They serve only to identify one resistor from another.) The defining characteristic of a series circuit is that there is only one path for electrons to flow. In this circuit the electrons flow in a counter-clockwise direction, from point 4 to point 3 to point 2 to point 1 and back around to 4.

Now, let's look at the other type of circuit, a parallel configuration:

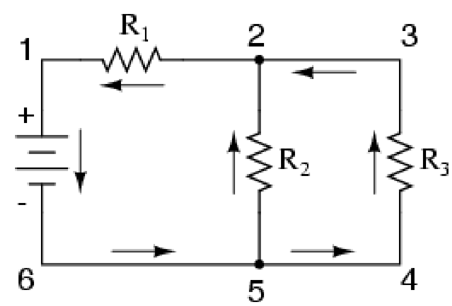


Again, we have three resistors, but this time they form more than one continuous path for electrons to flow. There's one path from 8 to 7 to 2 to 1 and back to 8 again. There's another from 8 to 7 to 6 to 3 to 2 to 1 and back to 8 again. And then there's a third path from 8 to 7 to 6 to 5 to 4 to 3 to 2 to 1 and back to 8 again. Each individual path (through R1, R2, and R3) is called a *branch*.

The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points. Looking at the schematic diagram, we see that points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. Note that all resistors as well as the battery are connected between these two sets of points.

And, of course, the complexity doesn't stop at simple series and parallel either! We can have circuits that are a combination of series and parallel, too:

Series-parallel



In this circuit, we have two loops for electrons to flow through: one from 6 to 5 to 2 to 1 and back to 6 again, and another from 6 to 5 to 4 to 3 to 2 to 1 and back to 6 again. Notice how both current paths go through R1 (from point 2 to point 1). In this configuration, we'd say that R2 and R3 are in parallel with each other, while R1 is in series with the parallel combination of R2 and R3.

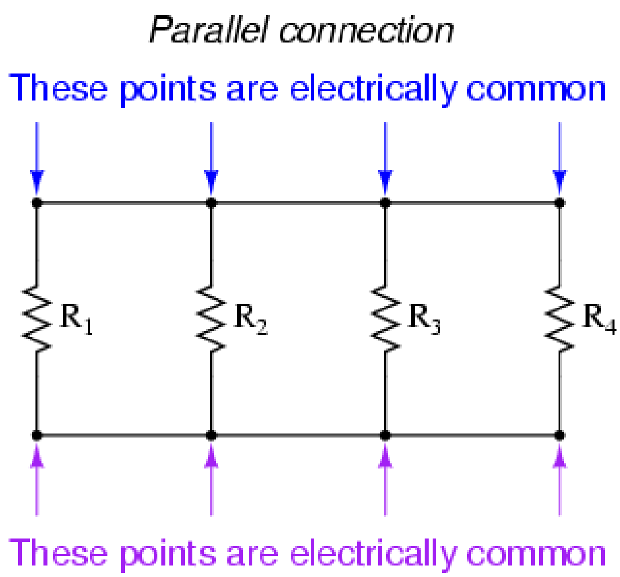
This is just a preview of things to come. Don't worry! We'll explore all these circuit configurations in detail, one at a time!

The basic idea of a "series" connection is that components are connected end-to-end in a line to form a single path for electrons to flow:

Series connection

only one path for electrons to flow!

The basic idea of a “parallel” connection, on the other hand, is that all components are connected across each other’s leads. In a purely parallel circuit, there are never more than two sets of electrically common points, no matter how many components are connected. There are many paths for electrons to flow, but only one voltage across all components



Series and parallel resistor configurations have very different electrical properties. We’ll explore the properties of each configuration in the sections to come.

REVIEW:

- In a series circuit, all components are connected end-to-end, forming a single path for electrons to flow.
- In a parallel circuit, all components are connected across each other, forming exactly two sets of electrically common points.
- A “branch” in a parallel circuit is a path for electric current formed by one of the load components (such as a resistor).

Source: http://www.allaboutcircuits.com/vol_1/chpt_5/1.html#