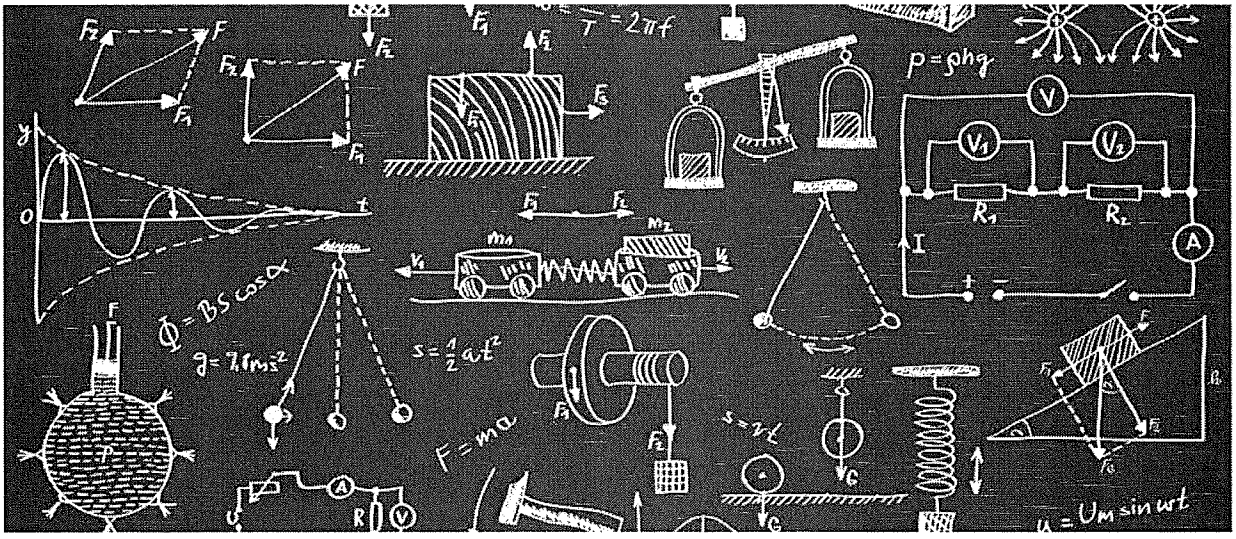
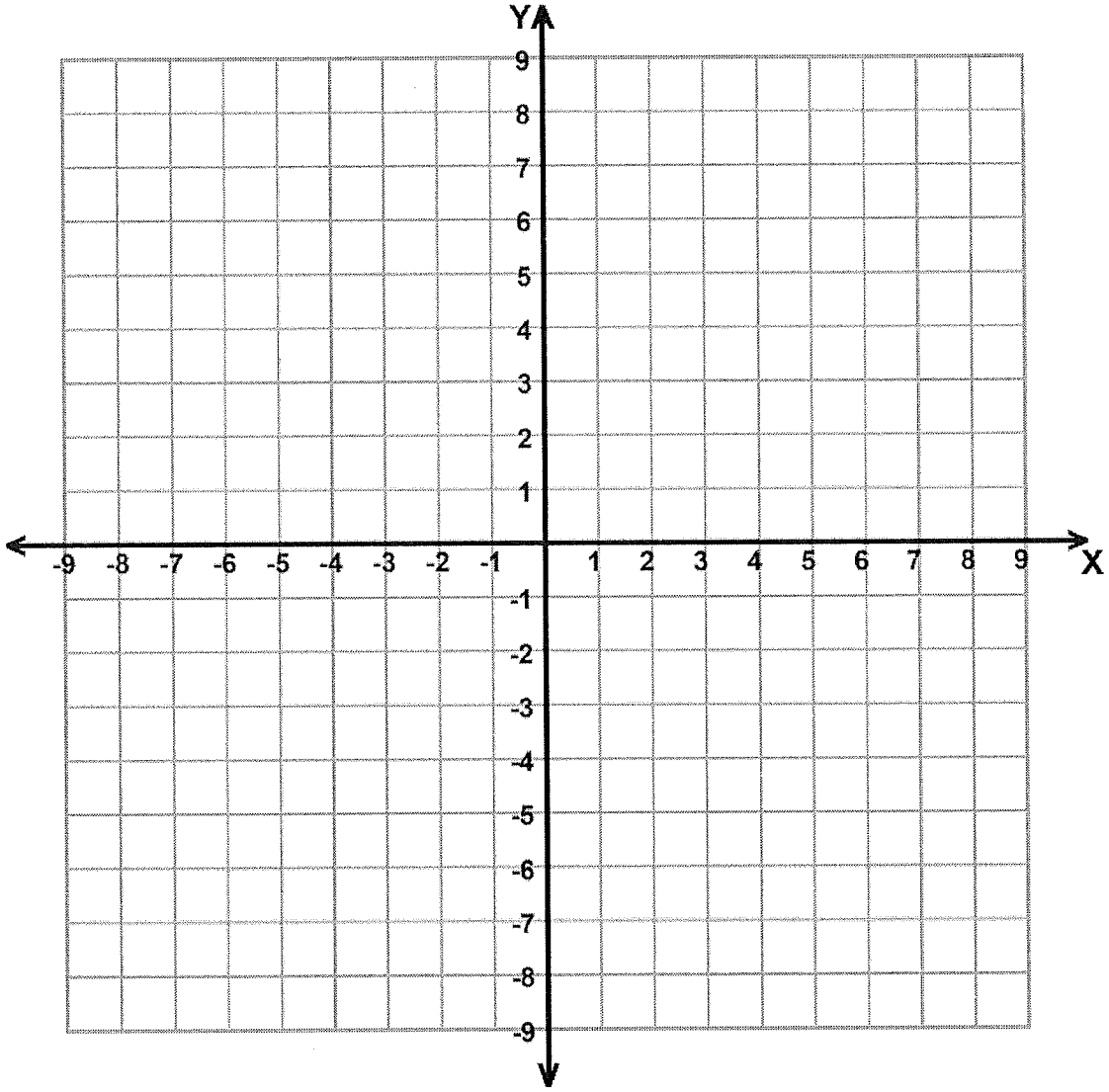
Name: _____

Physics



Graphing Notes

Four Quadrant Graphing Puzzle



Connect each sequence of points with a line.

(-3,0) , (-4,-1) , (-6,-2) , (-6,-3) , (-5,-4) , (-4,-4) , (-3,-4) , (1,-2) End of Sequence

(-1,1) , (5,3) , (6,5) , (7,5) , (7,3) , (9,2) , (8,1.5) , (6,2) , (2,-.5) End of Sequence

(-5,-3) , (-5.5,0) , (-5,0) , (-5,-6) , (-4.5,-6) , (-5,-3) End of Sequence

(-9,3) , (-7,4) , (7,-3) , (5,-4) , (-9,3) End of Sequence

(-6,-2) , (-4,-3) , (-2,-2) , (-1,-1) End of Sequence

(5,3) , (4,4) , (4.5,4.5) , (5.5,4) End of Sequence

(-4,-1) , (-2,-2) End of Sequence

Cartesian Coordinate BATTLESHIP

OBJECT OF THE GAME:

You are the admiral of a prestigious fleet of four ships. Your mission is to seek out and destroy the enemy fleet using your gigantic on board cannons.

FLEET SETUP:

Arrange your fleet on the Cartesian plane as follows:

Carrier	- 5 intersections	(see diagram below)
Cruiser	- 4 intersections	
Destroyer	- 3 intersections	
Submarine	- 2 intersections	

START OF PLAY:

The first admiral to attack is determined by a coin toss. Admirals then alternate attacking.

THE ATTACK:

To fire at an enemy the admiral must call out the ordered pair (x,y) representing the coordinate he or she wishes to attack.

DAMAGE REPORT:

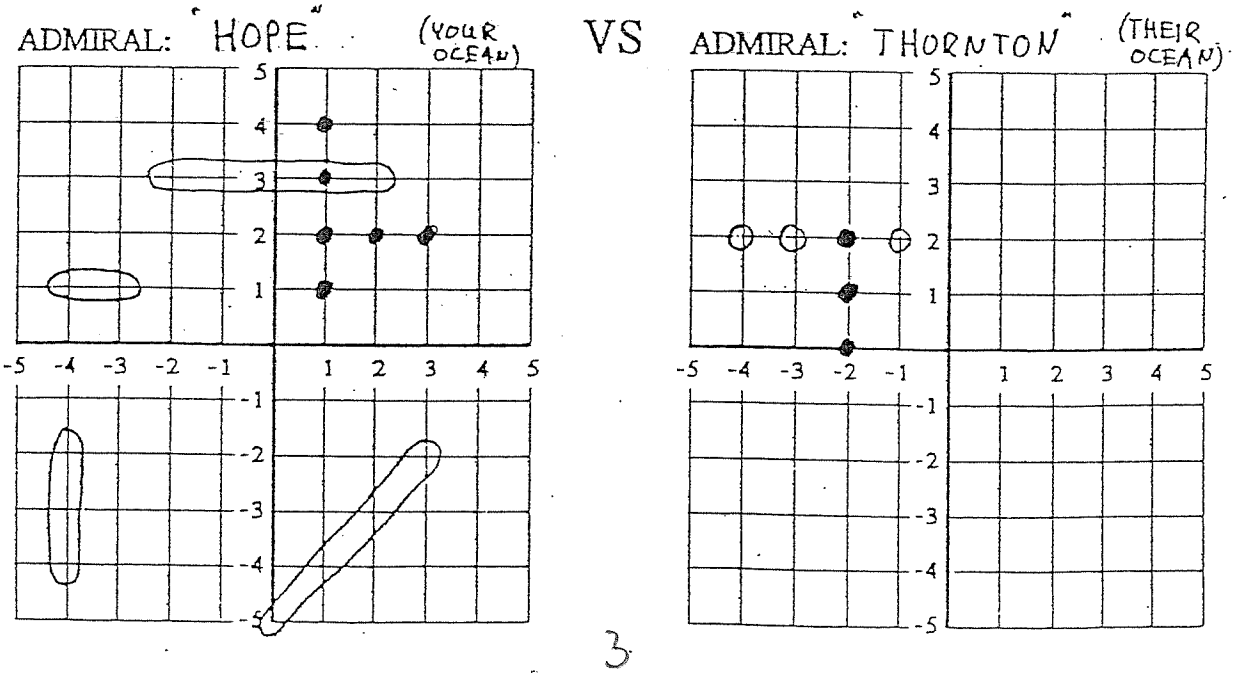
The admiral being shot upon must locate the coordinate being attacked and report either a "hit" or "miss". When the entire ship has been hit the admiral must report "hit and sunk".

MARKING YOUR CARTESIAN PLANE:

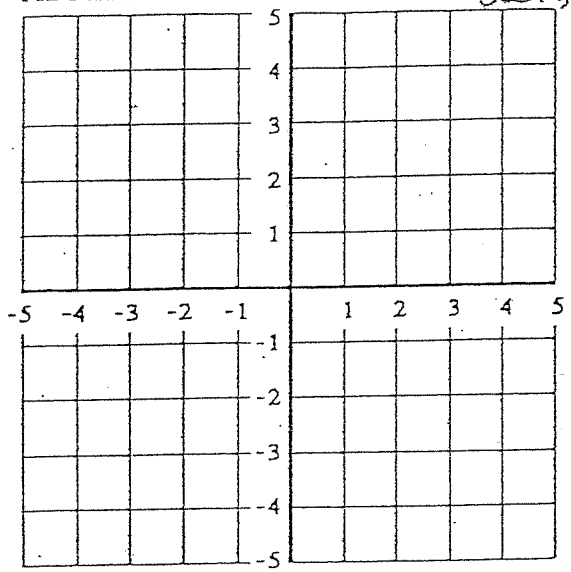
YOUR PLANE	THEIR PLANE
● = their shot (hit or miss)	○ = your shot (miss)
	● = your shot (direct hit)

NB: It is each players responsibility to keep track of shots fired and fired upon. The accidental attack on the same coordinate twice results in a wasted turn.

SAMPLE GAME GRID:

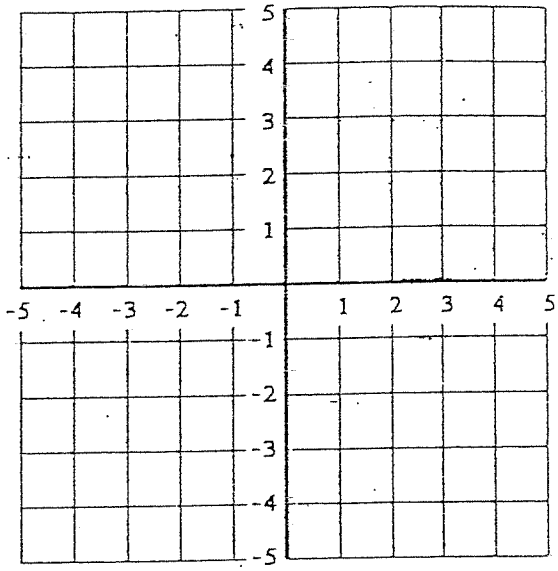


ADMIRAL: (my ocean)

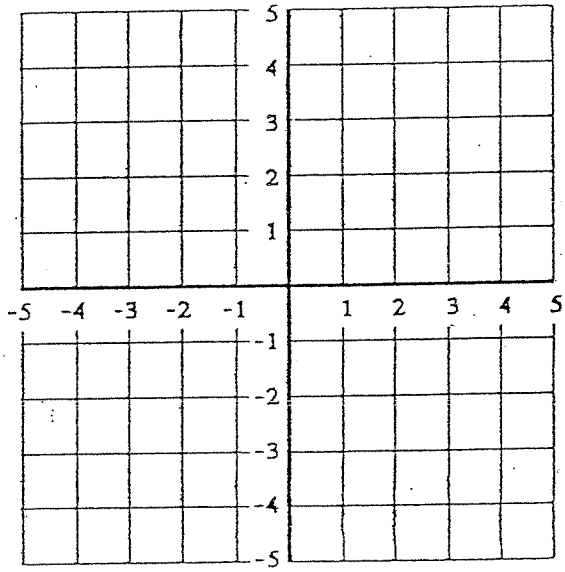


VS

ADMIRAL: (their ocean)

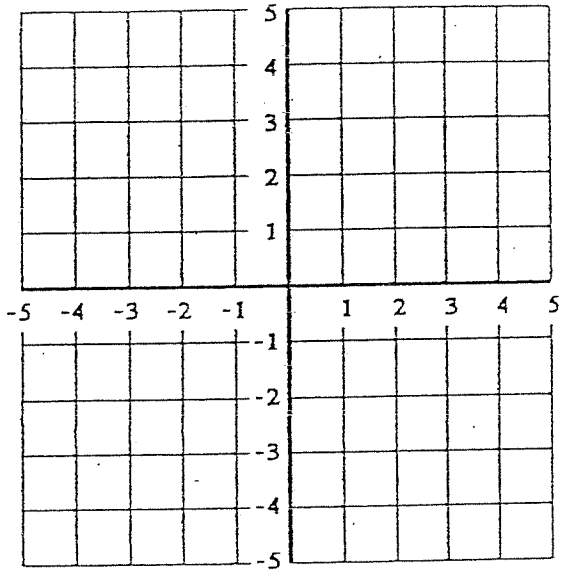


ADMIRAL:

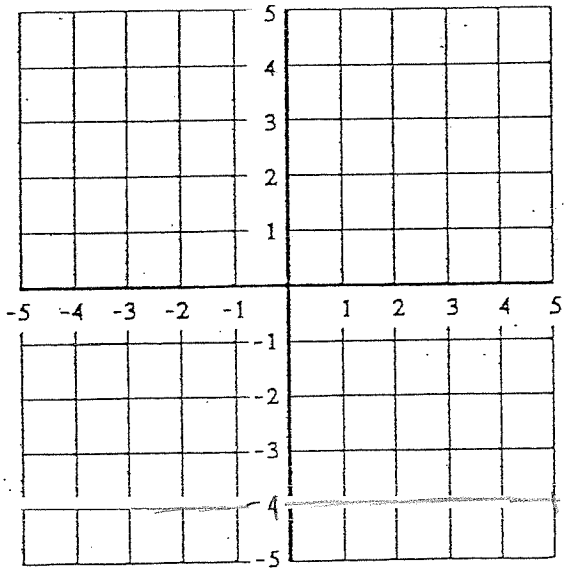


VS

ADMIRAL:

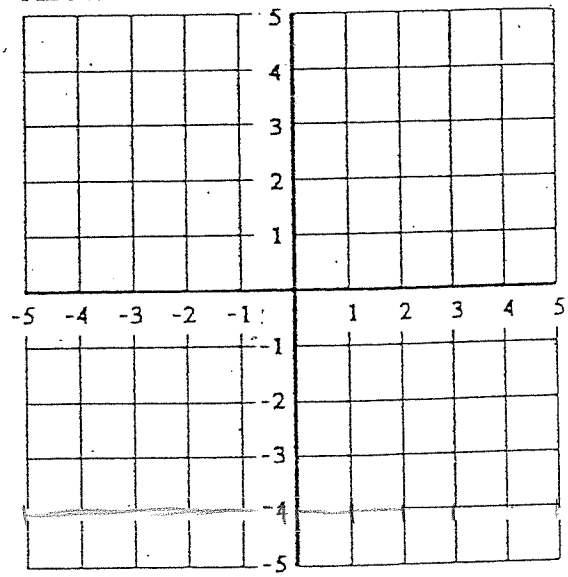


ADMIRAL:



VS

ADMIRAL:



"Finding X" **Name:** _____

In general:

- Deal with things added to/subtracted from the term with the variable, then things multiplied onto/divided into the variable.
- Look at what the number is doing relative to the variable, remove the number, and do the opposite to the other side.

A. Numbers being added/subtracted relative to the term with the variable.

Example. Solve for X:

$$X + 5 = 2$$
$$X \cancel{+ 5 - 5} = 2 - 5$$
$$X = -3$$

Or, simply: $X + 5 = 2$
$X \cancel{+ 5} = 2 - 5$
$X = -3$
Take to the other side and do opposite operation
(Opposite of + is -)

Try These. Solve for X:

a. $X + 3 = 6$ b. $X - 3 = 6$ c. $3 + X = -6$ d. $3 - X = 6$

B. Numbers being multiplied/divided relative to the term with the variable

Examples. Solve for X:

a. $5X = 15$

$\cancel{5}X/\cancel{5} = 15/5$

$X = 3$

(Op. of mult is divide)

Or, simply: $5X = 15$
$\cancel{5}X = 15 \div 5$
$X = 3$
Take to the other side and do opposite operation

b. $\frac{1}{2} X = 5$

$\cancel{\frac{1}{2}} X * \cancel{2} = 5 * 2$

$X = 10$

(Op. of divide is mult.)

Or, simply: $\frac{1}{2} X = 5$
$\cancel{\frac{1}{2}}X = 5 * 2$
$X = 10$
Take to the other side and do opposite operation

Try These. Solve for X:

a. $3X = 24$ b. $-3X = 24$ c. $X \div 4 = 6$ d. $\frac{1}{4} X = -6$

C. Putting it all together.

Example. Solve for the variable:

$3X - 5 = 40$

$3X - 5 + 5 = 40 + 5$ (deal with the term added/subtracted from the X term first)

$3X = 45$

$3X \div 3 = 45 \div 3$ (then deal with the number multiplied or divided onto X)

$X = 15$

Try These. Solve for the variable:

a. $4X + 5 = 21$ b. $-6A + 2 = 20$ c. $\frac{1}{2} R - 3 = 7$ d. $4 + 5Y = 19$

e. $7 - H = -9$ f. $-2 - 2F = -2$ g. $-\frac{1}{4} V + 8 = 5$ h. $X \div 5 + 2 = \frac{1}{5}$

i. $5 = 4Y - 3$ j. $7 = \frac{2}{5}H + 1$ k. $\frac{1}{4} = \frac{1}{4}R + 2$ l. $7 = 9 + 5V$

m. $2K + 3 = 3K + 5$ n. $5N - 3 = 4 - 7N$ o. $\frac{1}{2}M + \frac{1}{3} = 1 - M$ p. $-2P + \frac{4}{5} = 3 + \frac{1}{3}P$

Name: _____

Two-Step Equations: Whole Numbers

Sheet 1

Solve each equation.

1) $9c + 1 = 10$

2) $6y - 5 = 7$

3) $8 = 3a - 4$

4) $\frac{m}{5} + 9 = 11$

5) $13 + 7x = 27$

6) $17 - q = 6$

7) $\frac{n - 31}{4} = 2$

8) $1 + 2r = 35$

9) $42 + 5t = 8t$

10) $4p - 3 = 17$

Name : _____

Two-Step Equations: Fractions

Solve each equation.

1) $\frac{7}{6}d + \frac{4}{3} = -\frac{1}{3}$

2) $5\frac{1}{2} - u = \frac{9}{4}$

3) $-m - \frac{7}{8} = -10$

4) $\frac{2}{7} = \frac{4}{5} + 9q$

5) $2\frac{2}{5} = \frac{3}{8} + \frac{h}{\left(\frac{1}{3}\right)}$

6) $\frac{5}{9}c - \frac{3}{4} = \frac{7}{9}c$

7) $\frac{9}{4}\left(w - \frac{1}{9}\right) = \frac{7}{2}$

8) $\frac{y}{\left(\frac{5}{3}\right)} + 5 = 2\frac{5}{6}$

9) $-\frac{2}{3}p + \frac{8}{3} = -3p$

10) $-2\frac{1}{7}n - \frac{6}{7} = -1\frac{3}{7}$

Introduction to Current Electricity

Conductors/Insulators

A few definitions...

Electric current Ex:

Electron Flow Ex:

Conductor Ex:

Insulator Ex:

Semi-conductor Ex:

Conductance depends on:

1)
best:

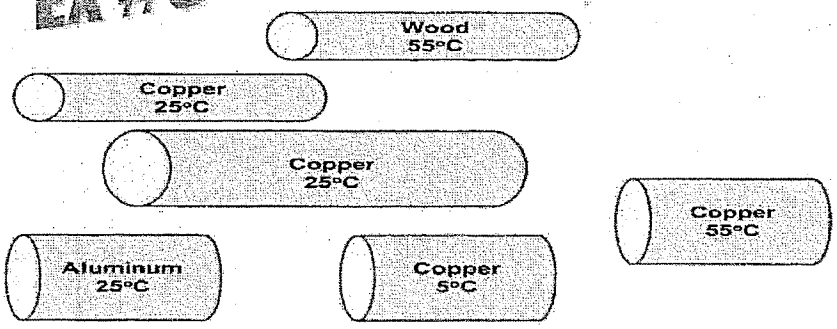
2)
best:

3)
best:

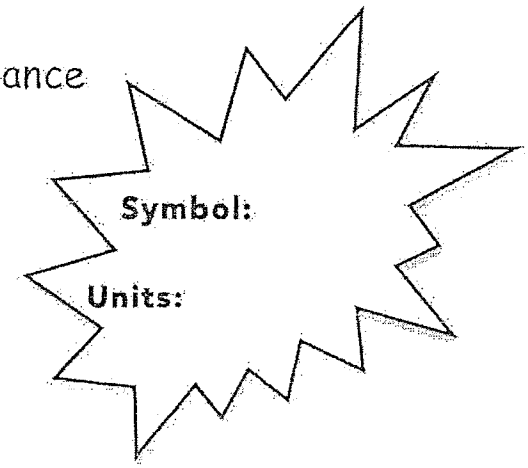
4)
best:

Examples:

Ex #3 Which wire is the **best** conductor?



Current, Voltage, Resistance



Current:

Current Intensity - the _____ that flow past a given point in a circuit _____ through a wire.

An _____ is the instrument used to measure current intensity

Symbol:

The current intensity in a circuit can be determined using the formula:

$$I = \frac{q}{t}$$

I is the current intensity in amps (A)
q is the charge in coulombs (C)
t is time in seconds (s)

NOTE:

Let's try some examples

1. What is the current flowing through a car headlight if there are 900 C of charge used in 1 minute?	2. How much charge does it take to operate an iPod for 15 minutes if the current is 2A?

Voltage (Potential Difference):

Potential Difference is the _____ transferred between _____ in an electrical circuit.

A _____ is used to measure potential difference

Symbol:

Symbol:

Units:

The potential difference in a circuit can be determined using the formula:

$$V = \frac{E}{q}$$

V is potential difference in volts (V)
E is the energy in joules (J)
q is the electric charge in coulombs (C)

NOTE:

Let's try some examples

1. In a house, how much energy is provided by 120V service providing 200C of charge?

Resistance:

Resistance is how _____ it is for current to flow

Symbol:

Units:

The potential difference in a circuit can be determined using the formula:

OHM'S LAW

R is the resistance in ohms (Ω)
V is potential difference in volts (V)
I is the current intensity in amps (A)

A resistor is used to:

1)

2)

Resistance is the opposite of conductance!

Conductor -

vs.

Resistor -

Let's try some examples

1. An stove element 30 Amperes going through it, and carries 120 volts of electricity, how much resistance is in this circuit?

2. A circuit has a potential energy difference of 240 V and offers a resistance of 6Ω, what is the intensity of the current flow?

3. A circuit has a resistance of 10Ω & a current intensity of 5A. What is the potential difference?

Moving Charges

The amount of charge that has flowed in a circuit can be calculated using the equation

Charge	**=**	**Current**	**x**	**time**
(in coulombs, C)		**(in amps, A)**		**(in seconds)**

$$Q = I \times t$$

1. What is an electric current? Use key words in your answer.

2. A current of 1.5A flows through an electric toothbrush for 90 seconds. How much charge has flowed through the toothbrush?

3. 350 coulombs of charge flows through an iron in 70 seconds. What is the current flowing through the iron?

4. If a current of 2A flows through a bulb for 5 minutes, how much charge has passed through the bulb?

5. How long would it take for 2000 coulombs of charge to flow through a motor if the current is 2.5A?

Voltage Energy Charge Worksheet

1. Find the unknown quantity:

a) V = ?
W = 45 J
Q = 15 C

b) V = 9 V
W = ?
Q = 150 C

c) V = 1.5 V
W = 225 J
Q = ?

2. The potential difference between the two terminals on a battery is 9 volts. How much work (energy) is required to transfer 10 C of charge across the terminals?

3. Ten joules of work (energy) are required to transfer 2 C of charge from X to Y. What is the difference in potential between these two points?

4. It requires 600 J of energy to transfer a quantity of charge between points C and D of a circuit which have a potential difference of 30 V. How much charge is transferred?

OHM'S LAW PROBLEMS

Complete the following questions. Show all work.

1. What current will flow through a wire of 2 Ω resistance, connected to a 6 V automobile battery?

2. What voltage is necessary to cause a current of 2 A through a wire of 40 Ω resistance?

3. A wire whose resistance is 3 Ω is connected to the poles of a storage battery and the voltage between the ends of the wire is 6 V. What is the current in the wire?

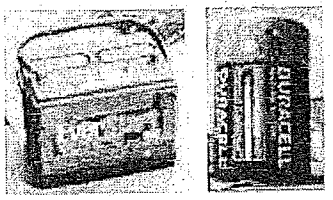
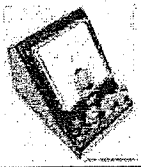
4. What is the resistance of a circuit in which a 100 V battery produces a 12 A current?

5. A carbon resistor permits 0.3 mA current to run through it when the potential difference across it is 5000 V. What is the resistance? (1000 mA = 1 A)

6. How much current will run through a 25 MΩ resistor with 10 000 volts across it? (1,000,000 Ω = 1 MΩ)

Circuits

- A circuit is made up of a _____, _____ & _____ that allow current to leave a _____, travel through the elements & return back to the power source.

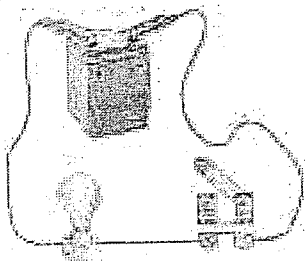
Picture	Part of a Circuit	Symbol
	Electric Cell	
	Two-cell battery	
	Switch	
	Light bulb - Lamp	
	Voltmeter	
	Ammeter	
Ex:	Resistor	

Use with textbook pages 280–285.

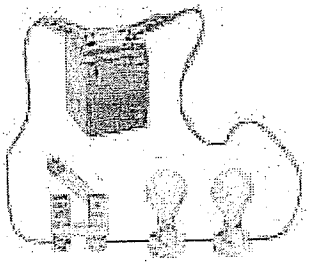
Drawing circuit diagrams

Use circuit symbols to draw circuit diagrams for each of the following.

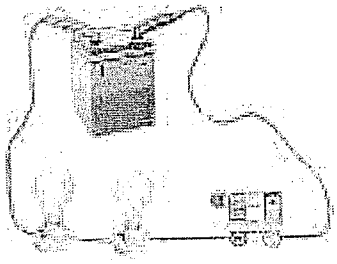
1.



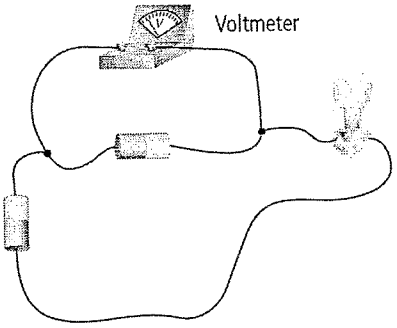
2.



3.



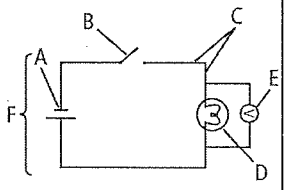
4.



Use with textbook pages 280–285.

Electric current

Match each Term on the left with the letter on the Diagram on the right. Each letter on the Diagram may be used only once.

Term	Diagram
1. _____ cell	
2. _____ bulb	
3. _____ switch	
4. _____ circuit diagram	
5. _____ conducting wire	

Circle the letter of the best answer.

6. What does the symbol —Ⓐ— represent?

   A. a load

   B. a battery

   C. a voltmeter

   D. an ammeter

7. Which of the following are correctly defined?

I.	ampere: unit for electric current
II.	ammeter: device used to measure current
III.	electric circuit: an incomplete pathway through which electrons can flow

   A. I and II only

   B. I and III only

   C. II and III only

   D. I, II, and III

8. Which of the following is not an example of an electric load?

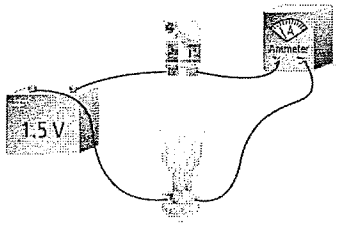
   A. a motor

   B. a heater

   C. a light bulb

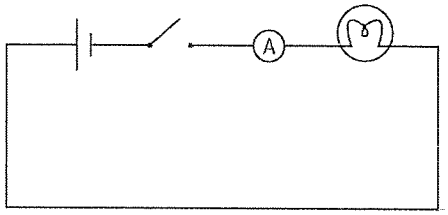
   D. a generator

Use the following diagram to answer question 9.

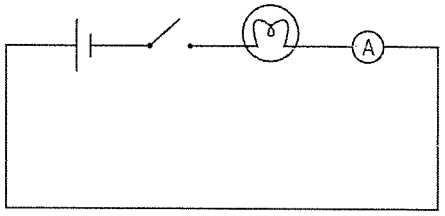


9. Which circuit diagram represents the illustration shown above?

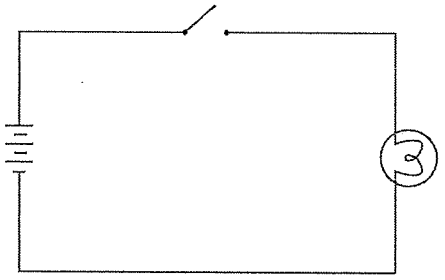
A.



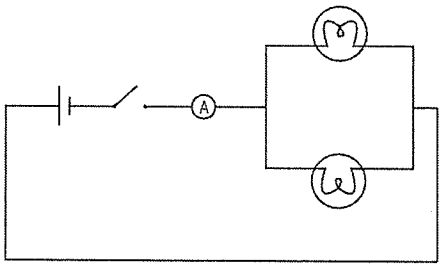
B.



C.

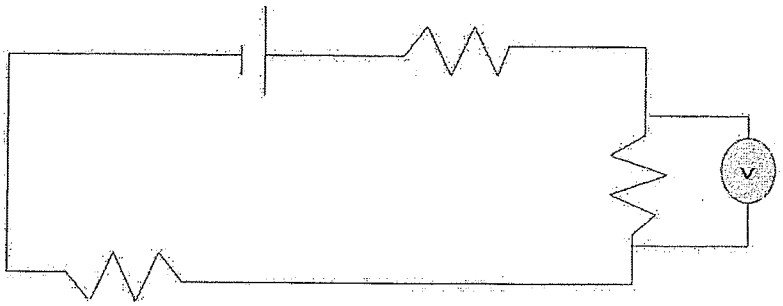


D.



Circuits, Series and Parallel

Example of a circuit



There are 2 types of circuits:

1. Series Circuit	2. Parallel Circuit
- Components are connected end to end - Current only follows one path - If one part of the circuit is broken, the entire circuit will stop functioning	- Circuit that contains at least one branch - Current can follow at least 2 different paths - If part of the circuit is defective another part may still be able to operate.

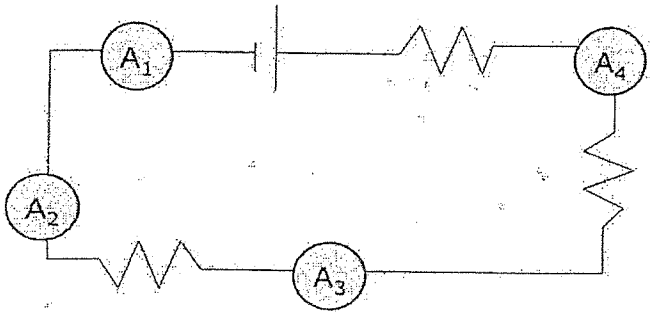
	Series	Parallel
Current (I)		
Voltage (V)		
Resistance (R)		

Ammeters must be connected in _____.

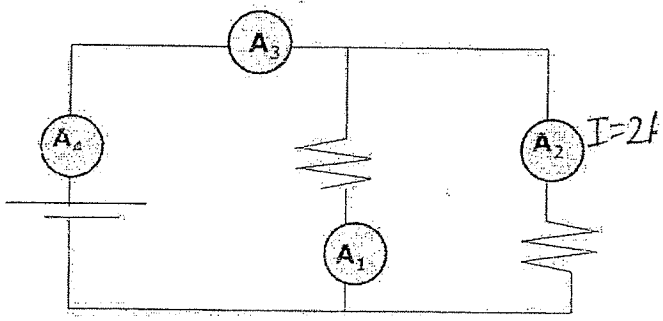
Voltmeters must be connected in _____.

Current:

Series: $I_{Total} = 3\,A$

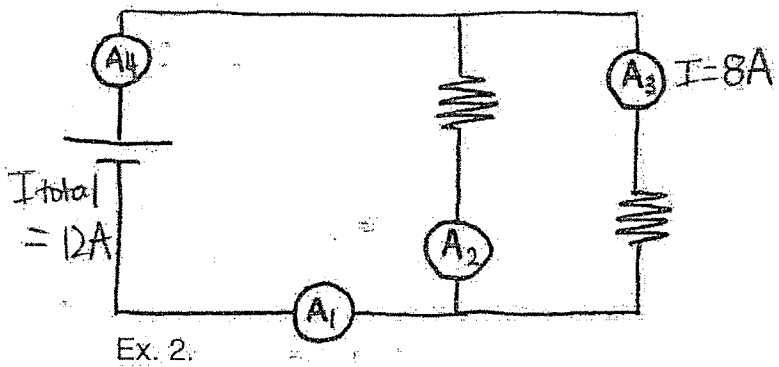


Parallel: $I_{Total} = 8\,A$



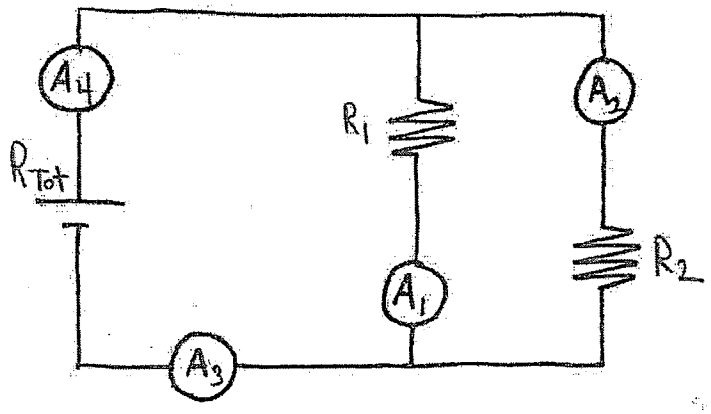
Examples:

Ex 1. What is the reading on the ammeters?

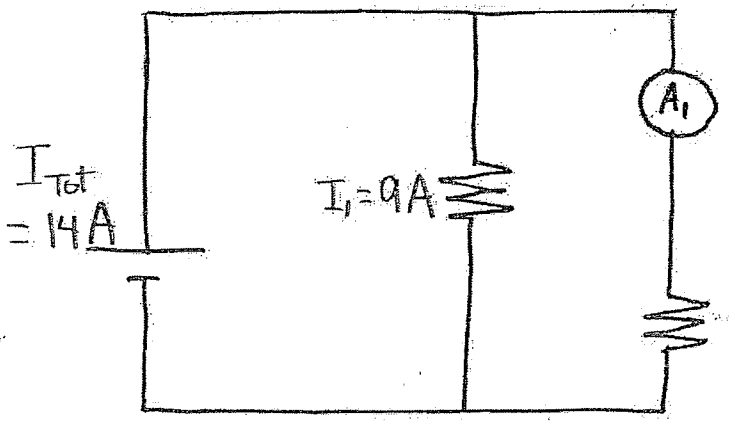


Ex. 2.

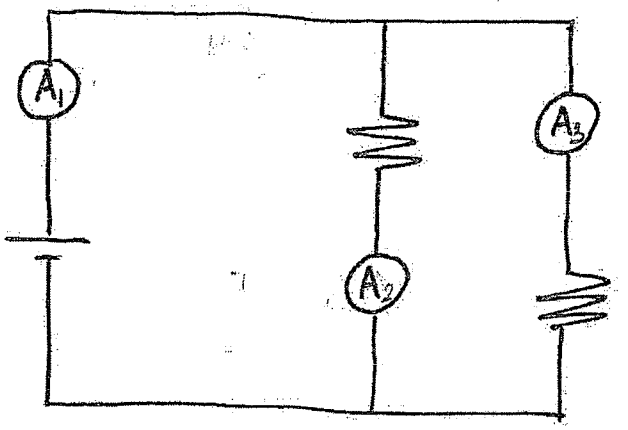
Which ammeter correctly measures the current flowing through R_1?	
Which ammeter correctly measures the current flowing through R_2?	
Which ammeter correctly measures the total current?	



Ex. 3. What is the reading on the ammeter (A_1)?

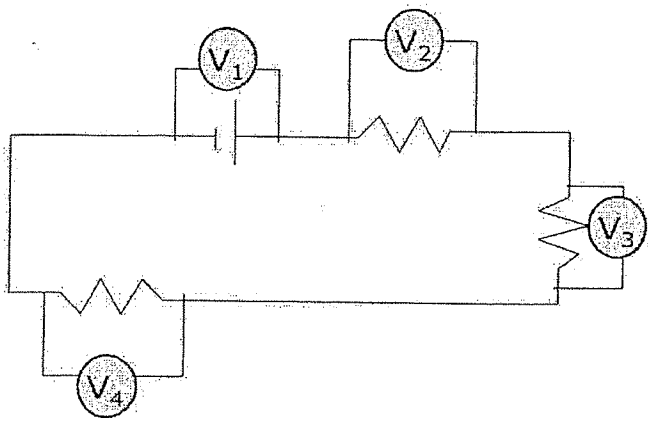


Ex. 4. If the reading on ammeter 2 (A_2) is 10 amps & the reading on ammeter 3 (A_3) is 4 amps, what is the reading on ammeter 1 (A_1)?

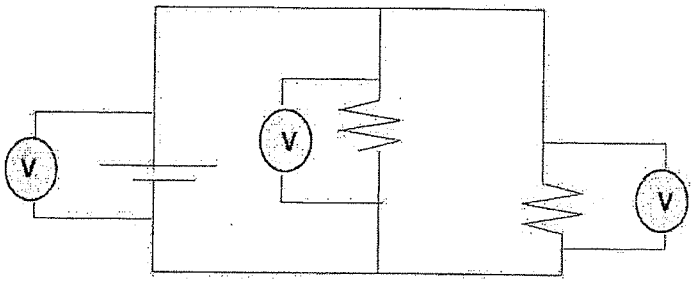


Voltage:

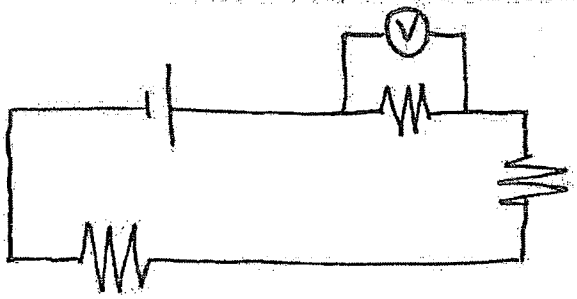
Series: Voltmeters do NOT read the same



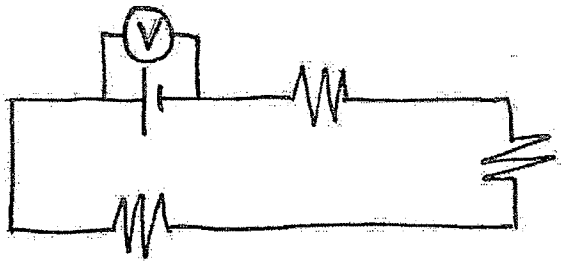
Parallel: Voltmeters will have the **same** readings.



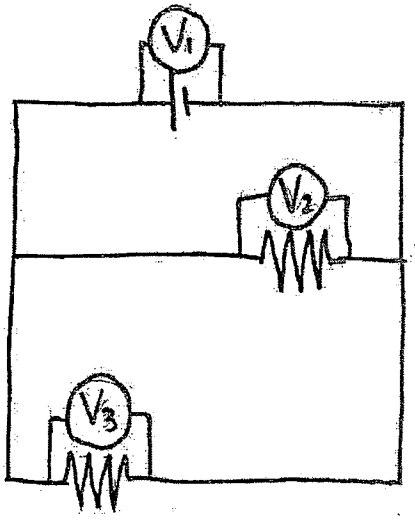
Ex. 5. For this series circuit, what is the reading on the voltmeter given the following information?



Ex. 6. For this series circuit, what is the reading on the voltmeter given the following information?



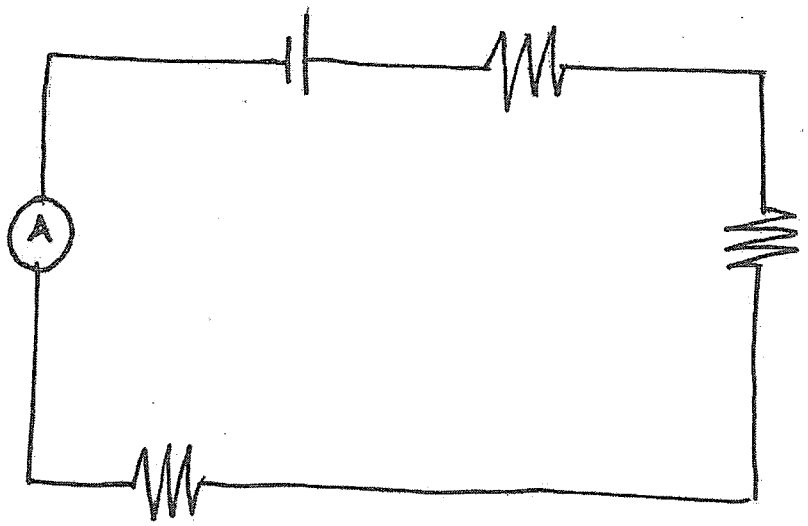
Ex. 7. What is the reading on the voltmeters? ⟶



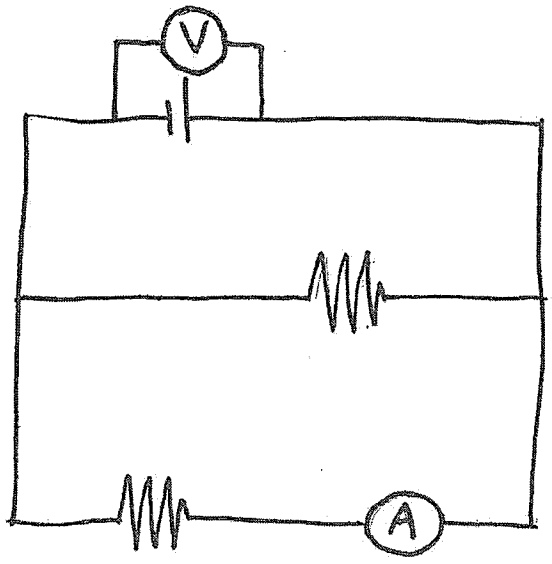
Ex. 8.

1. What is the voltage going through V_2 if the reading on the ammeter is 2 amps?

2. What is the voltage going through V_T if the reading on the ammeter is 2 amps?



Ex. 9. If the voltmeter reads 20V & the ammeter reads 1A, solve for the equivalent resistance, R_{Tot}?



Solving Series and Parallel Circuits Worksheet

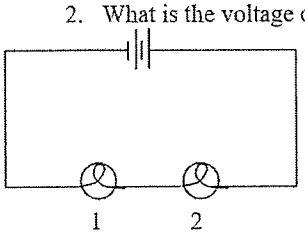
Use the examples in your notes to help you solve the unknown values in the following circuits. Don't forget to include units with your answers.

1. State the three mathematical equations for **series circuits** that explain how current, voltage and resistance in one part of the circuit is related to the total current, voltage or resistance (i.e. use V_1, V_2 for A); I_1, I_2 for B); and R_1, R_2 for C)) :

A) V_T = _____ B) I_T = _____

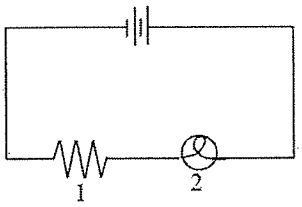
C) R_T = _____

2. What is the voltage of light bulb 1(V_1)? (show your calculations).



V_T = 6 V V_1 = _____ V_2 = 2 V

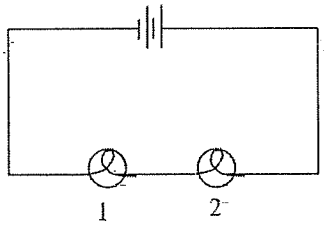
3. What is the total voltage (V_T) for the circuit? What is the current at the resistor (I_1)?



V_T = _____ V_1 = 3 V V_2 = 1 V

I_T = 6 A I_1 = _____ I_2 = 6 A

4. Calculate the total resistance using the information given and your Ohm's Law equations (R=V/I). *Hint- you will only need to use V_T as the voltage for the circuit in your calculation.

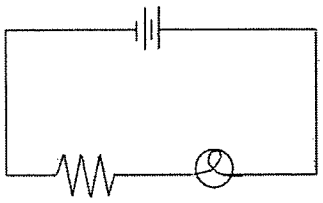


V_T = 10 V V_1 = 6 V V_2 = 4 V

I_T = 5A

R_T = _____

5. Solve for all of the missing values. Use your Ohm's Law equations (R=V/I) to solve for resistance.



V_T = _____ V_1 = 5 V V_2 = 3 V

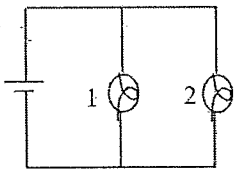
I_T = 2A

R_T = _____

6. State the two equations for **parallel circuits** that explain how current and voltage in one part of the circuit is related to the total current and voltage for the circuit (i.e. use V_1, V_2 for A); and I_1, I_2 for B)) :

A) $V_T =$ _____ B) $I_T =$ _____

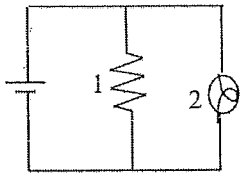
7. What is the voltage for light bulb 2 (V_2)? What is the current at light bulb 1 (I_1)?



$V_T = 6$ V $V_1 = 6$ V $V_2 =$ _____

$I_T = 12$ A $I_1 =$ _____ $I_2 = 7$ A

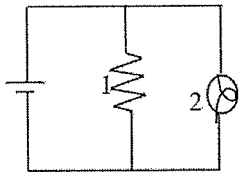
8. Solve for all of the missing values.



$V_T = 120$ V $V_1 =$ _____ $V_2 =$ _____

$I_T =$ _____ $I_1 = 16$ A $I_2 = 10$ A

9. Solve for all of the missing values. Use your Ohm's Law equations (R=V/I) to solve for total resistance.



$V_T =$ _____ $V_1 = 11$ V $V_2 =$ _____

$I_T =$ _____ $I_1 = 4$ A $I_2 = 8$ A

$R_T =$ _____

Create your own circuit and have a classmate solve it!

PHET Circuits Lab

READ CAREFULLY!!

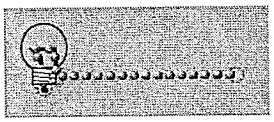
Start by getting together a couple of sheets of paper and something to write with ... colored pencils might be nice if you want to give your drawings some flair.

Then access this site: http://phet.colorado.edu/simulations/sims.php?sim=Circuit_Construction_Kit_DC_Only and choose to "Run Now!" ...

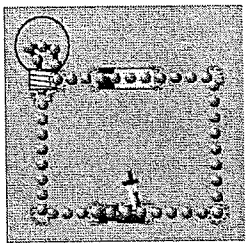
You need to build several kinds of circuits, make several measurements on each, record what you did by drawing the circuit on your paper and then labeling it appropriately ... you will also need to answer a few questions along the way (***write the questions in your notes*** as you answer them).

Step 1: Set up and play with the simulator ...

- make sure the 'Lifelike' button is clicked and it's turned on ...this will give you a more realistic picture of what you are building
- now, note that you have available a bunch of stuff ... wire, resistors, batteries, light bulbs, etc. ... you can grab these at any time and drag them out to the work surface ...
- grab a wire and do this ... you can make the wire longer by clicking on either end and moving it ...
- drag a resistor out ... and remove it by right clicking on it and choosing 'Remove' ... note that right clicking on an item/connection will typically give you options for dealing with that item such as deleting it or changing its value
- drag a light bulb out as well ... notice it has two points for connection ... one at the bottom and another at the top ...
- you connect items by dragging their ends over one another ... connect the wire to the light bulb ... and note that after you do this, they both move together as you drag them around ...

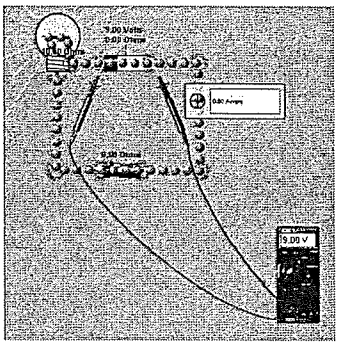


- you break connections by right clicking on the connection and choosing 'split junction' ... do this to the wire and bulb
- now grab some more wires, a light bulb and a switch out and connect them all together to form a simple series circuit where the bulb is turned on/off by using the switch ... you operate the switch by clicking on it and moving it ...



- click on the "Show Values" button and note how the values for each item is shown ... you will want to put these values on your diagrams ... and note that you will have to click this button almost every time you make a change to your simulation ...
- under 'Tools' check 'Voltmeter' and 'Non-Contact Ammeter' ... you will use these to measure voltages and currents in the circuits you build ...

- you can move these tools around and use them just like the real things we use in the classroom lab ... try it by measuring the voltage of the battery ...move the leads to the ends of the battery and you should see 9.0V in the display of the voltmeter ... to use the ammeter, just move its crosshairs over a wire and it will read the current flowing thru that wire ... try it and you should see a current of .90 amps (Ohm's law says I=V/R or 9.0V/10.0Ohms = .9)

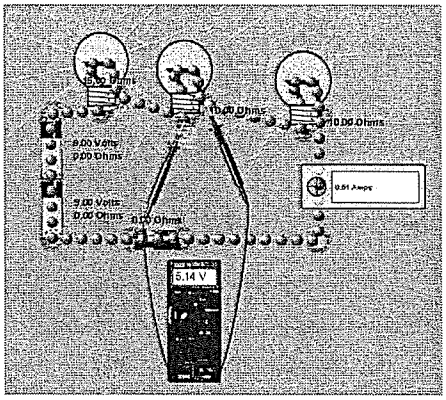


Step 2: Build a simple series circuit with one light bulb....

- guess what? ... if you followed all the instructions in Step 1 above, you've done this ... now just *draw it in your notes* ...

Step 3: Build a more complex series circuit...

- drag 3 bulbs out and connect them in a series circuit using two 9.0V batteries ...
- change the resistance of one of the 3 bulbs to 15ohms by right clicking on it and choosing 'Change Resistance' ... make sure you click 'Show Values' to see all of the values ... *draw your circuit in your notes* ...
- using the voltmeter, measure the voltage across each of the 3 light bulbs and *record it on your drawing* ...



Question #1: What is the relationship between the sum of the individual voltages and the total voltage of the batteries?

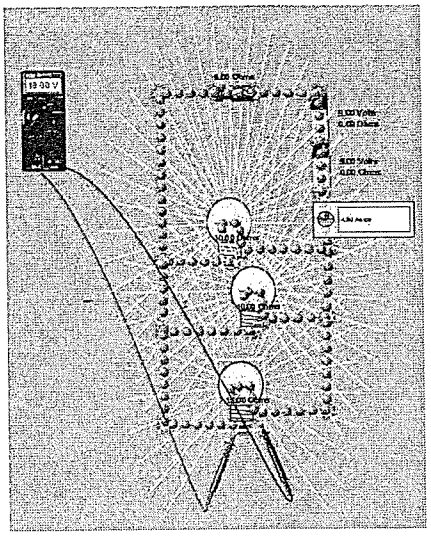
- using the ammeter, measure the current on all wires in your diagram ... and *record these on your drawing* ...

Question #2: How does the value of the current change around the circuit?

- now click on the 'Schematic' button to see how your circuit is represented with symbols for each element in your circuit ... *draw your schematic diagram in your notes* ... click on the 'Lifelike' button when you are finished ...
- break the connection for one of the light bulbs ....

Question #3: Describe what happens when the connection for one of the items in a series circuit is broken. Why does this happen?? ... your answer needs to describe this is terms of the electron flow.

Step 4: Build a parallel circuit ... you can either re-arrange the series circuit above or (recommended) click the 'Reset' button and start with a clean work area...



- drag 3 bulbs out and connect them in a parallel circuit with two 9.0V batteries ...
- change the resistance of one of the 3 bulbs to 15ohms by right clicking on it and choosing 'Change Resistance' ... make sure you click 'Show Values' ... *draw your circuit in your notes* ...
- using the voltmeter, measure the voltage across each of the 3 light bulbs and *record your values on your drawing* ...

Question #4: What is the voltage across light bulb?

- using the ammeter, measure the current in wire connected to each light bulb ... and *record these on your drawing* ...

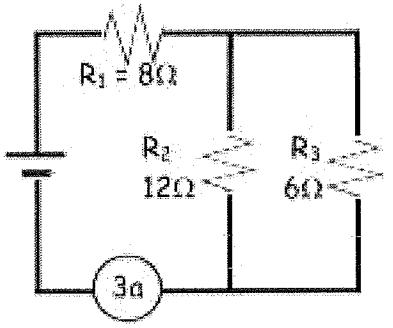
Question #5: What is the relationship between the sum of the individual currents flowing thru each light bulb and the total current provided by the batteries?

- now click on the 'Schematic' button to see how your circuit is represented with symbols for each element in your circuit ... *draw your schematic diagram in your notes* ... click on the 'Lifelike' button when you are finished ...
- break the connection for one of the light bulbs ....

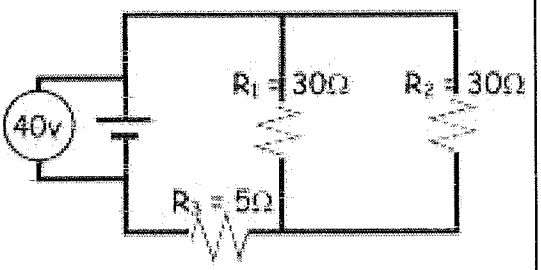
Question #6: Describe what happens when the connection for one of the items in a parallel circuit is broken. Why does this happen?? ... your answer needs to describe this is terms of the electron flow.

Do you have some time left? Then build a circuit with resistors instead of light bulbs and see how they behave as you change their configuration ...

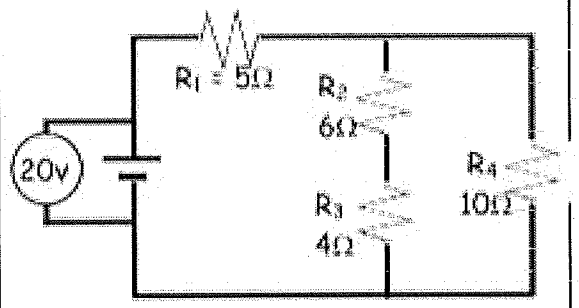
Worksheet: Complex Circuit Problems, Ep.905 Name _____



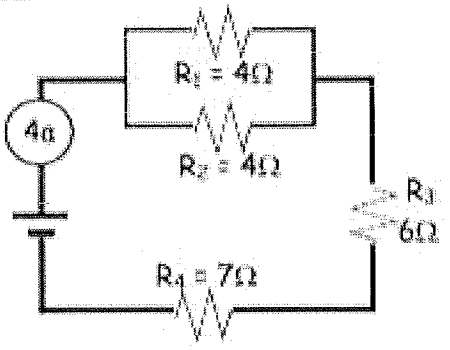
R_T = _____ I_T = _____ V_T = _____
V_1 = _____ V_2 = _____ V_3 = _____



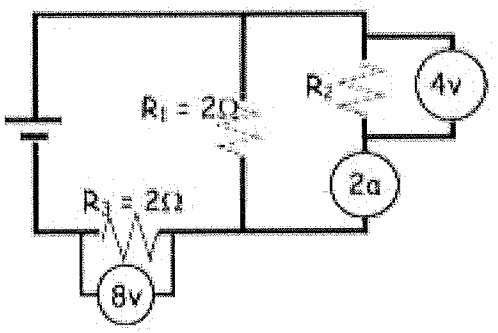
R_T = _____ I_T = _____ I_3 = _____
V_3 = _____ V_1 = _____ V_2 = _____
I_1 = _____ I_2 = _____



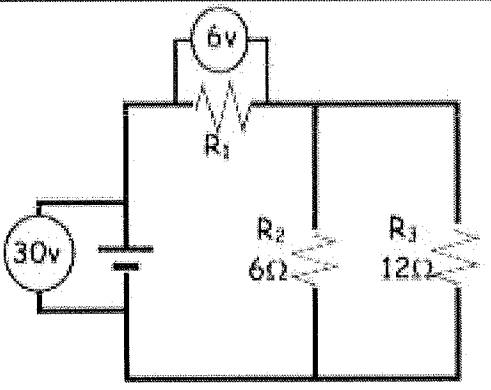
R_T = _____ I_T = _____ I_1 = _____
V_1 = _____ V_4 = _____ I_4 = _____



R_T = _____ I_T = _____ V_T = _____
I_1 = _____ I_3 = _____ V_4 = _____

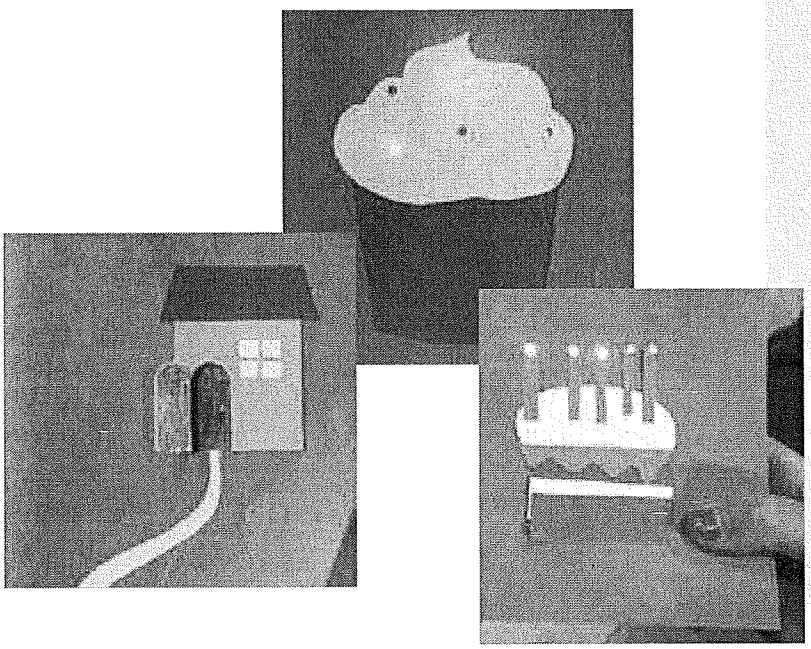


R_2 = _____ R_T = _____
I_3 = _____ I_T = _____ V_T = _____
V_1 = _____ I_1 = _____



V_2 = _____ V_3 = _____
I_2 = _____ I_3 = _____
I_1 = _____ R_1 = _____ R_T = _____

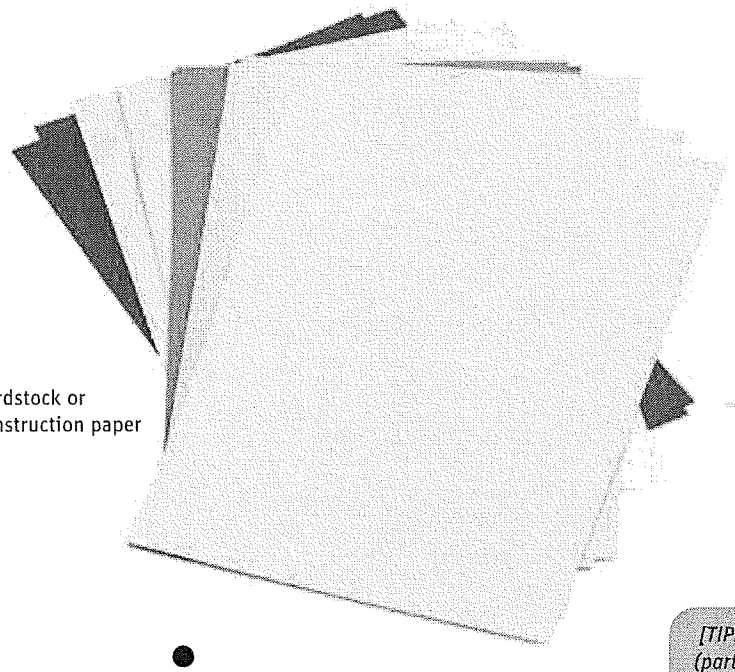
PAPER CIRCUITS



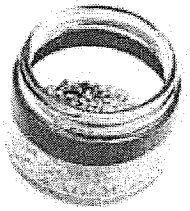
Make simple or complex electrical circuits on a piece of paper! Copper tape and surface-mount LEDs allow you to turn a fully functional circuit into a light-up greeting card, origami animals, or three-dimensional pop-up paper sculptures that have working lights in them.

BUILD IT!

Collect these things:

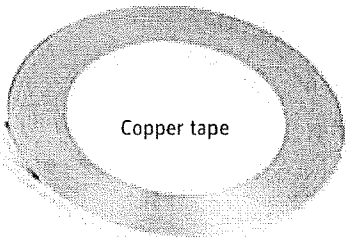


Cardstock or construction paper



Surface mount LEDs

3V coin cell batteries

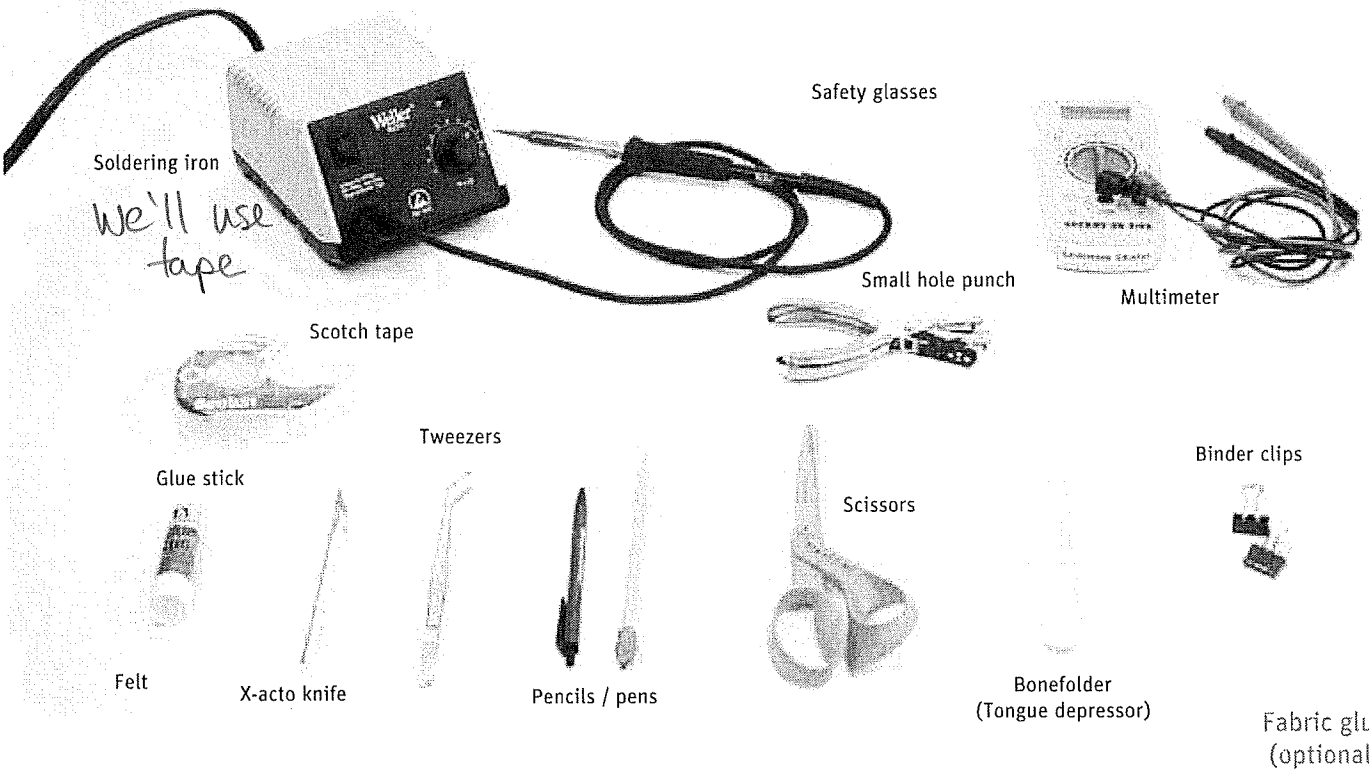


Copper tape

[TIP: You can get 5 mm copper tape, ready for use, from sparkfun.com (part #PRT-1-561). It is also often sold in hardware stores under the name of Slug Tape–it is taped to the lip of planters to prevent slugs and snails from climbing in. If you use slug tape, you might want to cut it into thinner strips before using it on your paper circuit.]

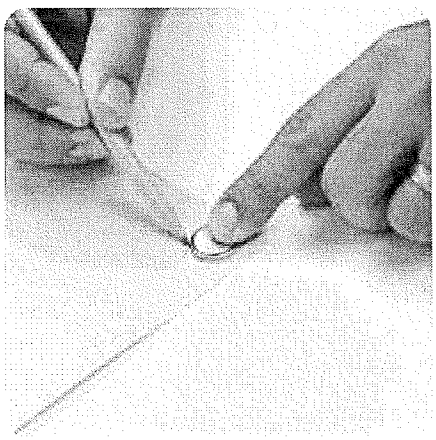
the tinkering studio

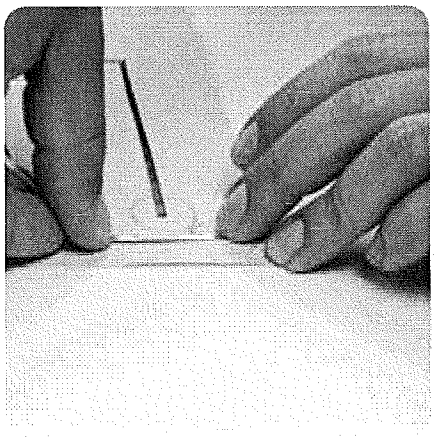
Other Helpful Materials:



TRY IT!

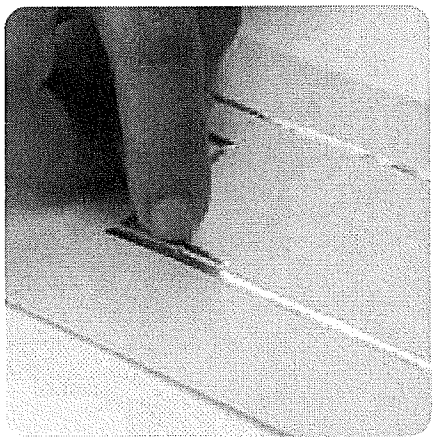
Getting started:

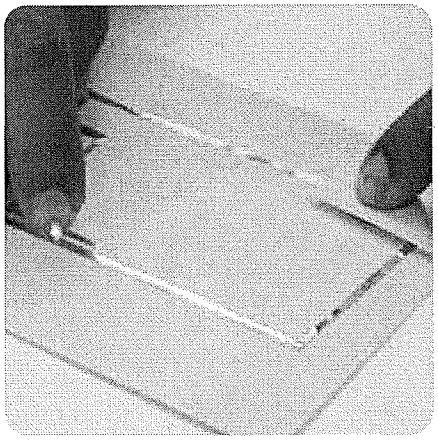


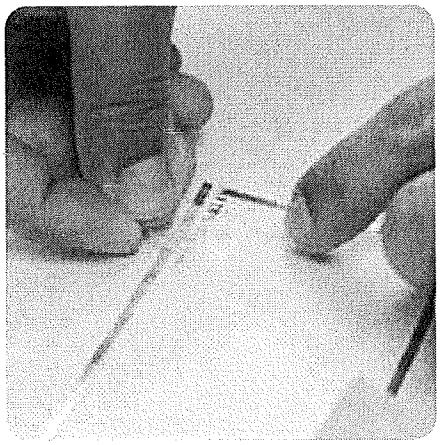


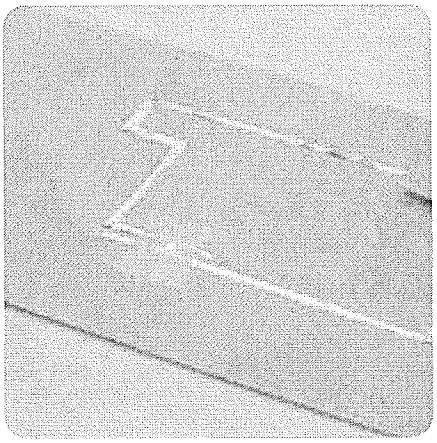
Start simple – fold over one corner of the paper and trace the battery on either side of the fold. Try taping down two strips of copper tape with each piece starting from one of the circles and ending about 1 mm apart (don't worry about how it looks for now).

Place a surface mount LED in the gap. Fold the battery in the tab you created earlier and see what happens. Does the light turn on? If not, try flipping the battery or gently pushing down on the light.



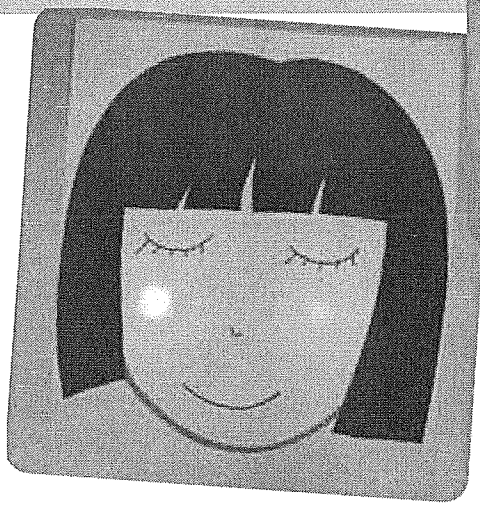


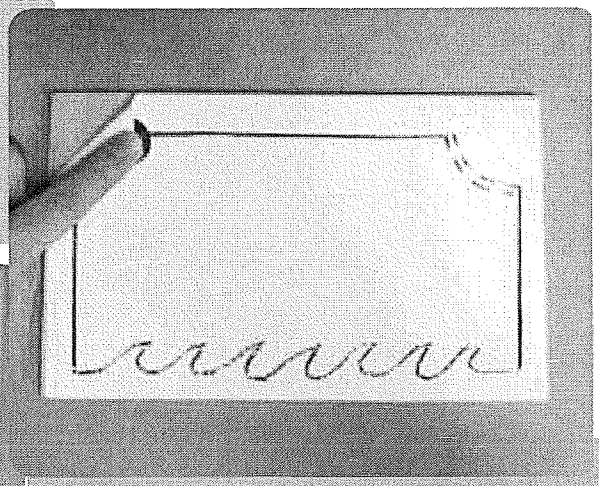




You can lay a piece of Scotch tape over your LED to secure it to the copper tape or solder the LED to the copper tape using a soldering iron. (See helpful techniques below for tips on soldering the lights.)

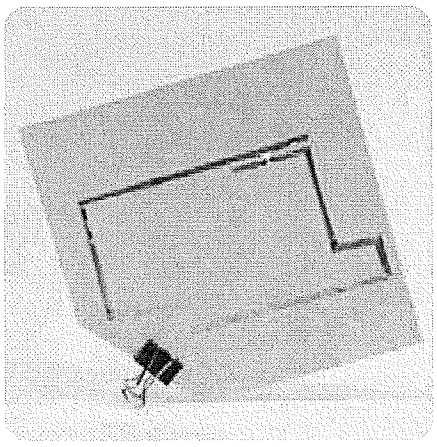
With these starting steps, the possibilities for creating your paper circuits are endless. You can **fold the copper tape into different designs** or make a collage that is lit by a hidden circuit on another piece of paper underneath.

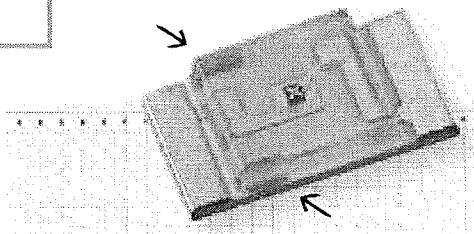




Could you make a battery holder somewhere else on the paper besides the corner? Or a switch that turns your lights on and off when pushed?

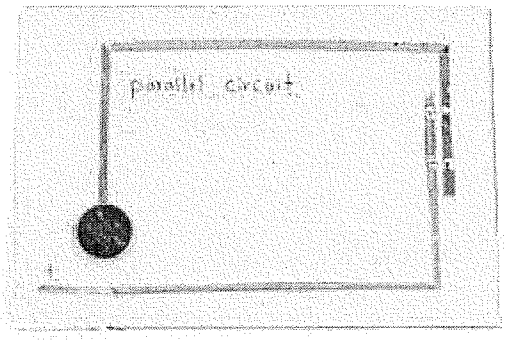
Binder clips are a great tool for holding the battery in place to keep the light turned on when displaying your circuit.

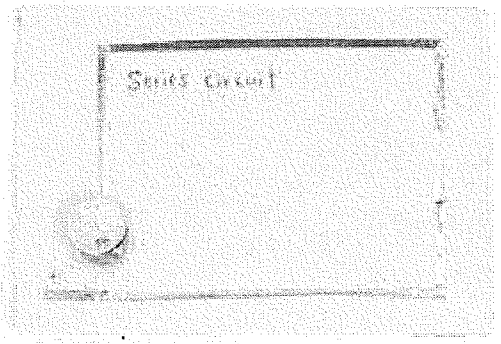




Look closely at your LED (a magnifying lens might help here). You'll notice one or two green markings on one side. These dots indicate the negative side of the LED. Being able to tell the positive from negative sides will come in handy later on, especially if you're using more than one light.

You can make cards with one light or many lights. When using multiple lights it's helpful to make a parallel circuit. It's possible to make series circuits, but you'll need an additional battery for each light.

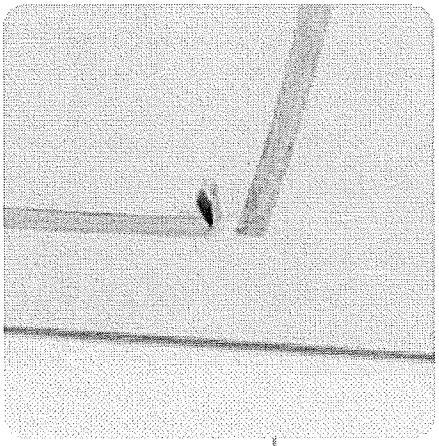




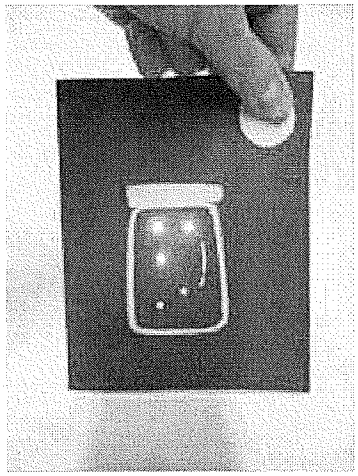
When making a parallel circuit, we like to **think of it as creating two copper tape pathways** that come very, very close together but don't touch. Your surface mount LEDs will have to bridge the gap between them, so we've found that placing them about 1 mm or less apart is ideal.

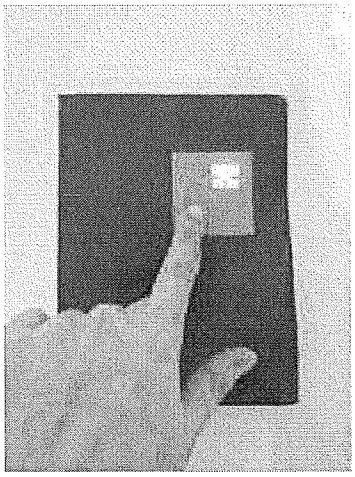
Make sure your LEDs are all oriented in the same direction, with all the positive leads touching the positive path, and vice versa. *(TIP: Many times if a light isn't working, it's oriented backwards.)*

When overlapping pieces of copper tape, **sometimes the adhesive acts like an insulator, blocking the electricity from flowing**. You can make a tiny solder "bridge" to fix the connection or fold a piece of copper back on itself (sticky side to sticky side) then Scotch tape that over the seam as a different type of "bridge."



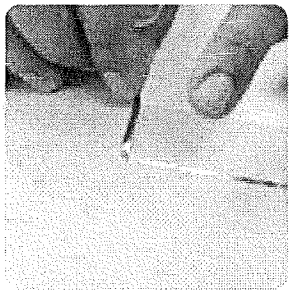
Depending on the LEDs you buy, you might find that some colors work together and other colors don't (for us, red, yellow, and green work together, as do blue and white). This could become a feature of your circuit where by pushing a switch the lights change colors. You could also experiment with resistors to make incompatible colors (like blue and green) work at the same time.

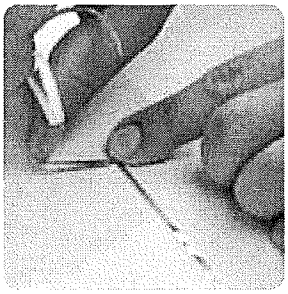


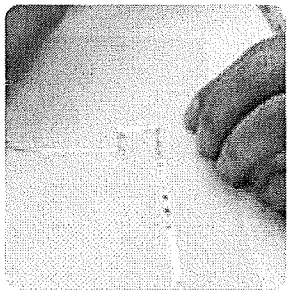


The LEDs make diffuse circles when shined through thin, light-colored paper. Cardstock can block the light, so poking holes in it with an X-acto knife or small hole punch will let the light shine through.

Helpful tape folding techniques:

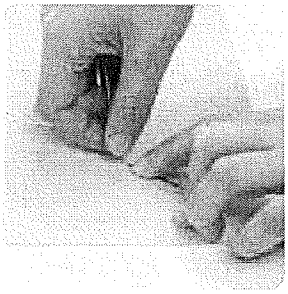


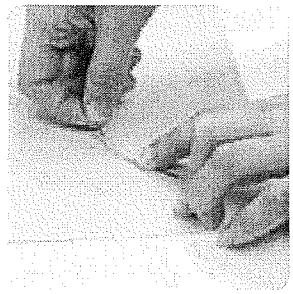


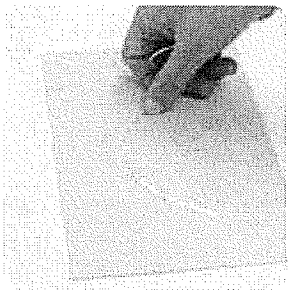


Making a sharp corner: Fold the copper tape back on itself and make a sharp crease. While holding down the crease, turn the tape the direction you would like it to go. Flatten the tape with a bone folder or Popsicle stick.

Making a curve: This works better with thinner tape. With one hand guide the tape along with curve you'd like to make. With the other hand, push down the tape to secure it to the paper. You might notice tiny puckers in the tape; you can smooth those out with a bone folder or Popsicle stick.





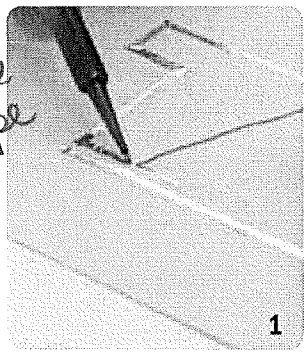


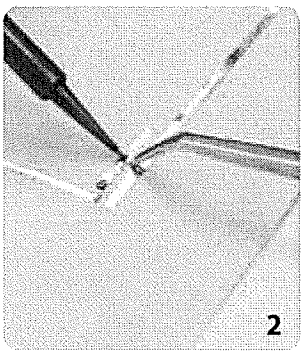
Soldering an LED:

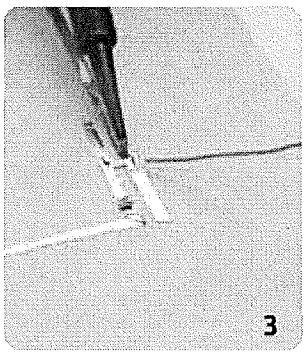
1) Place a dot of solder on one side of your copper tape where you would like the LED to be.

2) Pick up one of the LEDs with the tweezers and hold it right next to the blob of solder. With your other hand, melt the solder and stick the LED into the liquid metal. Hold the LED in place while the solder cools.

3) Now you should be able to solder the other side onto the other piece of copper tape. Make sure both the leg of the LED and the copper tape get hot enough for the solder to flow and connect to them.



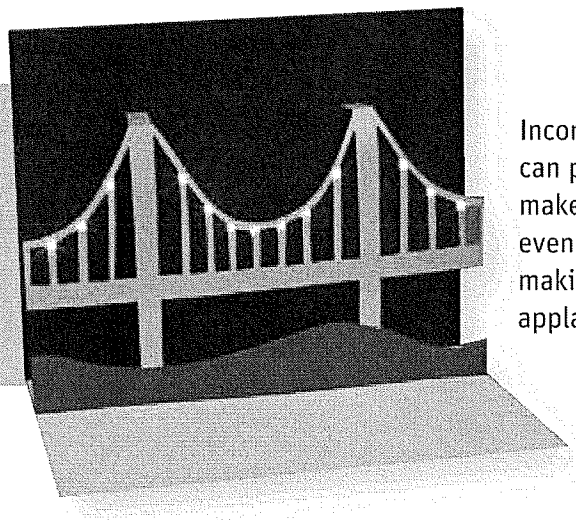




Test your design! And remember, working with a soldering iron takes time and practice, so don't be too frustrated if you don't get it perfect on the first try.

TAKING IT FURTHER

Origami and pop-ups: make your paper circuits three-dimensional by incorporating them into origami animals or pop up scenes.



Incorporate microcontrollers: You can program an ATTiny chip to make your lights blink, flicker, or even respond to sensors. Try making a circuit that responds to applause or changes in light.