



PHYSICS

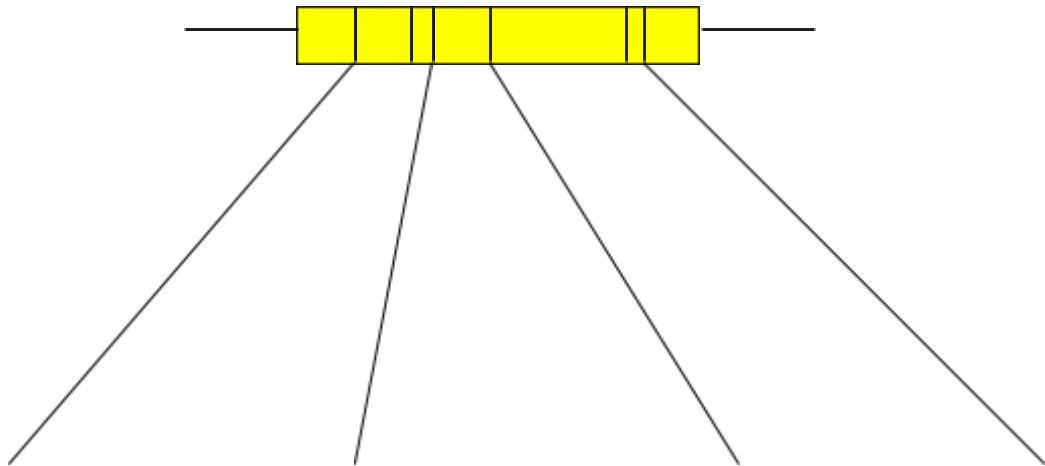
Unit 1 AOS 2 2018

Electric Circuit Exploration

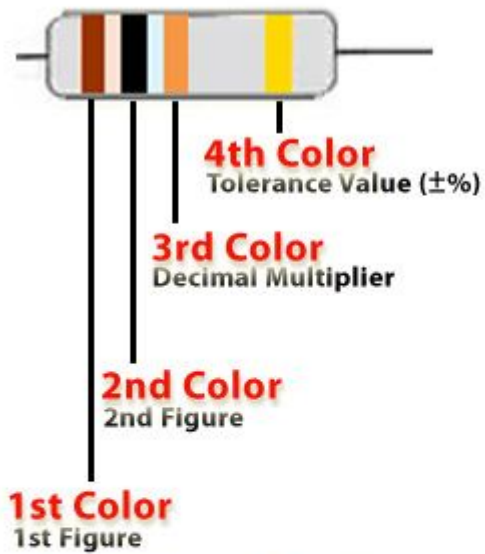
RESISTOR COLOUR CODE

RESISTORS USED IN ELECTRONIC CIRCUITS ARE SO SMALL THAT IT IS DIFFICULT TO LABEL THEM WITH THEIR RESISTANCE VALUE. INSTEAD, A COLOUR CODE IS USED, GIVING NOT ONLY THE RESISTANCE, BUT ALSO THE ACCURACY OF THE STATED VALUE OF THE RESISTOR (ITS TOLERANCE).

THE FIRST COLOURED BAND GIVES THE VALUE OF THE FIRST DIGIT, THE SECOND BAND THE SECOND DIGIT. THE THIRD BAND INDICATES THE NUMBER OF ZEROS THAT ARE TO BE ADDED TO THE FIRST TWO NUMBERS TO GIVE THE VALUE OF THE RESISTANCE (IN OHMS). THE FORTH BAND SHOWS WHETHER THE VALUE OF ACTUAL RESISTANCE IS WITHIN 5% OR 10% OF THE STATED VALUE.



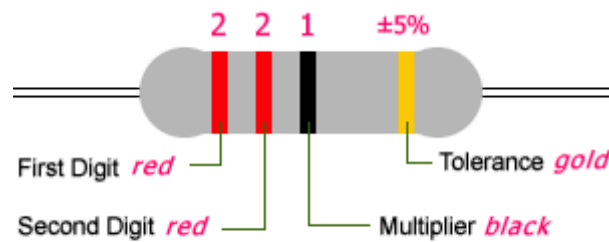
1 ST COLOUR BAND 1 ST DIGIT	2 ND COLOUR BAND 2 ND DIGIT	3 RD COLOUR BAND NUMBER OF ZEROS	4 TH COLOUR BAND TOLERANCE
BLACK 0	BLACK 0	BLACK NO ZEROS	GOLD 5% SILVER 10%
BROWN 1	BROWN 1	BROWN ONE ZERO	
RED 2	RED 2	RED TWO ZEROS	
ORANGE 3	ORANGE 3	ORANGE THREE ZEROS	
YELLOW 4	YELLOW 4	YELLOW FOUR ZEROS	
GREEN 5	GREEN 5	GREEN FIVE ZEROS	
BLUE 6	BLUE 6	BLUE SIX ZEROS	
VIOLET 7	VIOLET 7	VIOLET SEVEN ZEROS	
GREY 8	GREY 8	GREY EIGHT ZEROS	
WHITE 9	WHITE 9	WHITE NINE ZEROS	



Above shown resistor's colors are Brown, Black, Orange and Golden so its value is $10 \times 1000 = 10000\Omega$ or $10k\Omega$ with a tolerance of $\pm 5\%$

Color Name	Value As Figure	As Decimal Multiplier	Tolerance $\pm$
Black	0	$\times 1$	$\pm 20\%$
Brown	1	$\times 10^1$	$\pm 1\%$
Red	2	$\times 10^2$	$\pm 2\%$
Orange	3	$\times 10^3$	-
Yellow	4	$\times 10^4$	$\pm 5\%$
Green	5	$\times 10^5$	$\pm 0.5\%$
Blue	6	$\times 10^6$	$\pm 0.25\%$
Violet	7	$\times 10^7$	$\pm 0.1\%$
Grey	8	$\times 10^8$	$\pm 0.05\%$
White	9	$\times 10^9$	$\pm 10\%$
Golden	-	$\times 10^{-1}$	$\pm 5\%$
Silver	-	$\times 10^{-2}$	$\pm 10\%$

EXAMPLES:



A 22Ω Resistor
 22×1 Ohms with a tolerance rating of $\pm 5\%$



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Expt 6: The Thermistor

Article of Solar Cells

EXPERIMENT #1**VOLTAGE DROPS AROUND A CIRCUIT**

In this experiment you will investigate how the voltage changes as the current passes through various components that make up a circuit.

Theory

You will need to understand the meaning of voltage and current as they relate to charge, the meaning of electromotive force of a battery, and be able to connect a multimeter to correctly function as an ammeter and a voltmeter and also use it to measure the resistance of a fixed resistor (ohmmeter).

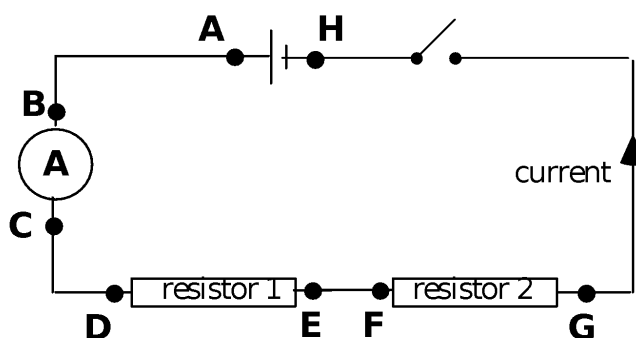
Equipment

- a DC variable power supply
- 100 ohm resistor
- 220 ohm resistor
- connecting wires
- two multimeters
- a switch.

Your task will be to construct various circuits and measure voltages and the current using a multimeter.

Procedure

1. Connect up the circuit shown.
2. Set the DC variable power supply to 6V



2. With the switch closed, use the multimeter set as a voltmeter to measure the voltage drop between the following points on the circuit. Note: Some readings will be zero!

a) A to B	0 V	b) B to C	16 mV
c) C to D	0.1 mV	d) D to E	1.785 V
e) E to F	0.2 mV	f) F to G	3.5 V
g) G to H	1.1 mV	h) A to H	6.68 V
i) D to G	5.73 V	j) Ammeter	0.017 A
3. Looking at the measurement for a), c), e) and g), can you suggest how much energy is used in the connecting wires?
Zero energy since the resistance in the wires are almost zero.

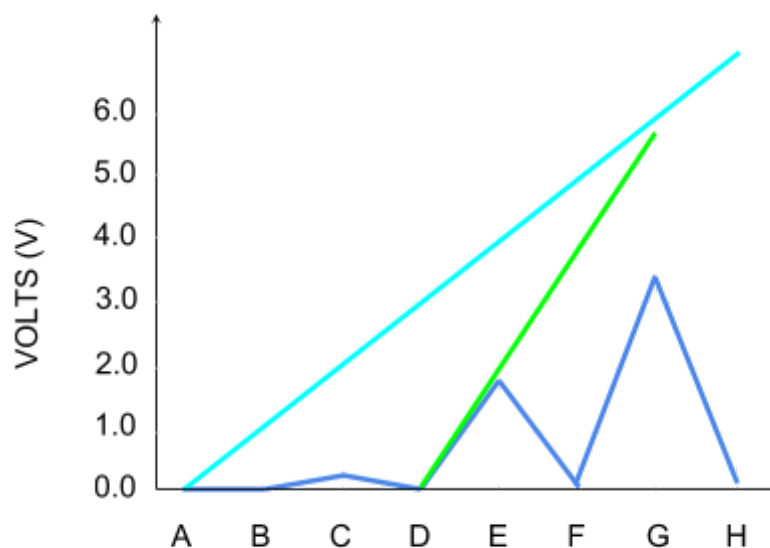
4. Reconnect the circuit with the multimeter set as an ammeter between the resistors. What do you notice about the reading?
Current is the same since the ammeter is set in series with the resistors and the current is the same in series.

Now disconnect the circuit and connect the voltmeter across the variable DC power supply. The reading of the voltmeter is a measure of the EMF (Electromotive Force) of the power supply.

$$\text{EMF} = 6.53 \text{ V}$$

5. What can you say about the EMF and the total energy transferred in all the circuit components?
The sum of the volts is equal to the total voltage supplied (6.53 V).
6. Now sketch a graph in the space below of how the voltage changes in each section, A - B, B - C, etc, as the current goes around the circuit, use your answers from Question 2.

Voltage Drop around the circuit (V)



EXPERIMENT #2**VOLTAGE-CURRENT CHARACTERISTICS OF VARIOUS ELECTRONIC COMPONENTS****Introduction**

When a voltage is applied across a component, the amount of the current going through it depends on its physical properties. How the current changes as the voltage is increased, also depends on the particular component.

Some components even respond differently, depending on which end is connected to the positive end of the battery.

In this next series of experiments you will be investigating the voltage-current characteristics of a selection of components and how these components combine together.

OHMIC RESISTOR

In this experiment you will be using a resistor, whose characteristics are similar to the metals that make up wires and the heating elements in electrical appliances.

Equipment:

2 - 12V variable DC power supply

2 x Multimeters

100 ohm resistor

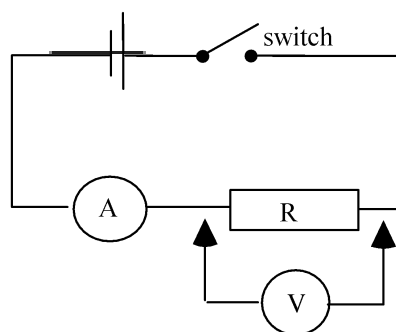
Connecting wires

Banana plugs and alligator clips

Switch

Construct the circuit below using a power supply. Record the current for voltages from 0 volts to 12 volt settings of the power supply.

Note that the voltage settings on the power supply only give a rough guide and the voltmeter should be used to give an accurate reading of the supply voltage. Also, the current will be small, so use the milliamp scale.



Voltage (V)	2.086	3.73	5.53	7.44	9.42	11.38
Current (mA)	0.02	0.037	0.055	0.074	0.094	0.114

Now plot the Voltage (Y - axis) against the Current in Amps on (X - axis) in the space over the page, and draw a line of best fit through the origin.

1. The gradient of this line is called the Resistance. Calculate from your graph the resistance of your resistor.

Resistance = 0.01

2. Write down a relationship between Voltage, Current and Resistance.

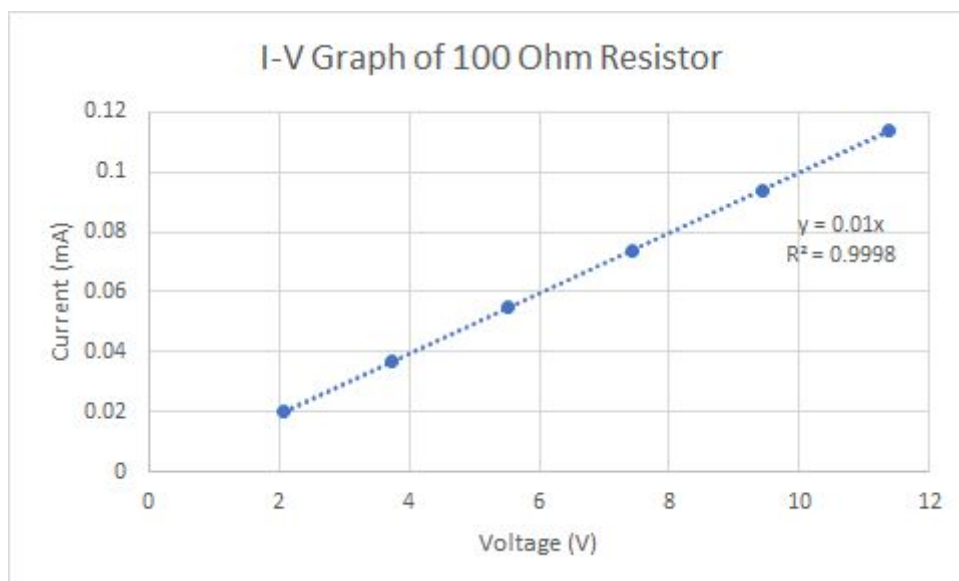
As voltage increases, current increases, whilst the resistor remains constant.

3. On your graph, draw a line you may get for a higher value resistance.

Unsure?

4. The unit of resistance is the "ohm", what would be the equivalent unit in terms of volts and amps?

$$1 \text{ Ohm} = 1\text{V/A}$$



EXPERIMENT #3**SERIES AND PARALLEL CIRCUITS**

For any electrical conductor, a graph can be drawn showing the current flowing versus the voltage across it.

In this experiment you will:-

- plot a voltage – current characteristics of two resistors on the one set of axes, then
- you will use the two graphs to predict the effective resistance if the two resistors were combined in series, and finally
- measure the current and voltage for the combined resistors and seeing if your measurements match your predicted graph.

And then repeat the last two steps for the two resistors connected in parallel.

Because you know that the resistors obey Ohm's Law, you only need to take three sets of readings to draw the voltage - current graphs for the resistors.

Equipment

2 - 12V DC variable power supply

2 x Multimeters

Two resistors 1 x 100 ohm and 1 x 220 ohm

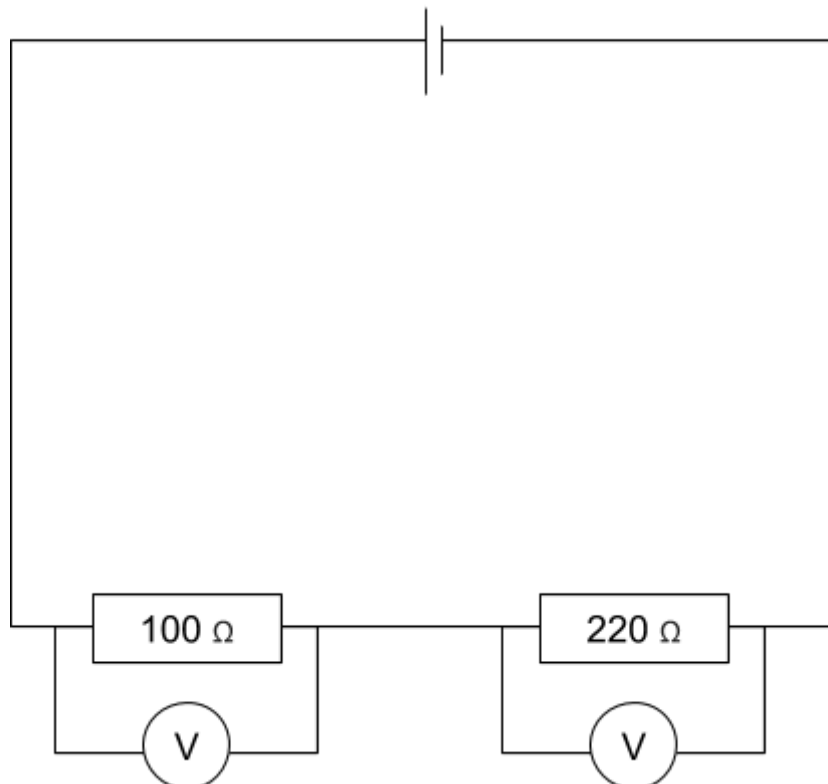
Switch

Connecting wires

Banana plugs and crocodile clips

Procedure

1. Set up a circuit to measure the voltage across and current through each resistor in a single series circuit - do not put them together yet - two circuits with one resistor in each and take the measurements. Draw your circuit below. (See the previous experiment if you are not sure)



2. Record 3 readings of Voltage and Current for each resistor (R1 and R2).

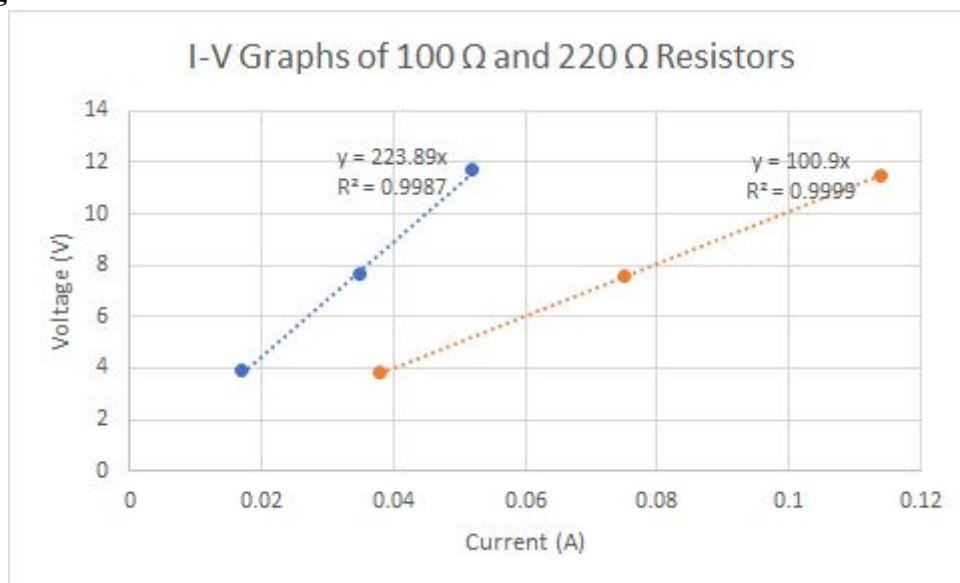
Resistor 1 (100
OHM)

Voltage (V)	3.86	7.59	11.48
Current (mA)	0.038	0.075	0.114

Resistor 2 (220
OHMS)

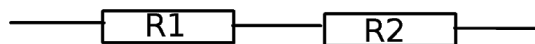
Voltage (V)	3.94	7.7	11.69
Current (mA)	0.017	0.035	0.052

3. Graph the Voltage and Current values for **BOTH** resistors on the one set of axes, putting the **Voltage** on the **Y-axis**.



Orange line: 100 Ω resistor
Blue line: 220 Ω resistor

series



In the **Series Circuit**, both conductors carry the **same current**.

This information can be used to predict the Voltage - Current graph for a Series connection.

4. **Construct your prediction of the line** for the Voltage-Current relationship for the Series Connection.

To do this, you use that fact that the **current through each resistor is the same**, but the total voltage drop is just the **sum of the individual voltages** across each resistor.

To plot the line, first select a current and go up your graph until you hit each line. This gives you the voltage drop across each resistor. Now add together these voltages and plot this value

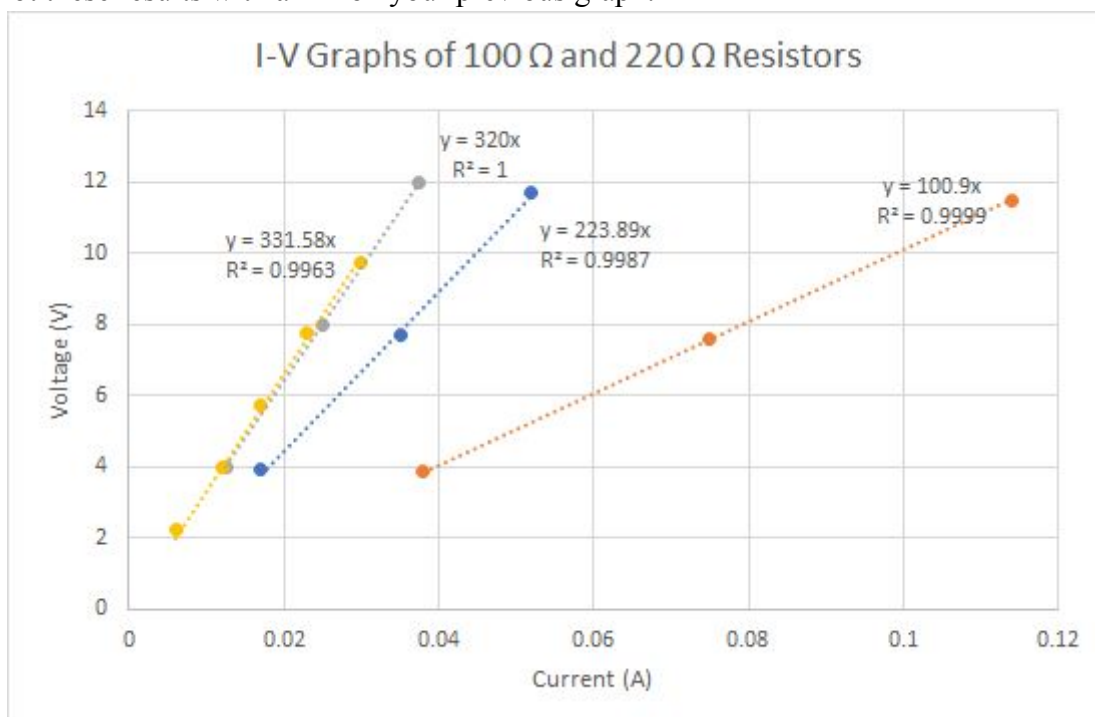
further up with the current line you started with.

Do this with other current values. Now draw your line for the predicted Voltage- Current relationship for the series connection.

5. Now to test your prediction. Place the two resistors in Series in your circuit and measure a set of Voltage and Current values.

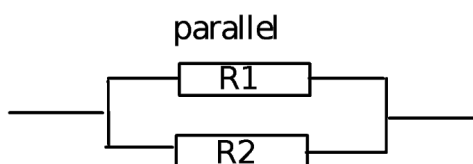
Voltage (V)	2.248	3.98	5.74	7.74	9.75
Current (mA)	0.006	0.012	0.017	0.023	0.03

6. Plot these results with a • on your previous graph.



Orange: 100 Ω resistor
 Blue: 220 Ω resistor
 Grey: Theoretical series graph
 Yellow: actual results to series trial

7. Do the experimental results agree with your prediction?
 Yes, however it is evident when looked upon the R squared value of the experiment that a slight error of 0.0037.
8. Explain how you could use this method to find the effective resistance of three resistances in series.
 You measure across all three resistors at once, find the gradient of the line and that is the effective resistance of the three resistors.



In a **Parallel Circuit**, both resistors have the **same voltage drop** across them.

This information can be used to predict the Voltage - Current graph for a Parallel connection.

$$R(\text{eff}) = 68.75\Omega$$

9. Construct your prediction of the line for the Voltage-Current relationship for the Parallel Connection.

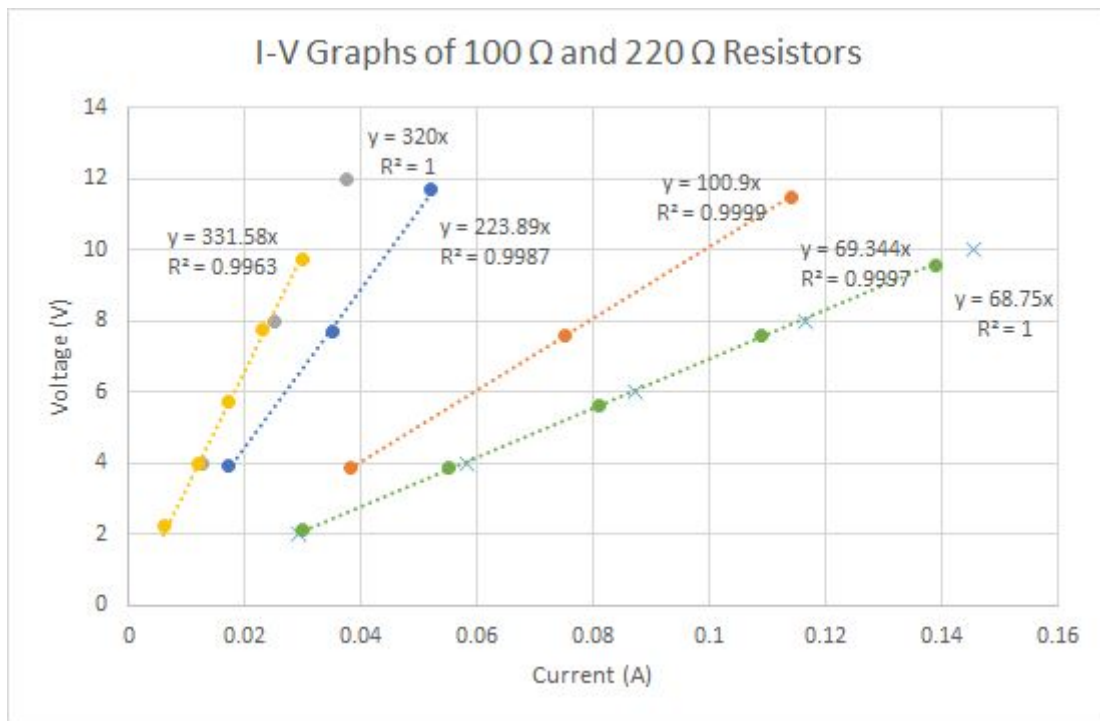
To do this, you use that fact that the **voltage drop across each is the same**, but the current coming in is just the **sum of the individual currents** going through each resistor.

To plot the line, first select a voltage and go across your graph until you hit each line. This gives you the current in each resistor. Now add together these currents and plot this value further across with the voltage line you started with. Do this with other voltage values. Now draw your line for the predicted Voltage-Current relationship for the parallel connection.

10. Now to test your prediction. Place the two resistors in Parallel in your circuit and measure a set of Voltage and Current values.

Voltage (V)	2.128	3.86	5.63	7.60	9.57
Current 220 (mA)	0.009	0.017	0.025	0.034	0.043
Current 100 (mA)	0.021	0.038	0.056	0.075	0.096
Total Current	0.03	0.055	0.081	0.109	0.139

11. Plot these results with an **X** on your previous graph.



Orange: 100 Ω resistor
 Blue: 220 Ω resistor
 Grey: Theoretical series graph
 Yellow: actual results to series trial
 Blue crosses: Theoretical parallel graph
 Green: actual results to parallel trial

12. Do the experimental results agree with your prediction?
 Yes, however similar to the previous experiment, there is a small error within the experiment. Although the hypothesis and the results had proved to be positive.

EXPERIMENT #4**LIGHT GLOBE FILAMENT RESISTANCE**

In this experiment, you will replace the resistor in the circuit from experiment #2 with a 12V light globe and remove the switch. Obtain the 12 volt globe from the trolley. Because the current drawn by the light is larger, you will need to use the amp range of the ammeter.

Equipment

2-12 V DC variable power supply
 2 x multimeters
 12 volt globe
 Connecting wires
 Banana plugs and alligator clips

Supply Voltage (V)	1.995	3.639	5.47	7.43	9.31	11.34
Voltage (V)	1.975	3.62	5.43	7.39	9.29	11.32
Current (A)	0.157	0.225	0.284	0.338	0.385	0.43

1. Plot your graph with **Voltage on the X - axis** as it is the independent variable. That is, the voltage and the properties of the component determine the size of the current.
2. Draw a smooth curve through your set of data. Describe the shape of your line.
It looks like a log graph or a square root graph.

3. The resistance of the globe is given by the Voltage divided by the Current that it produces. Calculate the resistance of the globe at voltages of 4, 8 and 12 volts.

$$R_{4V} = 13.19\Omega$$

$$R_{8V} = 26.39\Omega$$

$$R_{12V} = 39.58\Omega$$

4. Describe how the resistance of the globe changes as the voltage is increased?

Since voltage is increased, the resistance is simultaneously increased as more it shines brighter and therefore more energy is used.

5. Give an explanation for your answers to Question 2 & 3.

6. Is a light globe an Ohmic or Non-Ohmic device? Explain.

Non-ohmic. Since the graph is non-linear and therefore, Ohm's law can only be applied for discrete values.

EXPERIMENT #5**LIGHT DEPENDENT RESISTOR (LDR)**

The LDR is a semiconductor device whose resistance depends on the amount of light shining on it. For a particular light intensity, the device obeys Ohm's Law over a small range of voltage.

In this experiment you will be investigating how the Resistance of the LDR varies as it is moved closer to a light source, i.e. a light globe. The LDR is the small white device with the zig-zag lines across the top. Use a 240 V globe from the trolley as the light source.

Use the circuit from Experiment #3, replacing the resistor with the LDR.

Equipment

2-12 V DC variable Power Supply
 2 x Multimeters
 LDR
 240 V light globe as a light source
 Connecting wires, banana plugs and alligator clips
 Meter ruler or tape measure

- Place the LDR at about 50cm from the filament of the globe. Turn on the light, set the power supply to a voltage to give a measure reading and record the voltage and current. Repeat this for several values for the distance from the LDR to the light. Record your results in the table below and calculate the resistance for each distance.

Distance to Light							
Voltage (V)							
Current (mA)							
Resistance (ohm)							

- In the space given plot a graph of Resistance versus Distance.
- Describe the shape of the graph and suggest a relationship between the two quantities.

- If you wanted to check this relationship, what graph should you plot to achieve a straight line.

- Suggest an application for this device.

EXPERIMENT #6**THE THERMISTOR**

The Thermistor is a semiconductor device whose resistance changes with Temperature. For a particular temperature, the device obeys Ohm's Law over a small range of voltage. The Resistance changes in an exponential way with Temperature, and as the Temperature falls, the Resistance rises.

In this experiment you will be calculating the Resistance from voltmeter and ammeter measurements as the Thermistor cools down. You can then calculate the measure of your thermistor, which is the "Percentage Change in Resistance for each degree centigrade". The Thermistor will be placed in a beaker of hot water and allowed to cool down over time.

Use the circuit from Experiment #3. The thermistor is on the trolley.

Equipment

Urn for hot water

Thermistor, small beaker, thermometer, stand, boss head and clamp

2 x Multimeters

DC variable power supply set to 6 V

Switch, connecting wires, banana plugs and alligator clips

1. Add hot water from the urn to a small beaker. Place the thermistor in the beaker. Put the thermometer in the beaker and clamp it so that the bulb is at the same level as the thermistor.
2. Measure the temperature of the water, and close the switch to measure the Voltage and Current readings. Now calculate the Resistance. Do this for several temperature values over the next 10 minutes as the water cools down.

Temp	Voltage	Current	Resistance

3. Graph Resistance on the **Y** axis against Temperature on the **X** axis.
4. Describe the shape of the graph.
.....
5. Thermistors are compared by the percentage change in resistance for each degree centigrade. To find this value for your thermistor, read from your graph two sets of resistance - temperature values (R_1 , T_1 and R_2 , T_2).

The percentage change in the resistance (% change) = $(R_1 - R_2) \times 100 / R_1$.

The % change per degree centigrade is % change divided the temp difference, this equals
= % change / $(T_1 - T_2)$. Calculate this value for your thermistor:

R_1 :, T_1 :, R_2 :, T_2 :

% change /degree Celsius =
.....

6. Suggest an application for this device.:

Communication Article

Silicon Solar Cells Savour Sweet Sunshine of Success

Read the article. The information below explains some possibly unfamiliar words.

Glossary

<u>Word</u>	<u>Paragraph</u>	<u>Meaning</u>
Fabrication	1	Making
Irradiance	2	Intensity of light measured in Watts per square metre.
Current density	2	Read as current.
Spectral	3	Adjective from spectra
Photons	3	Particles of light
Semiconductor	3	Material that is neither an insulator, nor a good conductor, e.g. Silicon
Amorphous	5	No shape, applied to materials, it means not a single crystal, but lots of small crystals.
Obviate	6	do without

From Robert Hill at Newcastle upon Tyne Polytechnic, UK

A new world record efficiency has recently been reported for silicon cells by Martin Green and colleagues at the University of New South Wales, Australia (1989 Appl. Phys. Lett. 55, 1363). Such devices convert sunlight directly into electrical power via the photovoltaic effect first observed by Becquerel 150 years ago. The authors have been in the forefront of the revolution in silicon solar cell design and fabrication over the past 10 years, and this recent paper records the achievement of cells with an efficiency of 22.8 %. This record has since been surpassed by Green with a cell of 23.2 % efficiency, reported at the recent European Photovoltaics Conference.

Under standard test conditions of 1 kW/m^2 irradiance (similar to the Sahara Desert in summer at noon) the output of Green's cell is about 37 ma/cm^2 at 0.63 V . i.e. 23.2 mW peak. The current density varies linearly with irradiance, whilst the voltage has a logarithmic dependence, so the conversion efficiency increases in concentrated sunlight. Efficiencies of close to 30 % have been achieved by three different types of cell under sunlight concentrations of about 100 times standard condition.

Sunlight has a broad spectral range, whilst solar cells are most efficient for photons whose energy is close to the semiconductor band gap. A better match to sunlight can be achieved by a number of semiconductors each with a different band gap.

Such 'stacked solar cells' using Gallium Arsenide/Gallium Antimonide have recently achieved a new world record efficiency of 37 % in concentrated sunlight. Other combinations of semiconductors are being tried, and efficiencies over 40 % are expected in the next 2 –3 years.

Mass-produced cells are inevitably less efficient and a $10 \times 10 \text{ cm}$ commercial cell would generate about 3.5 A at 0.5 V under standard test conditions. Cells are usually used in modules, with 30 – 36 cells in series potted in a transparent rubber base with a glass front, metallised plastic back and an aluminium surround for environmental protection and mechanical strength. Module efficiencies have increased greatly, with a new world record 17 % efficient module announced recently by AEG. Both AEG and BP Solar have already demonstrated 16 % efficient modules, which will be put in to commercial production next year.

The cost of modules has decreased by a factor of about 6 over the past 10 years, to around \$9 per watt of peak output. New solar cell materials in the form of thin films semiconductors offer the potential of reducing this cost by a further factor of 5 –10. Amorphous silicon cells already power the ubiquitous solar calculator and many other consumer products; about 10 MW of amorphous cells is produced each year and output is set to double in 1990. Two other types of thin film cell are due to enter commercial production, based on copper indium diselenide and cadmium telluride. Both of these materials have demonstrated modules with efficiencies over 10 % and potentially longer lifetimes and low cost.

The market for solar vehicles and complete photovoltaic systems is growing rapidly – 35 MW in 1988 and all estimated 40 - 45 MW in 1989. Similar growth is set to continue for the foreseeable future. Apart from consumer products, the main sales are for telecommunications, cathodic protection, lighting, water pumping and vaccine refrigeration where tens of thousands of systems are performing with high reliability and great cost-effectiveness. Even in the UK, it is now cheaper to light a garden shed or telephone box with solar energy than run a mains cable more than 20 metres or so. Within the next 20 years we should see many tens of megawatts of solar cells used in the UK, for instance replacing the glazing of commercial buildings. Large scale power stations are already close to cost-effectiveness in California for their peak load (due to air-conditioning) and a major future use could well be in the electrolysis of water within a hydrogen based fuel economy to obviate the greenhouse effect. Land usage of such stations in sunny climates is the same as that for coal or nuclear stations but without their undesirable environmental impacts.

The three world records set in 1989 are significant technical achievements. Photovoltaics is no longer just an enthusiastic dream: it is a significant international industry and is set to become a major technology of the next century.

Silicon Solar Cells Savour Sweet Sunshine of Success

Name:.....

Questions

1. What does the author mean by the “photovoltaic effect”?
.....
.....
2. What are standard test conditions for solar cells?
.....
3. The Irradiance of 1 kWm^{-2} means that 1kilojoule of light energy passes through 1 square metre every second. Estimate the area of the roof of the Science and Art Building and calculate how many joules of energy would the roof receive in one hour on a sunny day.
.....
4. Using the information in Q’n 2, calculate the power input to a solar cell of area 1 sq cm from light under standard conditions.
.....
5. The output of Green’s new cell is 37 mA cm^{-2} at 0.63 V. Use the relationship between power, current and voltage to verify the output power stated in the article.
.....
6. The solar cell output in Question 5 is for 1.0 sq cm of solar cell. A solar photovoltaic plant covers 2.5 km^2 . Calculate the total power output of the plant if it used Green’s new cell.
.....
7. Calculate the efficiency of the solar cell using your answers to questions 4 and 5.
.....
8. Using the data in paragraph 4 calculate the power output of a 10 x 10 cm commercial cell under standard conditions.
.....
9. If a module is made up of 36 cells in series, what would be its power capacity?
.....
10. Why are the cells arranged in series and not in parallel?
.....
11. What is the cost of a 36 cell module?
.....
12. Each year producers make about 10 MW of amorphous cells. How many cells is this?
.....
13. Would electricity from a large solar power plant have greater, less or the same danger as electricity from a coal fired power station? Explain

.....

.....

1. Silicon Solar Cells savour sweet sunshine of success

1. Name: Answers

Questions

1. *What does the author mean by the “photovoltaic effect”?*
Electrical power from sunlight
2. *What are standard test conditions for solar cells?*
1 kWm⁻² irradiance.
3. *The Irradiance of 1 kWm⁻² means that 1kilojoule of light energy passes through 1 square metre every second. Estimate the area of the roof of the Science and Art Building and calculate how many joules of energy would the roof receive in one hour on a sunny day.*
Area = 30 x 150 m². Energy = 1,000 x 30 x 150 x 60 x 60 = 1.6 x 10¹⁰ Joules
4. *Using the information in Q'n 2, calculate the power input to a solar cell of area 1 sq cm from light under standard conditions.*
1sq m = 100 x 100 sq cm, so input power = 1kW/10,000 = 0.1 Watt
5. *The output of Green's new cell is 37 mA cm⁻² at 0.63 V Use the relationship between power, current and voltage to verify the output power stated in the article.*
P = VI = 37 x 10⁻³ x 0.63 = 23 mW = 0.023 W
6. *The solar cell output in Question 5 is for 1.0 sq cm of solar cell. A solar photovoltaic plant covers 2.5 km². Calculate the total power output of the plant if it used Green's new cell.*
Output power = 0.023 x 2.5 x 1000 x 1000 x 100 x 100 = 58 x 10⁷ W = 580 MW
7. *Calculate the efficiency of the solar cell using your answers to questions 4 and 5.*
Efficiency = (0.023 / 0.1) x 100/1 = 23%
8. *Using the data in paragraph 4 calculate the power output of a 10 x 10 cm commercial cell under standard conditions.*
Power output = VI = 3.5 x 0.5 = 1.75 W
9. *If a module is made up of 36 cells in series, what would be its power capacity?*
Power = 36 x 1.75 = 63 W
10. *Why are the cells arranged in series and not in parallel?*
To produce a greater voltage, in parallel produces a larger current for a small voltage.
11. *What is the cost of a 36 cell module?*
Cost = \$9 per watt, each cell produces 63 W, so cost of module = 9 x 63 = \$567
12. *Each year producers make about 10 MW of amorphous cells. How many cells is this?*
Power output of cell = 1.75 W, so number of cells = 10 x 10⁶ / 1.75 = 5.7 million.
13. *Would electricity from a large solar power plant have greater, less or the same danger as electricity from a coal fired power station? Explain*
Solar would have less environmental risk, the electrical risk, once the voltage is transformed to higher voltages, would be the same.