

TEACHER NOTES Ohm's Law

Georg(sic) Ohm 1787-1854(see Encarta)

Professor Laithwaite of Imperial College was the inspiration behind this program. He encouraged the use of plumbing analogies for teaching electricity, and this program is dedicated to his memory.

The plumbing analogy is designed to try and encourage class discussion and to consider the many similarities between the way electricity and water flow. By toggling between the circuit and water screen the similarities can be emphasised. There is a similarity to the plumbing circuit and a central heating system, i.e. there is a pump and the radiators act as resistors, and also there is a flow and return. A lot of physics can be taught by considering analogies and models.

Students also find it interesting to consider where the analogy breaks down such as if there were a hole in the water pipe. If you look at the water circuit, water would flow out from the top of the pressure pipes, so they should be longer.....

No.	Answer	Description
1	3(C)	Definition and hint available
2	3(C)	If the voltage is doubled the current doubles
3	4(D)	If 3V applied to 3 Ω , $I = V/R = 3/3 = 1$ A. Hint
4	2(B)	Temperature kept constant for Ohm's Law. Hint
5	1(A)	Gradient gives value of resistance $R = V/I$
6	2(B)	If 2mA through 3 k Ω , $V = IR = 2 \times 10^{-3} \times 3 \times 10^3 = 6$ V needed. Hint
7	2BFalse	If the temperature rises, the resistance rises
8	4(D)	$R = V/I$ Rearranging equations and magic triangle. Hint
9	3(C)	If 6V applied to 2 Ω , $I = V/R = 6/2 = 3$ A. Hint
10	1(A)Yes	Graph linear i.e. a straight line
11	2(B)	Ammeter should have zero resistance and be in series. Hint
12	4(D)	Voltmeter should have infinite resistance and be in parallel. Hint
13	1(A)	Same current flows through both resistors in series. Hint
14	2(B)	Same voltage applied across both resistors in parallel. Hint
15	2(B)	Fuse melts and breaks the circuit
16	2(B)	Bulbs A and B will light, the switch for C is open
17	4(D)	Total resistance is 6+4=10 Ω and $I = V/R = 10/10 = 1$ A
18	4(D)	Two batteries and a single bulb will be the brightest
19	1(A)	Diode acts in a similar way to a heart valve. Hint
20	1(A)Yes	Diode rectifies (allows current flow in one direction)

Some web pages about electricity are available at:

<http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/index.shtml>

Ohm's Law Worksheet

1. Define Ohm's Law

The current flowing through a resistor is directly proportional to the potential difference across its ends, provided the temperature remains constant.

2. Why is it better for the batteries to use the **kilo ohm** rather than an **ohm** range of resistors?

If the resistance is much higher, the current will be much lower and the batteries will not go flat very quickly e.g. with 6V and 1Ω, the current will be 6A. This could lead on to a discussion of fuses in the home, battery life for walkmen, minidisks, mobiles etc. and the advantages and disadvantages of rechargeable batteries.

3. Calculate data for the following chart and use the program to check the values, use $I=V/R$

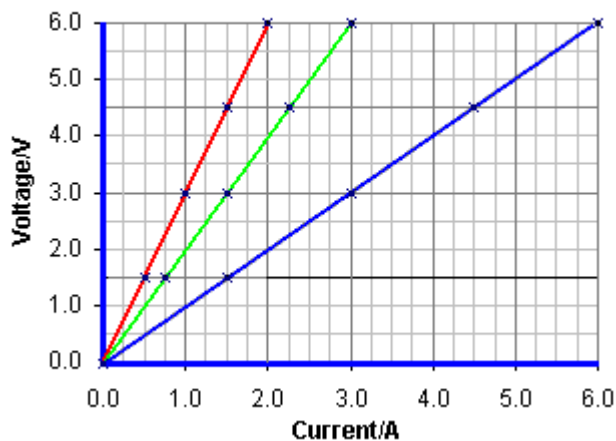
Resistor/Ω	1 k Ω	2 k Ω	3 k Ω
Voltage/V	Current/A	Current/A	Current/A
6.0	6.0	3.0	2.0
4.5	4.5	2.25	1.5
3.0	3.0	1.5	1.0
1.5	1.5	0.75	0.5

This can be done as a class exercise or individually.

4. Now try plotting a graph of **Voltage against Current** for each resistor on the same graph.

In this graph plotting exercise the weaker students could have a simple grid photocopied for them with the axes already drawn.

Voltage against Current



*For the steepest line
 $R=6.0/2 = 3 \Omega = 3 \Omega$
 For the middle line
 $R=6.0/3 = 2 \Omega = 2 \Omega$
 For the least steep line
 $R=6.0/6 = 1 \Omega = 1 \Omega$*

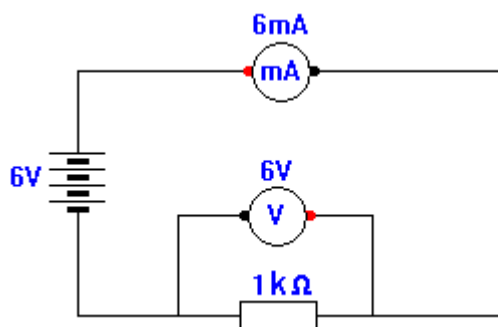
Note X axis in Amps

5. Measure the **gradient** of each line, do you notice anything?

$R=V/I$, so the gradient gives the value of the resistor provided Ohm's Law is obeyed. This is the main reason why the graph is drawn this way round. Some textbooks draw I against V so the straight-line gradient is $1/R$, which can be confusing.

Ohm's Law Practical

- Connect up the circuit and take readings of current and voltage.
Stress laying out the components first, and connecting the ammeter in series and the voltmeter in parallel. A train-set/Scaelectric analogy might be useful for the series part of the circuit.
N.B. To keep the voltage as constant as possible use low internal resistance batteries such as Duracell.

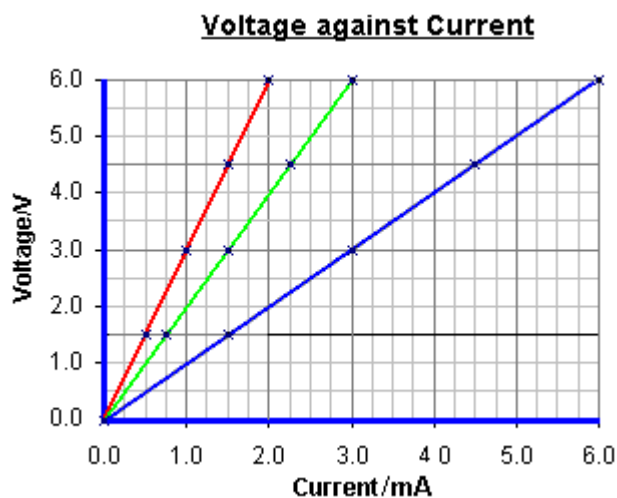


- Now change the values of the resistor and the number of batteries and complete the following table

		Approx. Values	Resistor		
			1 k Ω	2 k Ω	3 k Ω
Number of Batteries	Voltage /V		Current /mA	Current /mA	Current /mA
4	6.0		6.0	3.0	2.0
3	4.5		4.5	2.25	1.5
2	3.0		3.0	1.5	1.0
1	1.5		1.5	0.75	0.5
0	0.0		0.0	0.0	0.0

- Are the values exactly the same as the ones in the worksheet or program, if not can you explain this?
No. In this table the resistors are a thousand times bigger, and the current is not in amps but in milliamps which are a thousand times smaller. The resistors are normally accurate to about $\pm 10\%$, also the multimeter will probably have a little inaccuracy, so some variation in the readings will be normal. Some variation in battery voltage is also inevitable, especially when they start running down.

4. Now try plotting a graph of **Voltage against Current** for each resistor on the same graph. Reasonably able students can use graph paper.



N.B. X axis in milliamps

Measure the **gradient** of each line, do you notice anything?

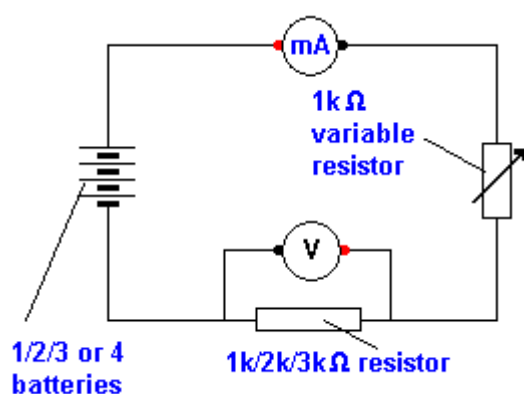
$R=V/I$, so the gradient gives the value of the resistor

For the steepest line $R=6.0/2 \times 10^{-3} = 3000 \Omega = 3 \text{ k}\Omega$

For the middle line $R=6.0/3 \times 10^{-3} = 2000 \Omega = 2 \text{ k}\Omega$

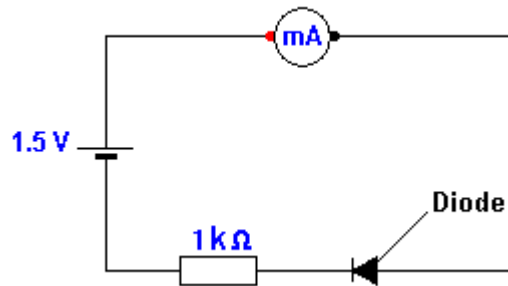
For the least steep line $R=6.0/6 \times 10^{-3} = 1000 \Omega = 1 \text{ k}\Omega$

The circuit below can also be used for a full investigation of Ohm's Law.



Other components can be used such as a bulb (probably with a 25Ω variable resistor) or a resistance wire. This can be done as coursework.

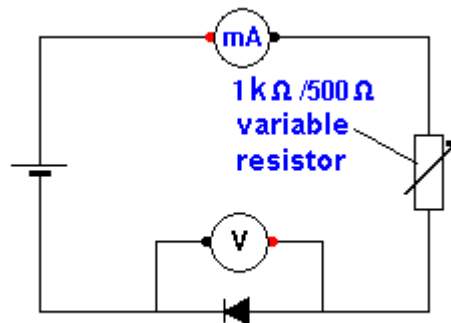
Diode Practical



Take a reading of the milliammeter, reverse the direction of the diode and then take another reading. What did you notice?

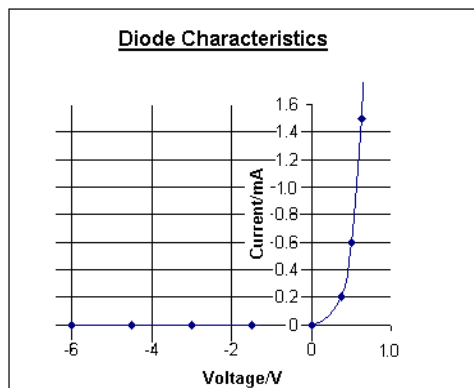
In the forward direction the current should be about 1mA, and when reverse biased it should be 0mA. The more able students could investigate the characteristics of a diode.

Diode Characteristics



Connect up the circuit as shown, and vary the value of the variable resistor. Draw up a table of current and voltage. Reverse the battery and record these readings. Plot the **current against forward and reverse voltage**. Check with your teacher to see what the graph should look like.

The diode should trigger at about 0.6 V, and the current should shoot up to about 10 mA or more. When reverse biasing the voltage can be -6.0V and the current should be 0 mA.



Very able students could consider the 'actual' resistance of the diode. This will not be the gradient, but the ratio of V/I at any given point. This concept is normally covered in AS physics.

ALTERNATING CURRENT A.C.

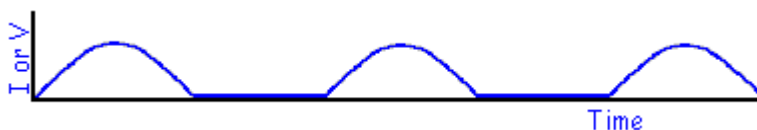
No.	Answer	Description
1	2(B)	<i>A.C. flows in BOTH directions</i>
2	4(D)	<i>Diode rectifies A.C.</i>
3	4(D)	<i>D.C. comes from batteries</i>
4	1(A)	<i>Yes. Hint shows that flow can be stationary</i>
5	3(B)	<i>Sine curve represents current and/or voltage against time</i>

This latest simulation uses the concept of a piston executing S.H.M. (simple harmonic motion). The flow (shown by the bending reed) and the voltage (shown by the pressure pipes) varies according to the sine curve which can be hidden or shown.

Discussion

(1) Sketch what you think A.C. would look like after it has been passed through a diode.

Half-wave rectified.



(2) How long does it take to charge up a typical mobile 'phone?

Normally about 2 hours.

(3) What is the big heavy object inside a mobile 'phone charger?

Transformer. This might be a good place to talk about power supplies, step up and step down transformers and efficient power transmission and electrical safety.

(4) Why does the charger get hot at the beginning of the charging cycle?

Initially a large current flows onto the flat battery causing heating of the transformer coils as they have some resistance (I^2R factor).

(5) Where in the home would you find D.C. power supplies?

Radio, stereo, answer-'phone, television, video, DVD player, computer, lots of devices have their own external power supplies.

Electrical Problems/Homework/Test

1. A bulb of $10\ \Omega$ carries a current of $1.2\ \text{A}$, what voltage is across the bulb?
 $V = IR$
 $V = 1.2 \times 10 = \underline{12\ \text{V}}$
2. A car's headlamps pass a current of $15\ \text{A}$. If the car's battery is $12\ \text{V}$, what is the overall resistance of the headlamp circuit?
 $R = V/I$
 $R = 12/15 = \underline{0.8\ \Omega}$
3. A $1\ \text{M}\Omega$ resistor is attached across a $12\ \text{kV}$ power supply, what current will flow?
 $I = V/R$
 $I = 12000/1000000 = \underline{0.012\ \text{A}} = \underline{12\ \text{mA}}$
Chance to discuss milli and Mega together with use of calculators, and mention that both forms of answer acceptable.
4. A hand-held neon screwdriver passes a current of $0.01\ \text{mA}$ when a $240\ \text{V}$ terminal is touched, what is the total resistance of the circuit?
 $R = V/I$
 $R = 240/0.01 \times 10^{-3} = \underline{24000000\ \Omega} = \underline{24.0\ \text{M}\Omega}$
5. A $12\ \text{V}$ battery is connected across a pair of $4\ \Omega$ and $2\ \Omega$ resistors in series. What current flows in each resistor, and what is the voltage across each one?
Total resistance = $4+2 = 6\ \Omega$ Total current $I = V/R = 12/6 = \underline{2\ \text{A}}$
For $4\ \Omega$ resistor $V = IR = 2 \times 4 = \underline{8\ \text{V}}$
For $2\ \Omega$ resistor $V = IR = 2 \times 2 = \underline{4\ \text{V}}$

