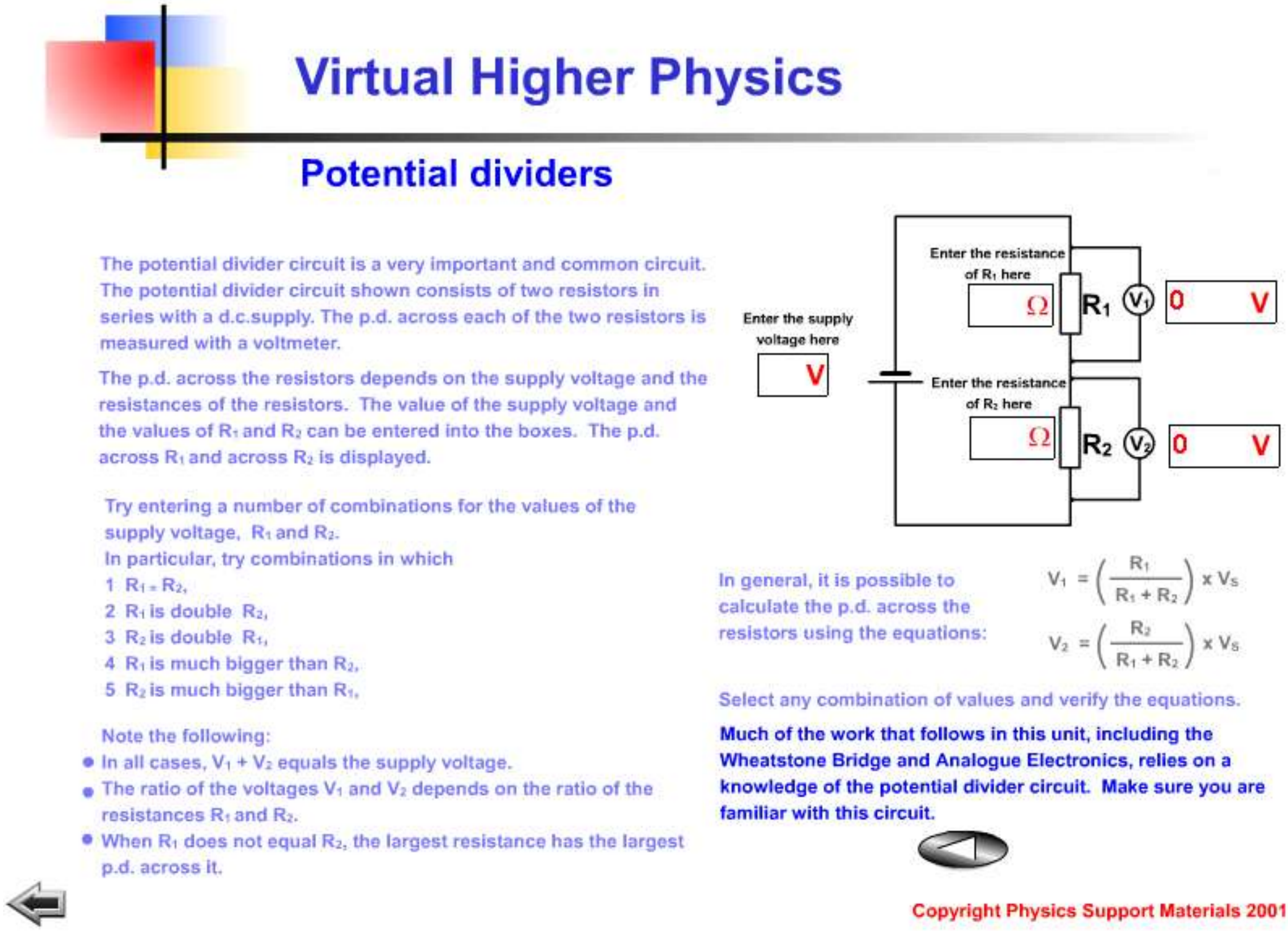
CONTENT STATEMENTS associated with ELECTRIC FIELD & RESISTORS IN CIRCUITS

[15] State the relationship among the resistors in a balanced Wheatstone bridge.

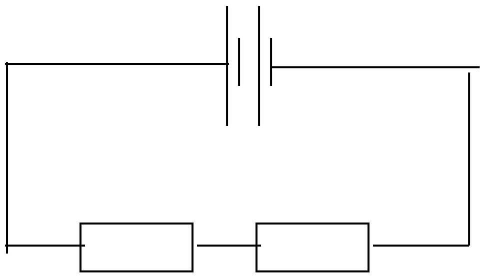
[16] Carry out calculations involving the resistances in a balanced Wheatstone bridge.

[17] State that for an initially balanced Wheatstone bridge, as the value of one resistor is changed by a small amount, the out-of-balance p.d. is proportional to the change in resistance.

[18] Use the following terms correctly in context; *terminal p.d., load resistor, bridge circuit, lost volts.*



Potential Dividers



The voltage across the branch of the circuit must be equal to the terminal p.d (potential difference). NB I am not using ε in this case, although they could be horrible and combine the question!

$$\frac{V_s}{R_T} = \frac{V_1}{R_1} = \frac{V_2}{R_2} = I$$

or from the information from Virtual Higher Physics

$$\frac{V_s}{(R_1 + R_2)} = \frac{V_1}{R_1} = I$$

rearrange

$$\frac{R_1 \times V_s}{(R_1 + R_2)} = V_1$$

$$\frac{R_1}{(R_1 + R_2)} \times V_s = V_1$$

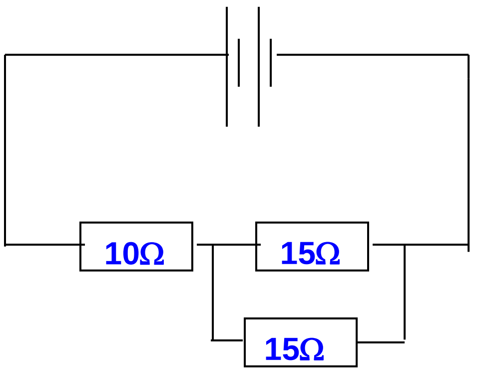
e.g

15Ω and 7Ω in series in a potential divider with a 12V supply

$$V_1 = \frac{V_s \times R_1}{R_t}$$

$$V_1 = \frac{12 \times 15}{22} = 8.2V$$

$$V_2 = \frac{12 \times 7}{22} = 3.8V \text{ or } V_s = V_1 + V_2, V_2 = 12 - 8.2 = 3.8V$$



If part of the circuit has a resistor in parallel with one of the resistors then this section has to be worked out first. Don't forget that if the two resistors are identical then the total resistance in the parallel section will be half the resistance of each of the reistors in parallel.

For example keeping the 12V supply a 10Ω resistor is placed in series with two 15Ω resistors in parallel, what is the voltage across each part of the circuit?

Well the 15Ω resistors in parallel would have a total resistance of 7.5Ω, if you don't believe me work it out!

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_t} = \frac{1}{15} + \frac{1}{15}$$

$$\frac{1}{R_t} = \frac{2}{15}$$

$$\frac{R_t}{1} = \frac{15}{2} = 7.5\Omega$$

Then work out the voltage divider part as previously, but using the total of the two parallel resistors instead of the top resistor.

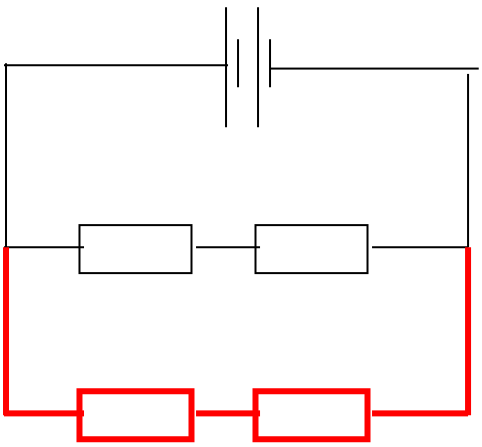
10Ω and 7.5Ω in series in a potential divider with a 12V supply

$$V_1 = \frac{V_s \times R_1}{R_t}$$

$$V_1 = \frac{12 \times 10}{17.5} = 6.9V$$

$$V_2 = \frac{12 \times 7.5}{17.5} = 5.1V \text{ or } V_s = V_1 + V_2, V_2 = 12 - 6.9 = 5.1V$$

You are likely to feel quite confident about this after practice; after all it was in the SG Physics Course.



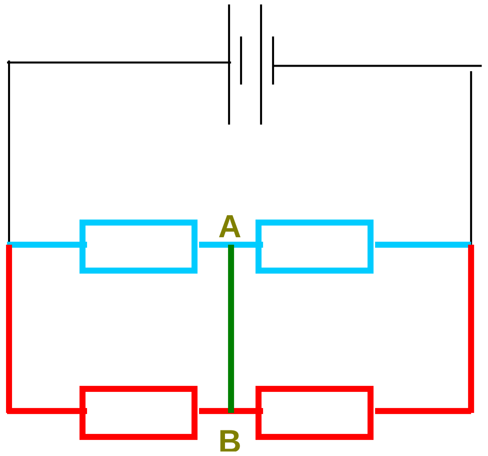
Now consider adding another branch to the circuit. The voltage drop across the bottom branch of the circuit must be equal to the voltage drop across the top branch. (According to the conservation of energy).

The voltage across each of the branches of the circuit must be equal to the terminal p.d (potential difference) as voltages in parallel are equal to the terminal p.d

The voltage drop across the resistors in the top branch is completely independent of the voltage dropped across each resistor in the bottom branch. If you don't believe me try it! Imagine that the top resistors are both 10Ω, if the voltage supply is 12V the voltage across each of the top resistors is 6V. If the resistors in the bottom were 12Ω and 24Ω, then 4V will be dropped across the 12Ω resistor and 8V will be dropped across the 24Ω resistor. Or if the top branch still contains our two 10Ω resistors and our bottom branch now has two 100Ω resistors then the voltage across each resistor will be 6V. However, the current in the top branch will now be 100 times that of the bottom branch. Use $V=IR$ to prove this using V as the terminal p.d and R as the total resistance of each branch.

But there is more….

If we put a wire connecting these two sets of resistors current can flow up or down the wire if there is a p.d. between A and B



You have now made a Wheatstone Bridge circuit. Use the Virtual Higher Experiments to find examples of the importance of these circuits.

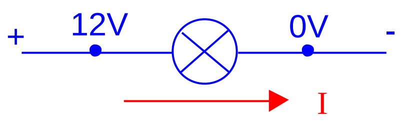
Movement of Charge

Which way does the current flow? You shouldn't be asked this as it is more of an AH question but here is the information that you need.

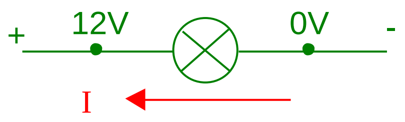
The +ve terminal of a power supply has a high potential.

The -ve terminal of a power supply has a low potential.

Conventional current suggests that +ve charge moves from areas of HIGH potential to LOW potential.



Electron flow says that electrons (-ve charge) moves from areas of LOW potential to HIGH potential.



When the resistors in each branch are balanced, the ratio of the resistors in the wheatstone bridge are equal and the formula below applies.

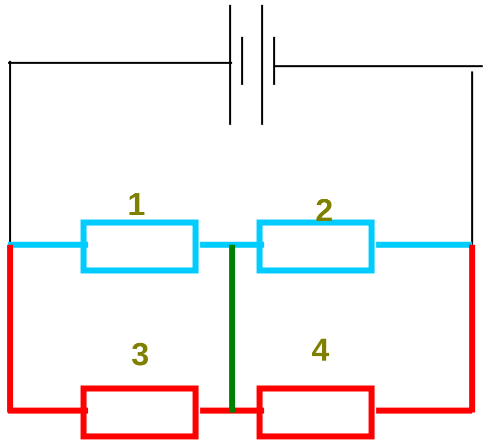
$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

or

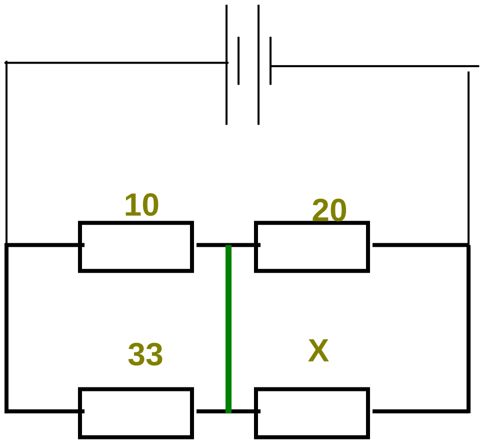
$$\frac{R_1}{R_3} = \frac{R_2}{R_4}$$

or

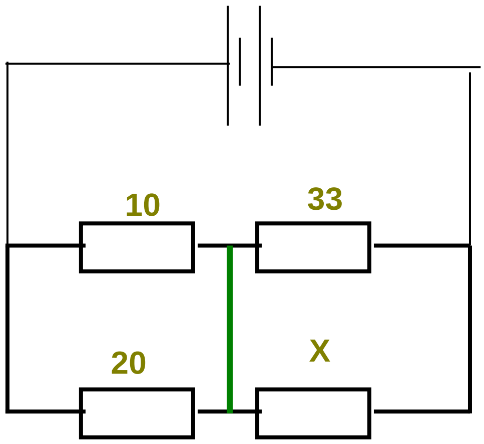
$$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$



Beware there are a few tricks that they can play on you with this simple formula. If the question refers to Resistors A,B,C and D for example it is not appropriate to give the above formula. You must talk in terms of R_A , R_B etc. Another trick is for them to be numbered in a clockwise direction. If this were the case the resistors 4, and 3 would be the other way and again the formula would have to be adjusted to accommodate this. Either stick to dividing the top resistors by the bottom resistors or left to right. Sometimes it is easier to do one rather than the other if the numbers are simple, eg



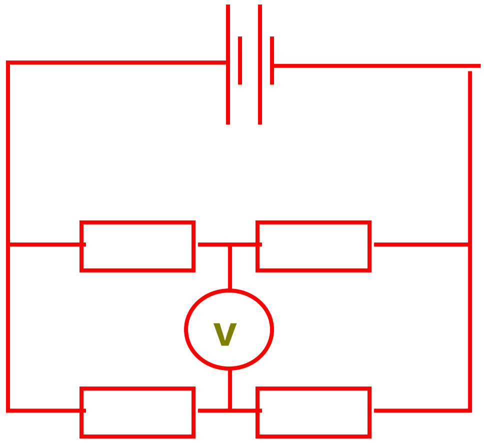
In this example it is easier to divide the left with the right because it is easy to see that resistor 2 is twice as big as resistor one, therefore for the formula to hold resistor 4 should be twice as big as resistor 3, ie 66Ω

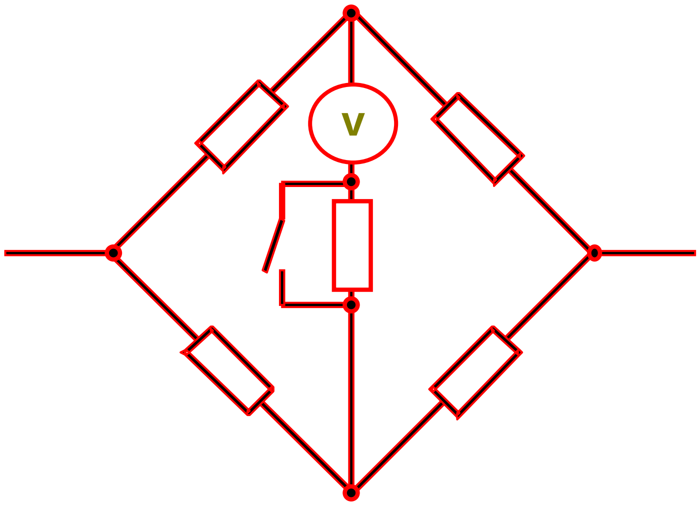


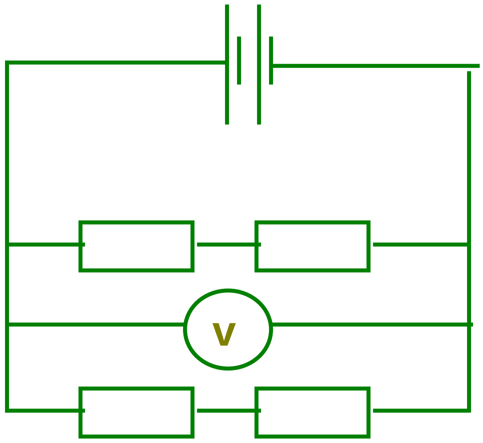
In the second example the two resistors have been moved it is not so obvious using the ratios that we had before what the value of X will be so here it is easier to divide top resistors by the bottom resistors.

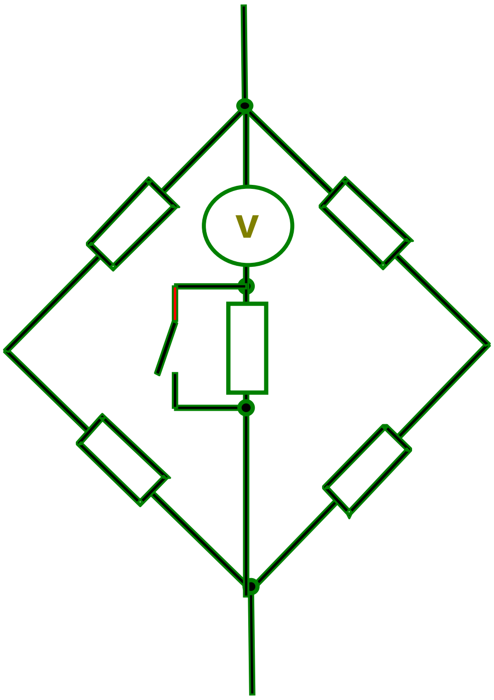
A third trick is to turn the whole equation upside down if you want a resistor that is on the bottom, ie use $\frac{R_2}{R_1} = \frac{R_4}{R_3}$ if you want to find R_4.

Two of the circuits below are wheatstone bridge circuits but two of the circuits below are circuits where the voltmeter is just reading the terminal p.d, as they are fixed in parallel across each of the branches. Can you spot which ones are which?



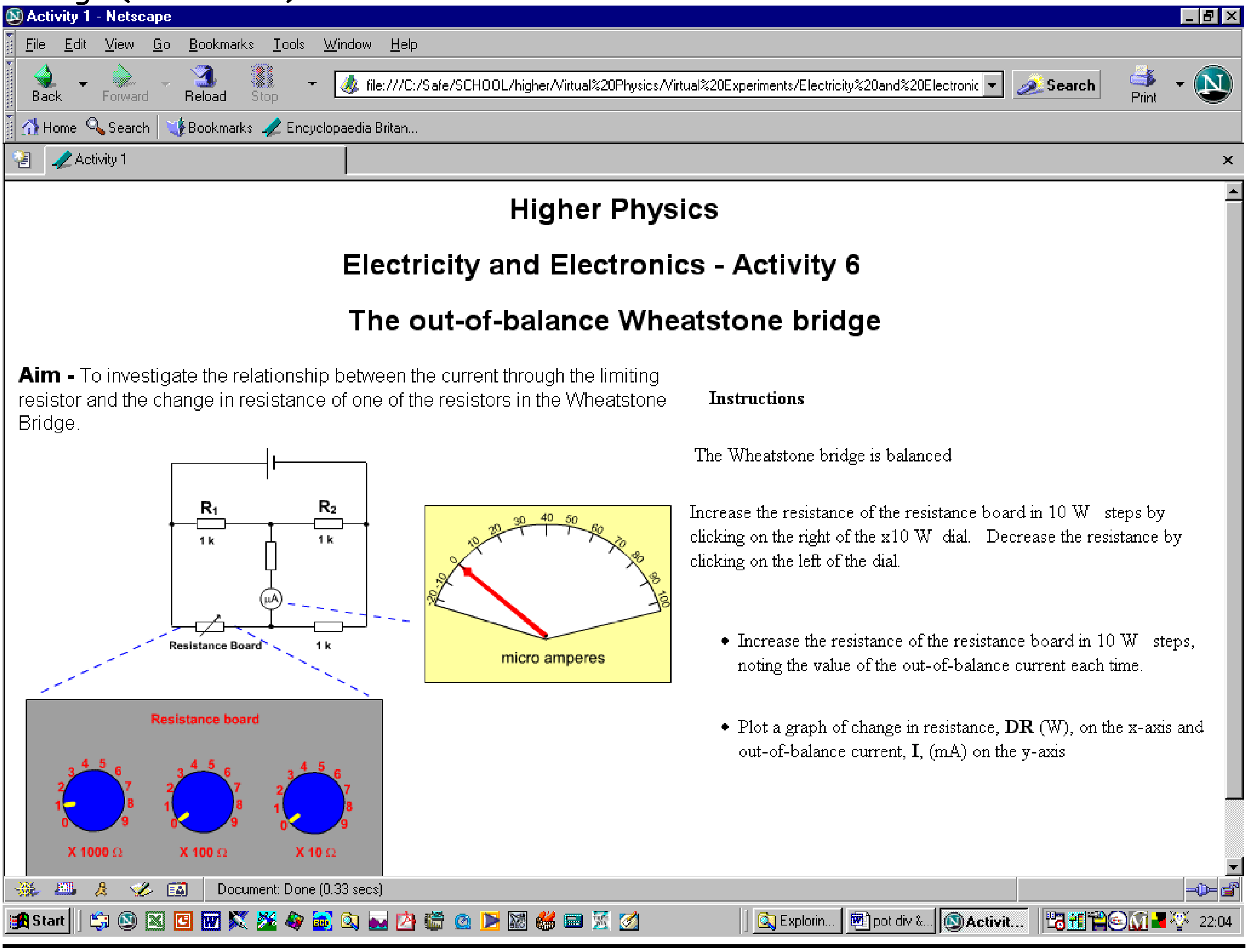






The top two circuits are wheatstone bridge circuits, the voltmeter is perpendicular to the inputs from the power supply. In the bottom two circuits the voltmeter runs in parallel to the power supply. Watch out for this in the exam. They have played nasty tricks on pupils who thought that they were doing a wheatstone bridge question when it was a straight voltages in parallel.

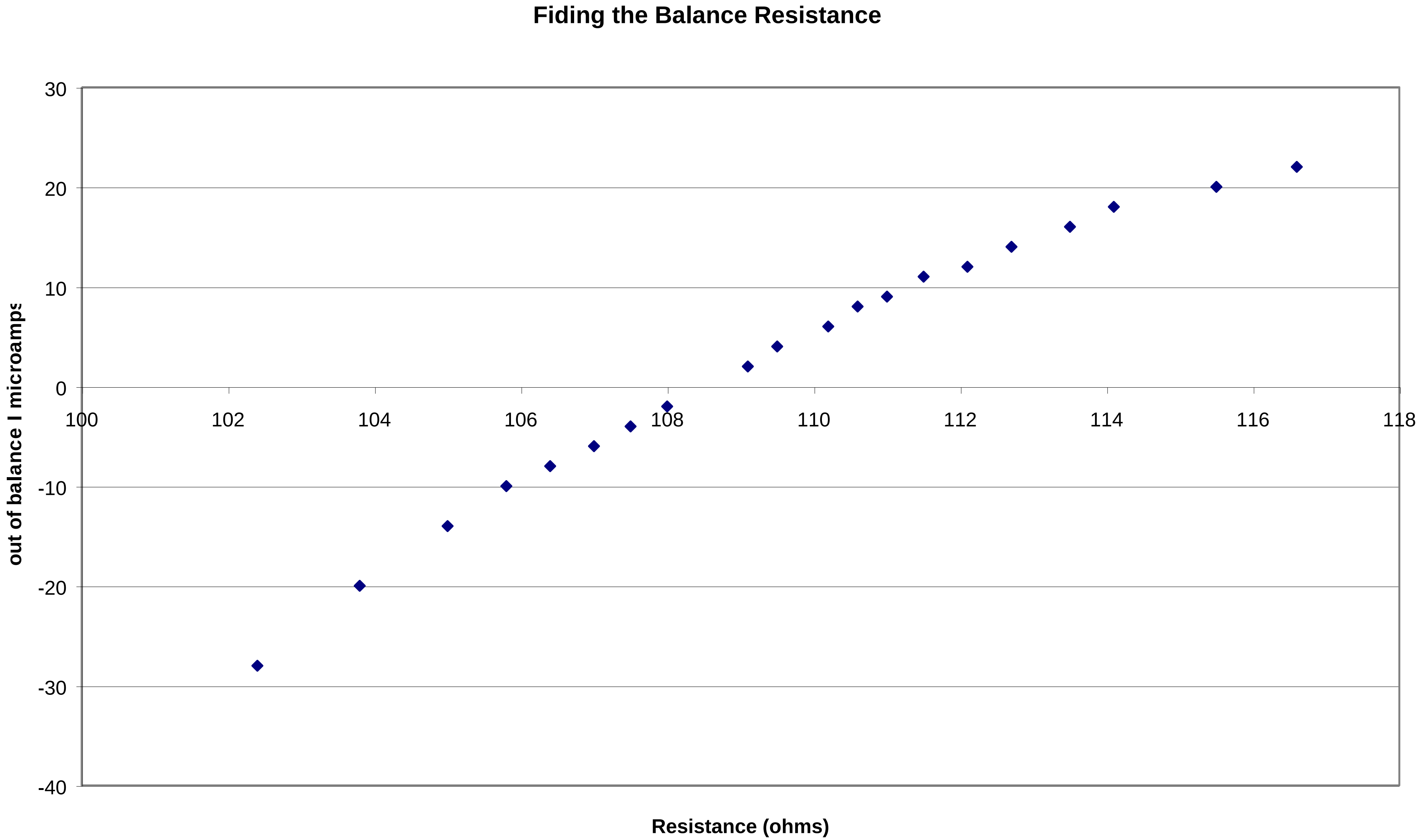
Finding the relationship between out-of-balance resistance and out-of-balance voltage (or current)



- Set up the Wheatstone Bridge using 1000Ω resistors.
- The resistance box should be set to vary between 990 Ω and 1010Ω.
- The bridge has now to be unbalanced by a ***known*** small amount and the reading on the voltmeter or ammeter noted. (Discuss the purpose of the resistor in series with the galvanometer!)
- Repeat the process of unbalancing the bridge with resistance both above and below the balance values.
- ***NB Make sure that your meter is connected the right way round, as you increase the resistance the value on the meter should become more positive not less!***
- Plot a graph of out-of-balance current (or voltage) against out-of-balance resistance.

Resistance	Out of Balance R	out of balance I
ohms	ohms	microamps
116.6	8.1	22
115.5	7	20
114.1	5.6	18
113.5	5	16
112.7	4.2	14
112.1	3.6	12
111.5	3	11
111	2.5	9
110.6	2.1	8
110.2	1.7	6
109.5	1	4
109.1	0.6	2
108	-0.5	-2
107.5	-1	-4
107	-1.5	-6
106.4	-2.1	-8
105.8	-2.7	-10
105	-3.5	-14
103.8	-4.7	-20
102.4	-6.1	-28

Error! Not a vain



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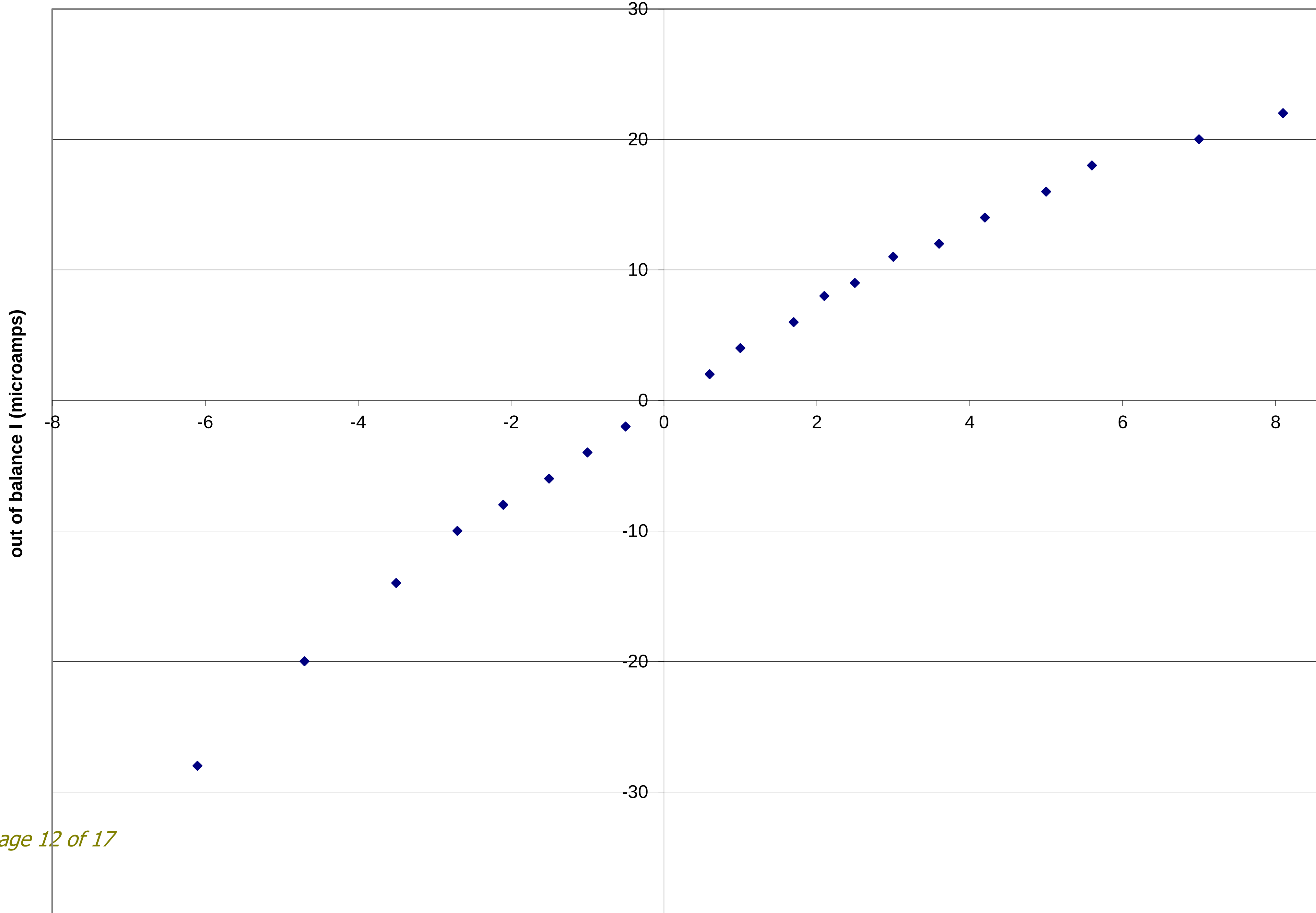

out of balance I (microamps)
30
20
10
0
-10
-20
-30
-8
-6
-4
-2
0
2
4
6
8

PLEASE NOTE ONCE A WHEATSTONE BRIDGE IS BALANCED CHANGING THE VOLTAGE OF THE POWER SUPPLY HAS NO EFFECT ON THE VOLTAGE. ACROSS THE BRIDGE.

Terminology that you need for this section:

Terminal potential difference is the voltage available to the external circuit. The sum of the emfs minus the lost volts.

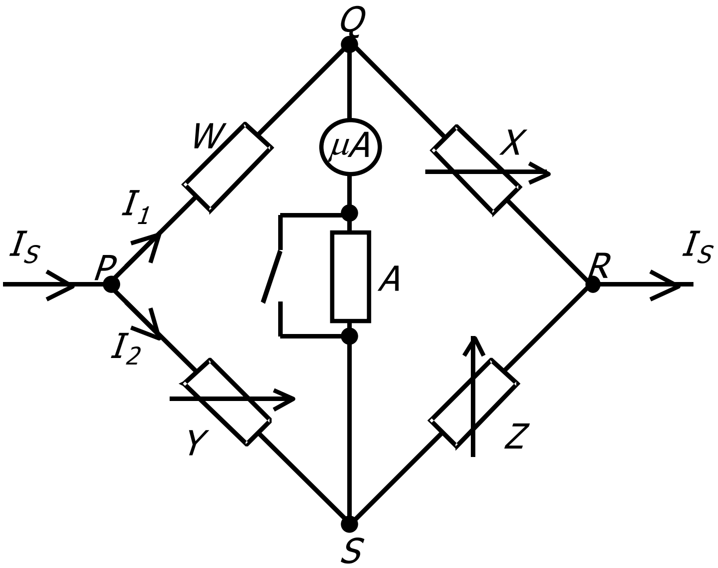
Bridge Circuit: An accurate way of measuring small changes in the resistance of a circuit. Its advantage is that it works on balancing voltages and thus producing zero deflection in the voltmeter or galvanometer (a very sensitive ammeter).

Load Resistor: An external resistance, often called the load but not necessarily a resistor. The presence of a load resistor (for example a bulb or motor are examples of loads) causes current to flow in a circuit.

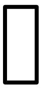
Lost volts: the potential difference across the internal cell, this is the voltage "lost" within the cell as charges pass through the cell and the term lost volts arises as lost volts are not available to the external circuit.

ASIDE

Wheatstone Bridges



= sensitive galvanometer to measure small currents

 A = resistor to protect the galvanometer.

W = unknown resistor

X, Y, Z = variable resistors.

Alter the values of X, Y and Z until no current flows between Q and S.
Short out A and repeat until no current flows between Q and S.
If the current is zero the p.d. across QS is zero.

In moving from P to Q, $I_1 \times W$ *volts are dropped.*
In moving from P to S, $I_2 \times Y$ *volts are dropped.*

For p.d. across QS to be zero: $I_1 \times W = I_2 \times Y$ ________ 1.

By the same argument: $I_1 \times X = I_2 \times Z$ ________ 2.

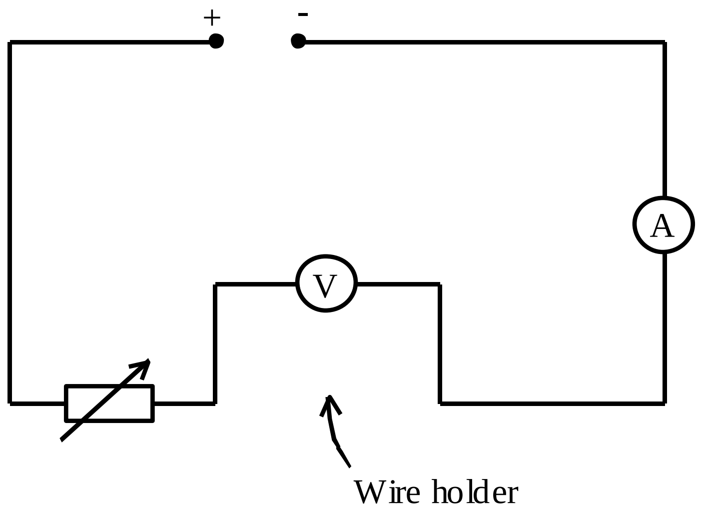
Divide 1. by 2.

$$\frac{I_1 W}{I_1 X} = \frac{I_2 Y}{I_2 Z}$$

$$\frac{W}{X} = \frac{Y}{Z}$$ ________ 3.

PRACTICAL 1

Aim: To check the formula for resistors in series against our experience, set up the following circuit:-

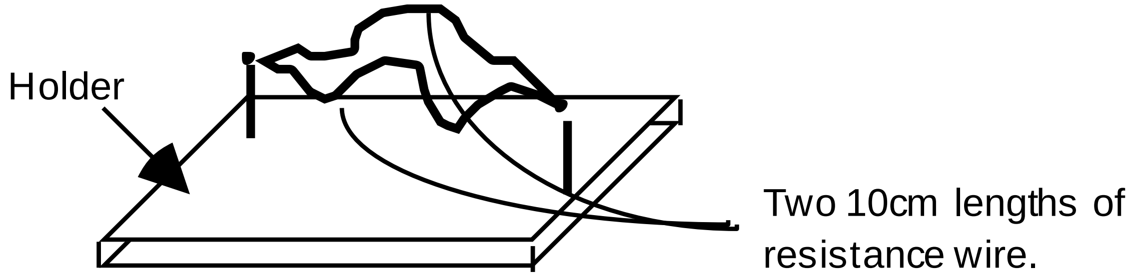


- Put 10cm of resistance wire into the holder and note the current and voltage readings.
- Feed out more wire so that 20cm of the same wire lies between the terminals of the holder. Adjust the variable resistor until the current is the same as for the 10cm length of wire. Note the voltmeter reading.
- PREDICT the voltage reading after you have adjusted the current when 30cm of wire stretches between the holder's terminals.
- DISCUSS why the voltmeter reading increases as the resistance wire is lengthened.

PRACTICAL 2

- Using the same basic apparatus as in the last Practical, put 10cm of resistance wire into the holder and note the current and voltage readings.

- Now put a second 10cm length of resistance wire into the holder along with the first piece.



- Use the variable resistor to adjust the voltage to the same as the previous value, then take note of the current.

- PREDICT what the current reading is after you have put 3 separate 10cm lengths of wire into the holder and adjusted the voltage to its previous value.

- DISCUSS why the current reading increases as the experiment progresses.