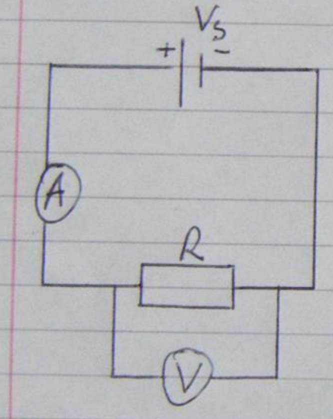
Wheatstone Bridge Circuits - B McMULLEN

What purpose do they have?

These circuits can measure resistances that are unknown to a great degree of accuracy and precision.

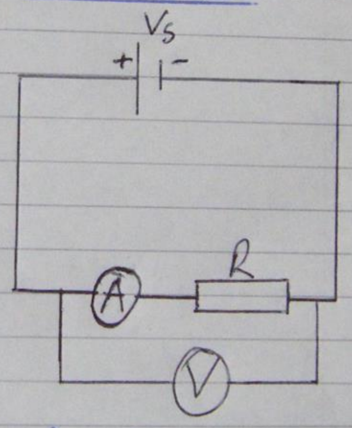
NAT 5 → The methods used to examine/measure resistance have flaws that we will examine.

CIRCUIT A



Precise and accurate for low resistances eg 10Ω

CIRCUIT B



Precise and accurate for high resistances eg 8000Ω

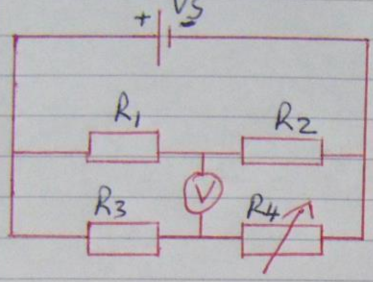
Neither of these set ups are suitable for MID-RANGE resistances eg 400Ω or 800Ω.

EXTRA INFORMATION

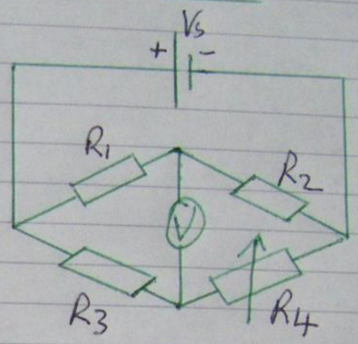
- —(A)— ⇒ have a very low resistance
- —(V)— ⇒ have a very high resistance.

Wheatstone Bridge formations.

1) Rectangular



2) Diamond



We can use an —A— or —V— or a galvonometer —G—.

(A galvonometer is simply a very sensitive —A— or —V—)

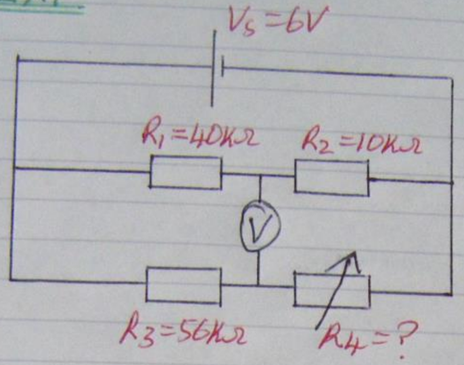
- R_4 above is an unknown variable resistor.
- R_4 is varied until the reading on —V— = 0V. This is the balance point of the Wheatstone Bridge circuit.

Balance point equation

$$\boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}} \quad \text{OR} \quad \boxed{\frac{R_1}{R_3} = \frac{R_2}{R_4}}$$

Ex1

Q



a) Calculate R_4 when the bridge is balanced.

b) What is the reading on (V) when the bridge is balanced?

A a) $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

$\Rightarrow \frac{40}{10} = \frac{56}{R_4}$

$\Rightarrow 40R_4 = 56 \times 10$

$\Rightarrow R_4 = \frac{56 \times 10}{40} = \underline{\underline{14k\Omega}}$

b) When the bridge is balanced (V) $= \underline{\underline{0V}}$.

Q c) What affect would increasing the supply voltage to 10V have on the reading on the voltmeter if:

i) Bridge is balanced
ii) Bridge is unbalanced.

A c) i) When the bridge is balanced there would be no change ie (V) $= 0V$

ii) When the bridge is unbalanced the reading on (V) would increase.

Power Equations

Power is the energy transformed per second.

$$\text{Power} = \frac{\text{Energy}}{\text{time}}$$

Energy → (Joules)
Power → (Watts)
time → (seconds)

$$\frac{E}{P \times t}$$

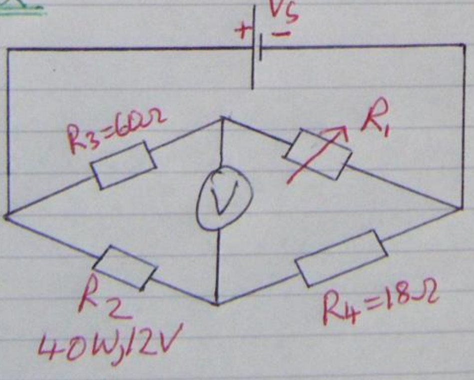
1. $E = Pt$
2. $P = \frac{E}{t}$
3. $t = \frac{E}{P}$

Three Electrical Power Equations

- $P = IV \Rightarrow P = IV \Rightarrow I = P/V \Rightarrow V = P/I$
- $P = I^2R \Rightarrow P = I^2R \Rightarrow I^2 = P/R \Rightarrow R = P/I^2$
- $P = V^2/R \Rightarrow P = V^2/R \Rightarrow V^2 = PR \Rightarrow R = V^2/P$

Ex2

Q



a) Calculate the resistance R_2

b) Find R_1 when the bridge is balanced.

A a) $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{12^2}{40} = \frac{144}{40} = \underline{\underline{3 \cdot 6\Omega}}$

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

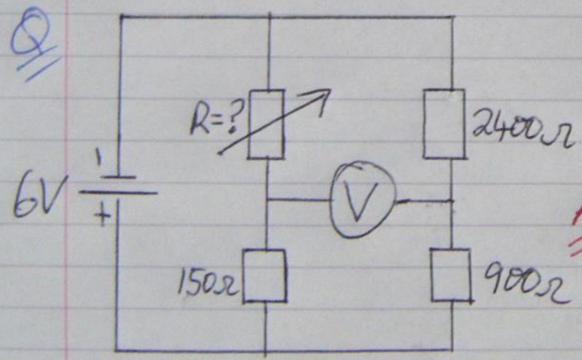
Top left over bottom Left = Top right over bottom right

$\Rightarrow \frac{60}{3 \cdot 6} = \frac{R_1}{18}$

$\Rightarrow R_1 = \frac{60 \times 18}{3 \cdot 6} = \underline{\underline{300\Omega}}$

Ex3

Q



Calculate R when the bridge is balanced.

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

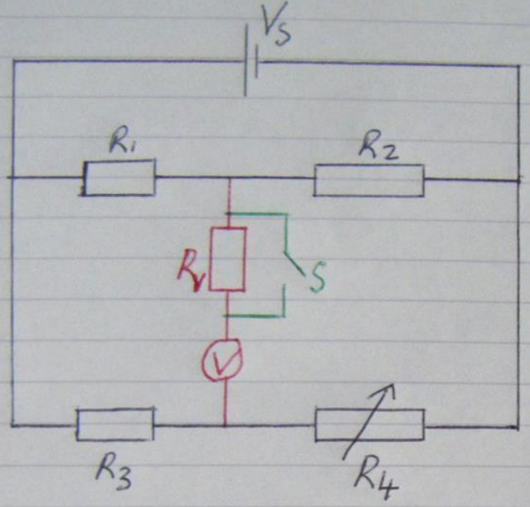
$\Rightarrow \frac{150}{900} = \frac{R}{2400}$

$\Rightarrow R = \frac{150 \times 2400}{900}$

$\Rightarrow \underline{\underline{R = 400\Omega}}$

Rotate the circuit so that the supply is on the top

Unbalanced Wheatstone Bridges

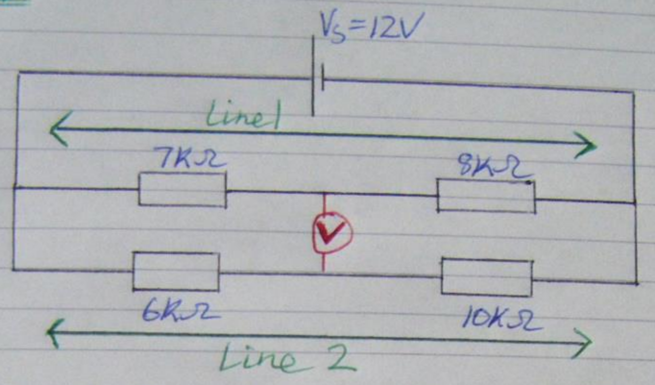


- When the bridge is balanced -(V)- = 0
- When the bridge is highly out of balance -(V)- = large
- R_V protects -(V)- when the bridge is highly out of balance.

- R_4 is varied until the reading on -(V)- decreases until it is near the balance point.
- The switch S is then closed which short circuits resistor R_V.
- The voltmeter then becomes more sensitive to very small variations in current or voltage.
- At balance point -(V)- = 0.

Unbalanced Wheatstone Bridge calculation

Ex4



Calculate the reading on (V)

Use the 'Bear Equation'

XXX $\boxed{V_2 = \left(\frac{R_2}{R_1 + R_2}\right) \times V_S}$ XXX

Line 1 7kΩ and 8kΩ

$$V_{7K} = \left(\frac{7}{(8+7)}\right) \times 12V = \frac{7}{15} \times 12V = \underline{\underline{5.6V}}$$

$$V_{8K} = \left(\frac{8}{(7+8)}\right) \times 12V = \frac{8}{15} \times 12V = \underline{\underline{6.4V}}$$

Check $V_S = V_{7K} + V_{8K} \Rightarrow 12V = 5.6V + 6.4V$ ✓

Line 2 6kΩ and 10kΩ

$$V_{6K} = \left(\frac{6}{(10+6)}\right) \times 12V = \frac{6}{16} \times 12V = \underline{\underline{4.5V}}$$

$$V_{10k} = \left(\frac{10}{6+10}\right) \times 12V = \frac{10}{16} \times 12V = \underline{\underline{7.5V}}$$

Check $V_S = V_{6k} + V_{10k} = 4.5V + 7.5V = 12V$ ✓

$-(V)- = 5.6V - 4.5V = \underline{\underline{1.1V}}$

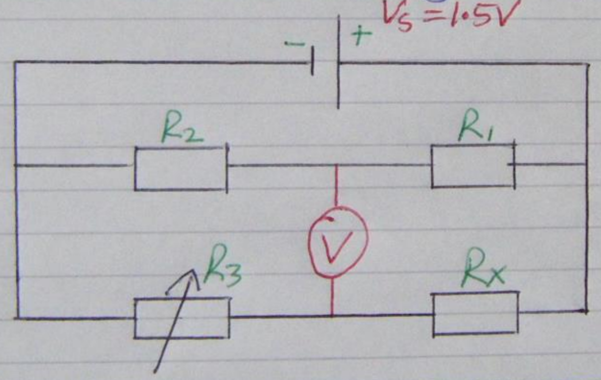
(LHS)

<u>OR</u>

$-(V)- = 7.5V - 6.4V = \underline{\underline{1.1V}}$

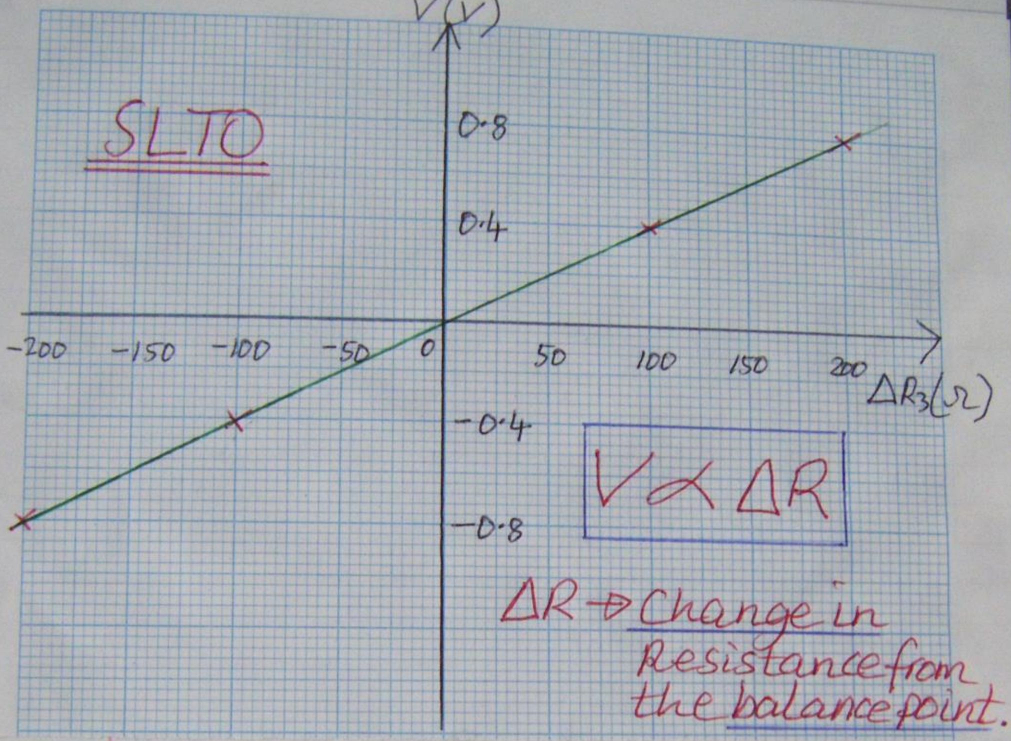
(RHS)

Wheatstone Bridge Experiment



Reading on $-(V)-$ (V)	$R_3 (\Omega)$	$\Delta R_3 (\Omega)$
• −0.8	1960	−200
• −0.4	2060	−100
• 0	2160	0
• +0.4	2260	+100
• +0.8	2360	+200

Bridge is balanced here!!



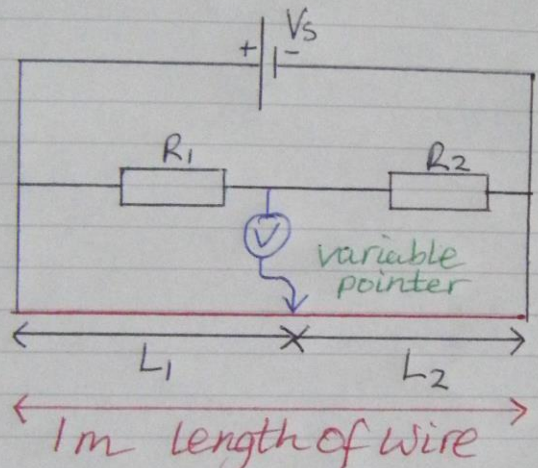
Conclusion

The out of balance current or voltage is directly proportional to the change in resistance (ΔR) away from the balance point.

Metre Bridge

This is a variation of the standard Wheatstone Bridge Circuit.

It contains two resistors and a metre length of wire rather than the standard four resistors.



$L_1 + L_2 = 1m$
$= 100cm$

$$\boxed{\frac{R_1}{R_2} = \frac{L_1}{L_2}}$$

Not in DB!!

Ex5

Q From the metre bridge circuit above, find L_1 and L_2 from the combination of resistances below:

a) $R_1 = 28k\Omega$ and $R_2 = 12k\Omega$

b) $R_1 = 8k\Omega$ and $R_2 = 32k\Omega$

A a) $\frac{R_1}{R_2} = \frac{L_1}{L_2} \Rightarrow \frac{28}{12} = \frac{L_1}{L_2}$

$\Rightarrow \frac{7}{3} = \frac{L_1}{L_2}$

$\Rightarrow \underline{\underline{L_1 = 70cm}}$ and $\underline{\underline{L_2 = 30cm}}$

b) $\frac{R_1}{R_2} = \frac{L_1}{L_2} \Rightarrow \frac{8}{32} = \frac{L_1}{L_2}$

$\Rightarrow \frac{1}{4} = \frac{L_1}{L_2}$

$\Rightarrow \underline{\underline{L_1 = 20cm}}$ and $\underline{\underline{L_2 = 80cm}}$