PENANG SANGAM HIGH SCHOOL

WEEK 20 **LESSON NOTES**

PHYSICS – Y13

STRAND 5: DIRECT CURRENT

SUB-STRAND: Galvanometer conversion, Wheatstone Bridge and Potentiometer

CONTENT LEARNING OUTCOME: To understand the concepts and solve problems.

Galvanometer conversion

A ***galvanometer*** is a device that operates when a torque acts on a current loop in the presence of a magnetic field. A galvanometer is used in the construction of both ammeters and voltmeters.

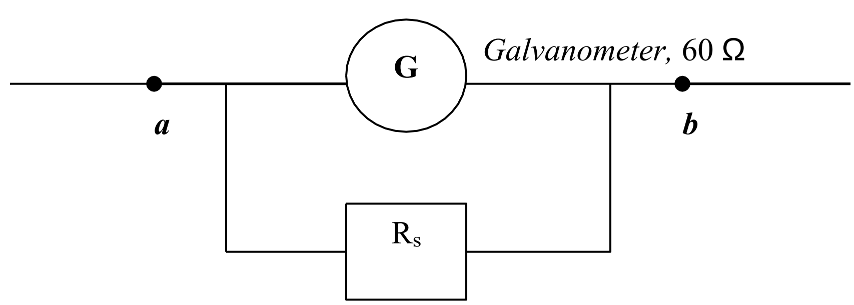
The Ammeter

A galvanometer has an internal resistance of approximately 100 Ω and is not suitable to be used as an ammeter because a resistance this large can considerably alter the amount of current in the circuit. Another limitation in a galvanometer is that it has a very small *full-scale deflection*. (The limit of measurement is very small.)

Example.

We want to convert a galvanometer of internal resistance 60Ω and *full scale deflection* (***fsd***) of 1 *m*A to an ammeter that has a full scale deflection of 2A. Calculate the resistance needed for the conversion.

A shunt resistance (R_s) has to be connected to the galvanometer in parallel, to carry the bulk of the current since the galvanometer can only take 1 *m*A of current at ***fsd.***



As the resistance of the galvanometer is 60 Ω, the potential difference across ***ab*** is given by

$$V = IR, \qquad V = (1 \times 10^{-3}\ \text{A})(60\ \Omega) = \underline{0.06\ \text{V}}$$

The resistance of the shunt resistor (R_s) can now be calculated as we know that the voltage across it is 0.06 V and the current at fsd in R_s will be (2 - 0.001) A = 1.999 A

$$R_s = \frac{V}{I} = \frac{0.006V}{1.999A} = \underline{0.030\ \Omega}$$

The value of the R_s is very low because it provides a path of very low resistance for carrying the bulk of the current.

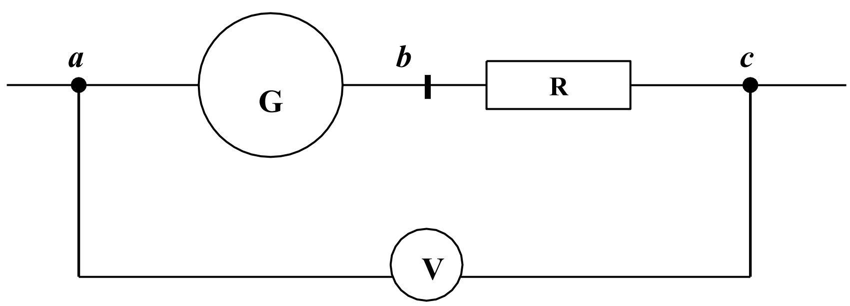
The Voltmeter

The voltmeter is used to measure the potential drop in a circuit and it is connected externally, across two points in the circuit. This means that the internal resistance of the voltmeter should be very high so that it does not allow any significant current to pass through and alter the circuit.

Example.

We want to convert a 60 Ω galvanometer with ***fsd*** of 1 *m*A into a voltmeter that can read up to 12V. Calculate the resistance needed for the conversion.

A resistance has to be connected to the galvanometer in series to increase its total effective resistance.



The current flowing through the galvanometer and the resistance will be same (1 mA).
The voltage across the galvanometer can be calculated using Ohm's Law

$$V_{ab} = IR = (0.001\ A)(60\ \Omega) = \underline{0.06\ V}$$

Since the fsd for the voltmeter is 12 V (V_{ac}) , the potential difference across the resistance (V_{bc}) is $V_{ac} - V_{ab}$, V_{bc} = (12 – 0.06) V
= $\underline{11.94\ V}$

The value of the resistance, R, is therefore

$$R = \frac{V_{ab}}{I} = \frac{11.94V}{0.001A}$$

$$= \underline{11\,940\ \Omega}$$

The value of the resistance, R is very high because a voltmeter should not provide a path for the current to flow.

Exercise

1. We require an ammeter for a current range of 0 to 1.0 A. A galvanometer is available that has a resistance of 100 Ω and gives a full deflection at current of 1.0 *m*A.
   (a) Draw a circuit diagram to show how the shunt resistance is connected.
   (b) Calculate the value of the shunt resistance required.

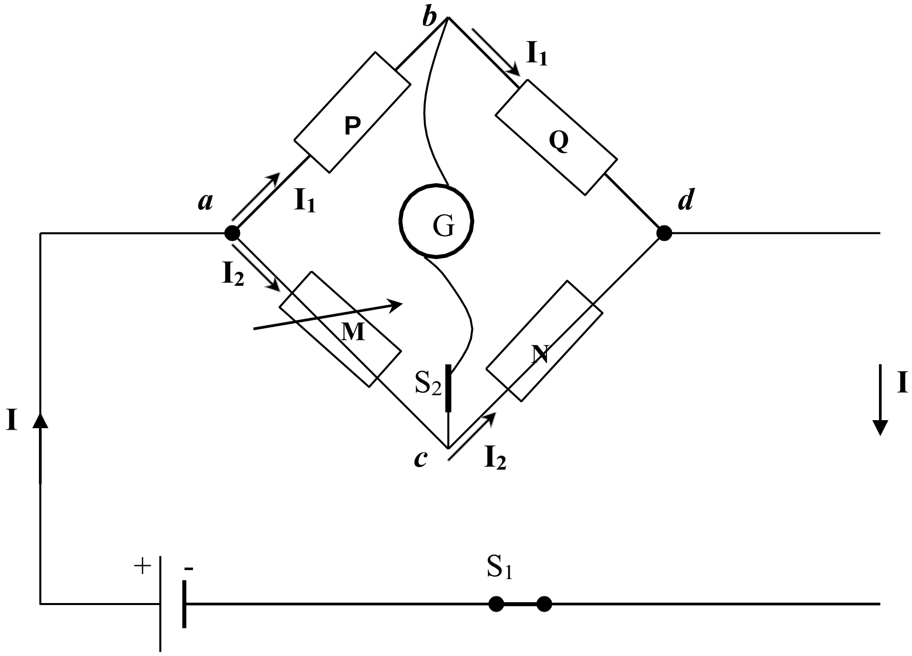
a)	b)

2. A galvanometer of internal resistance of 120 Ω, which has a full-scale deflection of 2 mA, is to be converted to a voltmeter to measure up to 12 V.
   (a) Draw a circuit diagram to show how the resistance is connected.
   (b) Calculate the value of the resistance required for the conversion.

a)	b)

The Wheat stone Bridge

This is a special circuit that can be used to determine the resistance of an unknown resistor by comparison with three other resistances.



When both the switches (S_1 and S_2) are closed and the galvanometer reads zero, the circuit is said to be balanced. Let **P** be the unknown resistance, and the other resistances can be varied to obtain the balance point. At balance point the precise values of the resistances Q, M and N can be taken. Then the unknown resistance can be calculated as outlined below.

$$\frac{P}{Q} = \frac{M}{N}$$

Example.

A bridge circuit is setup to determine the resistance of an unknown resistor. Three variable resistances are arranged and setup as shown in the previous diagram. These resistances are varied till the bridge is balanced. At balance point the resistances of Q, M and N are read to be (Q = 3 Ω , M = 2.5 Ω and N = 4 Ω). Calculate the value of P.

Using equation we can substitute directly;

$$\frac{P}{Q} = \frac{M}{N} \quad , \quad P = \frac{(3\ \Omega)\ 2.5\Omega}{4\Omega}$$

$$P = Q\ \frac{M}{N}$$

<u>P = 1.875 Ω</u>