Current

Electric current is the rate of flow of charge.

$$I = \frac{dQ}{dt}$$

Unit: Ampere (A)

Charge

Charge passing a given point is the product of current and time during which the current flows.

Total Charge is an integer multiple of the elementary charge:

$$Q = Ne$$

Unit: Coulomb (C)

One coulomb is the quantity of electric charge that pass a given point in a circuit when a steady current of 1 ampere flows through that point for 1 second.

$$I = nAvq$$

n: number density of charge carriers
v: drift velocity of charge carriers
q: charge of a charge carrier
A: cross-sectional area of conductor

Potential Difference

The potential difference between 2 points in a circuit is the energy converted from electrical energy to other forms of energy per unit electric charge moved between the 2 points.

$$V = \frac{W}{Q}$$

Unit: Volt (V)

One volt is the potential difference across two points in a circuit in which one joule of electrical energy is converted to other forms of energy when one coulomb of charge is moved between the two points.

Electromotive Force (e.m.f)

The e.m.f of a source is the energy converted from non-electrical energy per unit electric charge in driving a charge round a complete circuit.

$$E = \frac{W}{Q}$$

Unit: Volt (V)

E.m.f is about a source generating and supplying electrical energy to a circuit while P.D is a measure of the ability of a particular part of the circuit or device in the circuit to dissipate electrical energy.

Resistance

Ratio of the potential difference V across the device to the current flowing I across it.

$$R = \frac{V}{I}$$

Unit: Ohm (Ω)

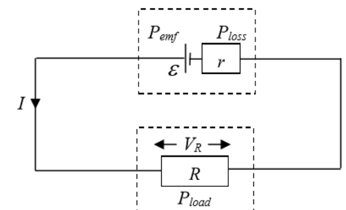
One ohm is the resistance of a device through which a current of one ampere flows when a potential difference of one volt exists across it.

Resistivity

Resistance and resistivity are related by

$$R = \rho\frac{l}{A}$$

Internal resistance of a cell



When switch is OPEN, voltmeter reads E, since no current flows and there is no potential drop across internal resistance r.

When switch is CLOSED, By principle of conservation of energy,

$$P_{cell} = P_R + P_r$$
$$I\varepsilon = IV_R + IV_r$$
$$V_R = \varepsilon - V_r = \epsilon - Ir$$

With the switch closed, current flows in the circuit and there is a potential drop across internal resistance r. Voltmeter reads V_r which is E minus the potential drop across r. We see that the terminal pd is lower than E now.

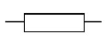
Power Dissipation

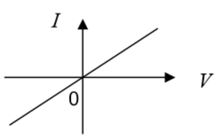
$$P = IV$$
$$P = I^2R$$
$$P = \frac{V^2}{R}$$

a) Ohmic conductor at constant temperature

Obeys Ohm's Law.

Metallic Conductor

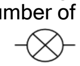


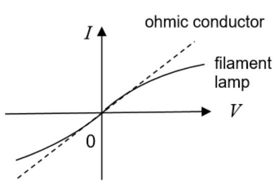


b) Filament lamp

Resistance increases with increasing temperature (when I and V are larger) due to more frequent collisions between free electrons and lattice atoms which vibrate more vigorously at higher temperatures. There is no change in number of charge carriers.

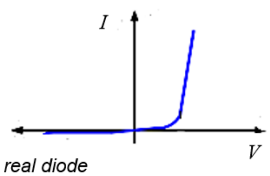
Filament Lamp

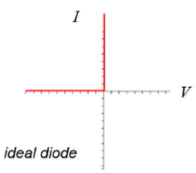


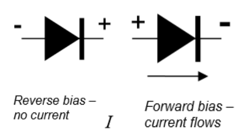


c) Diode

Conducts well in one direction, but badly in other direction. An ideal diode has no resistance in forward-bias and infinite resistance in reverse-bias.



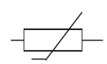


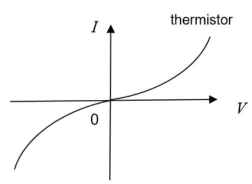


d) Negative Temperature Coefficient (NTC) Thermistor

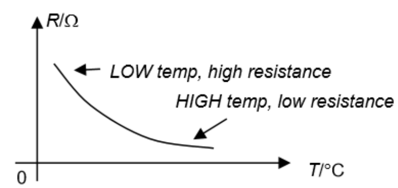
- Resistance decreases with increasing temperature due to large increase in number of charge carriers at high temperature (it is a semiconductor material). This effect overwhelms the increase in lattice vibrations.

Thermistor

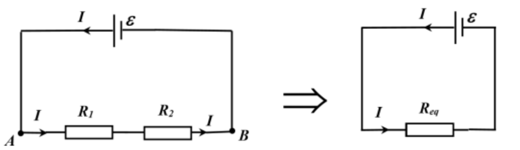




R-T graph for a thermistor



Series Circuit



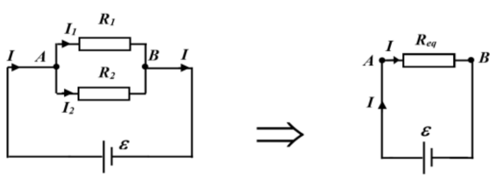
Consider 2 resistors in series (same *I* in both resistors).

$$V_{AB} = V_1 + V_2$$
$$IR_{equivalent} = IR_1 + IR_2$$
$$R_{equivalent} = R_1 + R_2$$

For *n* resistors,

$$R_{equivalent} = R_1 + R_2 + \cdots + R_n$$

Parallel Circuit



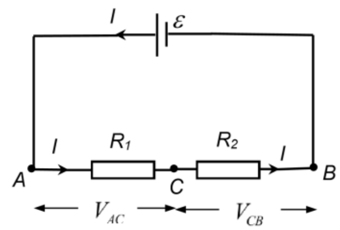
Consider 2 resistors in parallel (same *p.d.* across both resistors).

$$I = I_1 + I_2$$
$$\frac{V_{AB}}{R_{equivalent}} = \frac{V_{AB}}{R_1} + \frac{V_{AB}}{R_2}$$
$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2}$$

For *n* resistors,

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

Potential Divider Rule



Consider 2 resistors in series (same *I* in both resistors).

$$V_{AC} = \frac{R_1}{R_1 + R_2} V_{AB}$$
$$V_{CB} = \frac{R_2}{R_1 + R_2} V_{AB}$$

R1 **or** ***R2*** **can also be a…**

1) Thermistor

A semiconductor device whose resistance decreases as temperature increases.

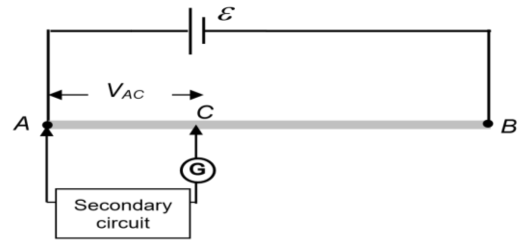
The *p.d.* across the thermistor thus varies with temperature and the circuit can be designed to trigger fire alarms and thermostats.

2) Light dependent resistor (LDR)

A semiconductor device whose resistance decreases as light intensity increases.

The *p,d,* across the LDR thus varies with illumination and the circuit can be designed to switch on lights when light intensity is low.

Potentiometer



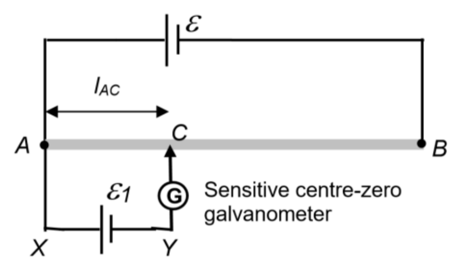
AB is a uniform length resistance wire.

Therefore, $R \propto length$ ($\therefore R = \rho \frac{l}{A}$)

From potential divider rule, $V_{AC} = \frac{R_{AC}}{R_{AB}} V_{AB} = \frac{L_{AC}}{L_{AB}} V_{AB}$

The potentiometer is like an ideal voltmeter which draws no current:

Determine an unknown e.m.f. *ϵ1* of a cell.



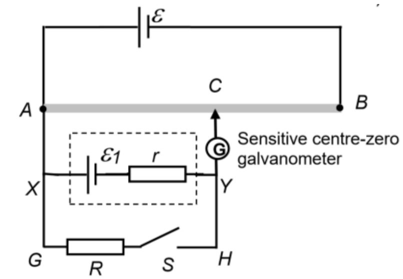
When galvanometer shows null deflection, no current flows in *AX* and *CY*. (note that there is still current flowing in *ABEF*).

$$\epsilon_1 = V_{XY} = V_{AC} = \frac{l_{AC}}{l_{AB}} V_{AB}$$

By measuring l_{AC}, l_{AB} and V_{AB} , the unknown ***ϵ1*** can be found.

Note: Whether or not ***ϵ1*** has internal resistance the balance length l_{AC} will not change. There is no current in *XY*, so there is no potential drop across the internal resistance of ***ϵ1***. V_{AC} is still equal to ***ϵ1***.

Determine unknown internal resistance *r* of a cell.



When galvanometer shows null deflection and switch is open, the balance length allows ***ϵ1*** to be found, as in case on the left.

When switch is closed and galvanometer reads null, while no current flows in *AX* and *CY*, a current flows within the lower circuit (*X* to *G* to *H* to *Y* to *X)* and V_{XY} is now less than ***ϵ1***.

This new V_{XY} can be found from the decreased balance length.

This V_{XY} is the terminal *p.d.* across the battery, which is also the potential drop or difference across *R.*

Thus with the switch closed,

$$V_{xy} = \epsilon_1 - Ir = \epsilon_1 - \left(\frac{V_{xy}}{R}\right) r$$

r can therefore be found, since V_{xy} , R and ϵ_1 are known.