# D.C. Circuits

(a) draw circuit diagrams with power sources (cell, battery, d.c. supply or a.c. supply), switches, lamps, resistors (fixed and variable), variable potential divider (potentiometer), fuses, ammeters and voltmeters, bells, light-dependent resistors, thermistors and light-emitting diodes

(b) state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems

(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems

(d) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems

(e) state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems

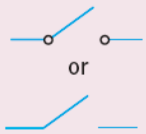
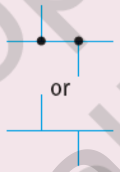
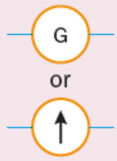
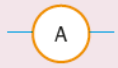
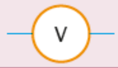
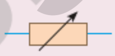
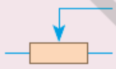
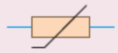
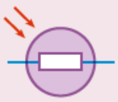
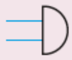
(f) recall and apply the relevant relationships, including $R = V/I$ and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit

(g) describe the action of a variable potential divider (potentiometer)

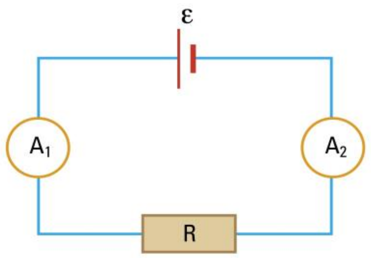
(h) describe the action of thermistors and light-dependent resistors and explain their use as input transducers in potential dividers

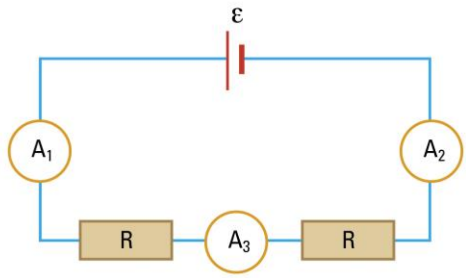
(i) solve simple circuit problems involving thermistors and light-dependent resistors

## Circuit Components

| Symbol | Device | Symbol | Device | Symbol | Device |
|---|---|---|---|---|---|
|  | switch |  | wires joined |  | galvanometer |
|  | cell |  | wires crossed |  | ammeter |
|  | battery |  | fixed resistor |  | voltmeter |
|  | d.c. power supply |  | variable resistor (rheostat) |  | two-way switch |
|  | a.c. power supply |  | fuse |  | earth connector |
|  | light bulb |  | coil of wire |  | capacitor |
|  | potentiometer |  | transformer |  | thermistor |
|  | light-dependent resistor (LDR) |  | semiconductor diode |  | bell |

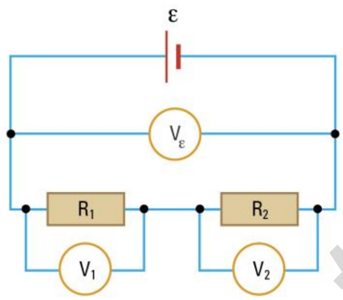
**Current in a series circuit**




Current in a series circuit is the ___________ throughout.

**Potential difference in a series circuit**




In a series circuit, the ______ of the potential difference across **each component** is equal to the potential difference **across the** ____________ **circuit ( = emf of the source)**.

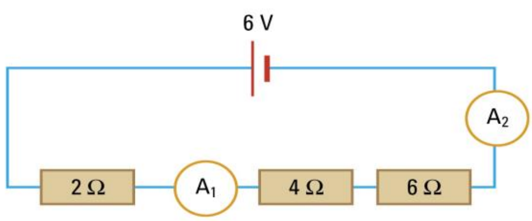
i.e. $V_\varepsilon = V_1 + V_2 = \varepsilon$

**Resistance**

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

**Total resistance in series:**

**Example 1**

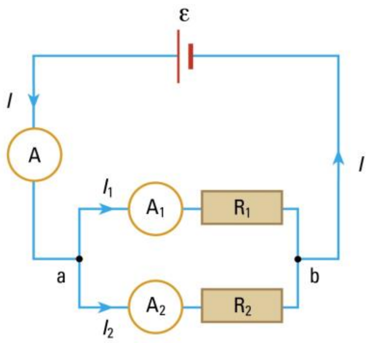



a) What is the total resistance in the circuit shown above?

b) What are the readings shown on ammeters $A_1$ and $A_2$?

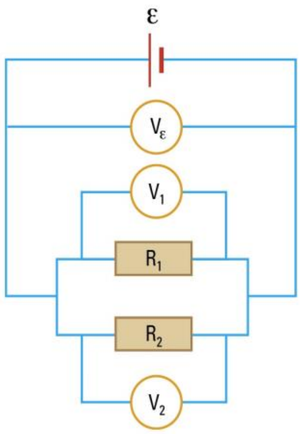
c) What is the p.d. across each resistor?

**Current in a parallel circuit**




I = $I_1 + I_2$

**Potential difference in a parallel circuit**



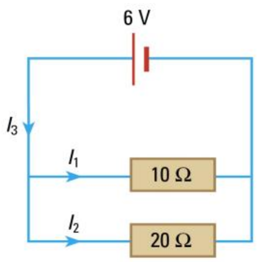

Potential difference across components in parallel is equal

$V_\varepsilon = V_1 = V_2 = \varepsilon$

**Total resistance in parallel**



**Example 2**



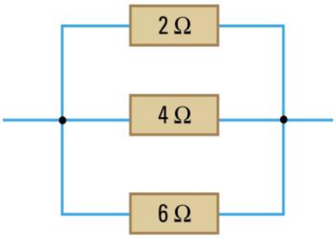

a) Find the currents $I_1$, $I_2$, $I_3$

b) What is the voltage or potential difference across the 10 Ω and 20 Ω resistors?

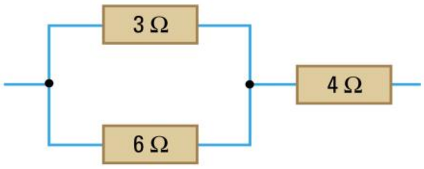
c) Calculate the effective resistance of the 10Ω and 20Ω resistors.

**Find the effective resistance of each of the following:**

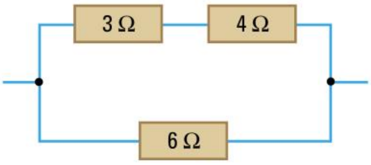
**a)**



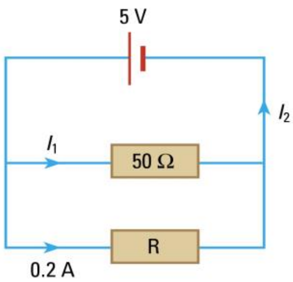

**(b)**




(c)

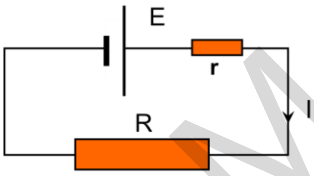


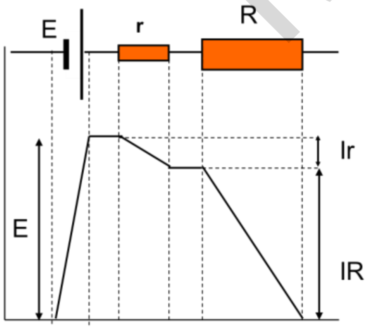

**Example 3**




Find $I_1$, $I_2$ and R

**Potential Difference in terms of energy**



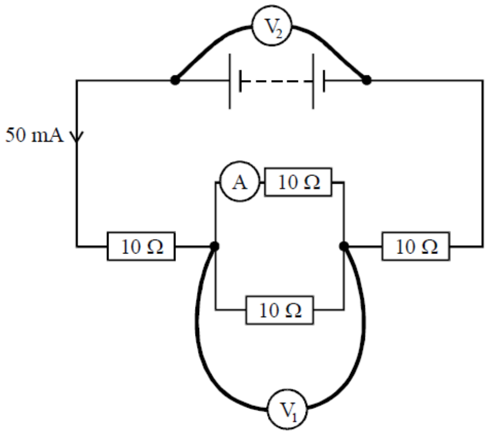

E = electromotive force

Ir and IR = potential difference

E = Ir + IR

(resourcefulphysics.org)

**Example 4**




Determine the reading on $V_1$, $V_2$ and A.

**Example 5**

The circuit shows a light bulb connected to 3 resistors and a 12 V source. Initially, all the switches are opened.

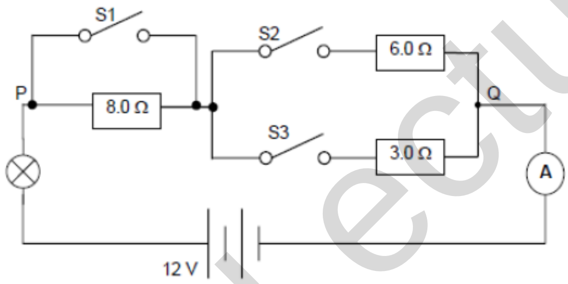



**Fig 7**

(a) S1 is opened and S2 and S3 are closed.

(i) Calculate the total resistance between points P and Q.

(ii) The ammeter registers a reading of 0.3 A. Calculate the resistance of the light bulb.

(iii) The lamp is switched on for 2 minutes. Calculate the amount of energy consumed by the lamp.

(b) S1, S2 and S3 are now closed. Describe and explain how the brightness of the lamp has changed as compared to (a).

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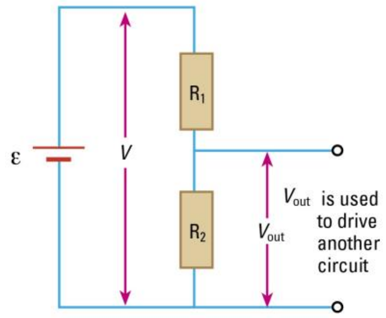
(c) The 8Ω resistor is a cylindrical wire of length L and radius R made from a certain type of material. It is replaced by another resistor of the same type but with 3 times the length and twice the radius. Calculate its resistance.

**Variable potential divider (voltage divider or potentiometer)**

- It is a circuit with resistors arranged in series.
- With it, we can divide a main voltage into two or more voltages.

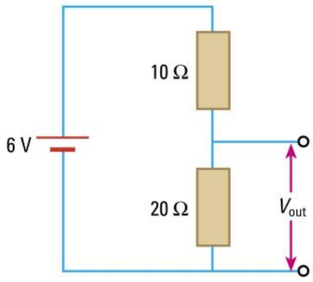
**Uses: e.g. street lamps, burglar alarms, thermostats**

**Type I (2 fixed resistors)**

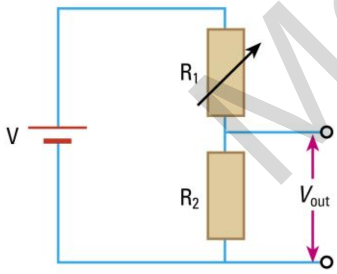



**Question 1**

Calculate $V_{out}$.

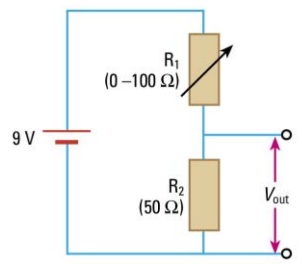



**Type II (Replace one of the fixed resistors with a variable resistor)**

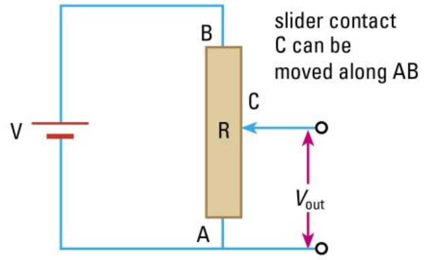



**Question 2**

The circuit shows a 9 V battery connected in series with a variable resistor $R_1$ and a 50 Ω resistor $R_2$. The resistance of the variable resistor $R_1$ can vary from 0 to 100 Ω. What are the maximum and minimum output voltages?



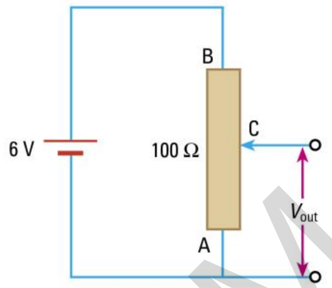

**Type III (Replacing the two resistors with a potentiometer)**




- The position of sliding contact C determines the ratio of the resistance since R ∝ *l* for a fixed cross-sectional area.
- To obtain a larger output voltage, the slider contact C is moved **towards** _________.

**Question 3**

A 6 V battery of negligible internal resistance is connected to a potentiometer with a maximum resistance of 100 Ω. Calculate the output voltage $V_{out}$ when the slider contact is at




(a) A,

(b) the midpoint between A and B.

(c) B.

**Type IV (Replacing one of the resistors with a input transducer)**

Transducers – Electrical or electronic devices that convert energy from one form to another.

- They respond to physical quantities like light and temperature.
- Input transducers – convert **non** electrical energy to electrical energy

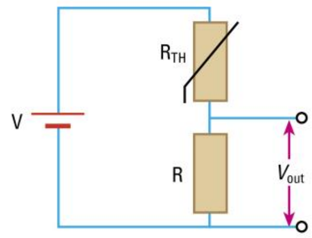
e.g. microphones, thermistors, light dependent resistors, photocells, thermocouples, pressure sensors and stress sensors

- Output transducers – convert electrical energy to other forms of energy

e.g. loudspeakers, lamps, LEDs, voltmeters and ammeters

**NTC (negative temperature coefficient) Thermistor:**

- **Hot (more mobile electrons) – resistance decreases**
- **Cool (fewer mobile electrons) – resistance increases**

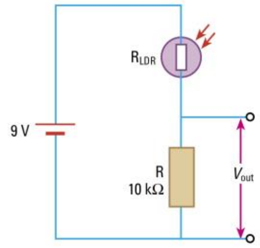



e.g. air conditioner connected to $V_{out}$

When temperature increases > preset temperature →$R_{TH}$ drops → $V_{TH}$ drops → $V_{out}$ increases → $V_{out}$ switches on cooling unit in the air conditioner which lowers temperature.

**LDR (light dependent resistor):**

- **Brightness increases (more mobile electrons) – resistance decreases;**
- **When brightness decreases (fewer mobile electrons) – resistance increases**



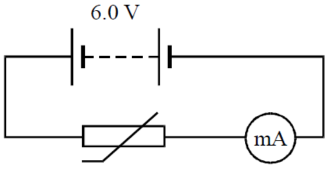

e.g burglar alarm

Burglar shines a light on safe which has a LDR →$R_{LDR}$ decreases →$V_{LDR}$ decreases → $V_{out}$ increases – alarm activated



**Question 4**

A **negative temperature coefficient thermistor** is used in the following circuit to make a temperature sensor.




Explain how the circuit works.

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**Question 5**

Fig 5.1 shows a circuit whose output potential difference, $V_{AIR}$ varies with the surrounding air temperature. Fig 5.2 shows how the resistance of the air temperature sensor varies with temperature.

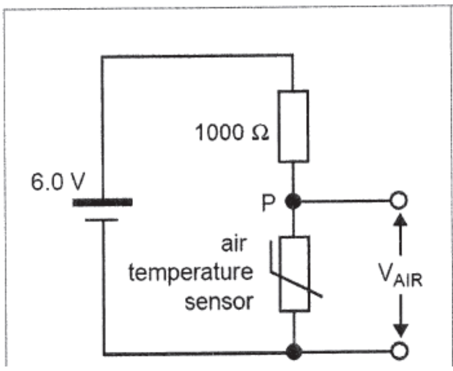


Fig 5.1

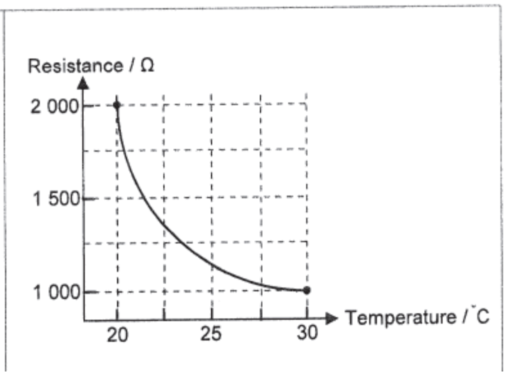


Fig 5.2

(a) Name the input transducer that can be used as an air temperature sensor.

……………………………………………………………………………………………………

(b) Show that at a temperature of 20˚C, the potential difference across the air temperature sensor, $V_{AIR}$ is 4.0 V.

(c) Calculate the current in the circuit when the air temperature is 20˚C. Express your answer in units of mA.

(d) How much power is dissipated in the 1000 Ω resistor when the air temperature is 20˚C?

($P = I^2R$)

**Question 6**

A student wants to provide lighting for a model house which she has made. She needs 3.0 V for her lamps but only has a 9.0 V battery, so she uses a linear resistor AB in the circuit below. The linear resistor is made from a high resistance uniform conductor.

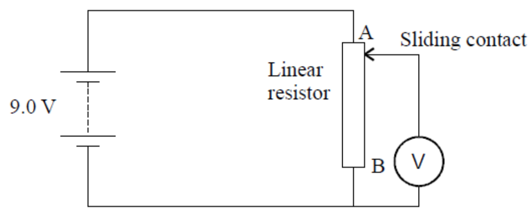


Fig 7

(a) What is the name of the device AB when used in this manner?

……………………………………………………………………………………………………..

(b) State the voltmeter reading when the sliding contact is at:

(i) A ……………………………..…… (ii) B ………………………………………

(c) Indicate on Fig 7 with the letter X to show where the sliding contact should be positioned such that the voltmeter reading is 3.0 V..

(d) The student replaces the voltmeter with a 3.0 V lamp but the lamp does not light. Explain why the lamp does not light.

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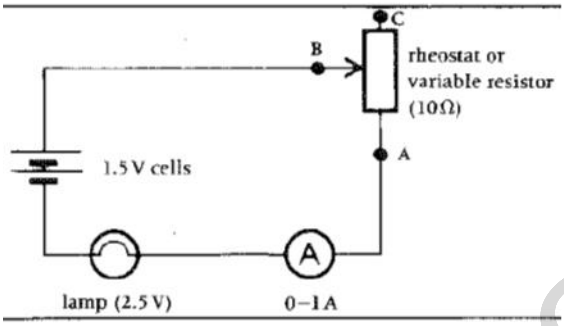
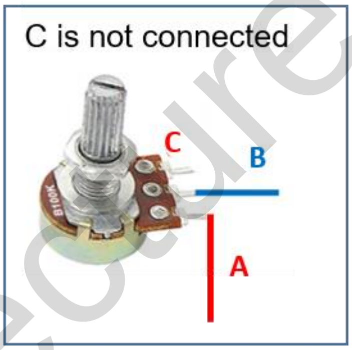
**Difference between a rheostat and potential divider**

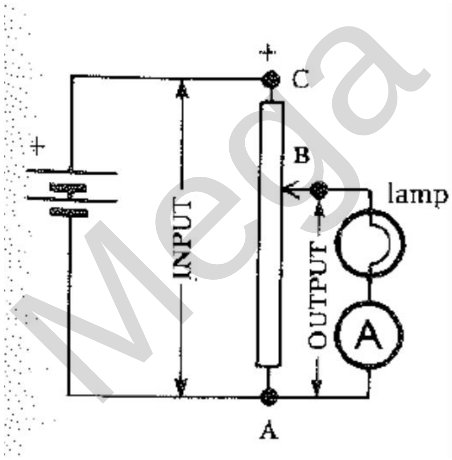
A rheostat uses only two terminals of a variable resistor while a potential divider uses all three terminals

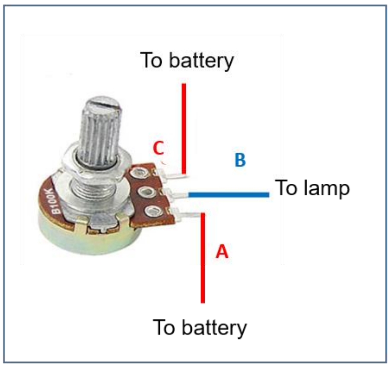
**Rheostat**




**Potential divider**




This means that when in use, the current in the lamp connected to a rheostat will never drop to 0 A while the current in the lamp connected using a potentiometer circuit can be reduced to 0 A. (Why?)