Section 4.4

Electric circuits

4.4.1 Circuit components

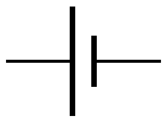
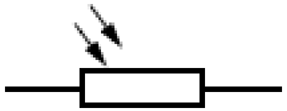
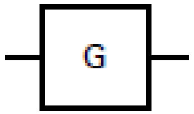
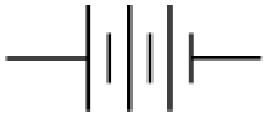
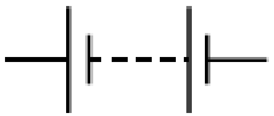
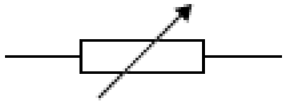
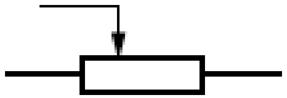
4.4.2 Combinations of resistors

4.4.3 Electronic circuits

4.4.4 Electrical safety

C. Chu

Circuit Symbols

cell		light dependent resistor		generator	
battery of cells	 or 	variable resistor		heater	
		potential divider		ammeter	
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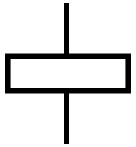
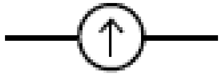
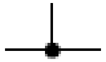
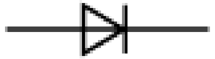
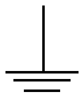
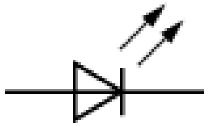
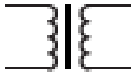
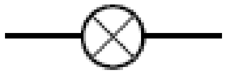
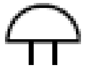
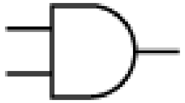
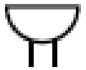
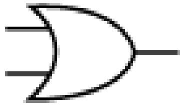
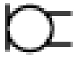
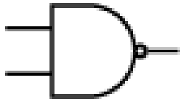
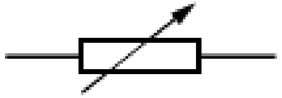
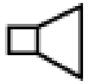
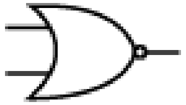
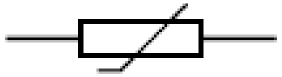
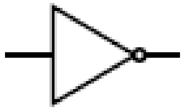
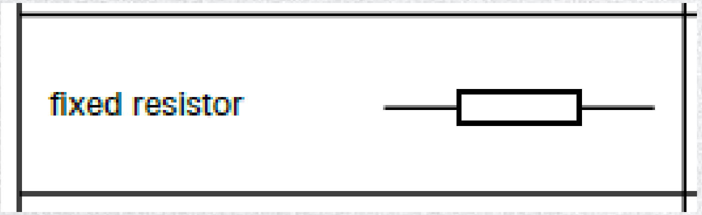
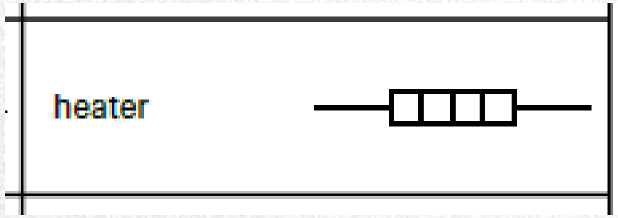
a.c power supply		relay coil		galvanometer	
junction of conductors		diode		oscilloscope	

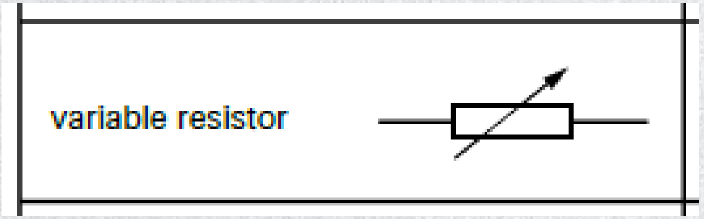
Circuit Symbols

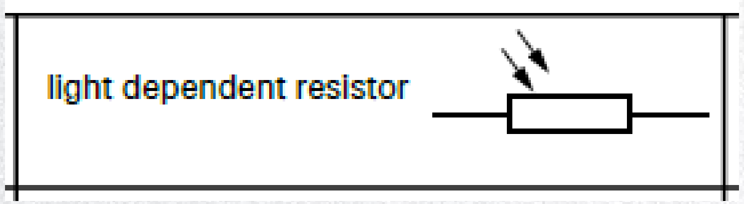
earth or ground		light-emitting diode		transformer	
lamp		electric bell		AND gate	
switch		buzzer		OR gate	
fixed resistor		microphone		NAND gate	
variable resistor		loudspeaker		NOR gate	
thermistor		motor		NOT gate	

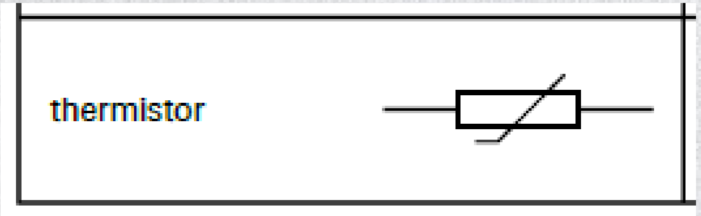
Circuit Symbols

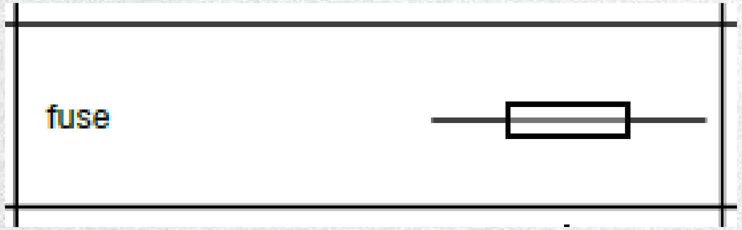




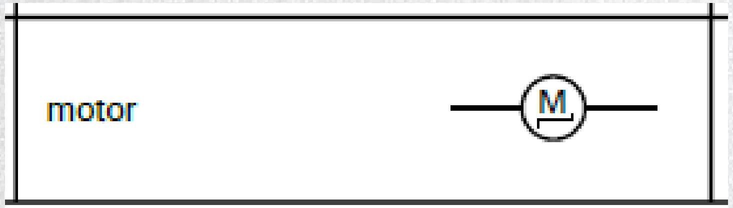


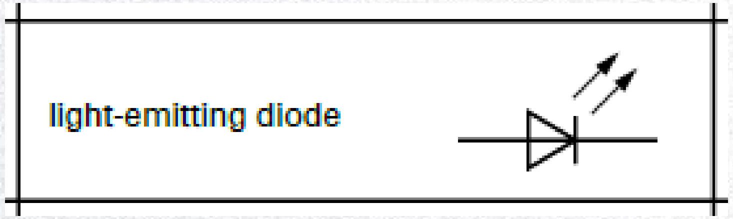


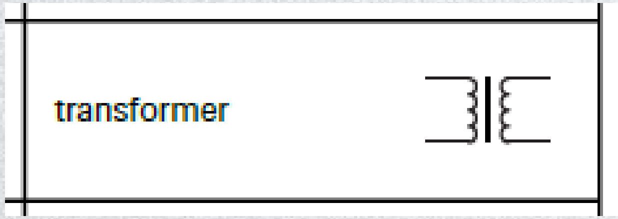


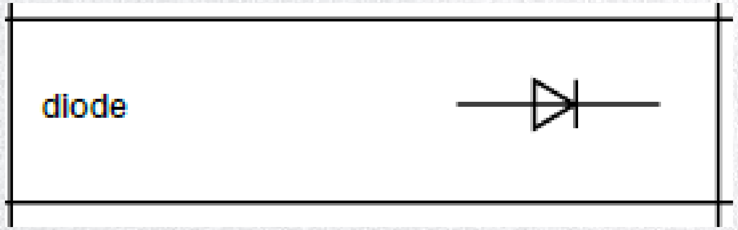


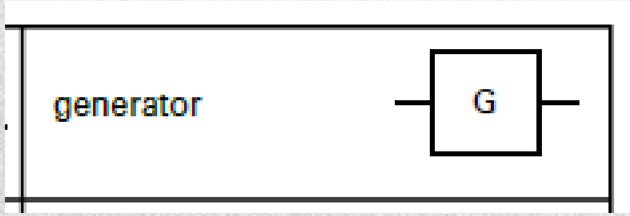
Circuit Symbols











Study question #1

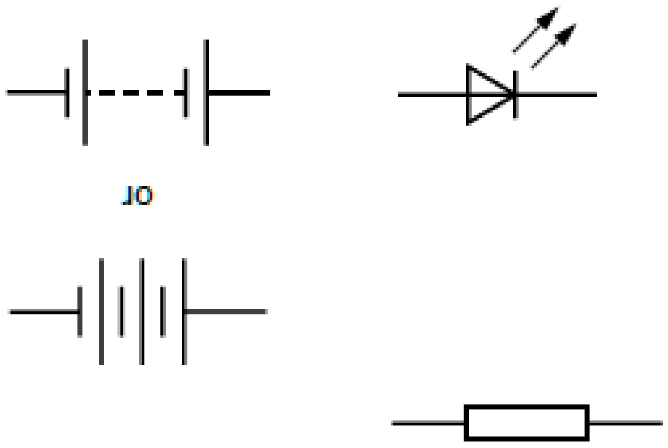
A light-emitting diode (LED) is a diode that emits light when there is a current in it. Draw a circuit diagram showing an LED, connected so that it is lit, in series with a battery and a fixed resistor. Use standard electrical symbols.

[4]

[Total: 4]

Study question #1

A light-emitting diode (LED) is a diode that emits light when there is a current in it. Draw a circuit diagram showing an LED, connected so that it is lit, in series with a battery and a fixed resistor. Use standard electrical symbols.

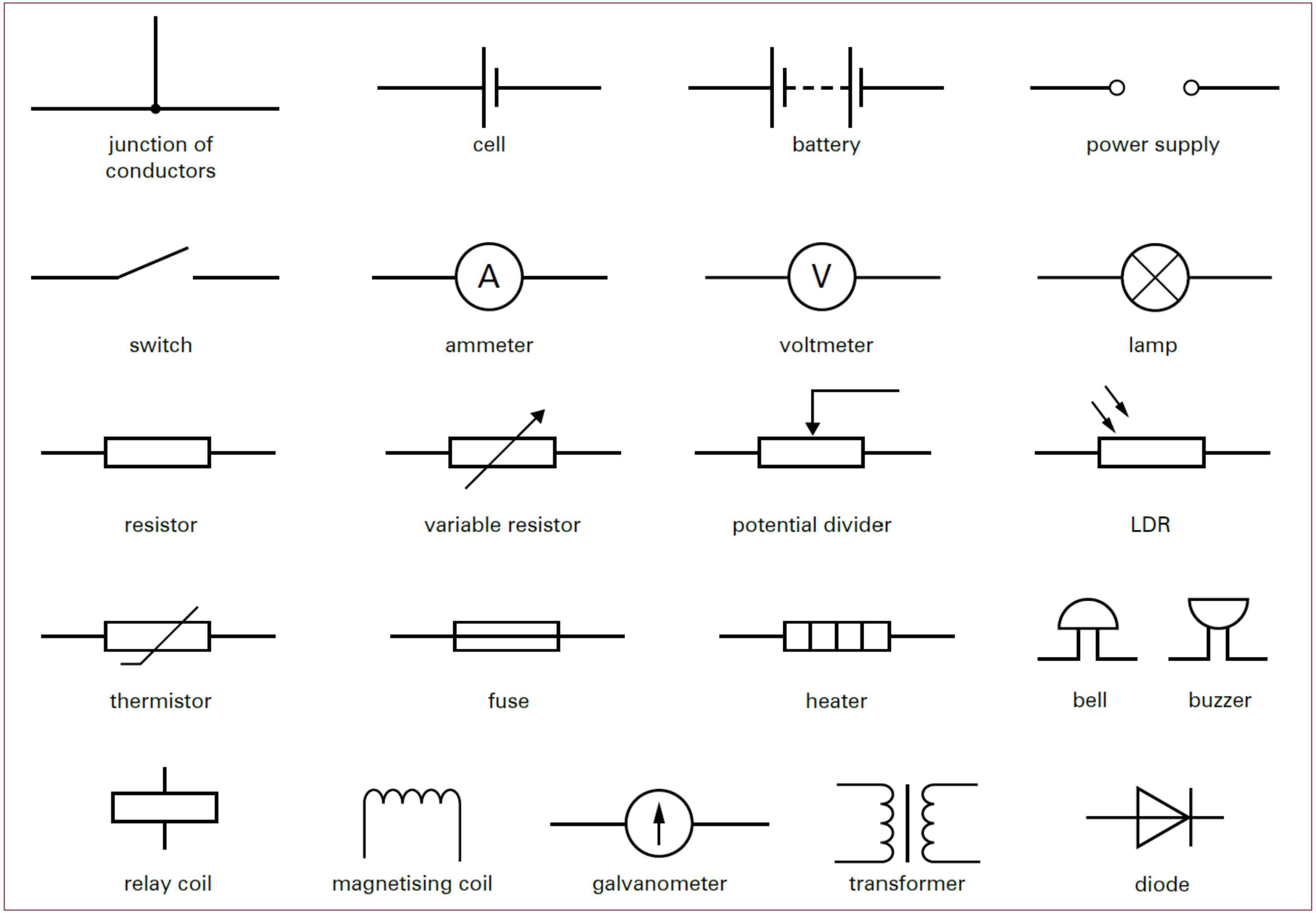


two circuit symbols correct (1) three circuit symbols correct (1) symbol for cell, battery or power supply **AND** two other circuit symbols in series (1) LED correct way round (1)	**4**

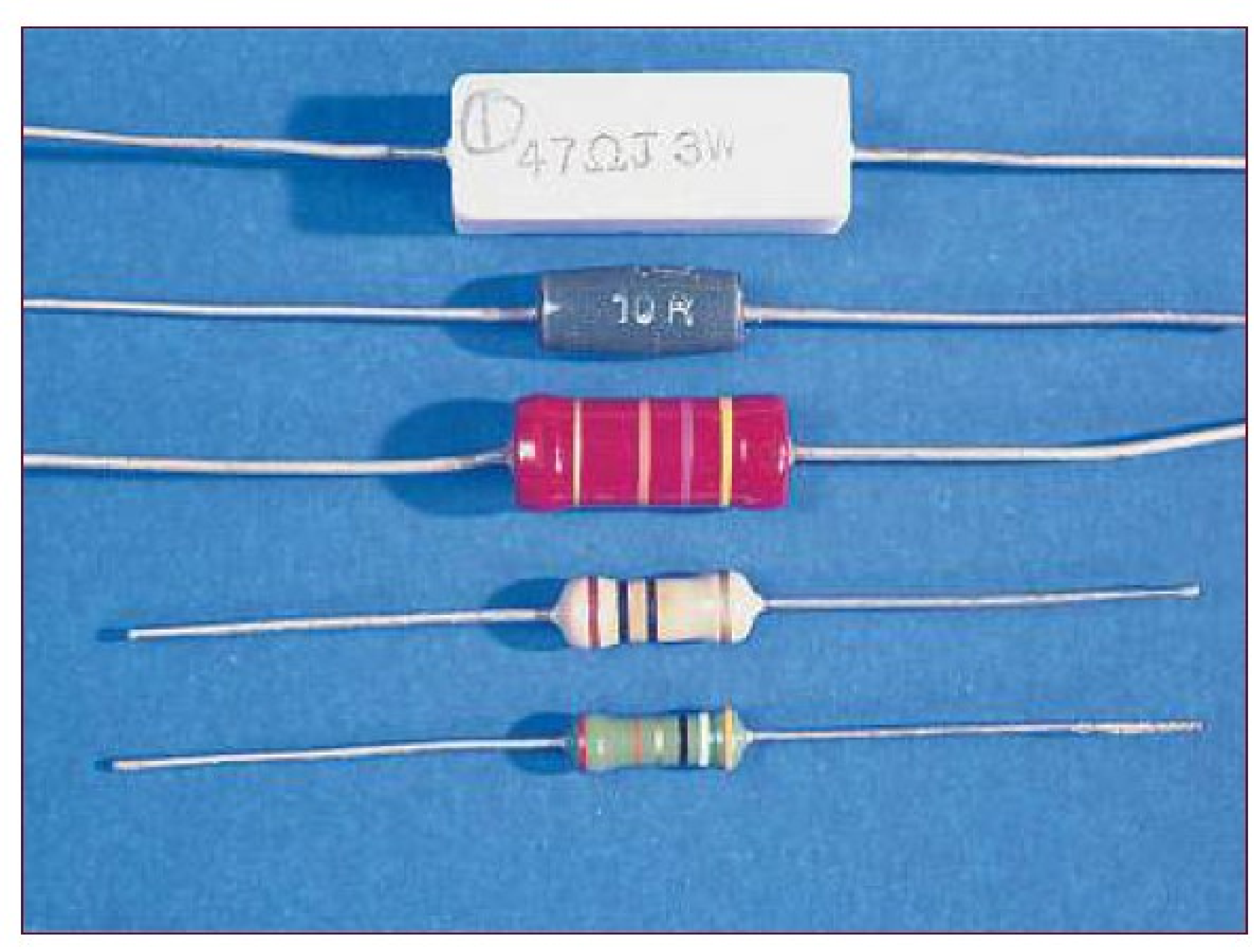
[4]

[Total: 4]

Review


junction of conductors
cell
battery
power supply
switch
ammeter
voltmeter
lamp
resistor
variable resistor
potential divider
LDR
thermistor
fuse
heater
bell
buzzer
relay coil
magnetising coil
galvanometer
transformer
diode

Resistors



A selection of resistors. Some have colour-coded stripes to indicate their value, and others use a number code.

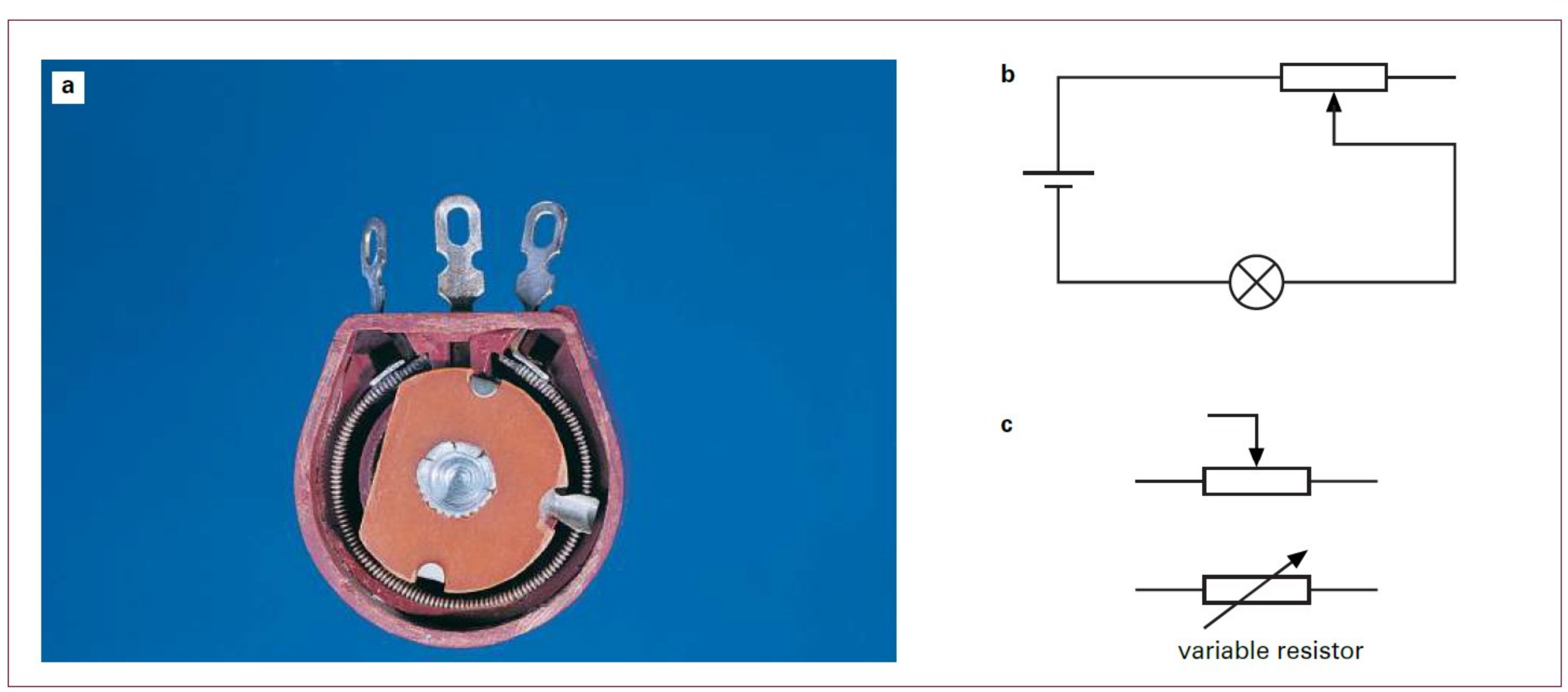
Resistors

- A resistor can be used to control the amount of current flowing around a circuit.
- A resistor has two terminals, so that the current can flow in one end and out the other.
- They may be made from metal wire (usually an alloy – a mixture of two or more metals with a high resistance) or from carbon.
- Carbon (like the graphite ‘lead’ in a pencil) conducts electricity, but not as well as most metals. Hence high-resistance resistors tend to be made from graphite, particularly as it has a very high melting point.

Variable Resistors

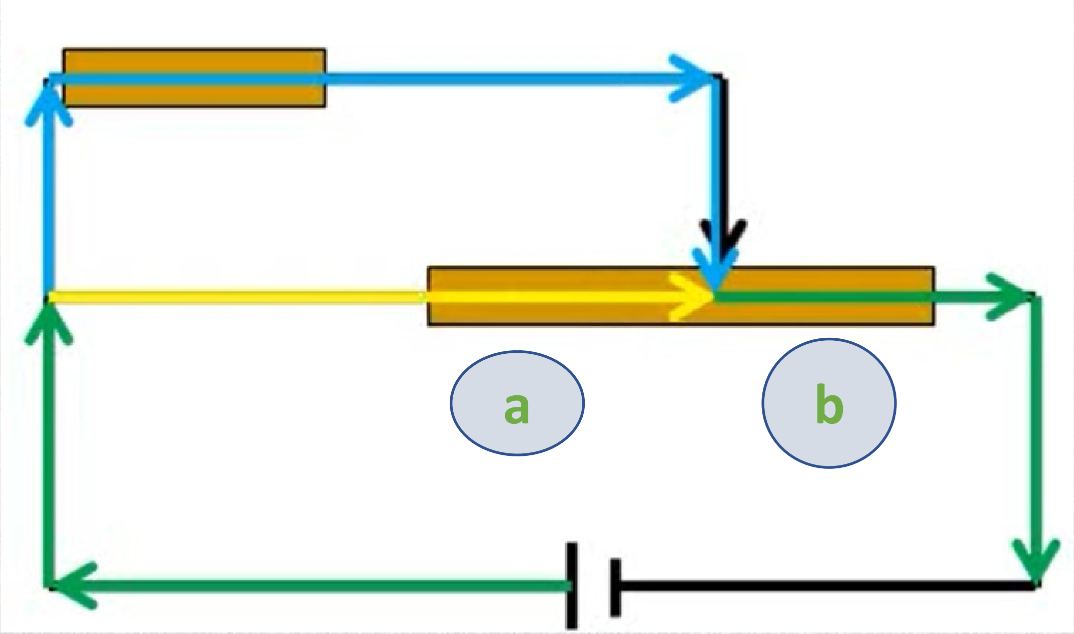
- A variable resistor (sometimes called a ***potentiometer***) can be used to alter the current flowing in a circuit.
- A variable resistor has *three* terminals. As the control is turned, the contact slides over the resistive track. The current enters at one end and flows through the track until it reaches the contact, where it leaves the resistor. The amount of track that it flows through depends on **the position of the contact**. Variable resistors like this are often used for the volume control of a radio or stereo system. (You may have come across a **rheostat**, which is a lab version of a variable resistor.)

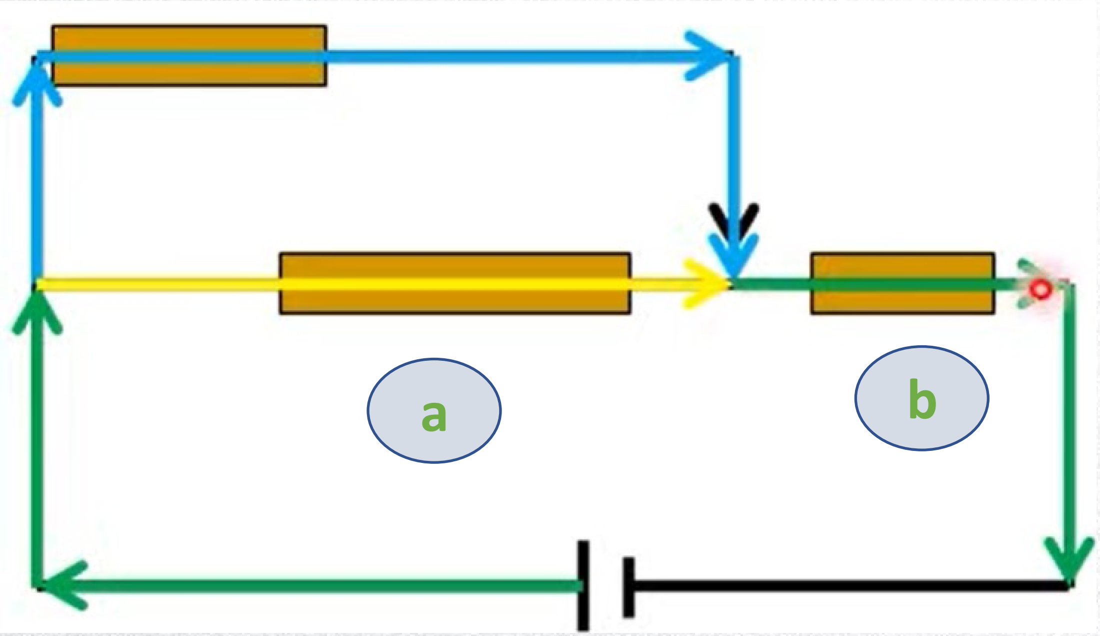
Variable Resistors



a. A variable resistor. The resistance in the circuit depends on **the position of the sliding contact**.
b. The current flowing around this circuit depends on **the position of the slider** on the variable resistor. Imagine sliding the arrow to the right. The current will then have to flow through more resistance, and so it will decrease.
c. Symbols for a variable resistor.

Variable Resistors

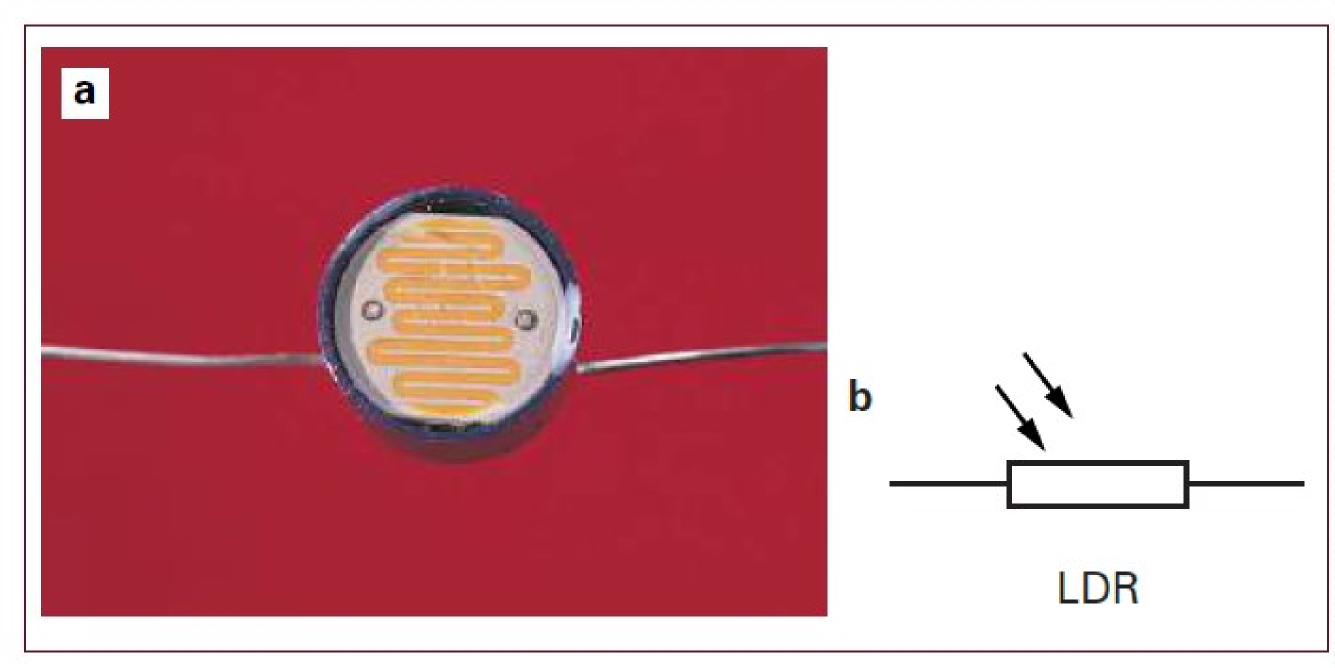




Light-dependent resistor (LDR)

- A **light-dependent resistor (LDR)** is a type of 'variable resistor' whose **resistance** depends on **the amount of light** falling on it.
- An LDR is made of a material that does not normally conduct well. In the dark, an LDR has a high resistance, often over 1 MΩ. However, light can provide the energy needed to allow a current to flow. Shine light on an LDR and its resistance decreases. In bright light, its resistance may fall to 400 Ω.
- LDRs are used in circuits **to detect the level of light**, for example in security lights that switch on automatically at night. Some digital clocks have one fitted. When the room is brightly lit, the display is automatically brightened so that it can be seen against its bright surroundings. In a darkened room, the display need only be dim.

● Light-dependent resistor (LDR)



a. A light-dependent resistor. The interlocking silver ‘fingers’ are the two terminals through which the current enters and leaves the resistor. In between (yellow-coloured) is the resistive material.

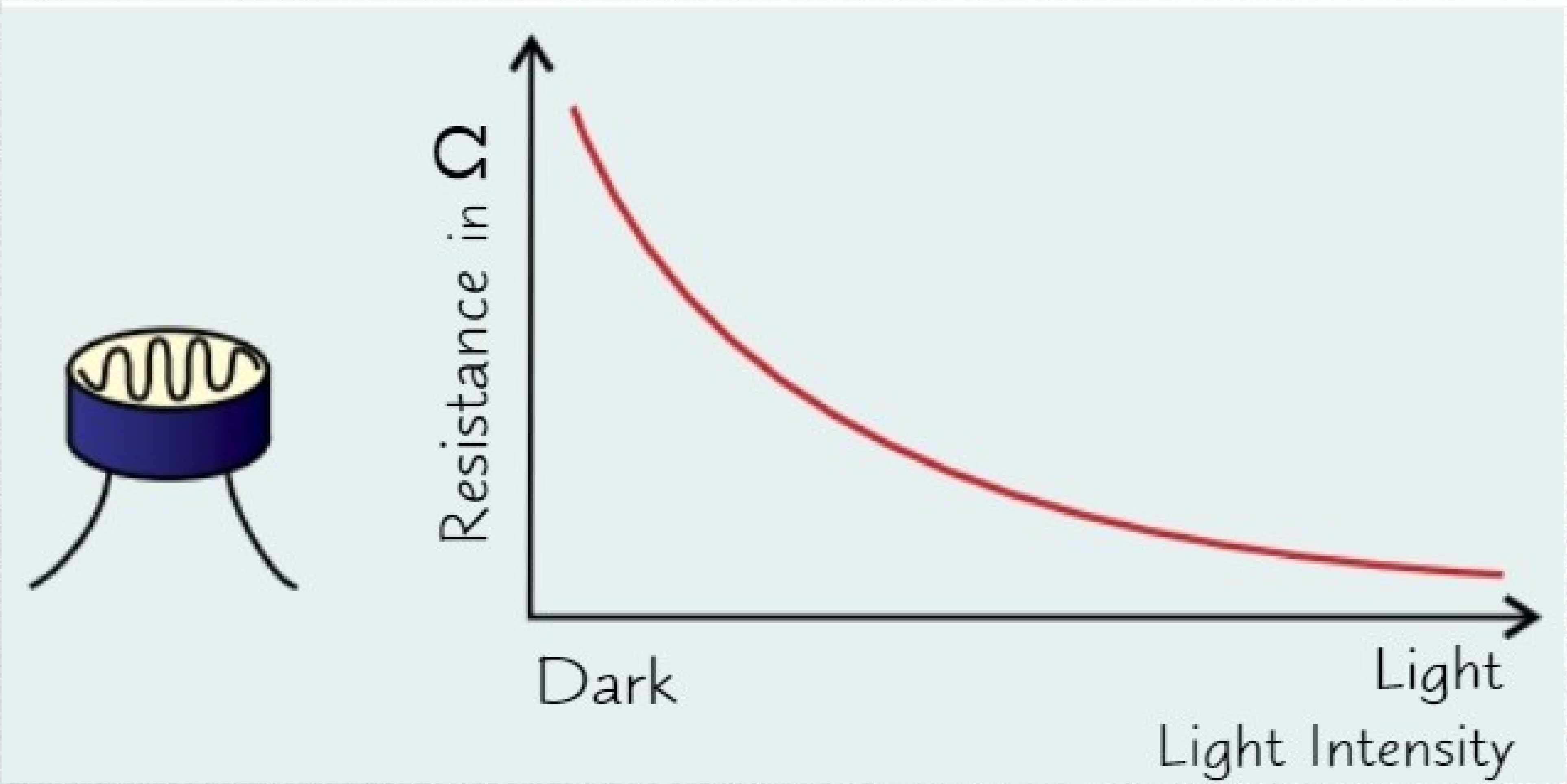
b. In the circuit symbol, the **arrows** represent **light shining on the LDR**.

Light-dependent resistor (LDR)

A **light-dependent resistor (LDR)** is a special type of resistor that changes its resistance depending on how much light falls on it:

- The greater the intensity of light shining on an LDR, the lower its resistance.
- In **bright** light, the **resistance falls**; and in **darkness**, the **resistance is highest**.
- Light provides the energy that releases more electrons, which means more charge carriers, so that there will be a higher current and a lower resistance.

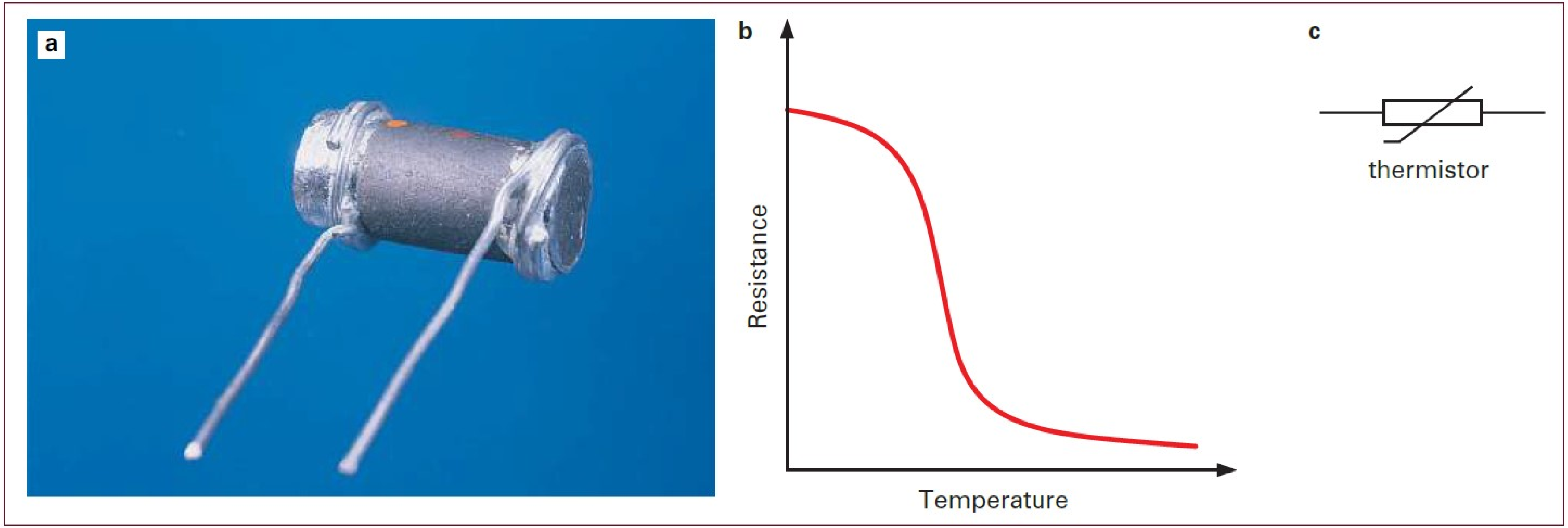
● Light-dependent resistor (LDR)



Thermistor

- A thermistor is another type of resistor whose **resistance depends on** its temperature.
- The resistance changes by a large amount over a narrow range of temperatures.
- For some thermistors, the resistance decreases as they are heated – perhaps from 2 kΩ at room temperature to 20 Ω at 100 °C. These thermistors are thus useful for temperature probes.
- For other thermistors, the resistance increases over a similar temperature range. These are included in circuits where you want to prevent over-heating.
- If the current flowing is large, components may burn out. With a thermistor in the circuit, the resistance increases as the temperature rises, and the high current is reduced.

Thermistor



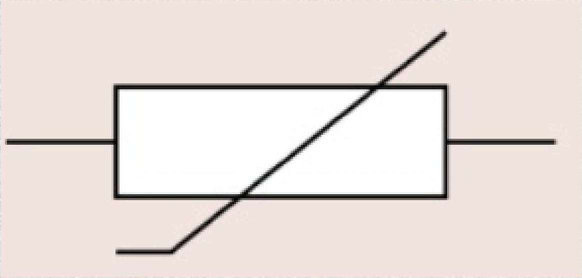
a. A thermistor.
b. The resistance of a thermistor depends on the temperature. In this case, in the middle of the curve, its resistance drops a lot as the temperature increases by a small amount.
c. In the circuit symbol, **the line through the resistor indicates that its resistance is not fixed but depends on an external factor** (in this case, the temperature).

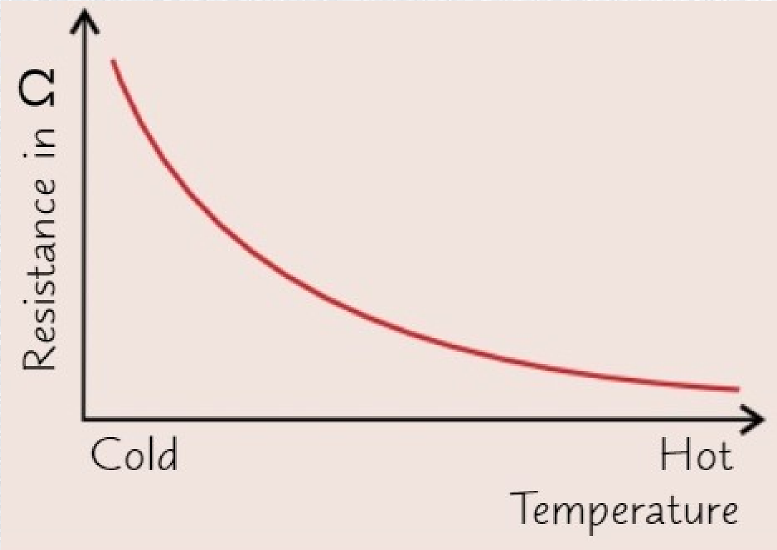
Thermistor

A **thermistor** is a temperature-dependent resistor:

1. In hot conditions, the resistance drops; in cool conditions, the resistance goes up.

2. Thermistors make useful temperature detectors, e.g. car engine temperature sensors, thermostats and fire alarms.

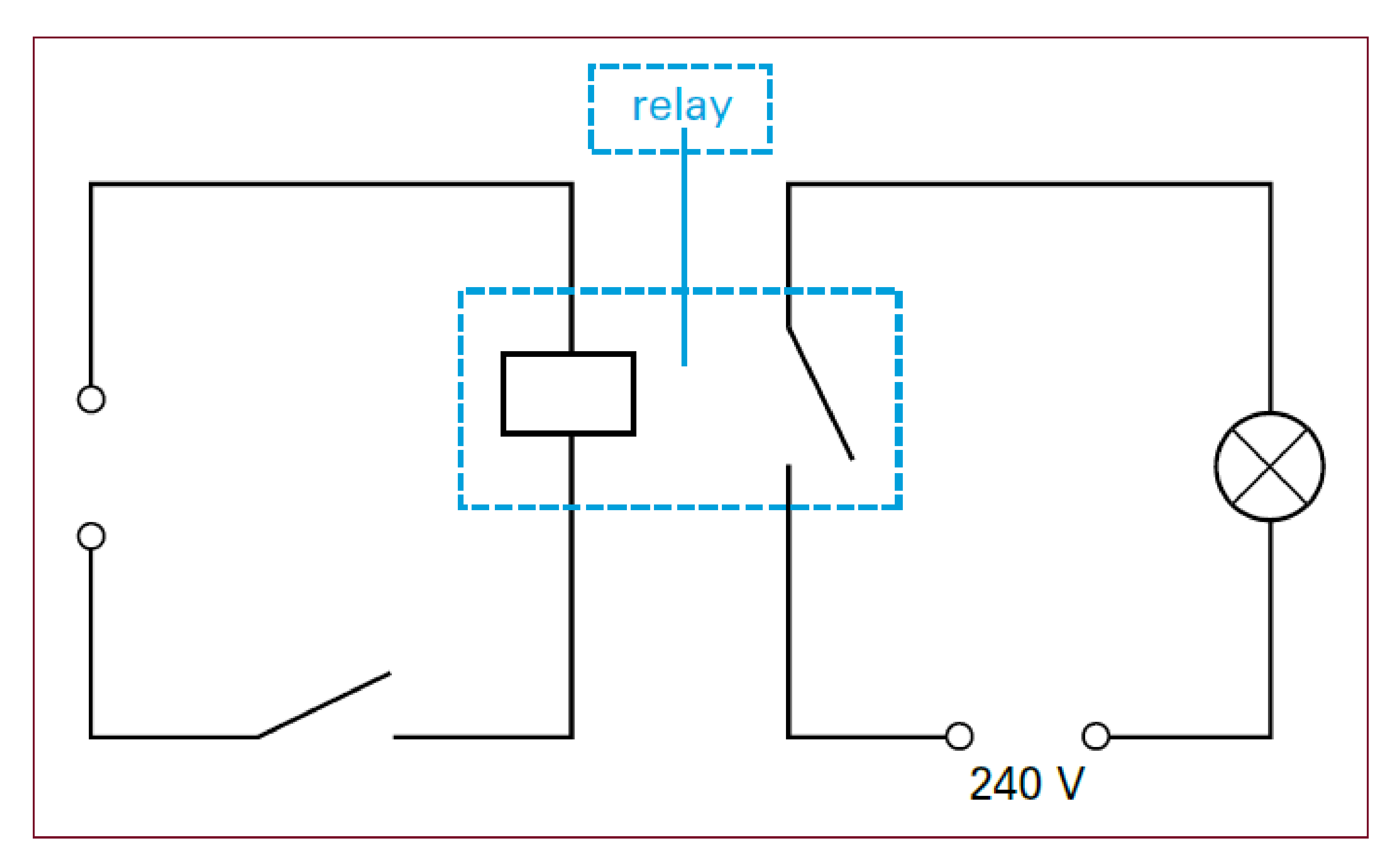




Relays

- A relay is a type of switch that works using an **electromagnet**.
- When a relay is used, there are **two complete circuits**:
  - ✓ the **electromagnet coil** of the relay (represented by a rectangle) is in one circuit
  - ✓ the **switch** is in the other circuit.
- When a current flows through the relay coil in the first circuit, it becomes magnetised. It pulls on the switch in the second circuit, causing it to close, and allowing a current to flow in the second circuit.
- The second circuit often involves a large voltage, which would be dangerous for an operator to switch, or which could not be switched by a normal electronic circuit (because these work at low voltage).

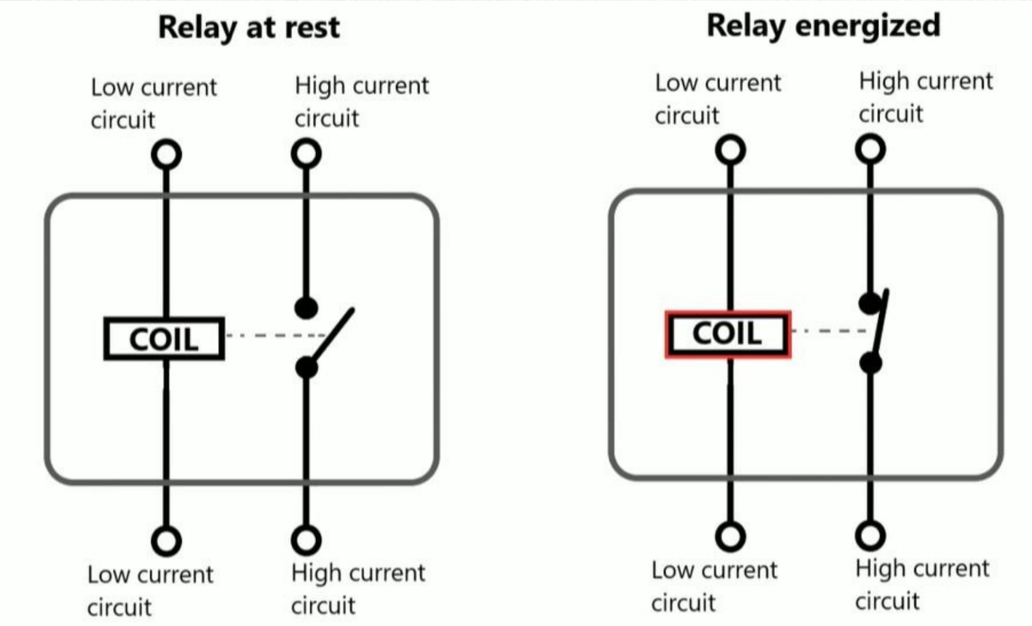
Relays



A relay is used to link two circuits together.

The relay is composed of **a coil and a switch** (shown in the blue dashed box).

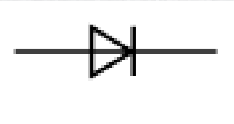
Relays



- A relay is an electrically operated **switch**.
- As electricity flows through the coil, it can energize the relay and it turns the coil into an **electromagnet**.
- The magnetic effect of this electromagnet attracts the open switch on the right and closes it to connect the circuit.
- A small current through the left circuit can be used to trigger the connection of the second circuit on the right which has much higher current flowing through it.

Diode

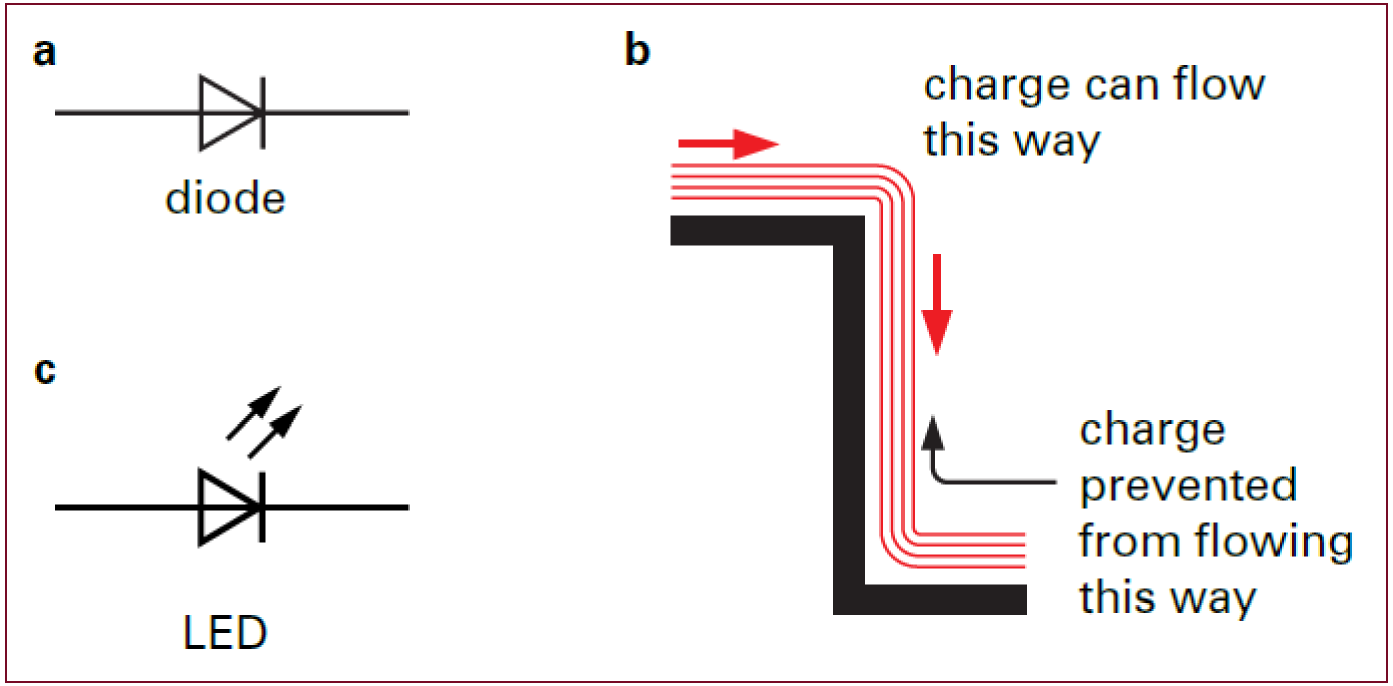
- A diode is a component **that allows electric current to flow in <u>one</u> direction only**. Its circuit symbol represents this by showing **an <u>arrow</u> to indicate the direction in which current can flow**. The **<u>bar</u>** shows that current is stopped if it tries to flow in the opposite direction.
- Some diodes give out light when a current flows through them. A diode that does this is called a **<u>light-emitting diode (LED)</u>**.
- Diodes are useful for **converting <u>alternating current</u> (which varies back and forth) into <u>direct current</u> (which flows in one direction only)**. This process is known as **<u>rectification</u>** and the diode acts as a **rectifier**.



Diode

- Rectification is necessary, for example, in a radio that operates from the mains supply. Mains electricity is alternating current (a.c.) but the radio works using direct current (d.c.).
- Light-emitting diodes are familiar in many pieces of electronic equipment. For example, they are used as the small **indicator lights** that show whether a stereo system or television is on.
- Modern **traffic lights** often use arrays of bright, energy-efficient LEDs in place of filament bulbs. These LED arrays use very little power, so they are much cheaper to run than traditional traffic lights. Also, they require little maintenance, because, if one LED fails, the remainder still emit light.

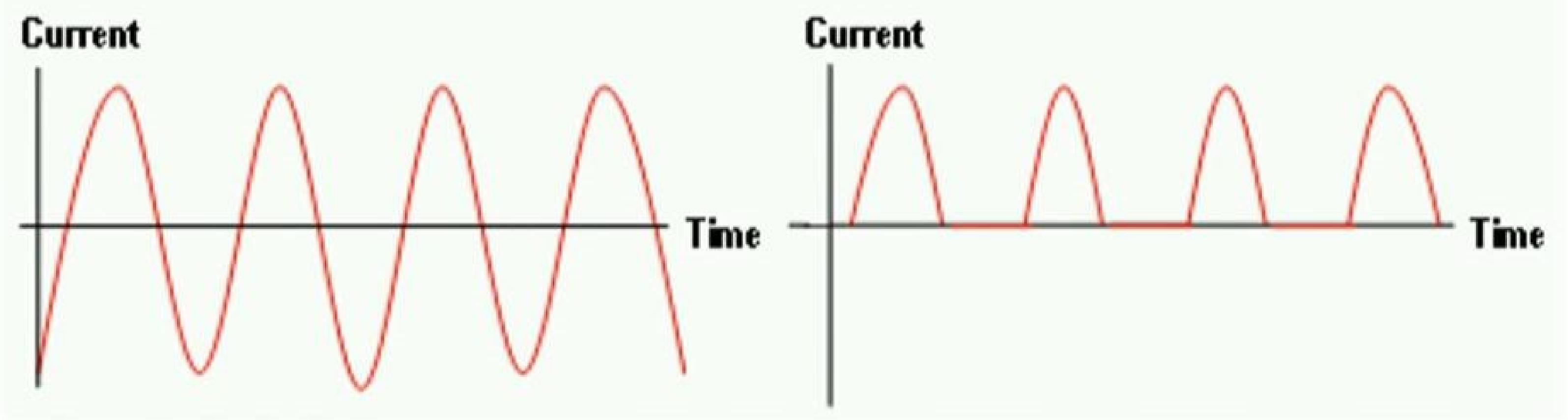
Diode



a. Circuit symbol for a diode. A diode allows current to flow in one direction only – in the direction of the arrow.
b. The arrow in the diode symbol shows the direction in which conventional current can flow through the diode.
c. Circuit symbol for a light-emitting diode. The arrows represent the light that is emitted when a current flows through it.

Diode

- A diode only allows one way flow of current through it (denoted by the arrow or direction of the triangle in the circuit diagram).
- This property of the diode is used in **the conversion of a.c. current to d.c. current (rectification).**



a.c. current – continuous change in direction of current

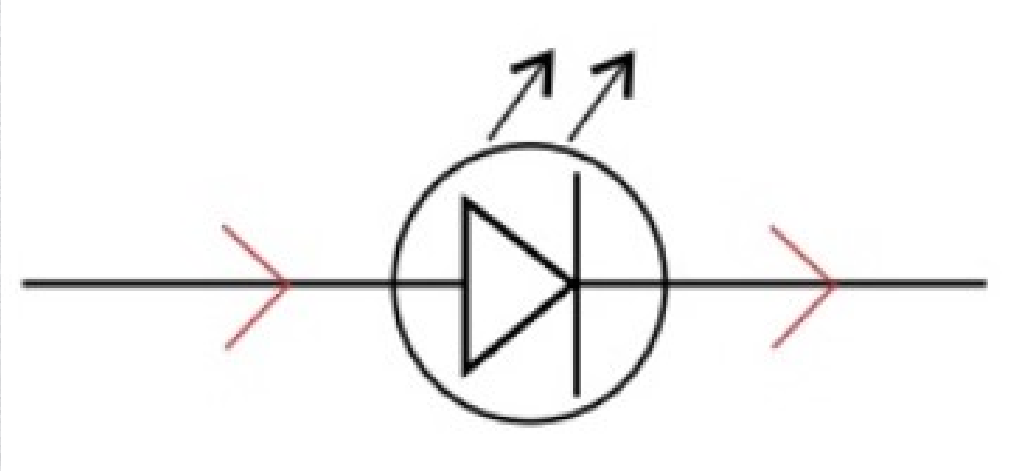
d.c. current – single direction of current

Light-emitting diode (LED)

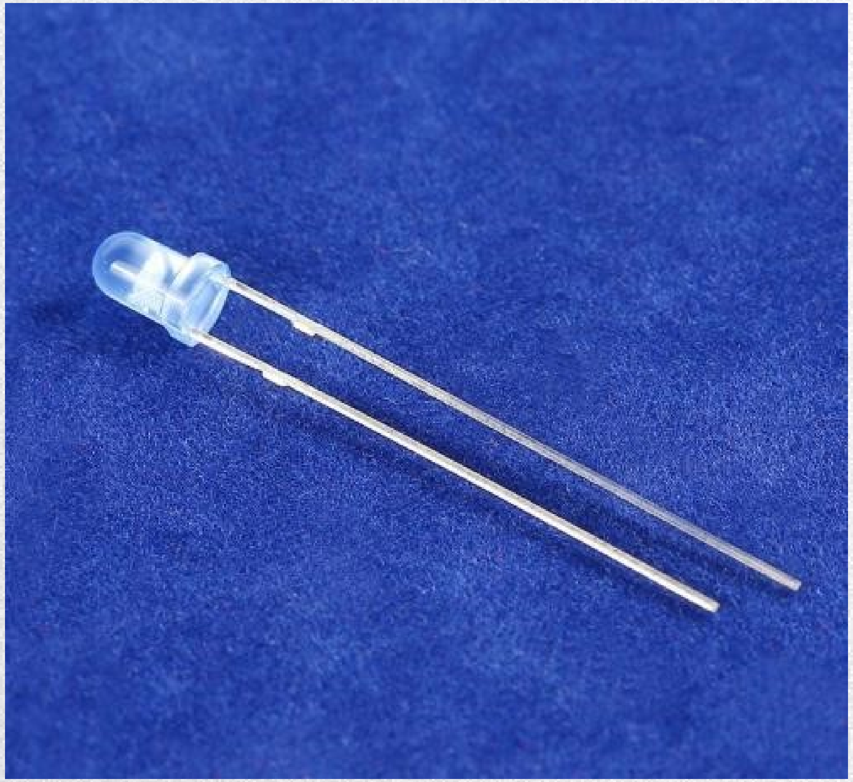
1. LEDs emit light when a current flows through them in the forward direction.

2. Practical applications: used for the numbers on digital clocks, in traffic lights, and in remote controls.

3. They do not have a filament that can burn out.



Light-emitting diodes (LED)



Study question #2

A simple circuit consists of an thermistor and a battery connected in a single loop. Describe how the current in the circuit changes as the temperature of the thermistor increases.

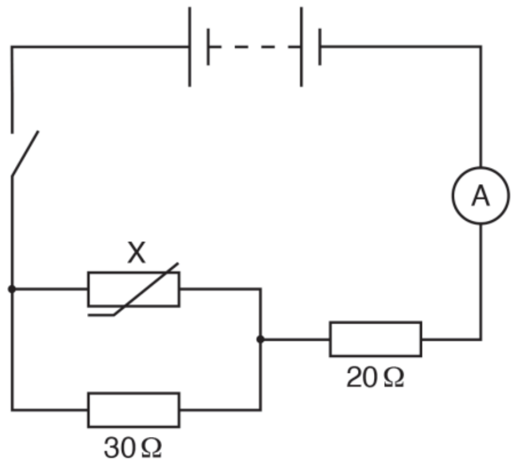
Study question #2

A simple circuit consists of an thermistor and a battery connected in a single loop. Describe how the current in the circuit changes as the temperature of the thermistor increases.

As the temperature of the thermistor increases, its resistance decreases. As the resistance decreases, the current rises since the voltage across the thermistor is constant and $voltage = current \times resistance$.

Study question #3

The diagram is a circuit diagram that includes component X.



(a) State the name of component X.

.... [1]

(b) The temperature of component X increases.

State and explain what happens to the ammeter reading.

....

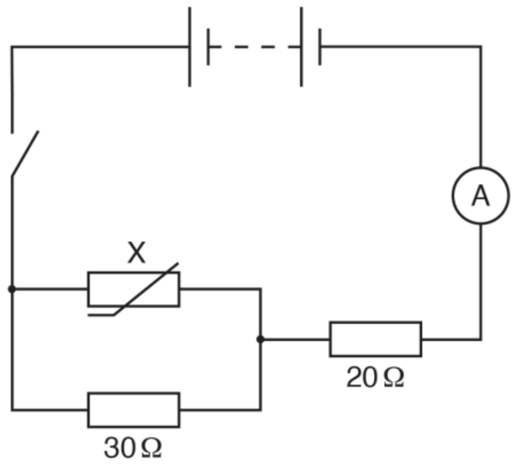
....

.... [2]

[Total: 3]

Study question #3

The diagram is a circuit diagram that includes component X.



(a) State the name of component X.

thermistor

[1]

(b) The temperature of component X increases.

State and explain what happens to the ammeter reading.

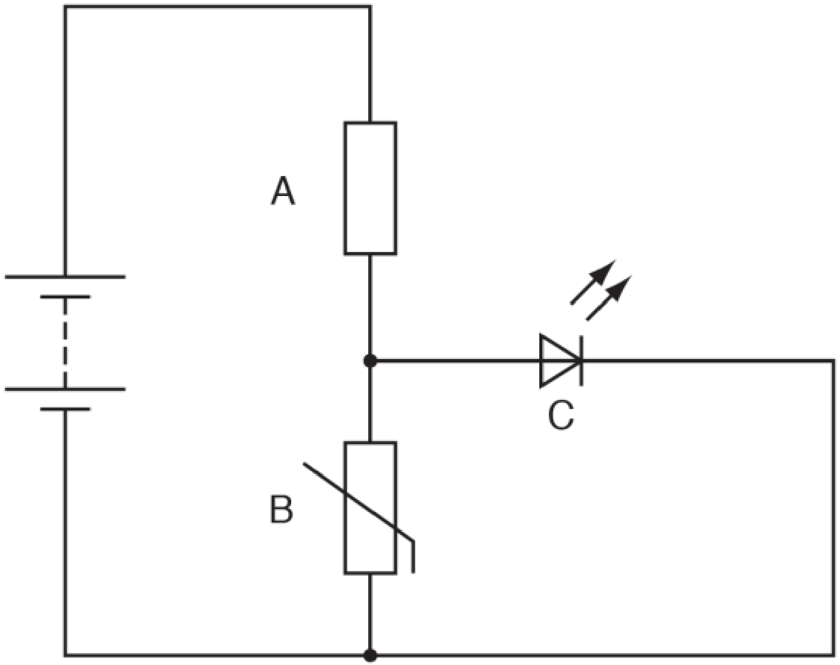
resistance of X decreases, total resistance of circuit decreases (1) ammeter reading increases (1)

[2]

[Total: 3]

Study question #4

The diagram is a circuit diagram.



(a) State the names of circuit components A, B and C.

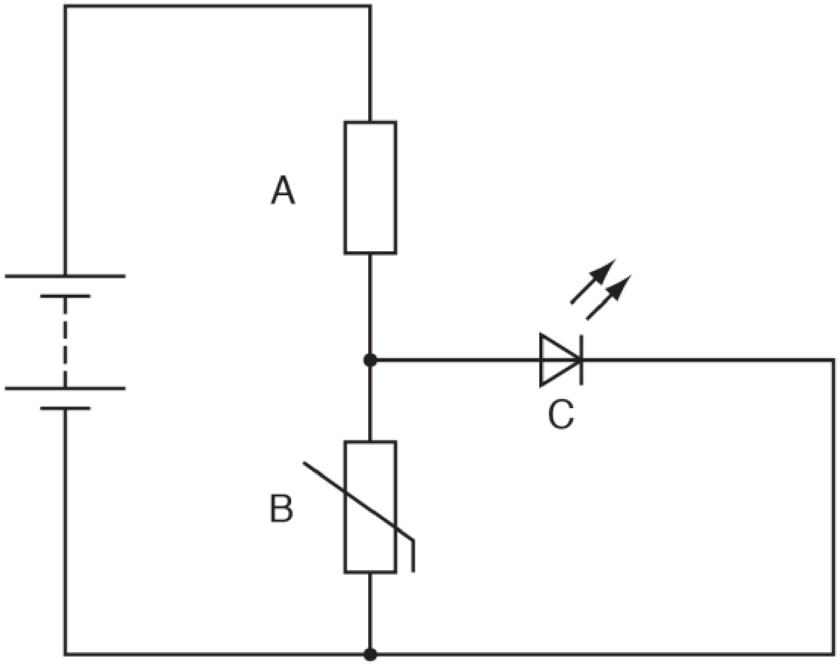
component A ....

component B ....

component C .... [2]

Study question #4

The diagram is a circuit diagram.



(a) State the names of circuit components A, B and C.

component A (fixed) resistor

component B thermistor

component C light emitting diode (LED) [2]

THANK
YOU

Section

4.4

Electric circuits

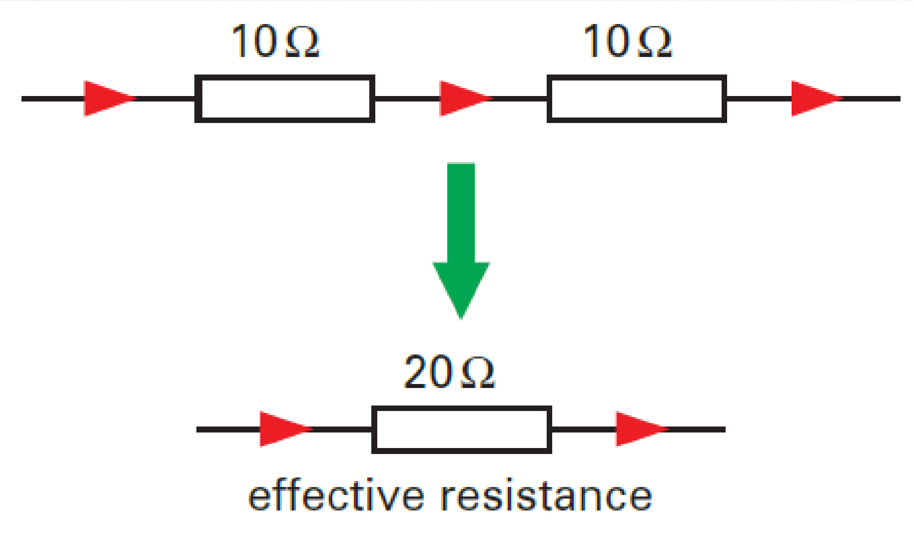
4.4.1 Circuit components

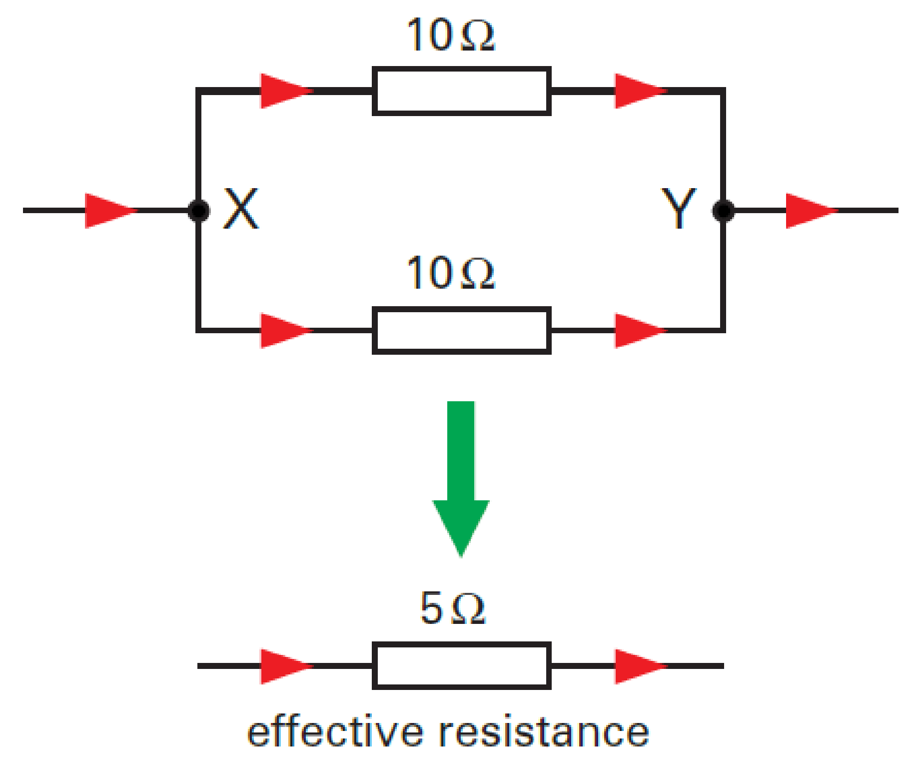
4.4.2 Combinations of resistors

4.4.3 Electronic circuits

4.4.4 Electrical safety

Combinations of resistors

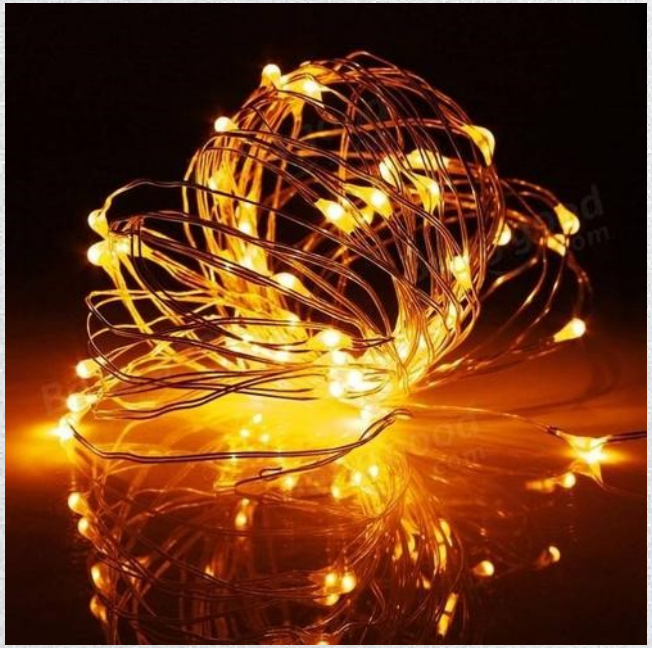




Series circuit

- Series circuit: all or nothing
- In series circuits, the different components are **connected in a line, *end-to-end*.**
- The **combined resistance** is equal to the sum of the resistances
- There's a bigger supply p.d. when more cells are in series.
- The **current** is the same everywhere. The size of the current depends on the total potential difference and the total resistance of the circuit.
- The **total potential difference** of the supply is shared between components. The p.d. for each component depends on its resistance.
- The **total resistance** of the circuit depends on the number of components and the type of components used. The total resistance is the sum of the resistance of each component in the circuit.

Series circuit



- If you remove or disconnect one component, the circuit is broken and they all stop working.
- This is generally not very handy, and in practice only a few things are connected in series, e.g. fairy lights.
- Festive lights are often wired together in series. This is because each bulb works on a small voltage. If a single bulb was connected to the mains supply, the p.d. across it would be too great. By connecting them in series, the mains voltage is shared out between them. The disadvantage of this is that, if one bulb fails (its filament breaks), they all go out because there is no longer a complete circuit for the current to flow around.

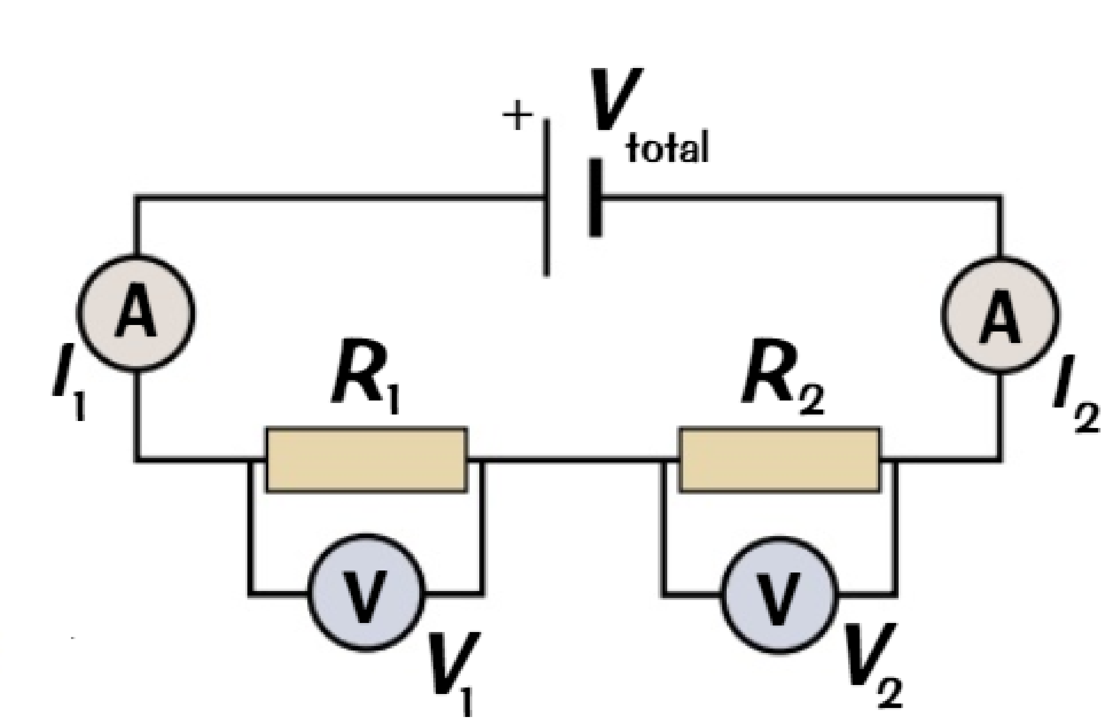
Series circuits

In summary:

$$V_{total} = V_1 + V_2 + \cdots + V_n$$

$$I_1 = I_2 = \cdots = I_n$$

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



Parallel circuit

- Parallel circuit: **everything is independent**
- Resistors in parallel are connected **side-by-side**.
- The effective resistance is less than the resistance of either resistor.
- The current from the source is greater than the current through either resistor.
- If you remove or disconnect one component, it will hardly affect the others al all.
- Everyday circuits often contain a mixture of series and parallel parts.

Parallel circuit

- The potential difference (*V*) is the same across all branches.
- Current (*I*) is shared between branches. The total current flowing around the circuit is equal to the total of all the currents through the separate components (The current from the source is larger than the current in each branch).
- In a parallel circuit, there are junctions where the current either splits or rejoins. The total current ($\sum I$) going into a junction equals the total current leaving it, as charge can't just disappear or appear.
- The current through a branch depends on the resistance (*R*) of the branch.
- **The total resistance** of the circuit **decreases** if you **add a second resistor in parallel** (the combined resistance of two resistors in parallel is less than that of either resistor by itself).

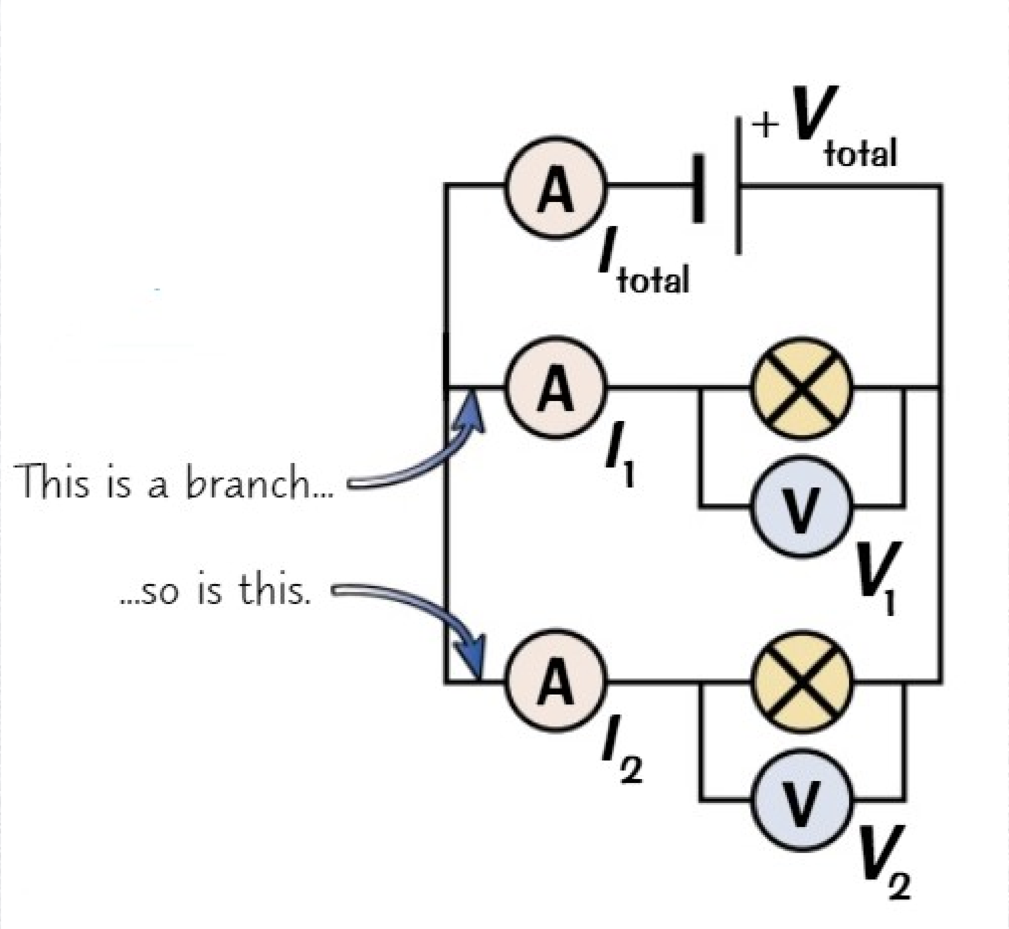
Parallel circuit

In summary:

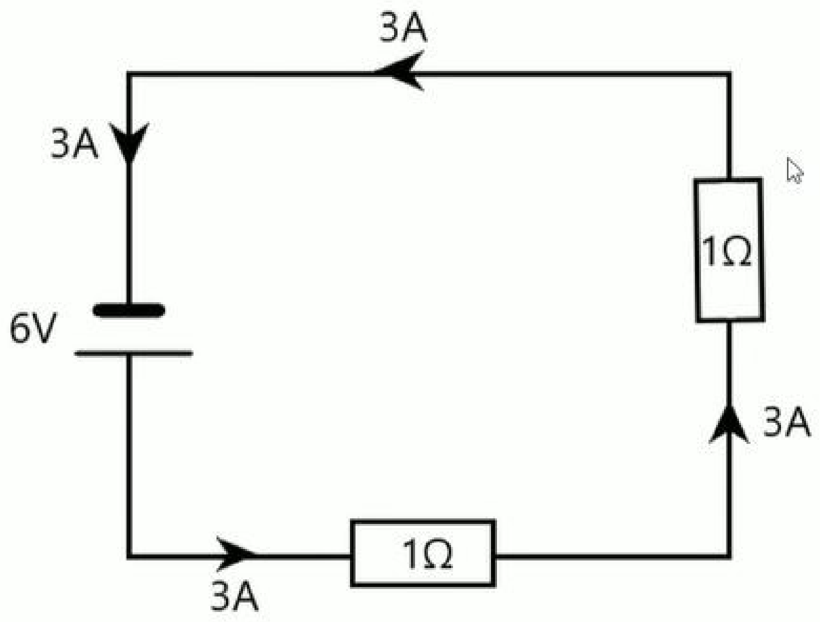
$$V_1 = V_2 = \cdots = V_n$$

$$I_{total} = I_1 + I_2 + \cdots + I_n$$

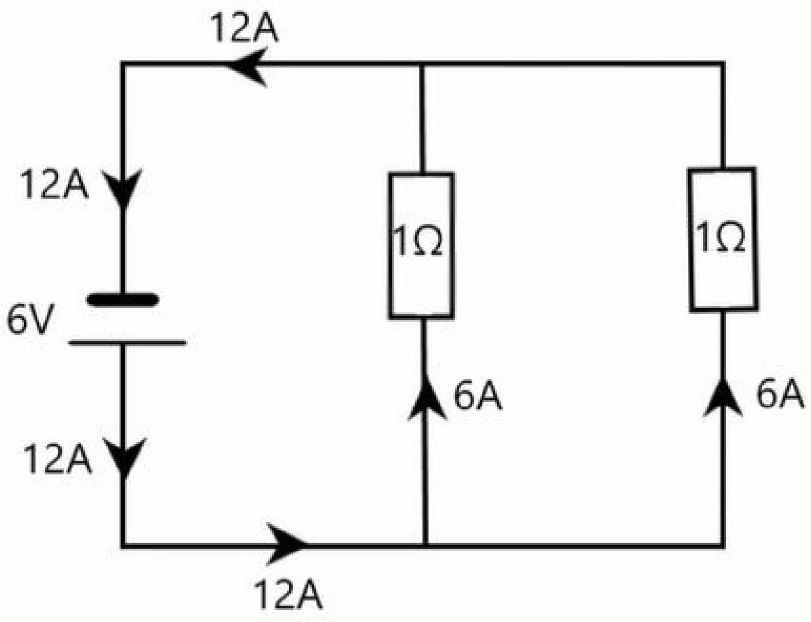
$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$



Series & Parallel Circuits



Series circuit forms a single path.



Parallel circuits have multiple branching pathways for electrical current

Series & Parallel Circuits

Series	Parallel
Current is the same all way round the circuit. i.e. 3A at all points	Current splits at the junction and is shared between the resistors. i.e. Current splits from 12A to 6A at the junctions
Adding resistors in series increases total resistance in circuit.	Adding resistors in parallel decreases total resistance in circuit
Total resistance is the sum of all individual resistances i.e. $1\Omega + 1\Omega = 2\Omega$	Total resistance is given by the formula $\frac{1}{\text{Total resistance}} = \frac{1}{R1} + \frac{1}{R2}$ i.e. $\frac{1}{\text{Total resistance}} = \frac{1}{1} + \frac{1}{1} = 2$ Therefore Total resistance $= \frac{1}{2} = 0.50$
Potential difference across each resistor can be calculated via V = IR i.e. V = 3 X 1 = 3V, so each resistor has a PD of 3V across it	Potential difference across each resistor can be calculated via V = IR i.e. V = 6 X 1 = 6V, so each resistor has a PD of 6V across it
In a series circuit, the potential difference is shared between the resistors. This is because the energy from the cell (EMF) is shared between resistors. i.e. EMF of 6V has split into 3V across each resistor	In a parallel circuit, the potential difference across each resistor is the same as the PD across the cell (EMF). This is because after picking up energy from the cell charge only passes through one of the resistors instead of both. i.e. EMF is 6V and each of the two resistors (in series) have 6V across it
If one of the resistors broke, the circuit would be broken instantly and no current would flow	If one of the resistors broke, the current could still flow through the second resistor, although the current would be smaller because there would now be greater total resistance in the circuit.

Study question #1

Calculate the current in a series circuit containing a 12 V battery, a 7 Ω resistor and 8 Ω resistor.

Study question #1

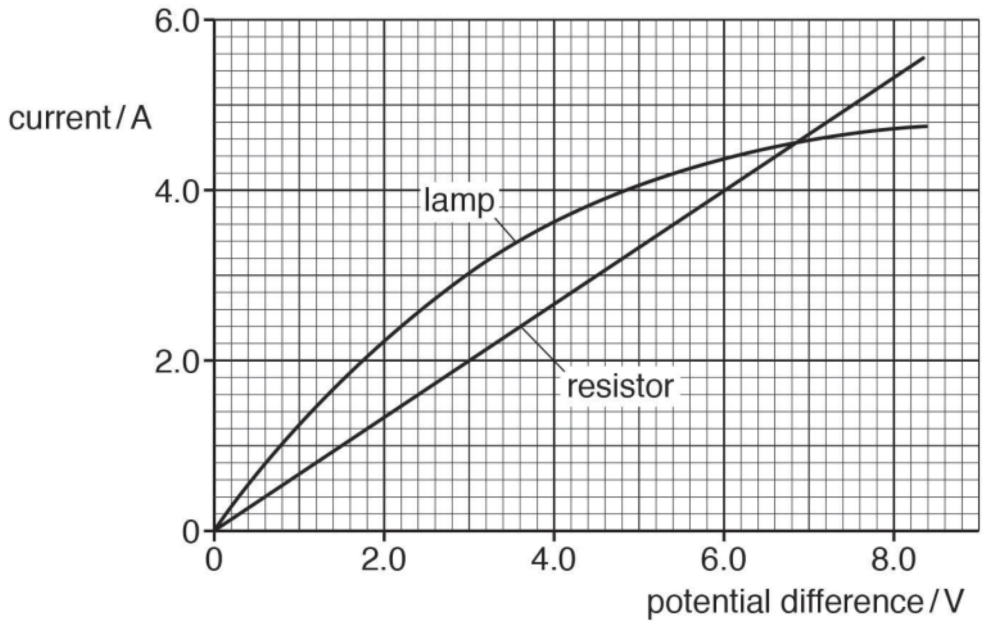
Calculate the current in a series circuit containing a 12 V battery, a 7 Ω resistor and 8 Ω resistor.

$$Total\ resistance, R_{total} = R_1 + R_2 = 7 + 8 = 15\Omega$$

$$I = \frac{V}{R} = \frac{12}{15} = 0.8\ A$$

Study question #2

The diagram shows the current-potential difference graphs for a resistor and for a lamp.



(a) The potential difference (p.d.) applied to the resistor is increased. Tick the box that indicates the effect on the resistance of the resistor.

☐ resistance increases

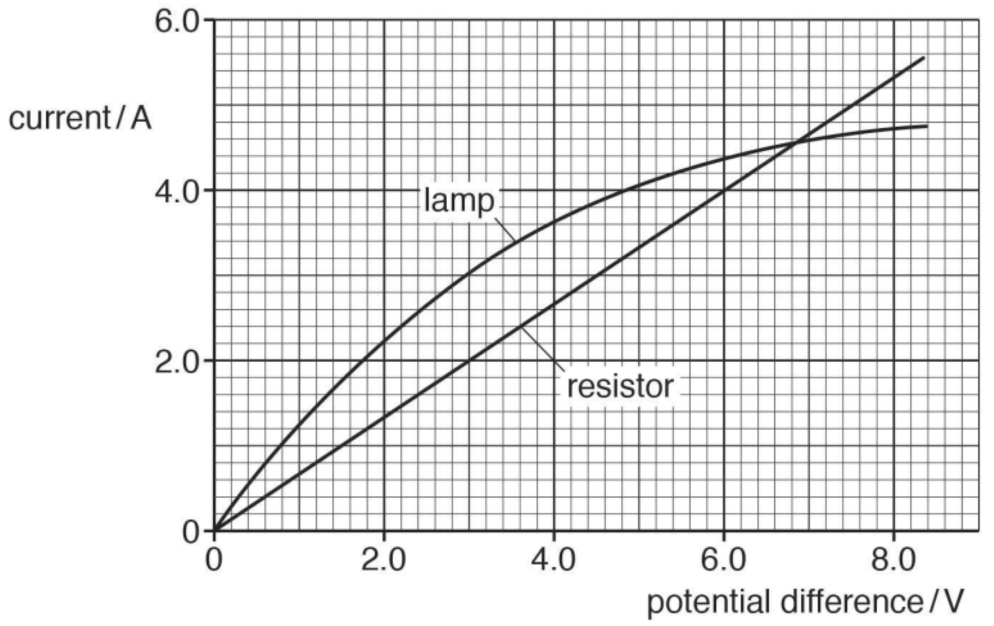
☐ resistance is constant

☐ resistance decreases

[1]

Study question #2

The diagram shows the current-potential difference graphs for a resistor and for a lamp.



(a) The potential difference (p.d.) applied to the resistor is increased. Tick the box that indicates the effect on the resistance of the resistor.

☐ resistance increases

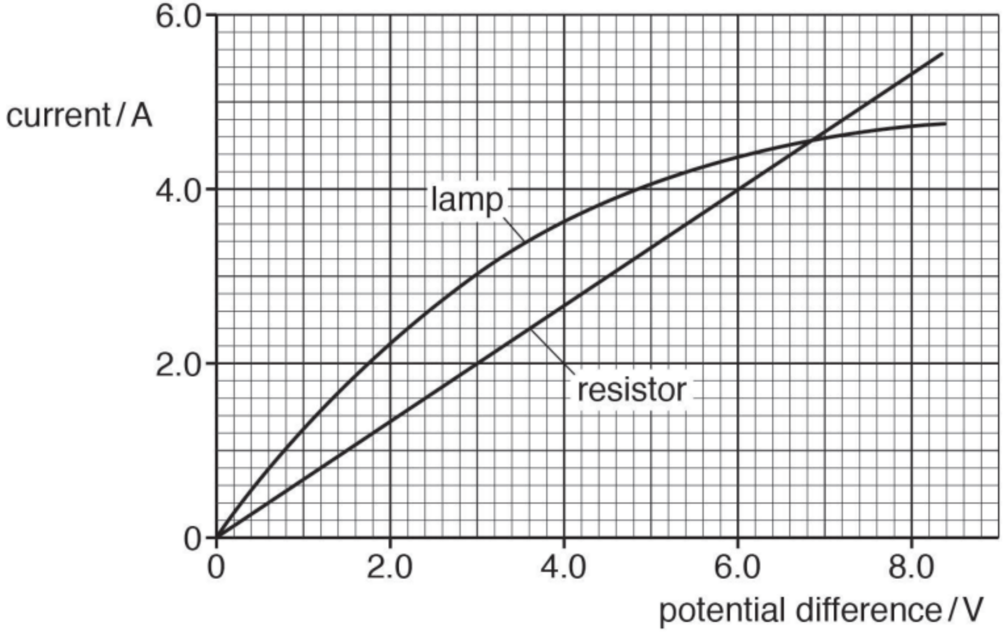
☑ resistance is constant

☐ resistance decreases

[1]

Study question #3

The diagram shows current-potential difference graphs for a resistor and for a lamp.

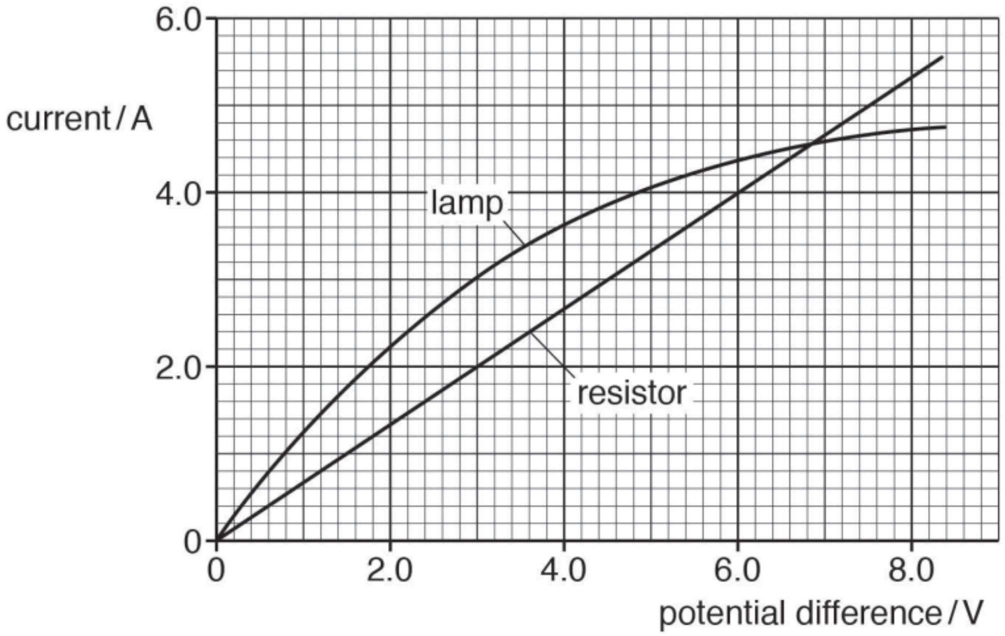


(a) The p.d. across the lamp is 6.0 V. Calculate the resistance of the lamp.

resistance = ... [2]

Study question #3

The diagram shows current-potential difference graphs for a resistor and for a lamp.



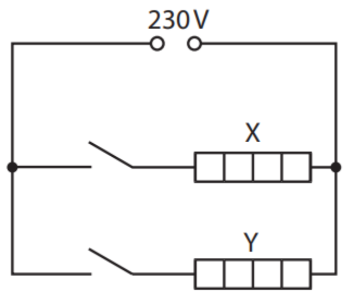
(a) The p.d. across the lamp is 6.0 V. Calculate the resistance of the lamp.

$$R = \frac{V}{I} = \frac{6}{4.4} = 1.4\Omega$$

resistance = ... 1.4Ω .... [2]

Study question #4

The electric circuit in a clothes dryer contains two heaters X and Y in parallel. The figure shows the circuit connected to a 230 V power supply.



When both switches are closed, the current in X is 3.5 A.

The resistance of X is double that of Y.

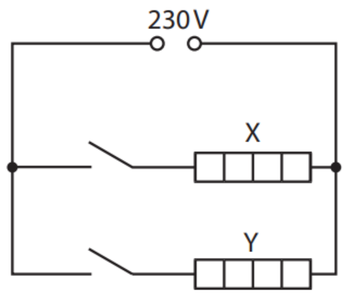
Determine the total resistance of X and Y in parallel.

resistance = ... [4]

[Total: 4]

Study question #4

The electric circuit in a clothes dryer contains two heaters X and Y in parallel. The figure shows the circuit connected to a 230 V power supply.



When both switches are closed, the current in X is 3.5 A.

The resistance of X is double that of Y.

Determine the total resistance of X and Y in parallel.

Given: $R_X = 2R_Y$

$$I_X = 3.5A$$

$$I_X R_X = I_Y R_Y$$

$$I_Y = \frac{I_X R_X}{R_Y} = 3.5 * 2 = 7A$$

$$I_{total} = 7A + 3.5\ A = 10.5A$$

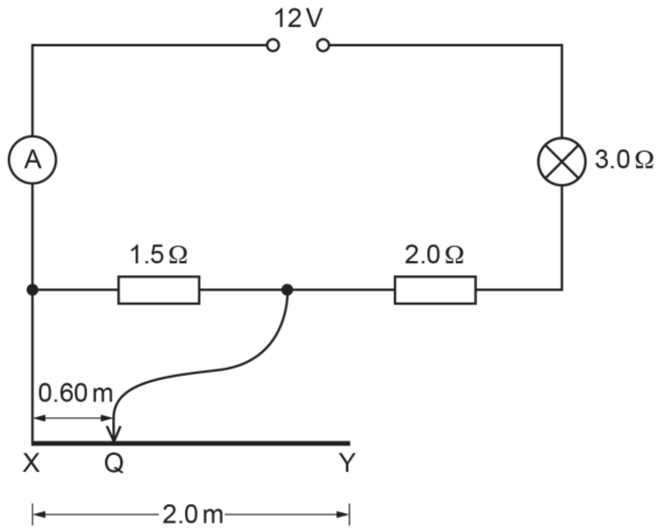
$$R_{total} = \frac{V}{I} = \frac{230}{10.5} = 22\Omega$$

resistance = ... 22Ω .... [4]

[Total: 4]

Study question #5

The diagram shows a circuit.



Line XY represents a uniform resistance wire with a length of 2.0 m.
The resistance of the 2 m length is 6.0 Ω.
The contact is made at Q where the distance XQ is 0.60 m.

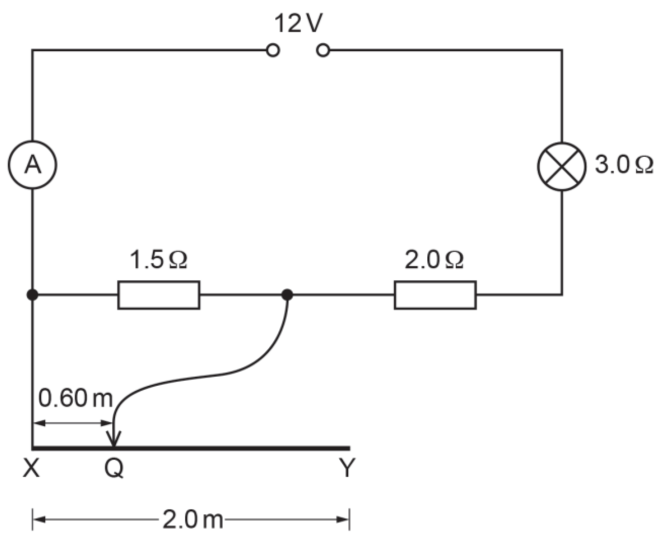
Calculate the resistance of the circuit.

resistance = ... [4]

[Total: 4]

Study question #5

The diagram shows a circuit.



Line XY represents a uniform resistance wire with a length of 2.0 m.
The resistance of the 2 m length is 6.0 Ω.
The contact is made at Q where the distance XQ is 0.60 m.

Calculate the resistance of the circuit.

$$R_{XQ} = 6 * \frac{0.6}{2} = 1.8\Omega$$

$$\frac{1}{R_p} = \frac{1}{1.5} + \frac{1}{1.8}$$

$$R_p = 0.82\Omega$$

$$R = 0.82 + 2 + 3 = 5.82\Omega$$

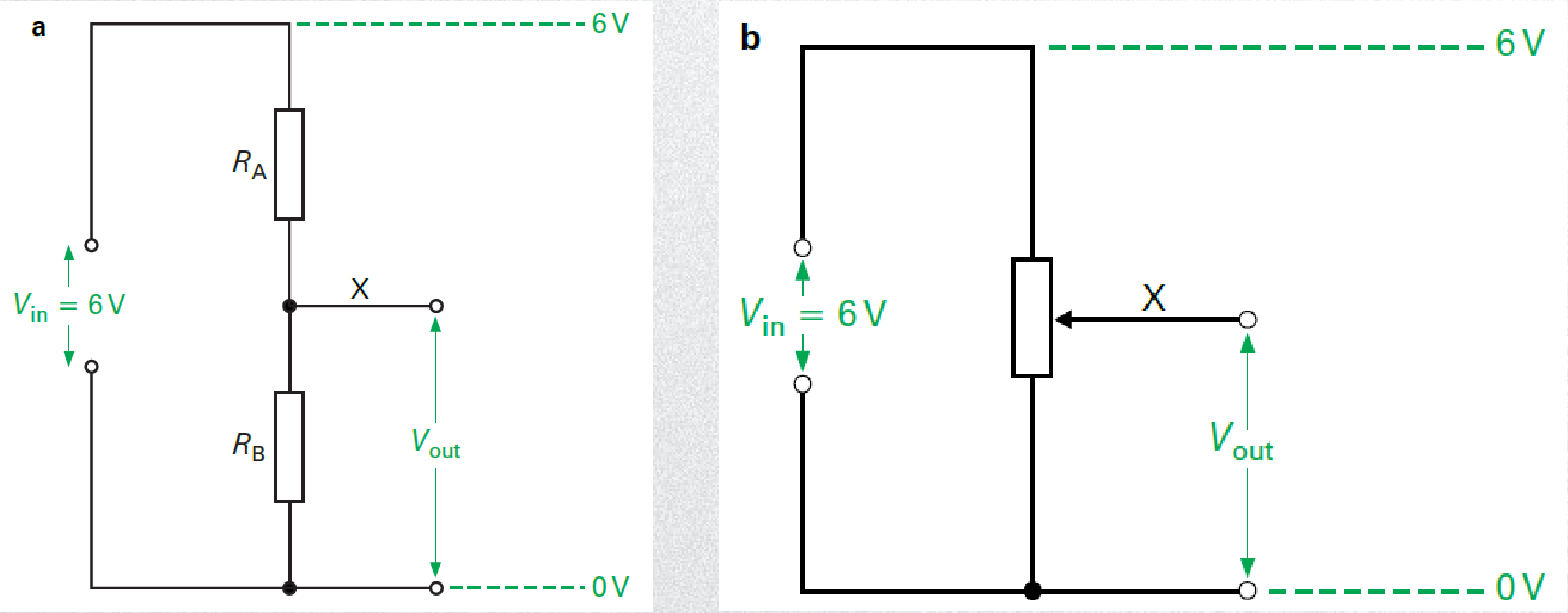
resistance = 5.82Ω [4]

[Total: 4]

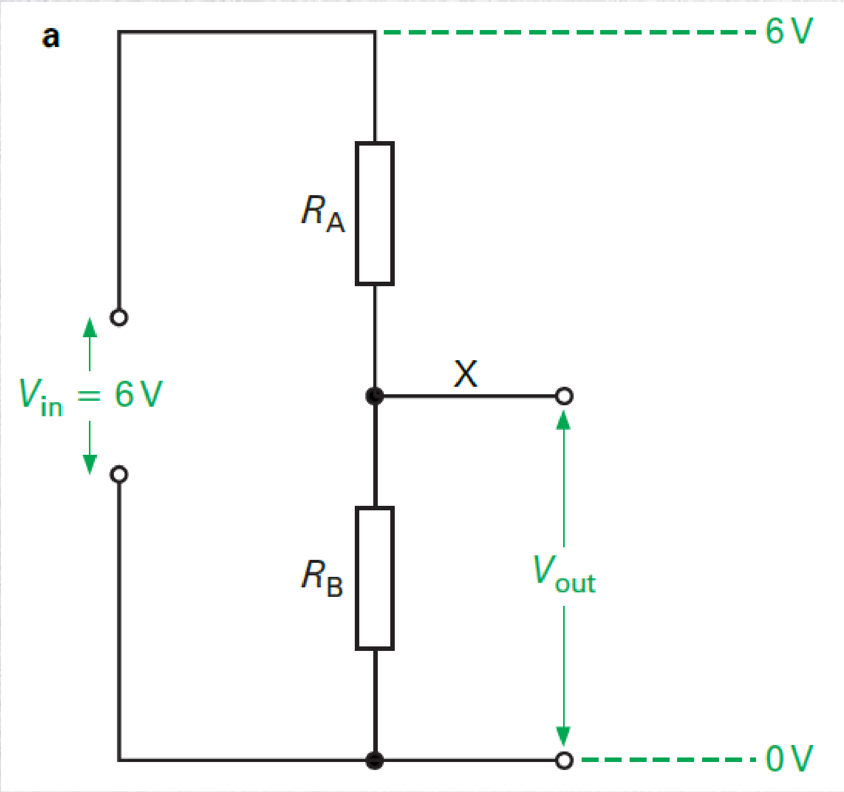
C. Chu

Potential-divider circuits

- A power supply or a battery provides a fixed potential difference. **To obtain a smaller p.d., or a variable p.d.**, this fixed p.d. must be split up using a circuit called a **potential divider**.

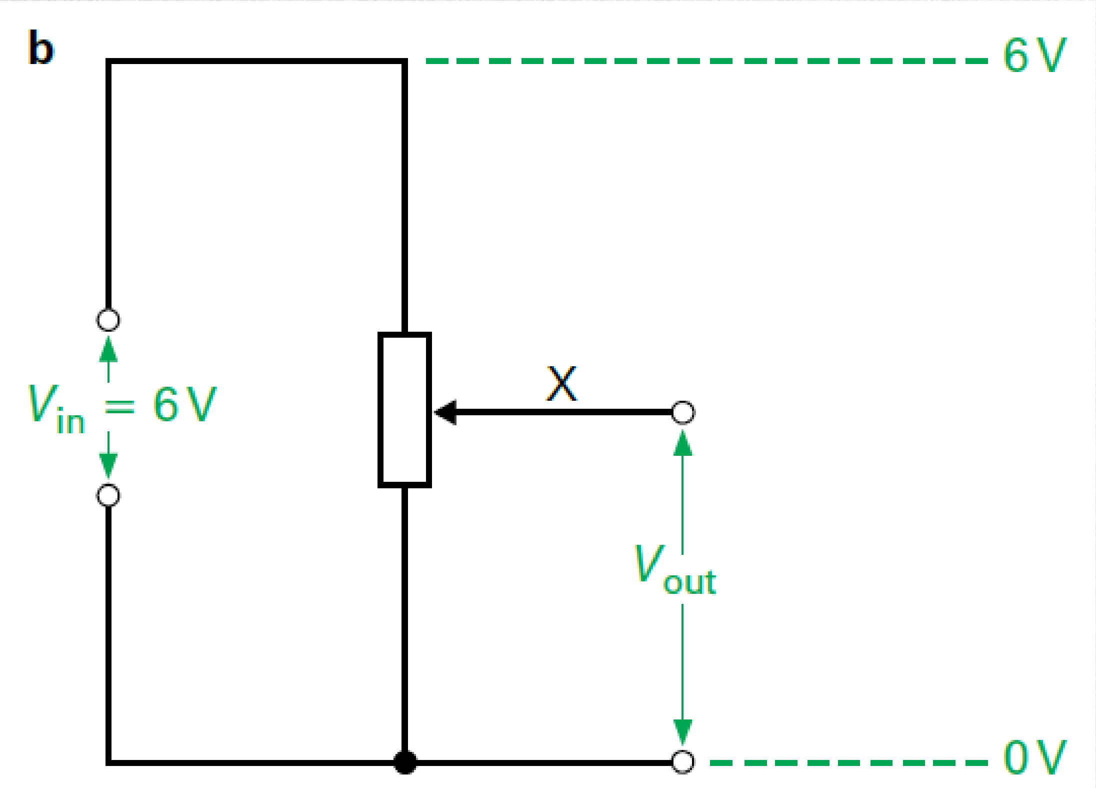


Potential-divider circuits



- The output voltage is a fraction of the input voltage. The input voltage is divided according to the relative values of the two resistors.
- Two resistors RA and RB are connected in series across the 6 V power supply. The p.d. across the pair is thus 6 V. The p.d. at point X, between the two resistors, will be part-way between 0 V and 6 V, depending on the values of the resistors. If the resistors are equal, the p.d. at X will be 3 V. The p.d. of the supply will have been divided in half – hence the name potential divider.

Potential-divider circuits



- **A variable resistor is used to create a potential-divider circuit,** which gives an output voltage that can be varied.
- By altering the resistance of the variable resistor, the voltage at X can have any value between 0 V and 6 V.

THANK YOU