Gleniffer High School

S3

Electricity

Summary Notes

Mr Downie 2021

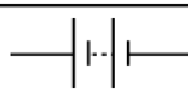
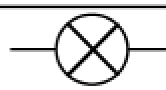
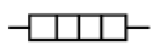
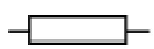
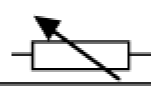
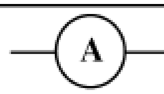
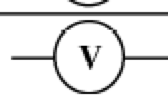
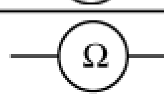
ELECTRICAL CIRCUITS

A circuit will always have a source of electrical energy, an electrical component and wires forming a complete path out from one end of the source and back to the other end. If the circuit is complete, there will be current. If the circuit is incomplete, there will be no current.

Each electrical component has a symbol - called a "circuit symbol". When we draw circuit diagrams, we draw the circuit symbol instead of trying to draw the component itself.

Circuit Symbols

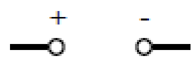
The following table is a list of the circuit symbols for all the electrical components needed for this course as well as a brief description of the function of the component.

Component	Circuit Symbol	Description
Battery		Supplies electrical energy.
Lamp		Converts electrical energy to light energy.
Switch		Open: breaks a circuit. Closed: completes a circuit.
Heater		Converts electrical energy into heat energy.
Resistor		Opposes current, it converts electrical energy into heat energy.
Variable resistor		A resistor whose resistance can be changed.
Motor		Converts electrical energy into kinetic energy.
Ammeter		Used to measure electric current - always connected in series.
Voltmeter		Used to measure voltage - always connected in parallel.
Ohmmeter		Measures resistance directly - use when component is not connected.
Fuse		A protection device. It melts when the current gets too high.

Alternating Current (a.c.) and Direct Current (d.c.)

All power supplies can be grouped into tow categories depending on the way they supply energy to the charges in a circuit.

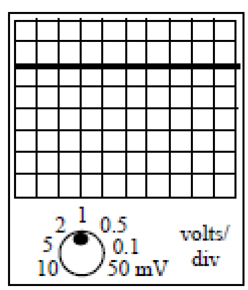
A d.c. supply produces a flow of charge in one direction only. The symbol for a d.c. supply is shown below:-



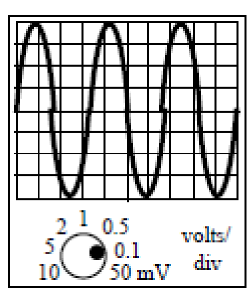
An a.c. supply produces a flow of charge in a circuit that regularly reverses direction. The symbol for an a.c. supply is shown below:-

A CRO can be used to display the voltage from both types of supply.

A d.c. supply would produce a horizontal trace.



Whereas, an a.c. supply would produce a trace that shows alternating peaks and troughs.



Current

Electric current is due to the flow of electrons.

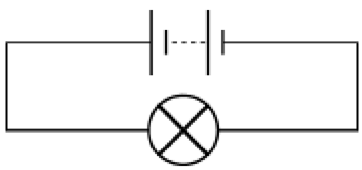
Electrons are negative charges which are found in an atom.

Measuring Current

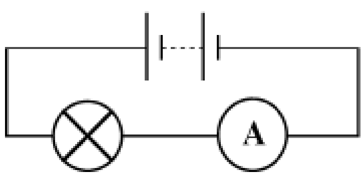
Current is measured using an ammeter.

To measure the current through a component always connect the ammeter in **series** with the component. This means **breaking the circuit** to insert the ammeter.

Before



After

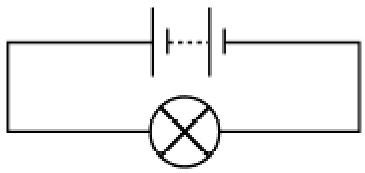


The circuit has an **ammeter inserted in series** with the lamp.

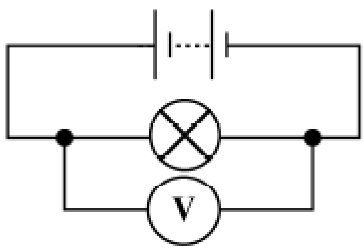
Measuring Voltage

- Voltage is a measure of the energy given to the charges in a circuit.
- Voltage is measured using a voltmeter.
- Voltage is measured in volts (V).
- To measure the voltage **across** a component, always connect the voltmeter in **parallel** with the component.
- This can be done **without breaking the circuit**. The voltmeter forms another parallel branch across the component.

Before



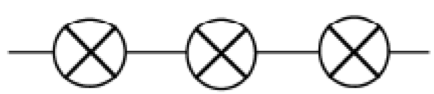
After



This circuit has a **voltmeter connected in parallel** across a lamp.

Series Circuits

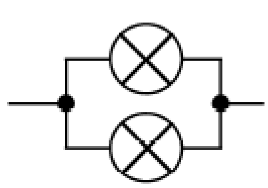
When components are connected to allow **only one path** for current, we say that the components are connected in **series**.



This diagrams shows three lamps connected in series.

Parallel Circuits

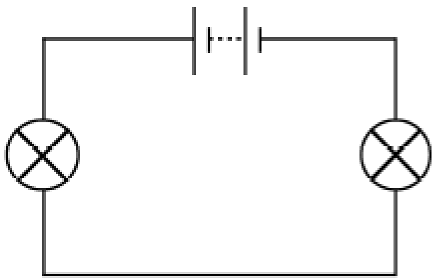
When components are connected to allow **more than one path** for current, we say that the components are connected in parallel.



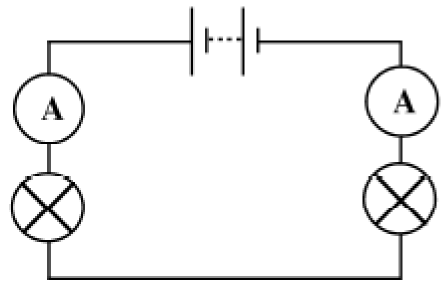
This diagram shows two lamps connected in parallel.

Current and Voltage in Series Circuits

The current through every component in a series circuit is identical and is the same as the supply current.



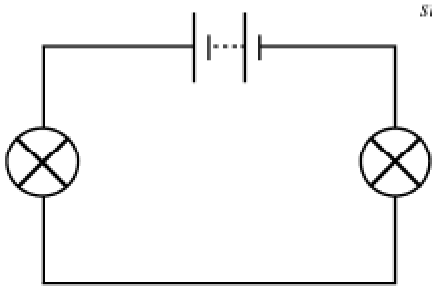
The current through each lamp can be measured directly.



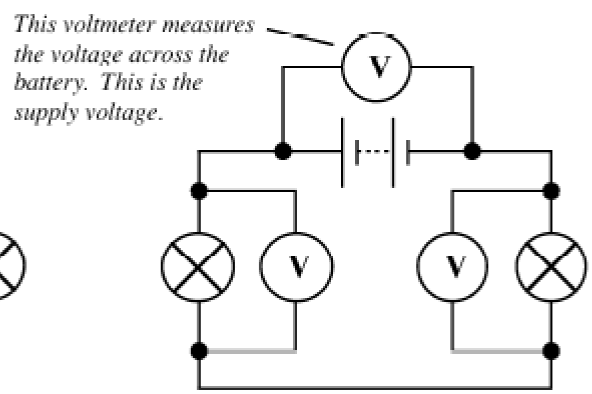
To measure the current in each lamp, connect an ammeter in series with each lamp.

Each ammeter will have the same reading.

The sum of the voltages across each component in a series circuit adds up to the supply voltage.



The voltage across each lamp can be measured directly.



To measure the voltage across each lamp, connect a voltmeter in parallel with each lamp.

The voltmeter readings across the lamps add up to the supply voltage.

Resistance

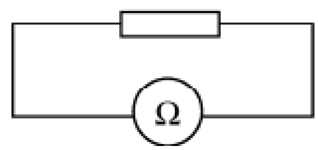
Materials oppose the flow of current and some materials oppose the flow by more than others. The opposition to the flow of current is called resistance. An increase in resistance will cause a decrease in the current.

Measuring Resistance

Resistance is measured in ohms (Ω).

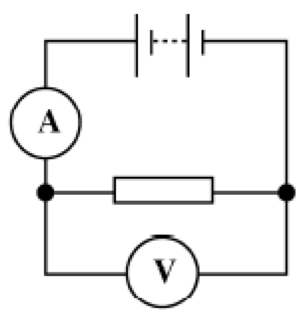
Resistance can be measured using an ohmmeter.

To measure resistance connect the ohmmeter directly across the resistor.



Ohm’s Law

The circuit shown below can also be used to find the value of a resistor.



Use the **ammeter** to get a value of the **current** through the resistor.

Use the **voltmeter** to get a value of the **voltage** across the resistor.

Use the following equation to calculate the resistance of the resistor.

$$resistance = \frac{voltage}{current}$$

This equation is a statement of **Ohm’s Law**.

Ohm's Law

Ohm's Law can also be written using symbols as:-

$$V = I \times R$$

Where,

V is the voltage (potential difference) measured in Volts (V)

I is the current measured in Amperes (A)

R is the resistance measured in Ohms (Ω)

Example One

The current through a resistor is 0.1 amperes when the voltage across it is 12 volts. Calculate the resistance.

Current = 0.1 amperes	Resistance = Voltage / Current
Voltage = 12 volts	Resistance = 12 / 0.1
Resistance =?	Resistance = 120 Ω

Example Two

Calculate the value of the voltage across a 6 Ω resistor when a current of 2 amperes is flowing through the resistor.

R = 6 Ω	V = I x R
I = 2 A	V = 2 x 6
V =?	V = 12 V

Example Three

A 24V battery is connected to an 8Ω resistor. What is the value of the current that flows through the resistor?

V = 24 V	V = I x R
R = 8 Ω	24 = I x 8
I =?	I = 24 / 8
	I = 3 A

Resistors in Series

When more than one component is connected in series, the total resistance of all the components is equivalent to one single resistor, R_T. The value of R_T can be calculated using:

$$R_T = R_1 + R_2 + ...$$

For components in series, R_T is always greater than the largest individual resistor value.

Resistors in Parallel

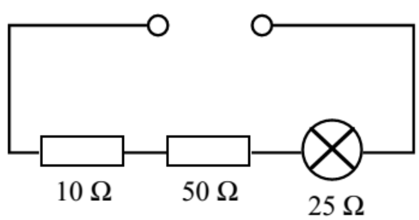
When more than one component is connected in parallel, the total resistance of all the components is equivalent to one single resistor, R_T. The value of R_T can be calculated using:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ...$$

For components in parallel, R_T is always less than the smallest individual resistor value.

Example One

Calculate the total resitance of the circuit shown below.



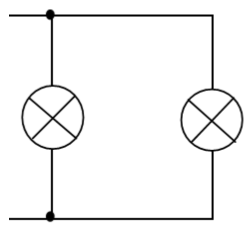
$R_T = R_1 + R_2 + R_3$

$R_T = 10 + 50 + 25$

$R_T = 85\ \Omega$

Example Two

Calculate the total resistance of the circuit shown below if the lamps have resistance values of 15 Ω and 35 Ω.



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{15 \cdot 0} + \frac{1}{35 \cdot 0}$$

$$R_T = 10 \cdot 5\ \Omega$$

ELECTRICAL POWER

When comparing electrical appliances or components it is often useful to know their power ratings.

Power is defined as the energy transferred per unit time. This definition leads to the following equation:

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

where,

P is the power measured in Watts

E is the energy measured in Joules

t is the time measured in seconds

It should be noted that power ratings can also be quoted in Joules per second (Js^{-1}).

Knowing the value of an appliance's power rating allows it to be fitted with the correct fuse. 3A fuses are most suited to appliances with a power rating under 720W and 13A fuses are most suited to appliances with a power rating over 720W.

Example

A kettle uses 0.9 MJ of energy in 5 minutes. Calculate the power rating of the kettle.

E = 0.9 MJ = 0.9×10^6 J

T = 5 minutes = 5 x 60 = 300 s

P =?

P = E / t

P = 0.9×10^6 / 300

P = 3000 W

Power, Current and Voltage

Electrical power is also dependent on the potential difference (voltage) across the component, its resistance and the current flowing through it. This means that power can also be calculated using the following equations:

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

Example One

The current flowing through a mains operated lamp is 0.26A. Calculate the power rating of the lamp.

I = 0.26 A	P = IV
V = 230 V (mains voltage in the UK)	P = 0.26 x 230
P = ?	P = 60 W

Example Two

A data source states that the optimum operating conditions for a 1 kΩ resistor happen when energy is transferred through it at a rate of 0.4 Joules per second.

a) Calculate its optimum operating current.

b) Calculate the potential difference (voltage) across it under optimum conditions.

a)

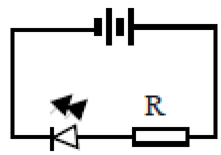
R = 1 kΩ = 1 x 10^3 Ω	P = I^2R
P = 0.4 Js^{-1} (or W)	0.4 = I^2 x 1 x 10^3
I = ?	I = 0.02 A

b)

R = 1 kΩ = 1 x 10^3 Ω	P = V^2 / R
P = 0.4 Js^{-1} (or W)	0.4 = V^2 / 1 x10^3
V = ?	V = 20 V

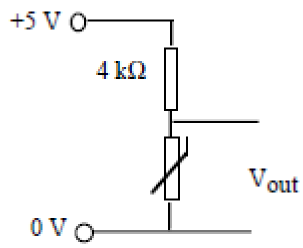
Electronic Circuits Theory

An LED is a small, usually plastic, output device that is often used as a warning indicator on an appliance. In a circuit diagram the LED is always shown with a series resistor. The series resistor prevents large currents flowing through the LED. This ensures that the LED will not melt.



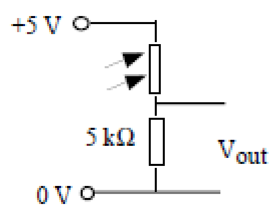
Note that the current in the above circuit will flow into the vertical line on the LED symbol. If the LED was reversed, current would not be able to flow and it would not light up.

A thermistor is an input device that is often used in temperature sensing circuits. When the temperature around a thermistor is increased its resistance will decrease and vice versa. (**T**emperature **U**p **R**esistance **D**own **T.U.R.D**)



In the above circuit the reading at V_{out} will increase as the temperature around the thermistor decreases. This increase in V_{out} could allow another component or circuit to be activated. This is the principle behind frost detection circuits.

An LDR is an input device that is often used in light sensing circuits. The resistance of an LDR will increase when the light level around it decreases and vice versa. (**L**ight level **U**p **R**esistance **D**own **L.U.R.D**)

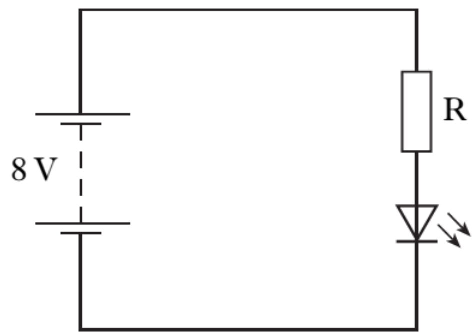


In the above circuit as the light level increases, the resistance of the LDR will decrease. This means that there will be less voltage needed across the LDR. As the available voltage has to be shared out between the LDR and the resistor, the voltage V_{out} will increase. This increase in V_{out} could allow another component or circuit to be activated. This is the principle behind automatic blinds.

Electronic Circuits Calculations

Example One

In the electronic circuit shown below the LED has an operating voltage of 2V and an operating current of 15mA. Calculate the value of the resistor R.



This is a typical assessment calculation question that would be worth 4 marks. This should tell you that the solution needs a calculation and an extra step.

In this example the extra step needs you to find the potential difference (voltage) across the resistor, R, before you attempt the calculation.

R = ?

I = 15 mA = 15×10^{-3} A

$V_{across\ resistor} = V_{supply} - V_{LED}$

$V_{across\ resistor} = 8 - 2 = 6$ V

V = IR

$6 = 15 \times 10^{-3} \times R$

R = 40 Ω

Electronic components are often used in **potential (voltage) divider circuits.** A potential (voltage) divider circuit uses two or more components to divide up the available potential difference (voltage) from the supply. The potential difference from the supply is divided across the component in proportion to their individual resistance values. The greater the resistance the greater the potential difference (voltage) and vice versa. There are two equations that are useful when carrying out **potential (voltage) divider** calculations.

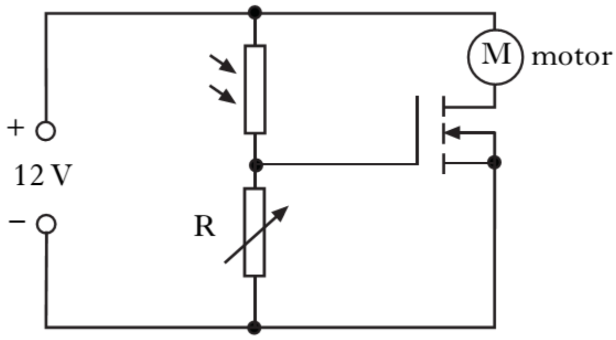
$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

Example Two

An office has an automatic blind that closes when the light level outside is too high.

The circuit for the blind is shown below.



The resistance of the LDR on a cloudy day is 3000Ω and the variable resistor is set to a value of 600Ω.

Calculate the voltage across the variable resitor.

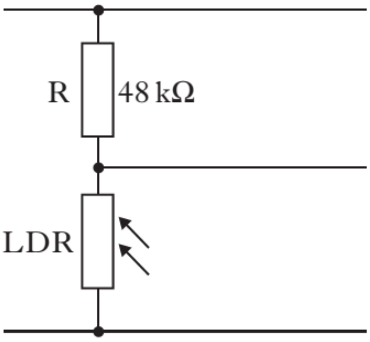
$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$$

$$V_2 = \left(\frac{600}{600 + 3000}\right) \times 12$$

$$V_2 = 2 \cdot 0 \text{ V}$$

Example Three

A part of an electronic circuit is shown below.



When the LDR has a resistance of 2kΩ the potential differnce across it is 0.36V.

Under these conditions calculate the the potential difference across the resistor.

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

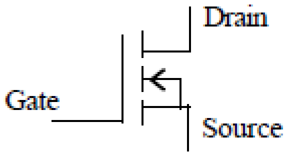
$$\frac{V_1}{0.36} = \frac{48000}{2000}$$

$V_1 = 8.64$ V

Transistors

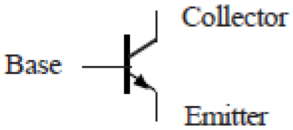
All transistors operate as **automatic electronic switches**. There are two different types of transistor that are included in this course.

N-channel enhancement MOSFET (Metal Oxide Semiconductor Field Effect Transistor).
Symbol:



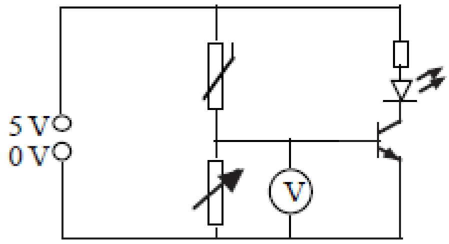
For a typical MOSFET when the voltage across the gate and source reaches 1.8V it will switch on

NPN Transistor.
Symbol:



For a typical NPN transistor when the voltage across the base and emitter reaches 0.7 V it will switch on.

Transistor Circuits

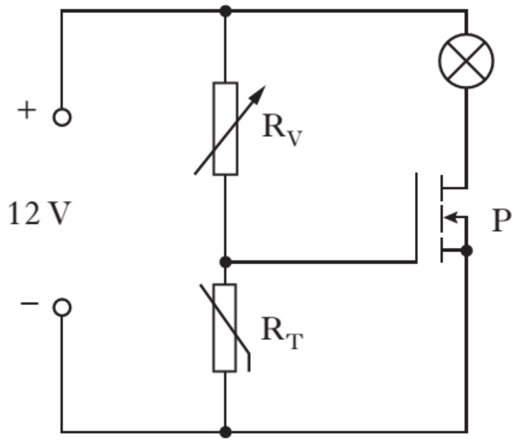


In the above circuit, when the temperature increases the resistance of the thermistor will decrease. This means there will less voltage needed across the thermistor. As the available voltage has to be shared out between the thermistor and the variable resistor, the voltmeter reading will increase.

When the reading reaches 0.7 V the NPN transistor will be able to switch on. This will allow the LED to light up. So this circuit could be used to give a warning when the temperature gets too high e.g. an incubator.

Example

The circuit shown switches a warning lamp on or off depending on the temperature.



a) Name component P.

b) As the temperature increases the resistance of the thermistor, R_T, decreases. State what happens to the voltage across R_T as the temperature increases.

When the voltage applied to component P is equal to or greater than 2.4V, component P switches on and the warning lamp lights.

R_V is adjusted until its resistance is 5600Ω and the warning lamp now lights.

c) For these conditions calculate:

i) the voltage across R_V

ii) the resistance of R_T

d) The temperature of R_T now decreases. Will the warning lamp stay on? Explain your answer.

Solution

a) MOSFET

b) The voltage across R_T will decrease.

c)

i) The 12 V supply voltage has to be divided between the two components. If the voltage across R_T is 2.4 V, the voltage across R_V must be 12 – 2.4 = 9.6 V.

ii)

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$\frac{9.6}{2.4} = \frac{5600}{R_2}$$

$$R_2 = 1400\Omega$$

d) When the temperature falls the warning lamp will stay on. This happens because as the temperature decreases the resistance of thermistor R_T will increase. As the value of resistance R_T increases the voltage across R_T will also increase. This will keep the voltage that switches on the MOSFET above 2.4 V and the warning lamp will stay on.

$$E_p = mgh$$

$$E_k = \frac{1}{2}mv^2$$

$$Q = It$$

$$V = IR$$

$$R_T = R_1 + R_2 + \ldots$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_s$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

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

$$P = IV$$

$$P = I^2 R$$

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

$$E_h = cm\Delta T$$

$$p = \frac{F}{A}$$

$$\frac{pV}{T} = \text{constant}$$

$$p_1V_1 = p_2V_2$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$d = vt$$

$$v = f\lambda$$

$$T = \frac{1}{f}$$

$$A = \frac{N}{t}$$

$$D = \frac{E}{m}$$

$$H = Dw_R$$

$$\dot{H} = \frac{H}{t}$$

$$s = vt$$

$$d = \bar{v}t$$

$$s = \bar{v}t$$

$$a = \frac{v-u}{t}$$

$$W = mg$$

$$F = ma$$

$$E_w = Fd$$

$$E_h = ml$$