Grove Academy

National 5 Physics

Area: Electricity

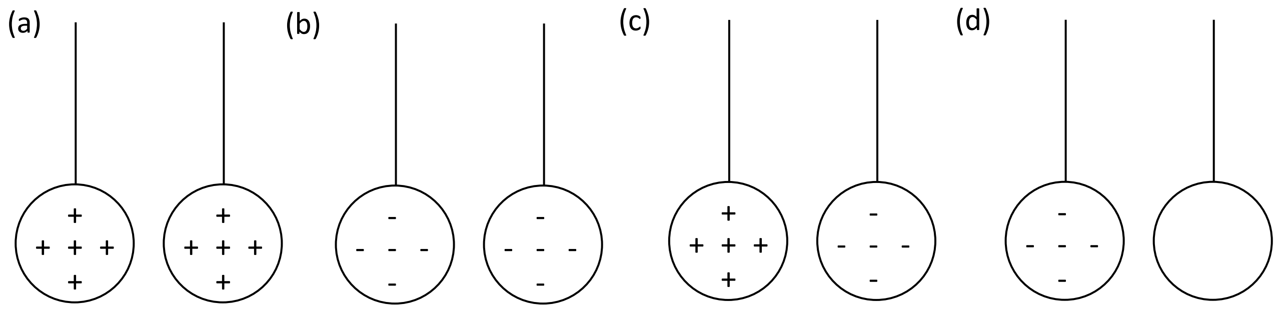
Problems

Section 1 - Electrical Charge Carriers

Charge and Current

1. State what happens when:
   (a) two positive charges are brought close together;
   (b) two negative charges are brought close together;
   (c) a positive charge is brought close to a negative charge.

2. In a classroom experiment, two metallised polystyrene spheres are hung from a thread, as shown below. Copy the diagrams and use arrows to show the direction of movement of each sphere.



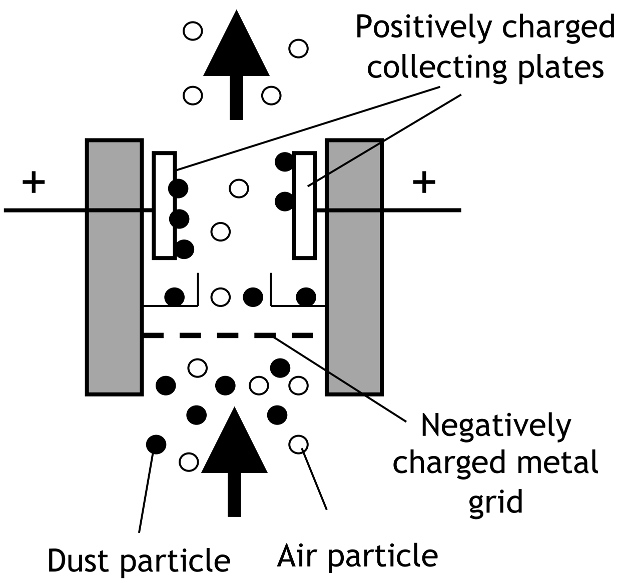
3. Explain how a photocopier uses a positively charged copy plate and negatively charged toner particles to create a copy of an image on a piece of paper.

4. Vehicle manufacturers charge the body of cars and use charged paint to give cars their final colour. By using your knowledge of electrostatics:
   (a) Explain how this results in an even coat of paint over the whole surface of the car.
   (b) Explain how this limits the amount of paint that is wasted.

5. Cling film is used to keep to keep food fresh. Cling film becomes sticky because of electrostatic charges.
   (a) Describe how a piece of cling film becomes charged.
   (b) Explain why cling film will stick to a plastic bowl for a long time but loses its sticking power quickly when placed on a metal bowl.

6. An electrostatic precipitator can be used to remove dust particles from the air.

   (a) Use the diagram to the right to explain how it works.
   (b) Explain why electrostatic precipitators are useful in fossil fuel power stations.



7. State the definition of the term ‘current’.

8. Calculate how much charge flows along a wire when 2 mA of current flows for 1 minute.

9. If 7200 C of charge flows through a wire in 4 hours, calculate the current in the wire.

10. Calculate how long it would take to transfer a charge of 2 C through a wire, if the current in the wire is 0.4 mA.

11. A current of 0.5 A flows through a circuit in a time of 2 s.
    (a) Calculate the total charge flowing through the circuit.
    (b) Calculate how many electrons flowed through the circuit, if a single electron carries a charge of 1.60×10^{-19} C.

12. A current of 6.5 A flows through a hairdryer for 5 minutes. Calculate the charge that flows through the hairdryer during this time.

13. When playing a game, an Xbox 360 has 1368 coulombs of charge flowing through it every hour. Calculate the current flowing through the console.

14. An electric kettle has 9.5 A of current flowing through it as it boils water. Calculate how long it takes the kettle to boil, if 2100 C of charge flows through it before it switches off.

Alternating and Direct Current

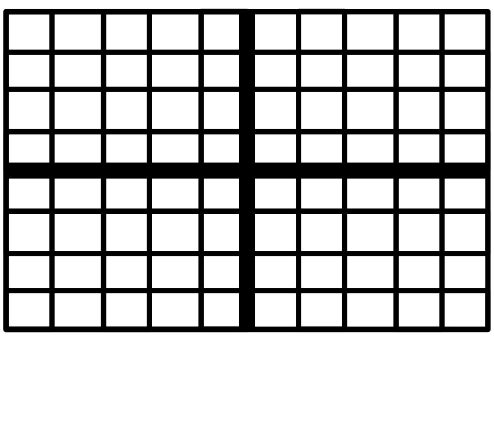
1. Identify which of the images to the right supplies a.c and which supplies d.c.

2. Describe the difference between the current from an a.c. supply and the current from a d.c. supply.

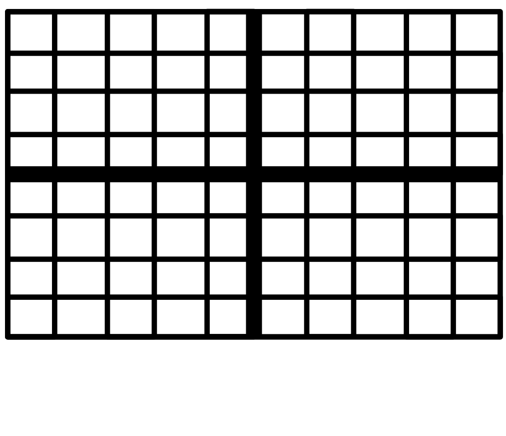
3. State the value of:
   (a) mains voltage;
   (b) mains frequency.

4. Copy and complete the oscilloscope screens to show the traces for an a.c. signal and for a d.c. signal:

a.c. supply



d.c. supply



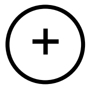
Section 2 – Potential Difference

1. State what is meant by an electric field.

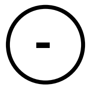
2. Define the term 'potential difference' in terms of energy and charge.

3. Copy the following diagrams and add to them showing the electric field lines AND their direction.

(a)



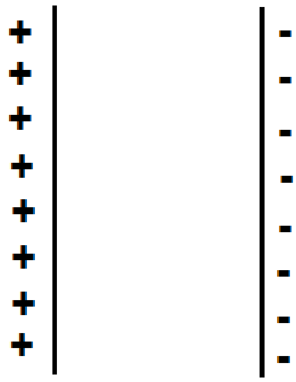
(b)



(c)

(d)

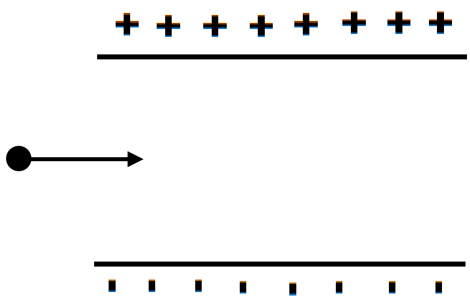
(e)



4. Refer to the diagrams in question 3.
   Describe the motion of each of the following particles placed in the electric fields:

   (a) an electron placed in the electric field of part (a)
   (b) an alpha particle place between the plates in part (e)
   (c) a proton placed in the electric field of part (b)
   (d) a neutron placed between the charges in part (d)
   (e) a beta particle placed between the charges in part (c)

5. A uniform electric field exists between the two parallel plates shown below.



   Charged particles enter the field between the plates as shown above.
   Copy the diagram and complete it to show the paths of each of the following particles:

   (a) alpha particle;
   (b) electron;
   (c) neutron.

   Label each path clearly.

Section 3 – Ohm's Law

1. State the equation which relates the potential difference across a component, the current through the component and the resistance of the component.
   Define the symbol and state the units for each of the variables.
2. Calculate the voltage across a 125 Ω lamp that has a current of 1·84 A flowing through it.
3. Calculate the resistance of a lamp that allows 610 mA of current to flow through it when there is a potential difference of 12 V across it.
4. Calculate the current flowing through a piece of 10·0 kΩ resistance wire when a potential difference of 15·0 V is across it.
5. A variable resistor can be adjusted from 10 Ω to 10 kΩ. It is connected to a 24 V supply.
   Calculate:
   (a) the maximum current flowing through the variable resistor;
   (b) the minimum current flowing through the variable resistor.
6. In an experiment, a lamp is connected to a variable supply and left on for a few minutes until its brightness is constant.
   The voltage across the lamp is changed to different values and the current flowing through it is measured.
   The results are shown in the table.

   Draw a line graph of these results and use the gradient of the straight line to find the resistance of the lamp.

Voltage / V	*Current* / A
0	0
2	0.44
4	0.88
6	1.33
8	1.78
10	2.22

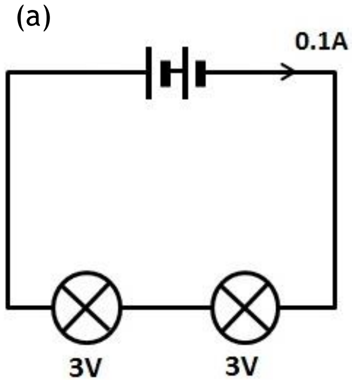
7. The same experiment is repeated except this time, the measurements are made immediately after turning on the lamp. The results are shown in the table.

   Draw a line graph of these results and explain why a straight line is not found.

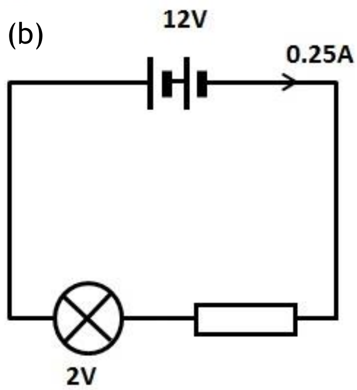
Voltage / V	*Current* / A
0	0
2	0.18
4	0.45
6	0.98
8	1.78
10	2.22

7. Calculate the resistance of each of the components in the following series circuits:

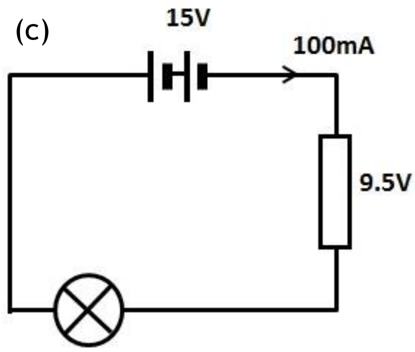
(a)



(b)

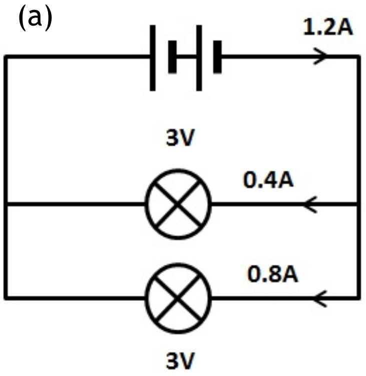


(c)



8. Calculate the resistance of each of the components in the following parallel circuits:

(a)



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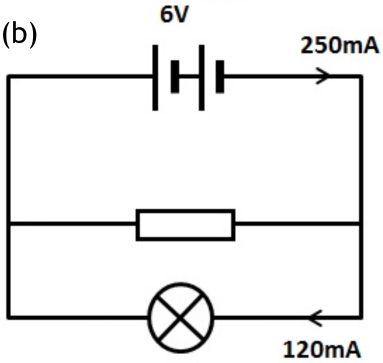

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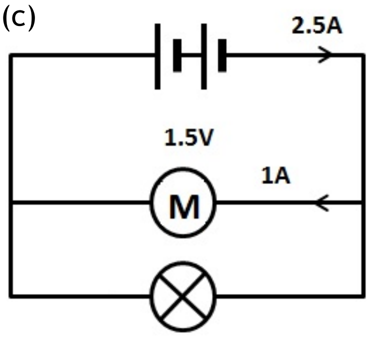

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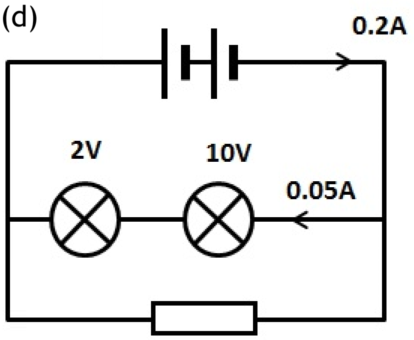

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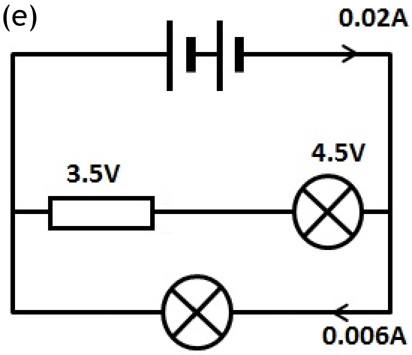
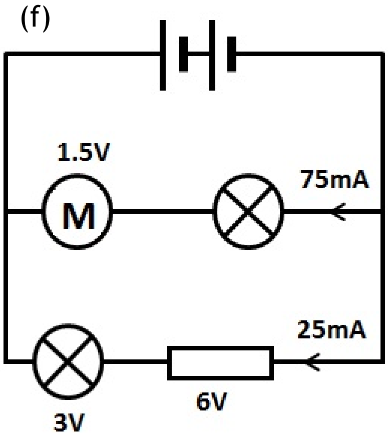
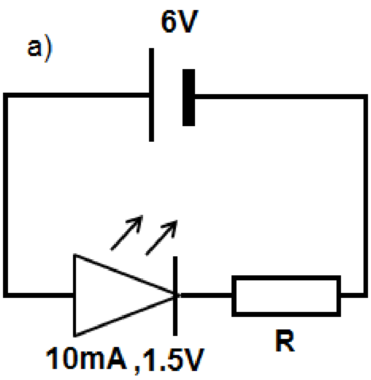


(f)



9. Calculate the resistance of the resistor, R, required to protect the L.E.D. in each circuit:

a)



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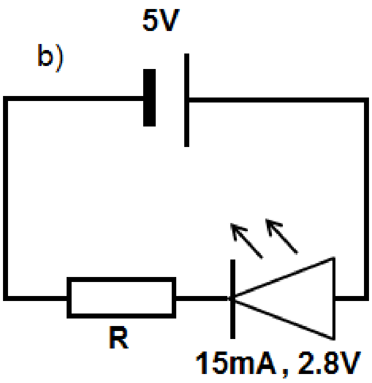

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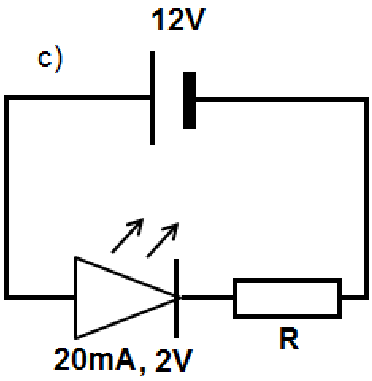

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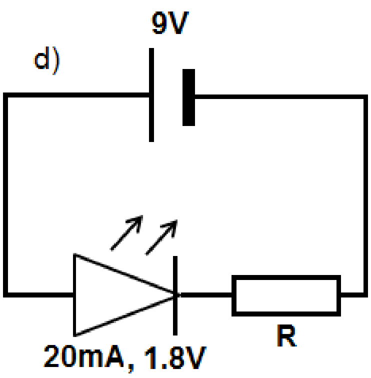

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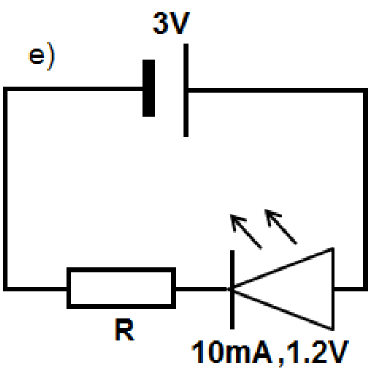
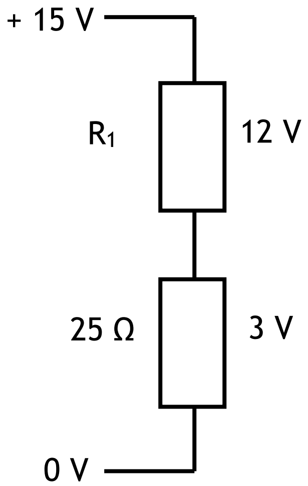


Potential Dividers

10. State what happens to the voltage across a resistor as its resistance is increased.

11. Calculate the value of resistor R_1 in each of these voltage divider circuits.

(a)


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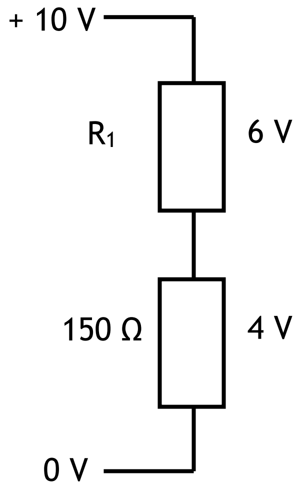

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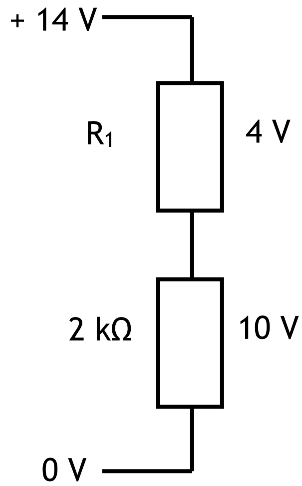
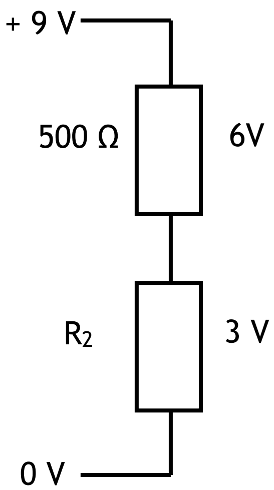
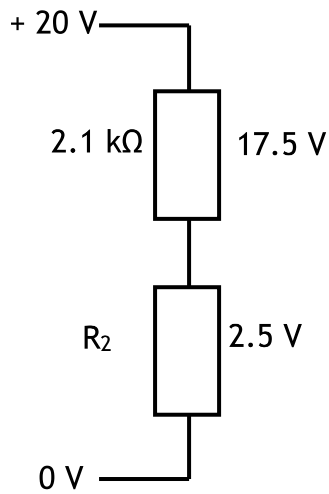


12. Calculate the value of resistor R_2 in each of these voltage divider circuits.

(a)


(b)


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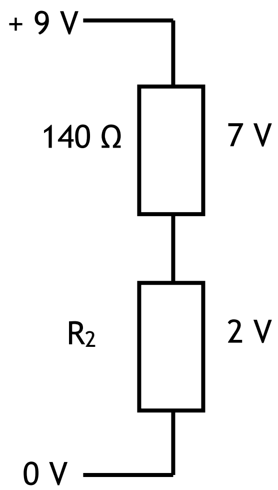
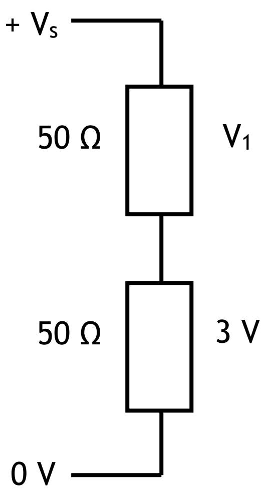
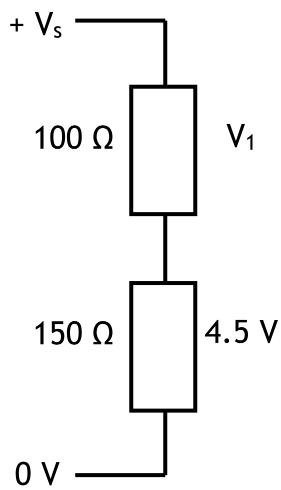
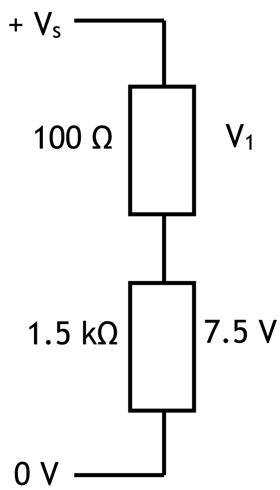


13. Calculate the value of voltage V_1 in each of these voltage divider circuits.

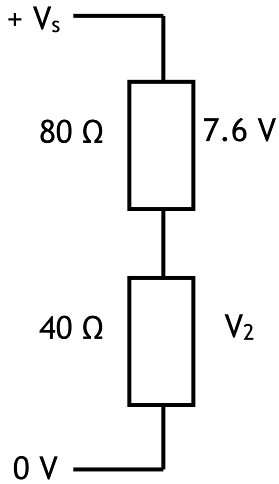
(a)


(b)


(c)


14. Calculate the value of voltage V_2 in each of these voltage divider circuits.

(a)



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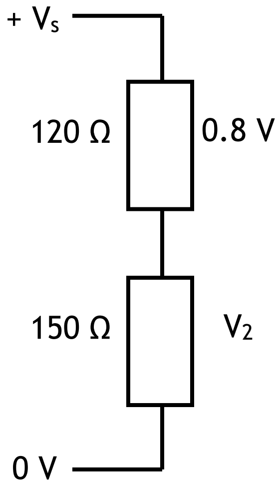

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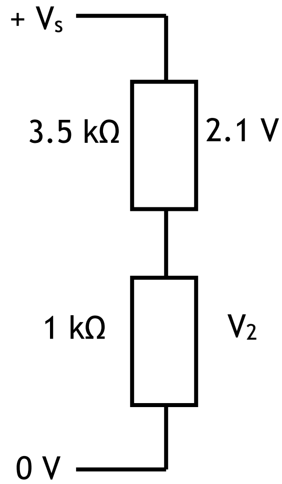
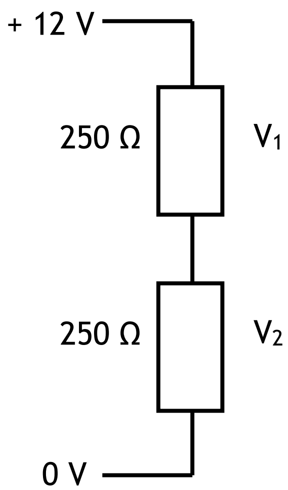


15. Calculate the voltages V_1 and V_2 in each of these voltage divider circuits.

(a)



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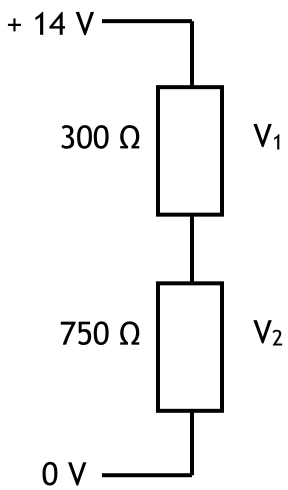
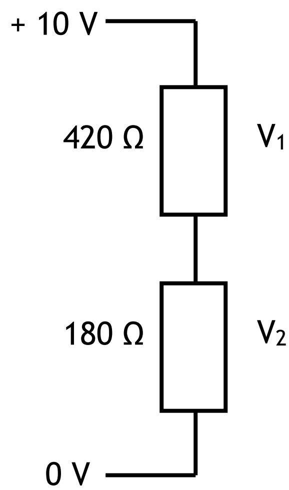


(c)



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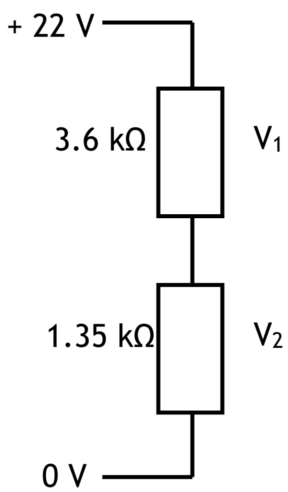

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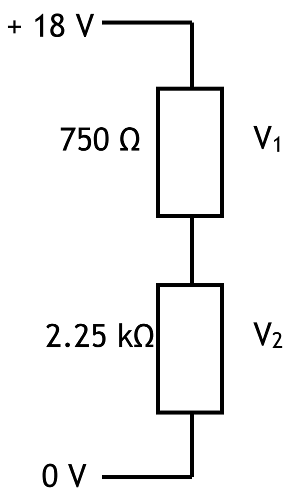

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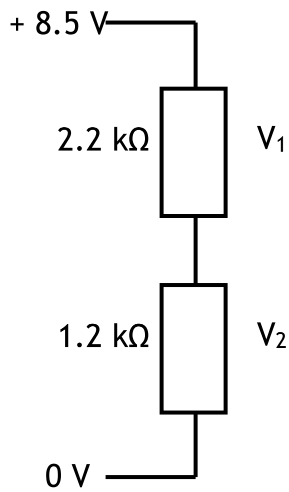


Section 4 – Practical Electrical and Electronic Circuits

Circuit Symbols

1. (a) Draw and label the circuit symbols for the following electrical components:

Relay	**Battery**	**Lamp**	**Switch**
Resistor	**Voltmeter**	**L.E.D.**	**Motor**
Ammeter	**Ohmmeter**	**Loudspeaker**	**Buzzer**
Diode	**a.c. Supply**	**Capacitor**	**Photovoltaic Cell**
L.D.R.	**Fuse**	**Microphone**	**Variable Resistor**
Switch	**Thermistor**	**Solenoid**	**Thermocouple**
Cell	**d.c. Supply**	**Oscilloscope**	

(b) Draw a table with the following headings:

input devices	output devices	measuring devices	power supplies

Sort the devices listed in part (a) into the appropriate columns in the table.
Note that 'fuse' does not fit into any category, and some of the devices may fit into more than one category.

(c) Identify the energy change which takes place in the following components:

Relay	**Motor**	**Lamp**	**Buzzer**
Microphone	**Photovoltaic Cell**	**L.E.D.**	**Solenoid**
	Thermocouple	**Loudspeaker**	

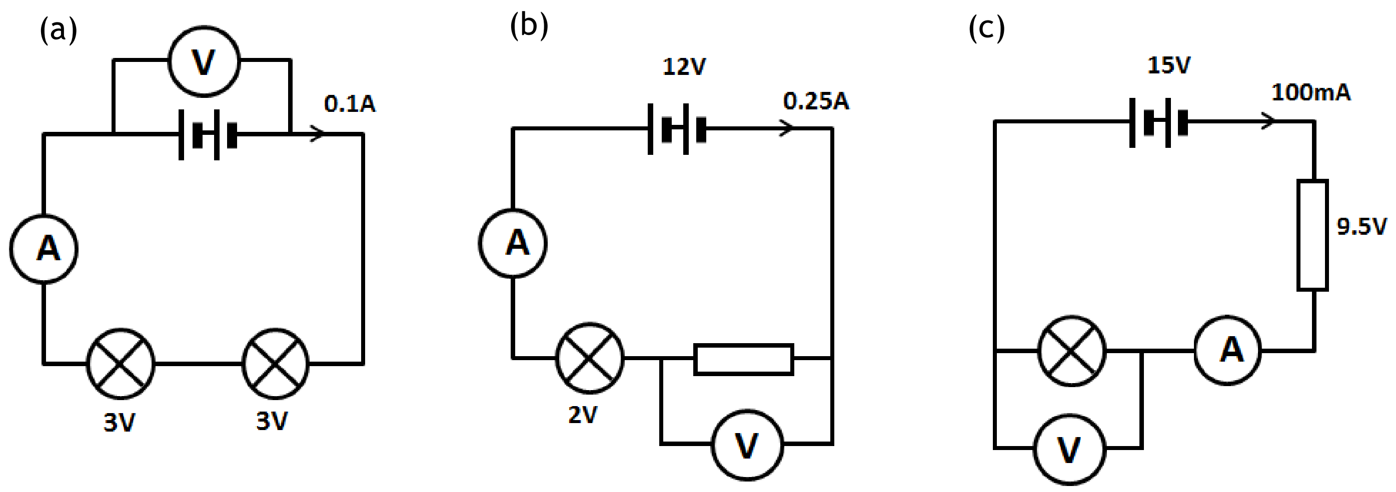
(d) Identify which output device would be most suitable as a low-oil indicator in a car.

(e) Identify which input device would be suitable for providing a time delay for a camera flash.

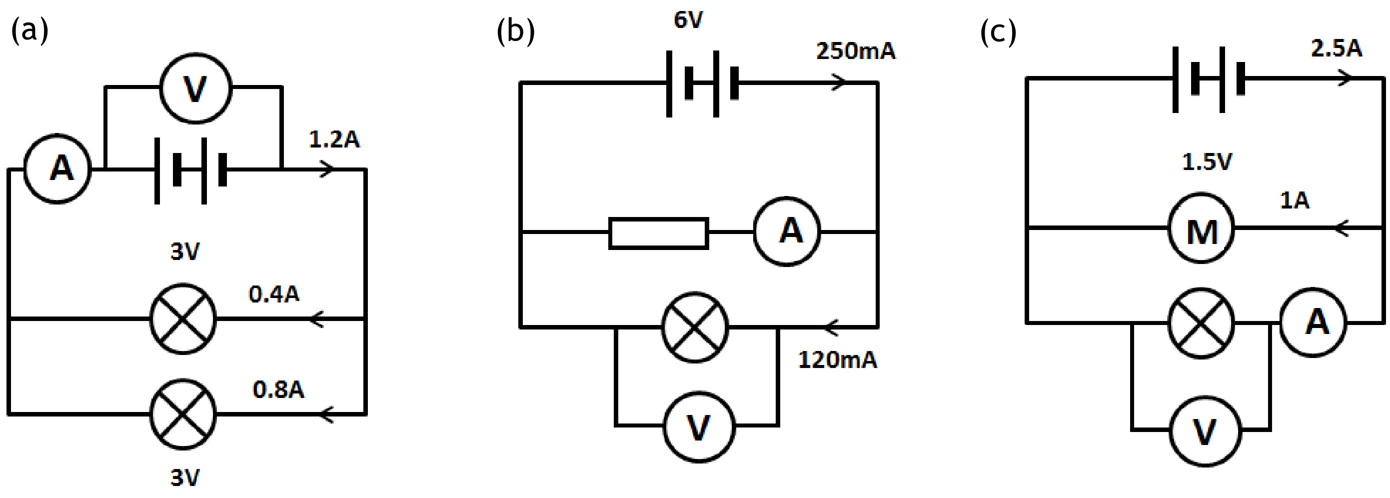
(f) State the purpose of a fuse.

2. Design circuits based on the following descriptions:
   (a) A series circuit containing a battery, a lamp, an ammeter and a voltmeter.
   The ammeter should measure the current through the lamp and the voltmeter should measure the potential difference across the lamp.
   (b) A parallel circuit containing a battery, 2 lamps, an ammeter and a voltmeter.
   The ammeter should measure the current drawn from the battery and the voltmeter should measure the potential difference across the battery.
   (c) A parallel circuit containing a battery, 2 lamps, an ammeter and a voltmeter.
   The ammeter should measure the current through ONE of the lamps and the voltmeter should measure the potential difference across the same lamp.

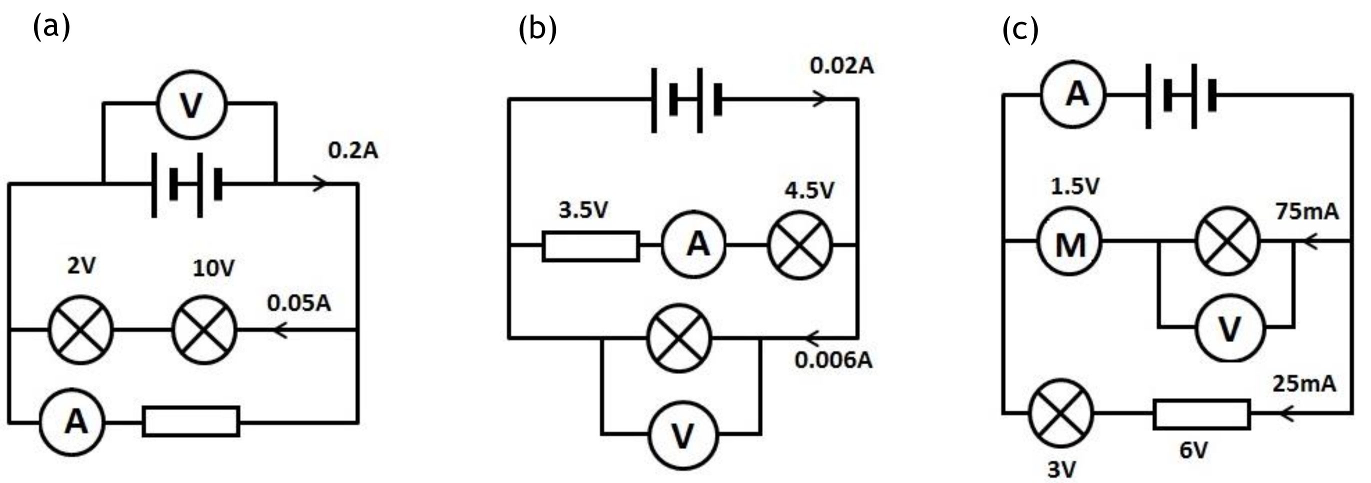
3. Determine the missing ammeter and voltmeter readings for the following series circuits:



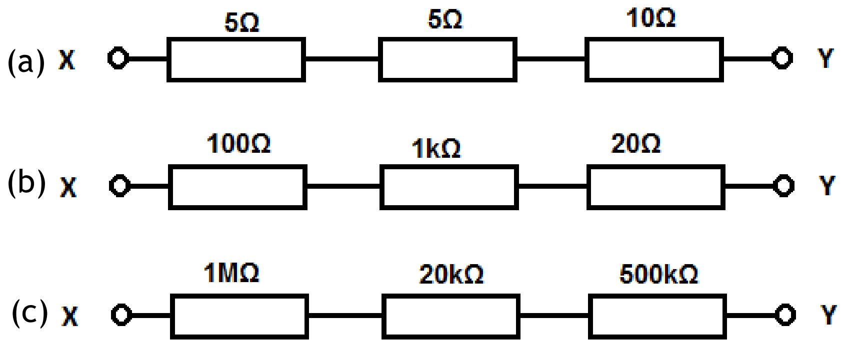
4. Determine the missing ammeter and voltmeter readings for the following parallel circuits:



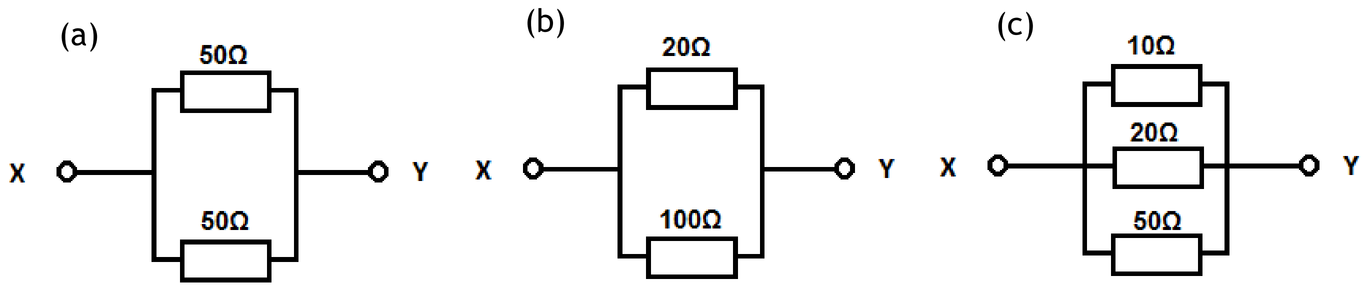
5. Determine the missing ammeter and voltmeter readings for the following parallel circuits:



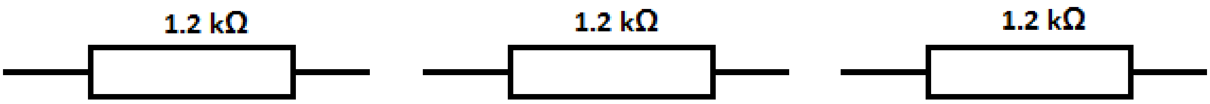
6. Calculate the total resistance between X and Y for each network:



7. Calculate the total resistance between X and Y for each network:



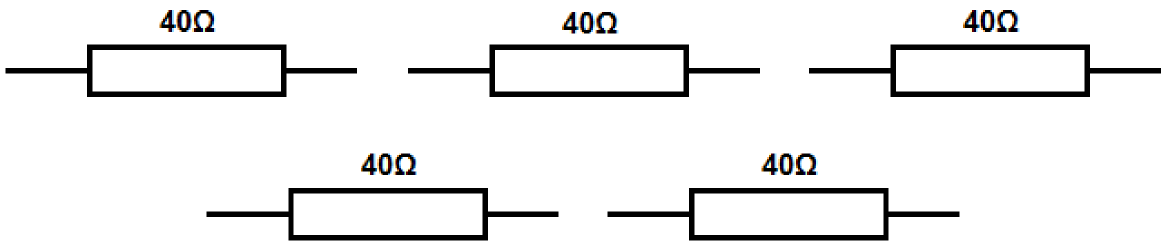
8. In a science lesson, a student is given three 1.2 kΩ resistors.



Determine the:

(a) highest possible resistance that could be achieved by combining these resistors;
(b) lowest possible resistance that could be achieved by combining these resistors.

9. In another science lesson, a student is given five 40 Ω resistors.

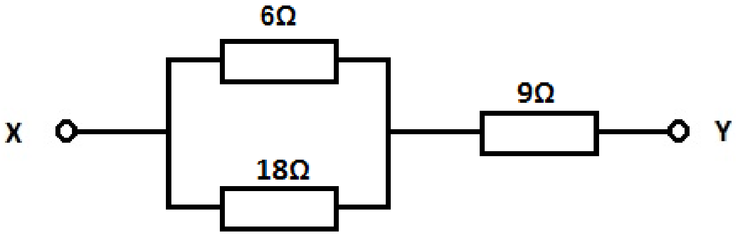


Show how the student could combine ***all*** five resistors so that the total resistance of the circuit is:

(a) 200 Ω
(b) 8 Ω
(c) 50 Ω
(d) 80 Ω
(e) 48 Ω
(f) 32 Ω

10. Calculate the total resistance in each of the following networks:

(a)



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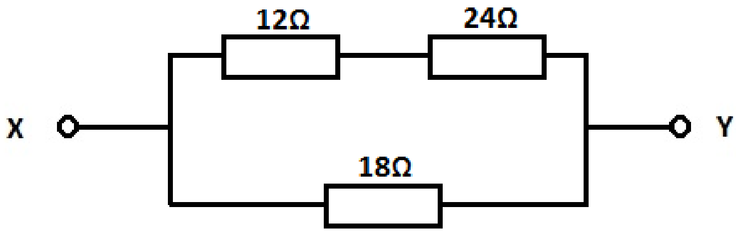

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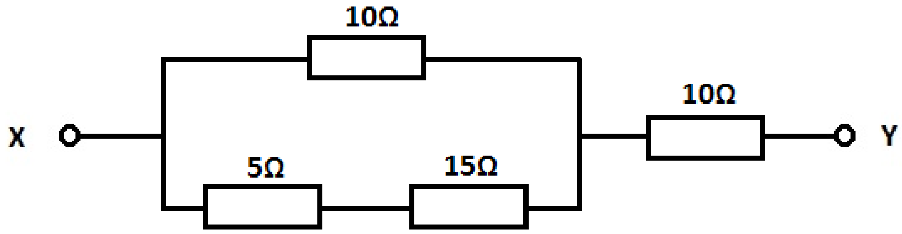

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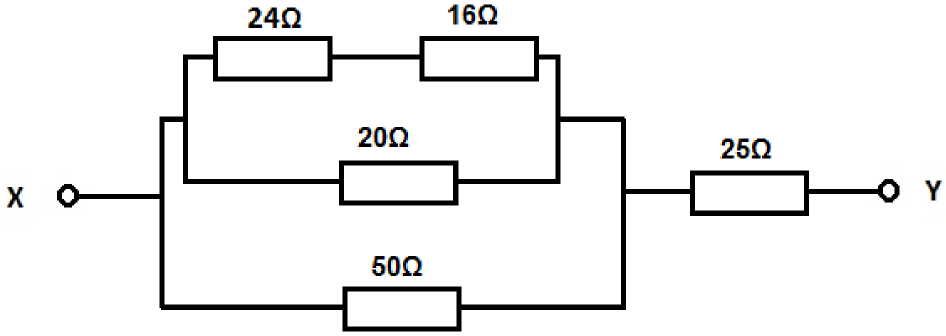
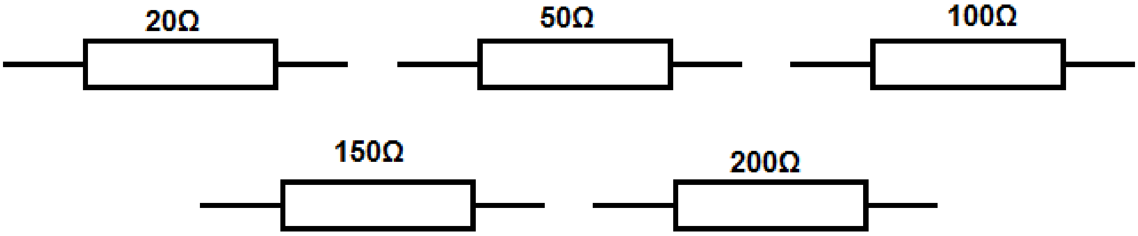
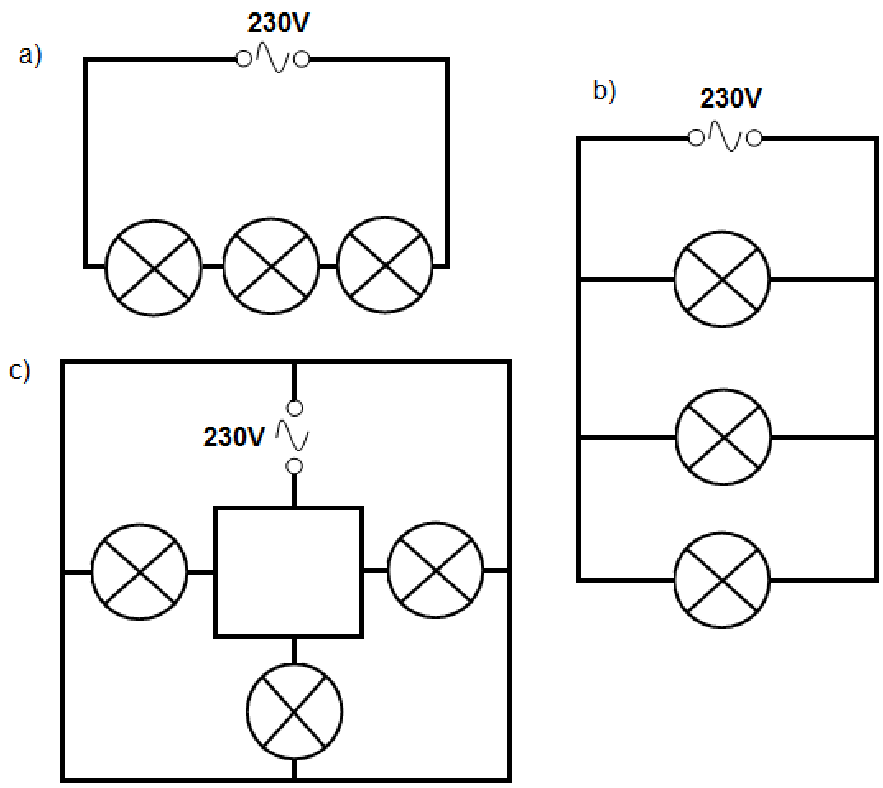


11. Use all of the resistors shown to produce five different combination resistances. Draw the network for each and calculate the resistance of each network.

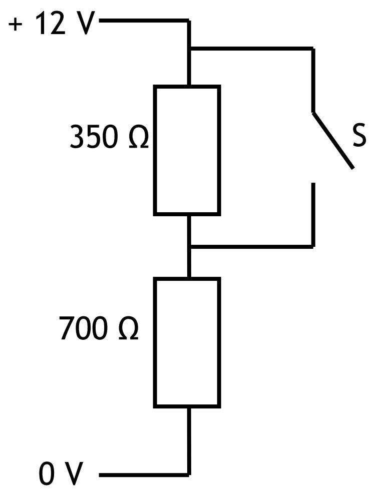


12. Lighting circuits in the home can be set up in three different ways, as shown below. State the advantages and disadvantages of each layout.

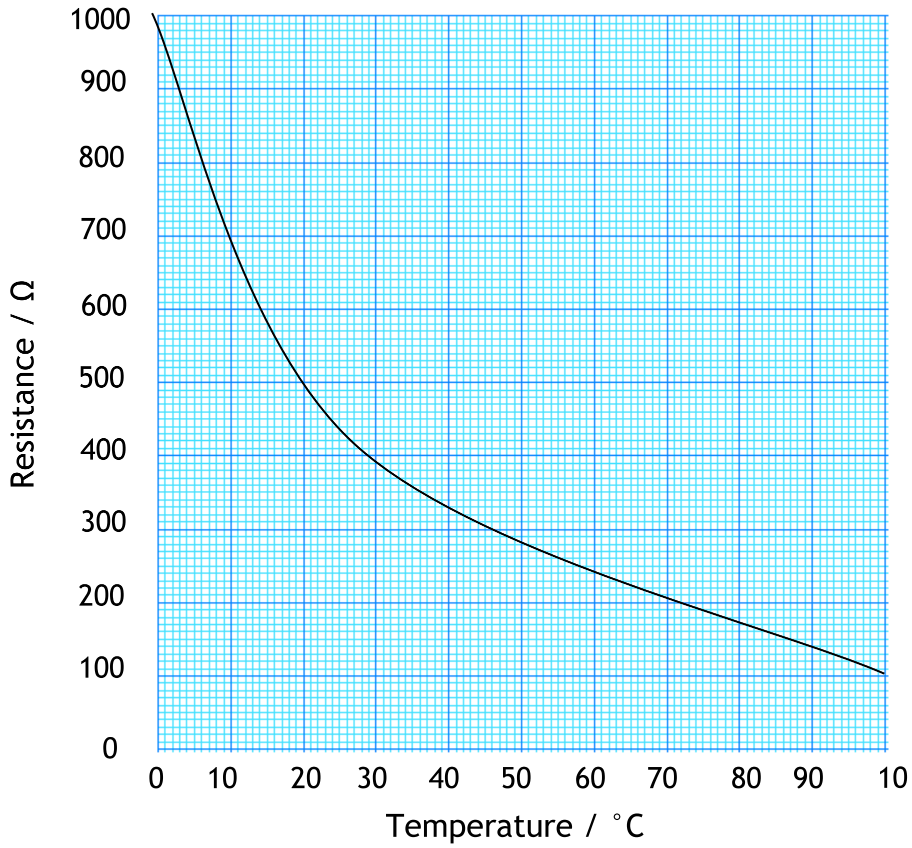


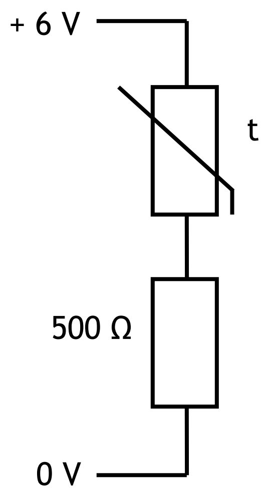
Switching Circuits

13. A potential divider with two resistors is set up as shown in the diagram.
    (a) Calculate the value of the voltage across the 350 Ω resistor when the switch is open.
    (b) Calculate the value of the voltage across the 700 Ω resistor when the switch is open.
    (c) State the value of the voltage across the 350 Ω resistor when the switch is closed.
    (d) State the value of the voltage across the 700 Ω resistor when the switch is closed.



14. The graph of the resistance of a thermistor over different temperatures is shown.

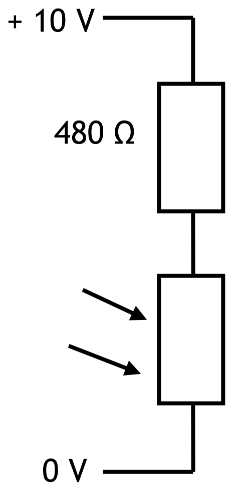




The thermistor is placed in series with a 500 Ω resistor, as shown above.

(a) Determine the resistance of the thermistor when the temperature is 10 °C.
(b) Calculate the voltage across the thermistor when the temperature is 10 °C.
(c) Calculate the voltage across the 500 Ω resistor when the temperature is 10°C.
(d) Calculate the voltage across the 500 Ω resistor when the temperature is 20 °C.
(e) Determine the temperature at which the voltage across the 500 Ω resistor is 5 V.

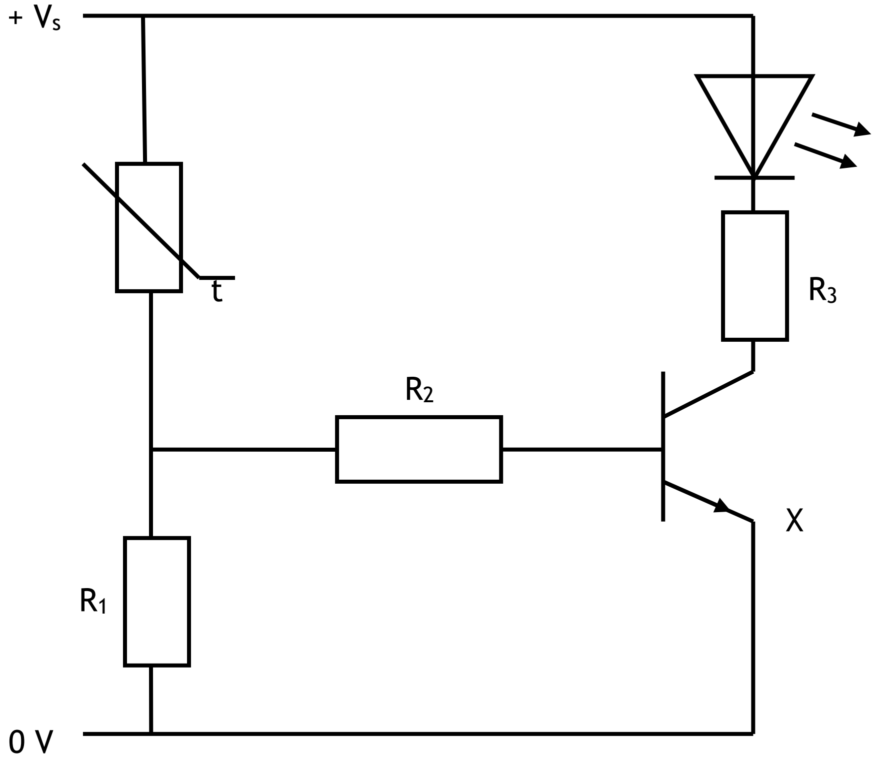
15. An LDR is placed in series with a fixed resistor as shown. The circuit is set up in a room where the lights can be turned off and on. The resistance of the LDR at different light settings is shown in the table.



Light Setting	Resistance (Ω)
Off	720
On	160

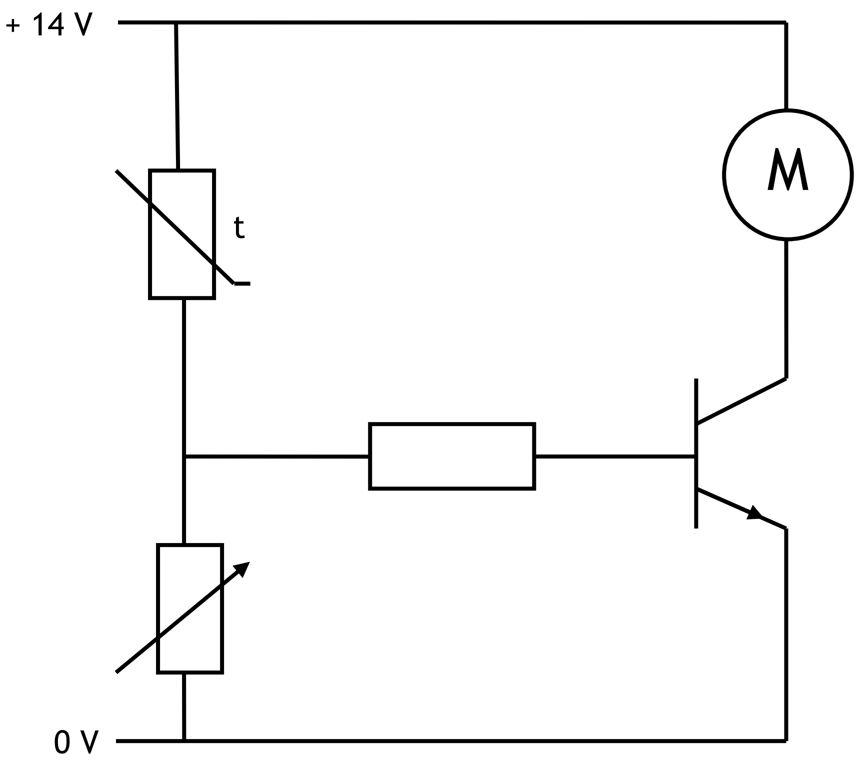
(a) Determine the voltage across the LDR when the lights are off.
(b) Determine the voltage across the LDR when the lights are on.
(c) Calculate the current flowing through the resistors when the lights are on.

16. A thermistor is used in a switching circuit, as shown.



(a) State the name of component X.
(b) Explain how this circuit operates to warn a chef that the temperature of a fridge is too high.
(c) State how this circuit could be altered to warn a chef that the temperature of a fridge is too low.

17. A thermistor is used in a switching circuit, as shown.



The variable resistor is set to a value of 100 Ω and it is noted that the motor is off. The temperature of the thermistor is then increased.

(a) State the voltage across the thermistor at the moment the motor turns on.
(b) Determine the resistance of the thermistor at the moment the motor turns on.
(c) The variable resistor is adjusted so that the motor turns on when the resistance of the thermistor is 2.85 kΩ.
Calculate is the resistance of the variable resistor.
(d) State a possible use for this circuit and explain how it would work.

Section 5 – Electrical Power

Power, Energy and Time

1. Calculate the power developed in a capacitor which stores 40 mJ of energy and is discharged in 0.03 s.

2. Calculate how much energy is dissipated in 1 hour by a 3 kW electric fire.

3. Calculate how long it takes to completely discharge a battery which stores 2×10^3 MJ of energy and is used to power a 6 kW heater.

4. A 12 V power supply is connected to an immersion heater. Calculate the power of the heater if it is used for 2.5 minutes and provides 9 kJ of energy.

5. Calculate how much energy is used when three 100 W lightbulbs, an electric fire with two bars each rated at 2 kW, and a 600 W television are all switched on for three hours.

6. A 20 mW L.E.D. is run from a small battery which stores 50 kJ of energy. Calculate how long the L.E.D. will remain on for using this battery.

Power, Current and Voltage

7. Calculate the power consumption of the following devices:
   (a) A 2 V L.E.D. drawing 10 mA;
   (b) A lamp connected to the mains supply which draws 0.5 A;
   (c) A kettle connected to the mains which draws 12.5 A.

8. Calculate the current drawn from the power supply by the following devices:
   (a) A mains heater rated at 2 kW
   (b) A 6 W electric robot using a 12 V battery
   (c) A hand-held fan with a power rating of 50 W which uses four 1.5 V batteries

9. Calculate the voltage required to run the following appliances at their correct power rating:
   (a) A 1500 kW generator drawing 30 A
   (b) A hair-dryer rated at 1.6 kW drawing 6.9 A
   (c) A 40 W torch which draws 2.5 A

10. In an American school, a pupil measures the current flowing through some different mains appliances with given power ratings. The results of this experiment are shown in the table to the right.
    Draw a line graph of power against current, and use the gradient of the straight line to calculate the mains voltage in the USA.

Power Rating (W)	Current (A)
100	0.91
250	2.27
400	3.64
600	5.45
800	7.27
1250	11.36

Power and Resistance

11. Combine the equations $P = IV$ and $V = IR$ in order to derive the equation, $P = I^2R$.

12. Copy and complete this table:

	Power (W)	*Current* (A)	*Resistance* (Ω)
(a)		1.5	100
(b)		0.8	50
(c)	500		125
(d)	34		850
(e)	735	7.0	
(f)	36	0.06	

13. Calculate the power rating of a lamp that has a resistance of 5 Ω and a current of 1.2 A flowing through it.

14. Calculate the current flowing through a 50 Ω heating element in a toaster if it has a power rating of 800 W.

15. Calculate the resistance of a 1200 W electric convection heater that has a current of 5.0 A flowing through it.

16. Combine the equations $P = IV$ and $I = \frac{V}{R}$ to derive the equation $P = \frac{V^2}{R}$.

17. Copy and complete this table:

	Power (W)	*Voltage* (V)	*Resistance* (Ω)
(a)		10	5
(b)		6	72
(c)	25		9
(d)	1.8		20
(e)	20	20	
(f)	400	230	

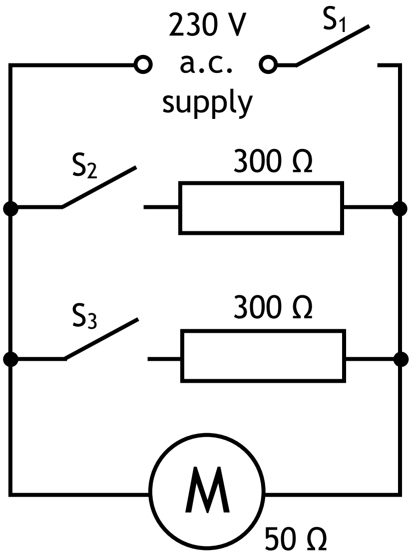
18. Calculate the power rating of a mains television that has a resistance of 529 Ω.

19. Calculate the voltage across a portable electric shaver that has a resistance of 2.45 Ω and a power rating of 20 W.

20. Calculate the resistance of an 800 W mains powered coffee machine.

21. A 130 W tropical fish aquarium is connected to the mains.
    a) Calculate the resistance of the aquarium.
    b) Calculate the current flowing through the aquarium.
    c) Calculate how much energy is used up by the aquarium in 24 hours.

22. A hairdryer has three heat settings: *cold*, *warm* and *hot*.
The hairdryer is made up of two 300 Ω resistors and a 50 Ω motor that are connected in parallel with the mains supply, as shown in the diagram below.



(a) State the energy change that occurs when current flows through a resistor.
(b) Determine which switches are closed when the hairdryer is blowing out warm air.
(c) Calculate how much current is drawn from the mains when the hairdryer is blowing out cold air.
(d) Calculate the power rating of the hairdryer when it is blowing out cold air.
(e) Calculate the total resistance of the hairdryer when it is blowing out hot air.
(f) Calculate the power rating of the hairdryer when it is blowing out hot air.
(g) Calculate how much electrical energy the hairdryer will use if it blows cold air for 1 minute and hot air for 8 minutes.

23. Explain why it is useful to use a very high voltage in transmission lines.

24. Wires used in transmission lines have a resistance of 0.0025 Ωm^{-1}. Calculate how much power is lost by transmission lines carrying a current of 12 A if the length of the lines are:

(a) 1 m long;
(b) 30 m long;
(c) 2.5 km long.