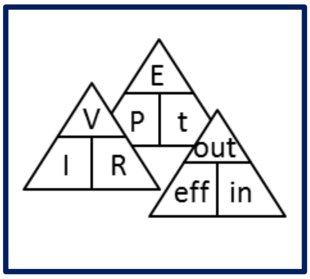
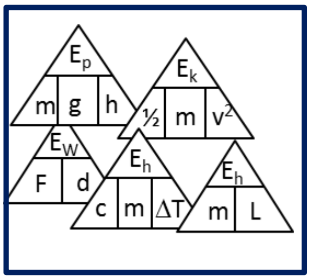
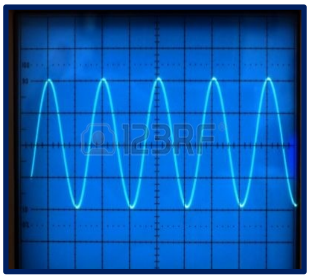
Hyndland Secondary School

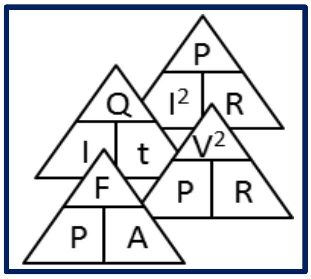
Ultimate Collection revised for CfE

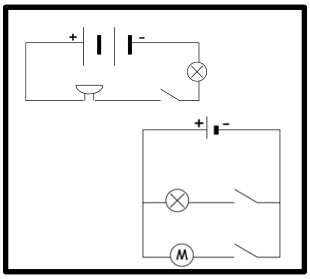
N4 N5 Physics

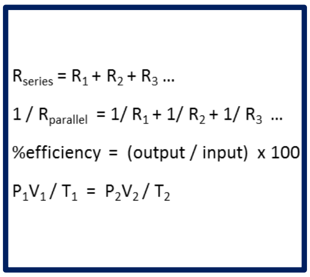


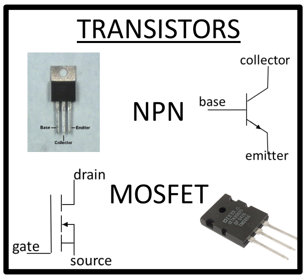












Electricity & Energy

Problems - S4

Data Sheet

Speed of light in materials	
Material	*Speed in ms^{-1}*
Air	3×10^8
Carbon	3×10^8
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	2.1×10^8
Water	$2{\cdot}3 \times 10^8$

Gravitational field strengths	
	Gravitational field strength on the surface in
Earth	9.8
Jupiter	23
Mars	3.7
Mercury	3.7
Moon	1·6
Neptune	11
Saturn	9
Sun	270
Venus	8.9
Uranus	8·7

Specific latent heat of fusion of materials	
Material	*Specific latent heat of fusion in Jkg^{-1}*
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Iron	2.67×10^5
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Specific latent heat of vaporisation of	
|Material	*Sp.l.ht vap(Jkg^{-1})*
Alcohol	$11{\cdot}2 \times 10^5$
Carbon dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

Speed of sound in materials	
Material	*Speed in ms^{-1}*
Aluminium	5 200
Air	340
Bone	4 100
Carbon dioxide	270
Glycerol	1 900
Muscle	1 600
Steel	5 200
Tissue	1 500
Water	1 500

Specific heat capacity of materials	
Material	*Specific heat capacity in Jkg^{-} ${}^{o}C^{-1}$*
Alcohol	2 350
Aluminium	902
Copper	386
Glass	500
Ice	2 100
Iron	480
Lead	128
Oil	2 130
Water	4 180

Melting and boiling points of materials		
Material	*Melting point in °C*	*Boiling point in °C*
Alcohol	-98	65
Aluminium	660	2470
Copper	1 077	2 567
Glycerol	18	290
Lead	328	1 737
Iron	1537	2 737

Radiation Weighting Factors	
Type of Radiation	*Radiation Weighting Factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3

1 Efficiency

National 4

In this section you can use the following two equations:

$$\textbf{efficiency} = \frac{\textbf{useful energy out}}{\textbf{useful energy in}}$$

$$\textbf{efficiency} = \frac{\textbf{useful power out}}{\textbf{useful power in}}$$

Helpful Hint

Efficiency is usually expressed as a percentage and you should change percentages to decimals before using this equation.

Example 1

A generator in a thermal power station converts 1 000 J of kinetic energy into 800 J of electrical energy. What is the efficiency of the generator?

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{useful energy in}} = \frac{800}{1000} = 0{\cdot}8 = \mathbf{80\%}$$

Example 2

A motor is 65 % efficient. What power can this motor deliver when it receives 2 000 W?

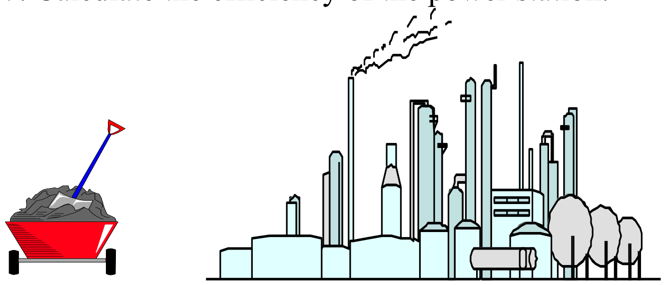
$$65\ \% = 0{\cdot}65 = \frac{\text{useful power out}}{2\ 000}$$

useful power out = 0·65 x 2 000 = **1 300 W**

1. Find the missing values in the following table.

	Efficiency (%)	*Useful energy in*(J)	*Useful energy out*(J)
(*a*)		1 400	700
(*b*)		675	135
(*c*)	80	1 200	
(*d*)	45		1 500
(*e*)	60	300	
(*f*)	25		6 000

2. A coal fired power station has a power output of 200 MW. The power produced by the boiler is 340 MW. Calculate the efficiency of the power station.



3. A turbine converts 65 000 J of heat energy into 13 000 J of kinetic energy. What is the efficiency of the turbine?

4. A generator converts 3 156 MJ of kinetic energy into 450 MJ of electrical energy. What is the efficiency of the generator?

5. A thermal power station converts 420 MJ of chemical energy into 124 MJ of electrical energy. What is the efficiency of this power station?

6. An electrical pump used in a pumped storage hydroelectric power station is 80 % efficient. How much work can the pump do if it is supplied with 25 kJ of energy each second?

7. An oil fired power station which is 40% efficient produces an output of 300 MW. How much power must be supplied to the station to produce this output?

8. The output from an oil-fired power station is 250 MW and it is 32 % efficient. How much power must be provided by the oil to produce this output?

9. The Glenlee hydroelectric power station produces 24 000 kW of electricity. How much power is provided by water falling from the reservoir if the station is 25 % efficient?

10. The boiler of a thermal power station releases $2{\cdot}8 \times 10^8$ J of heat energy for each kilogram of coal burned. The generator of the power station produces $1{\cdot}26 \times 10^8$ J of electrical energy for each kilogram of coal burned. What is the efficiency of this power station?

11. The tidal power station at the Rance in Brittany, France opened in 1966. Each of the 24 turbines can generate an output of up to 10 MW from the tidal currents funnelled into the river estuary. Assuming that each turbine is 45 % efficient calculate the power of the tide required to generate 10 MW at one turbine.

12. Water flowing into the turbines of a hydroelectric power station loses $4{\cdot}5 \times 10^6$ J of potential energy each second. How much electrical energy could this power station produce if it is 35 % efficient?

13. A house has solar panels covering an area of 10 m^2 to provide domestic hot water. The solar power received by each square metre is 180 W on a summer day and the panels are 20 % efficient. Calculate the heat energy that would be produced by the panels on such a day.

14. The average power in waves washing the north Atlantic coast of Europe is 50 kW per metre of wave front. What length of wave front would be required to generate 10 MW of electricity from these waves using a 45 % efficient wave - power device?

15. The 3 MW wind turbine at Burger Hill in Orkney provides energy for the national grid. If this turbine is 25 % efficient calculate how much energy is wasted each second in this system.

2. Basic Electrical Components

National 4 and 5

1. Find out and draw the symbol for each of the following electrical and electronic components:

   (a) lamp

   (b) connecting lead

   (c) battery

   (d) cell

   (e) motor

   (f) resistor

   (g) switch

   (h) variable resistor

   (i) voltmeter

   (j) ammeter

   (k) fuse

   (l) buzzer

   (m) bell

2. Draw a circuit consisting of one lamp, one switch, one battery and one buzzer connected in series.

3. Draw a circuit that will allow 3 bulbs to be switched on and off separately. Each bulb will require its own switch. The circuit should operate from 2 batteries connected in series.

3. Electronic Systems – Output Devices

National 4 and 5

1. Which of the components in the list below are output devices?

bulb	thermistor	relay	thermocouple
solenoid	loudspeaker	dynamo	LED
LDR	buzzer	motor	microphone

2. Which output device could be used in a central locking system of a car?

3. What would be an appropriate output device for a public address system?

4. Select an output device which could be used to raise and lower blinds automatically in a luxury flat.

5. Which output device is useful for digital displays on hi-fi systems?

6. Draw the symbol for each of the output devices you identified in question 1.

4. Electronic Systems – Input Devices

National 4 and 5

In this section you can use the equation:

$$V = IR$$

where **V** = voltage in volts (V)
I = current in amps (A)
R = resistance in ohms (Ω).

Helpful Hint
When choosing an input device for an electronic system, think about what type of energy the device has to detect.

capacitor	**microphone**	**photovoltaic cell**
thermocouple	**thermistor**	**light dependent resistor (LDR)**

1. Select from the list above a suitable input device for each of the following:

   (*a*) Public address system in a railway station

   (*b*) Digital thermometer

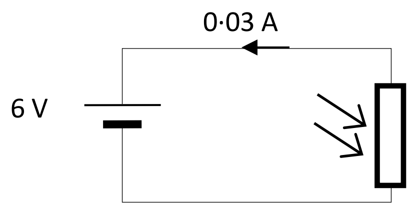
   (*c*) Photographers light meter

   (*d*) Time delay circuit for courtesy lights in a car

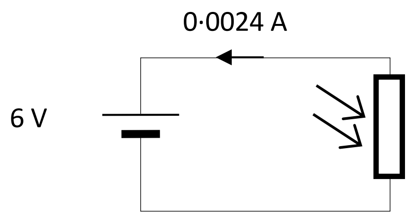
   (*e*) Pilot light flame detector in a gas central heating system

   (*f*) Sunlight hours recorder at a weather station.

2. The circuits below show two identical LDR's each connected to a 6 V supply. One LDR is placed in a cupboard and the other is placed beside a window.



Circuit (i)

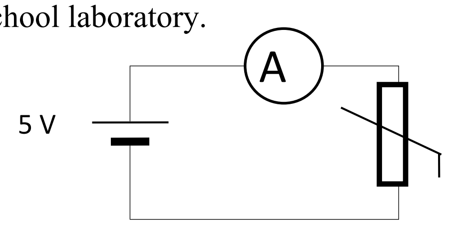


Circuit (ii)

   (*a*) Calculate the resistance of each LDR.

   (*b*) State which circuit shows the LDR in the cupboard.

3. The following circuit shows a thermistor connected to a 5 V supply and placed in a school laboratory.



One morning the ammeter gave a reading of 1·25 mA. Later in the same day the reading had risen to 2·5 mA.

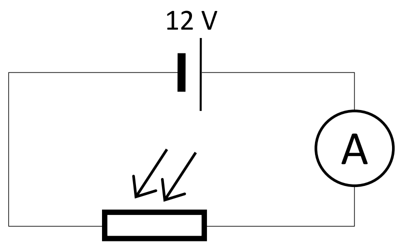
(*a*) Calculate the resistance of the thermistor in the morning.

(*b*) State what happened to the temperature in the room during the day? Explain your answer.

4. The following information for an LDR was found in a components catalogue.

Light Source	*Illumination* (lux)	*Resistance* (kΩ)
moonlight	0·1	10 000
60 W bulb at 1m	50	2·4
fluorescent light	500	0·2
bright sunlight	30 000	0·02

This LDR is connected to a 12 V supply with an ammeter in series as shown in the diagram.



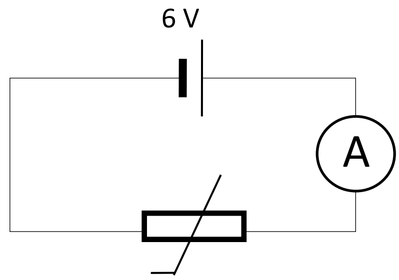
(*a*) Determine the resistance, in ohms, of the LDR when exposed to fluorescent light?

(*b*) Calculate the ammeter reading when a lamp with a 60 W bulb is placed 1 m away from the LDR?

(*c*) For one source, the ammeter gives a reading of 0·6 A. Determine which light source is being used.

5. A pupil uses a thermistor as a simple electronic thermometer. She connects the thermistor to an ammeter and places the thermistor into a beaker of hot water. The ammeter gives a reading of 8 mA.

Temperature (°C)	*Resistance* (Ω)
20	3 750
40	198
60	750
80	350
100	200



(*a*) Determine the temperature of the water in the beaker?

(*b*) The pupil adds some more water to the beaker and the ammeter gives a new reading of 1·6 mA. Determine whether the pupil added hot or cold water to the beaker.

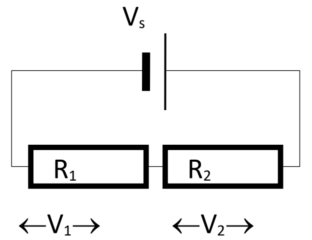
(*c*) Calculate the new temperature of the water.

(*d*) Determine the ammeter reading when the water reaches boiling point.

5. Potential Divider Circuits

National 5 Extension

In a series circuit the supply voltage is **divided up** between the components in the circuit i.e.

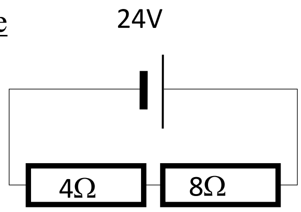


$V_s = V_1 + V_2$

where V_s = supply voltage
V_1 = voltage across R_1
V_2 = voltage across R_2

From Ohm's law we know that since current is constant in a series circuit, the higher the resistance of a component the greater the potential difference across it.
This idea is used in the following example to calculate the potential difference across components in a 'potential divider' i.e. series circuit.

Example



Use the fact that the voltage 'split' across each component is in the same ratio as the resistance of each component.

$$V_1 = \frac{R_1 \times V_s}{R_t} = \frac{4 \times 24}{12} = 8\text{V}$$

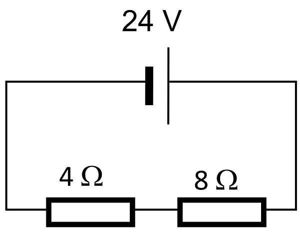
$$V_2 = \frac{R_2 \times V_s}{R_t} = \frac{8 \times 24}{12} = 16\text{ V}$$

where R_t = total resistance

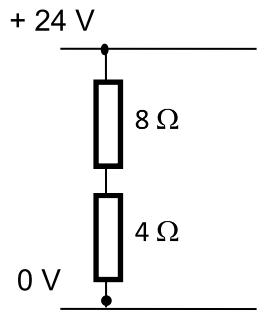
(Remember to check your answer e.g. does $V_1 + V_2 = V_s$)

Lastly!
Circuit problems in electronics are usually drawn slightly differently than you are used to seeing.

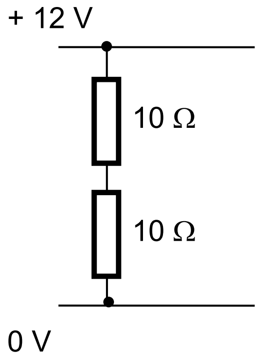
e.g.



would be drawn as



Find the potential difference across each resistor in the following circuits:

(1)


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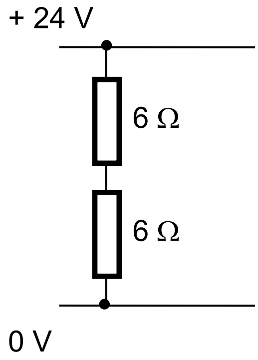
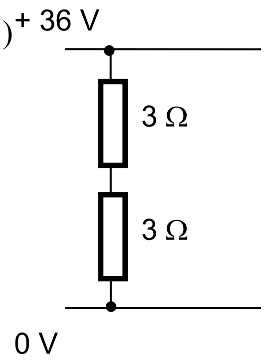


(3)


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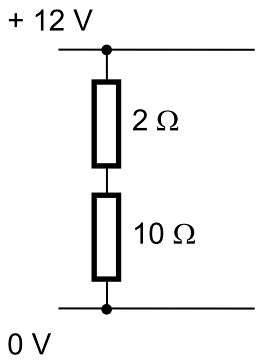

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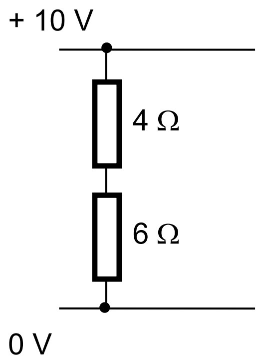

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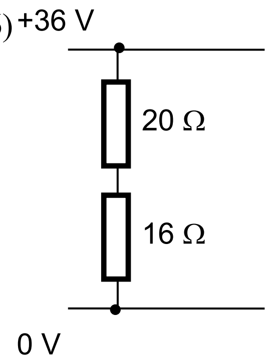

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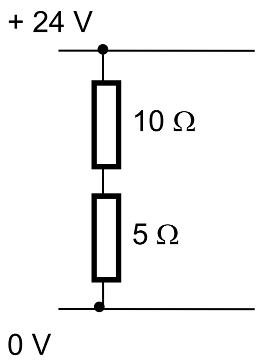

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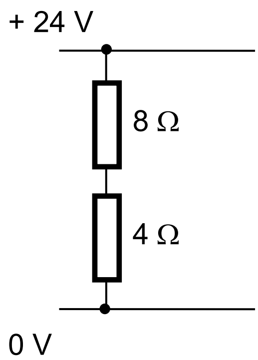

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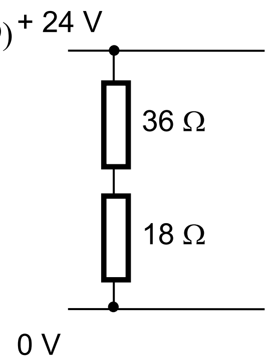

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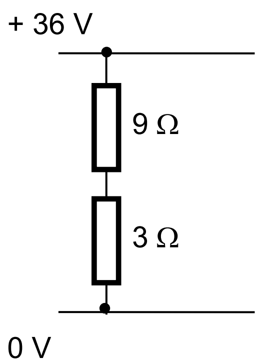

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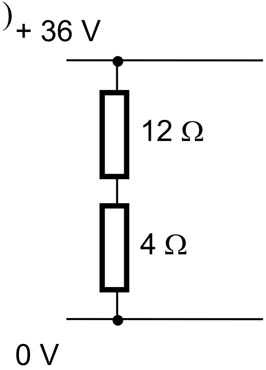

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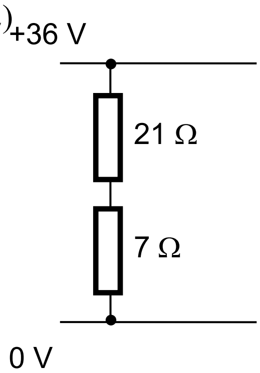

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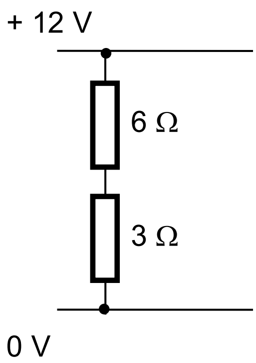

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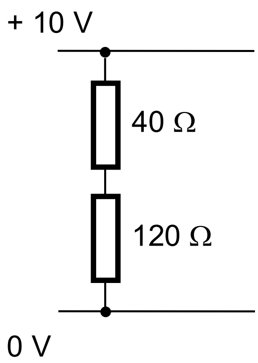

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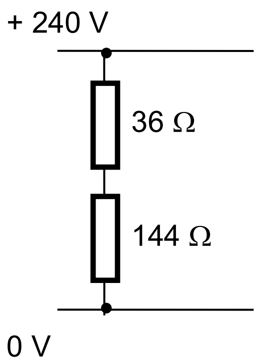

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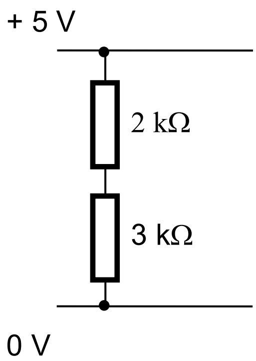

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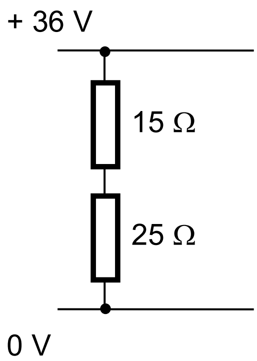

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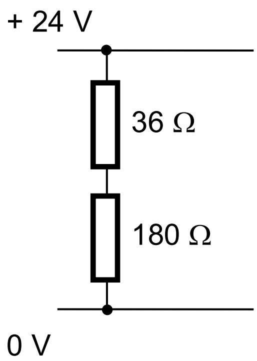

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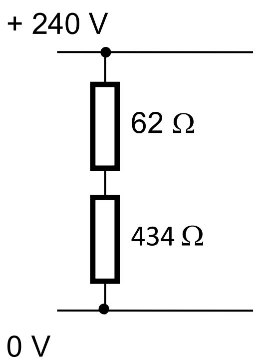

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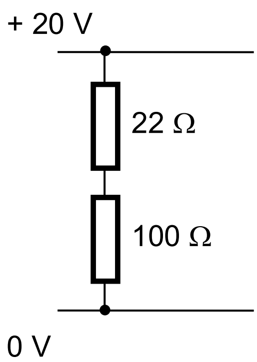


Helpful Hint
LDR's and thermistors often make up part of a potential divider circuit in electronic systems. It is important to remember that the **resistance** of these components varies with external conditions.

Use the following data to answer questions 21 – 25.

The tables below show how the resistances of a certain LDR and thermistor vary with external conditions.

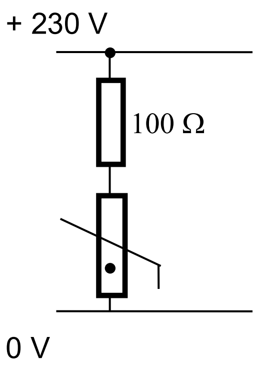
LDR

light condition	***resistance (Ω)***
dark	10 000
light	2 500
bright	20

Thermistor

temperature (°C)	***resistance (Ω)***
10	4 000
40	1 980
100	200

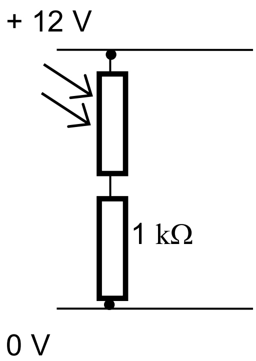
21. The following circuit is part of the input to an electronic frost alarm.



Calculate the potential difference across the thermistor when it is

(a) 10 ° C
(b) 40 ° C

22. The following circuit could be part of a light meter for a camera.

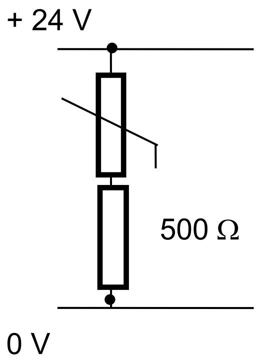


Use the information above to find the potential difference across the LDR when it is:

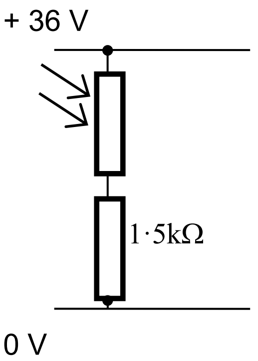
(*a*) dark
(*b*) light

23. Calculate the potential difference across the **resistor** in the following circuit when the temperature is:

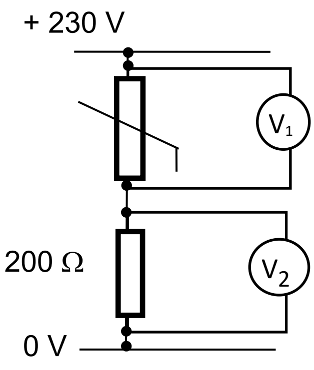
(*a*) 100 °C
(*b*) 40 °C



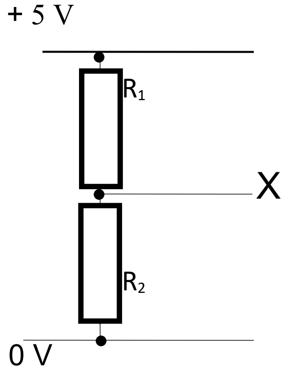
24. A young engineer designs part of an electronic system to trigger an alarm when it gets too bright.
Determine the 'trigger voltage' across the resistor in the following system when the light level becomes 'bright'.



25. Determine the temperature at which the following voltmeters will show identical readings.



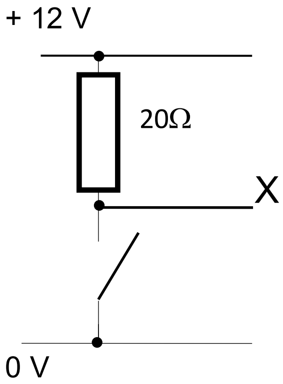
Helpful Hint
In a circuit like the following:



You are often required to calculate the "potential" at point X
This is the same as the voltage (or potential difference) across resistor R_2.

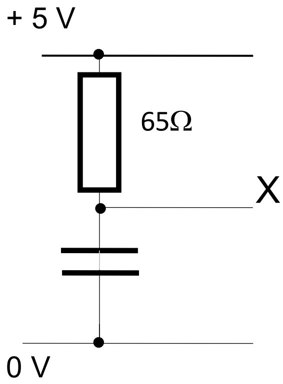
Calculate the potential at X in questions 26 - 30.

26.



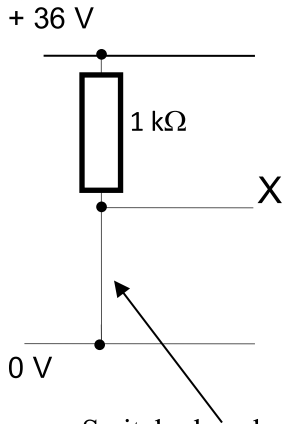
Switch open

27.



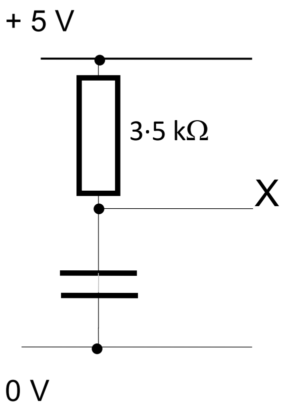
Capacitor uncharged

28.



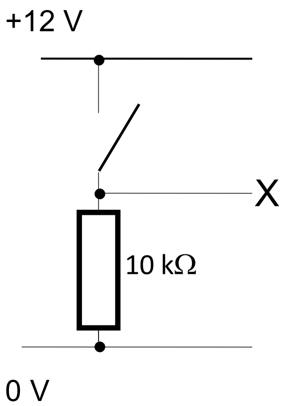
Switch closed

29.



Capacitor fully charged

30.



Switch open.

6. Transistor Basics & Switching Circuits

National 5 (Transistor Basics)

1. Draw the symbol for the npn transistor and label each terminal.

2. For what do the letters MOSFET stand?

3. Draw the symbol for the n-channel enhancement MOSFET and label each terminal.

4. Transistors can be used as switches that are controlled by a voltage.

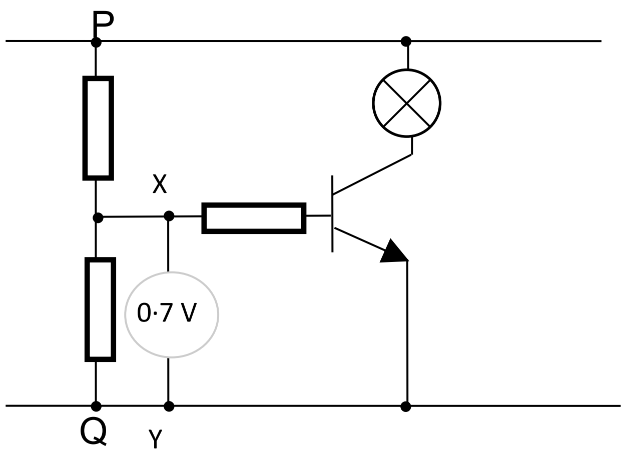
   (a) State the switching voltage for the npn transistor.
   (b) State the switching voltage for the n-channel enhancement MOSFET.

5. On your diagrams for questions 1 and 3, indicate where this "switching voltage" should be.

National 5 Extension (Switching Circuits)

Helpful Hint

A transistor operates as a switch in a circuit. An npn transistor switches 'ON' when the voltage across XY, in the diagram below, is above approximately 0·7 V.



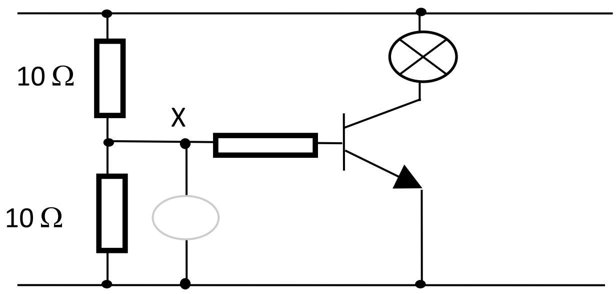
For the n-channel enhancement MOSFET, this switching voltage is approximately 2V.

In the last section you studied potential dividers. A potential divider is usually placed between P and Q. Various components can be used to make up the potential divider but it is always the potential difference across XY which switches on or off the transistor.

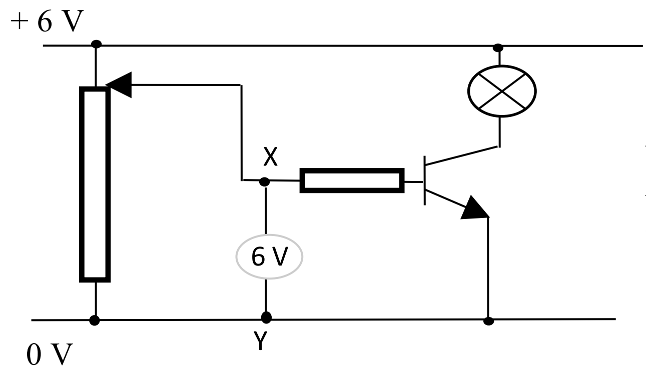
Some examples are shown on the next page.

Examples for the NPN Transistor

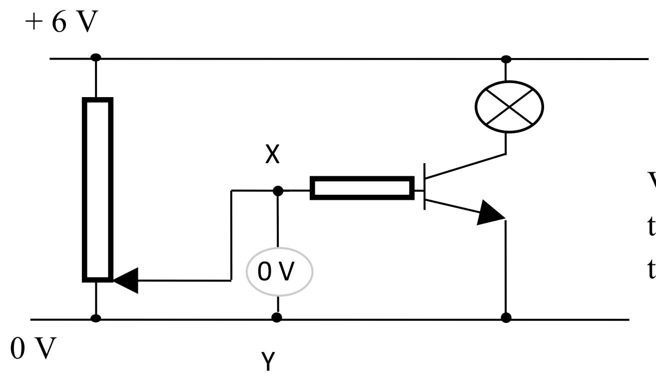
(*a*) The potential divider can be two resistors in series



(*b*) The potential divider can be a Potentiometer

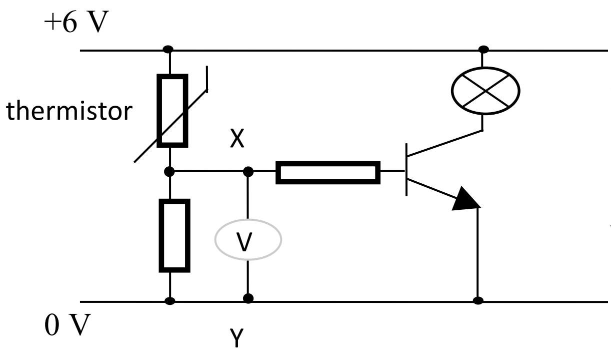


Voltage across XY is 6 V so transistor conducts and bulb lights.



Voltage across XY is 0 V so transistor does not conduct therefore bulb is OFF.

(*c*) The potential divider may contain a sensor (the words in **bold** will change depending on the type of sensor and its position in the potential divider.)



*As the **temperature increases**, the resistance of the **thermistor decreases**.*

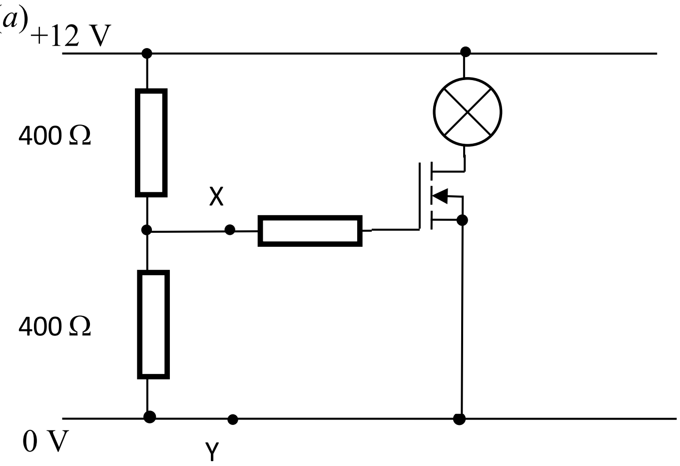
So does its voltage.

*This means the voltage across XY **increases**.*

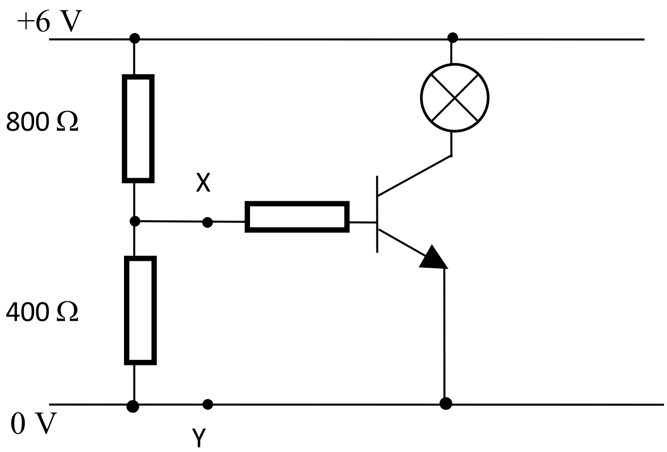
*Eventually it will be **hot** enough that this voltage will become **greater** than **0.7V** so the transistor and **bulb** will switch **ON**.*

1. For each of the following circuits calculate the potential difference across XY and then state whether the output device is ON or OFF.

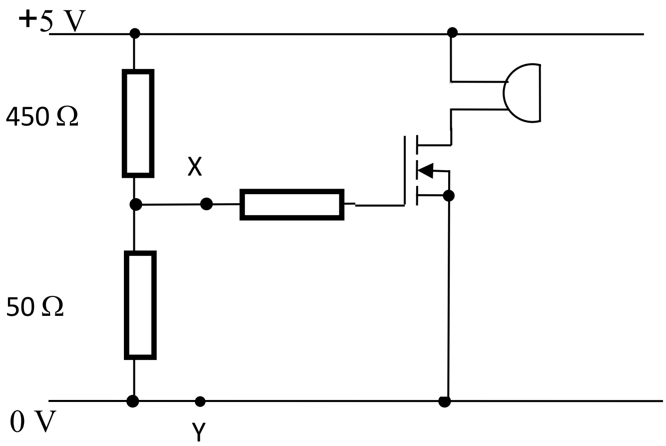
(*a*)



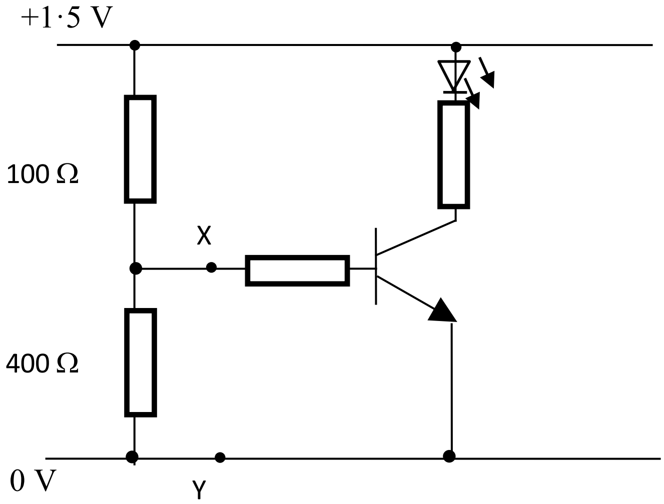
(*b*)



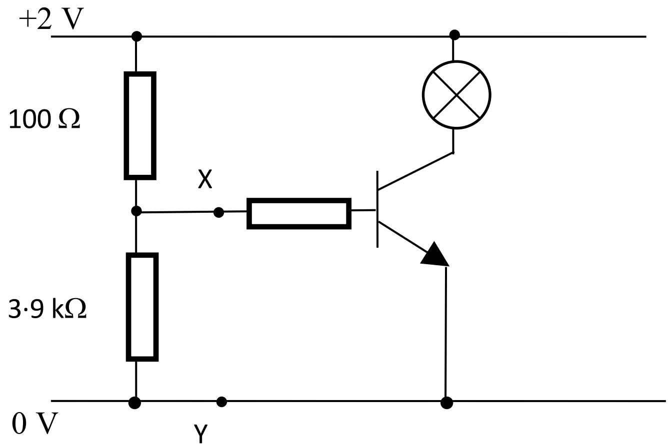
(*c*)



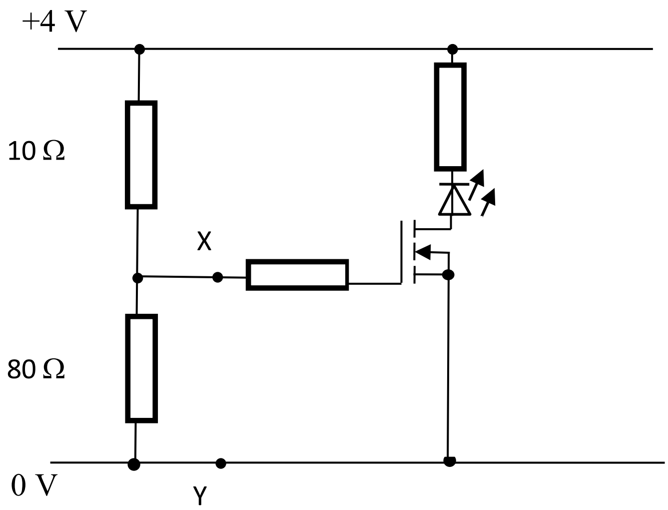
(*d*)



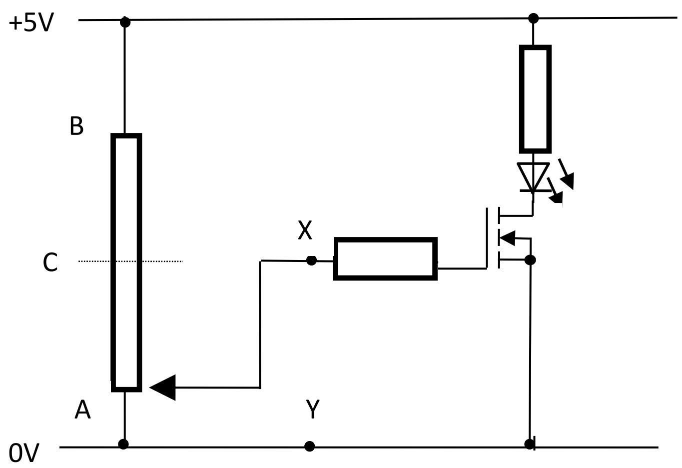
(*e*)



(*f*) (Hint! Think here!)



2. Consider the following circuit.



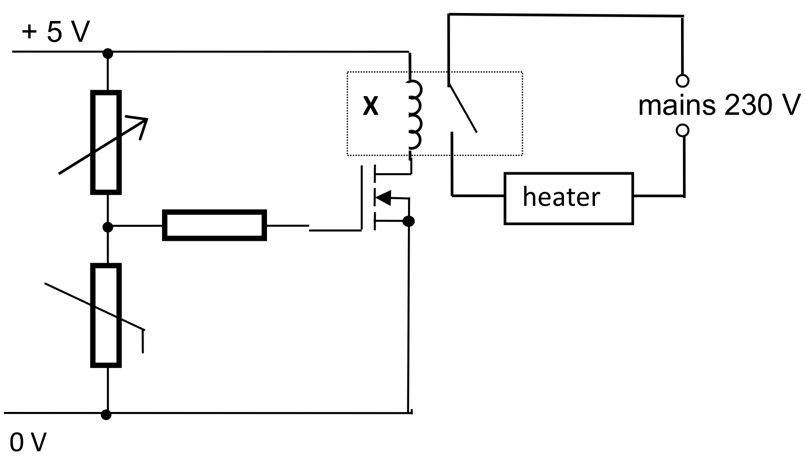
(*a*) What is the voltage across XY when the sliding connection is at point A?

(*b*) Does the LED light when the sliding connection is at point A?

(*c*) Does the LED light when the sliding connection is at point B? Explain your answer.

(*d*) Does the LED light when the sliding connection is at point C? Explain your answer.

3. The following circuit is used to switch on an electric heater automatically when the temperature in a room falls below a certain value.

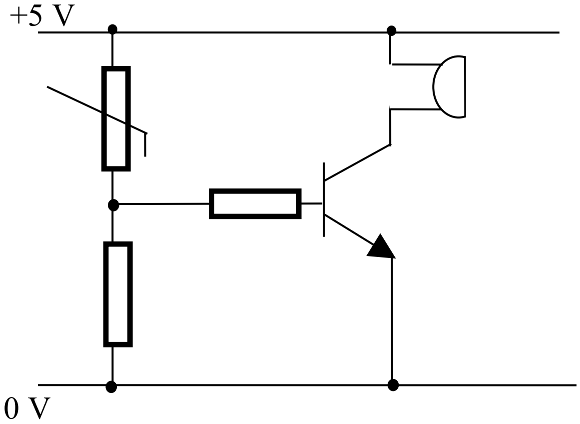


(*a*) Explain how the circuit operates.

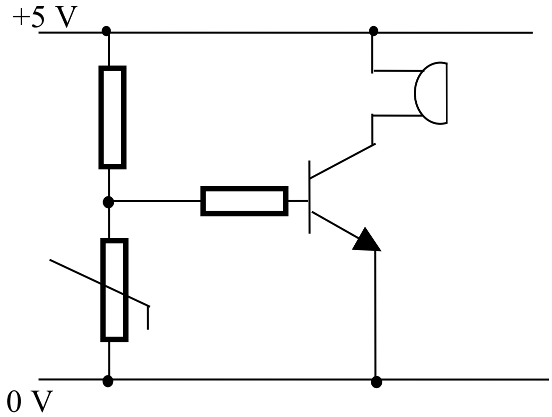
(*b*) What would be the effect of decreasing the resistance of the variable resistor?

(*c*) Why would it be unsuitable to put the heater at point X instead of the relay?

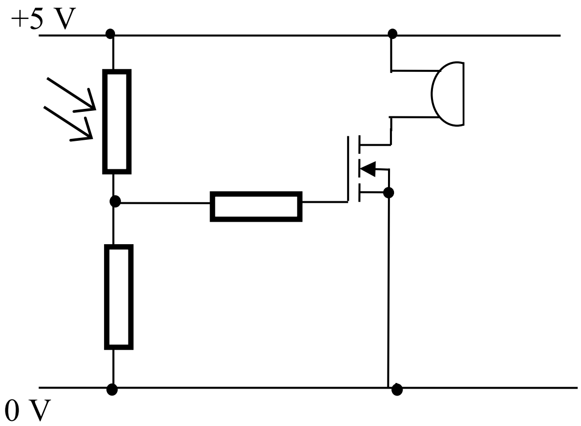
4. Study the four circuits shown below.



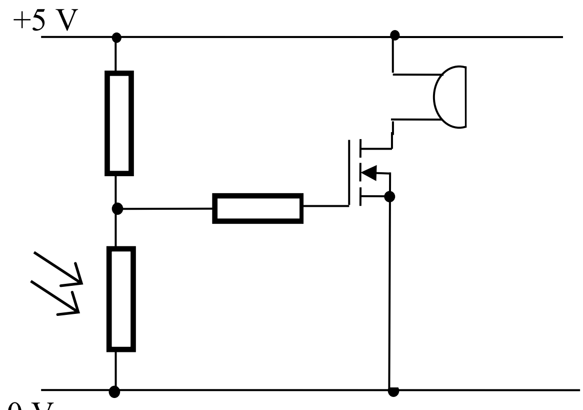
Circuit A



Circuit B



Circuit C



Circuit D

(*a*) Which circuit could be used to remind drivers at night to put on their headlamps? Explain your answer.

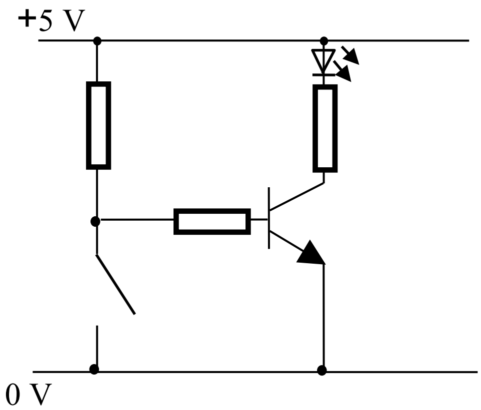
(*b*) Which circuit would be useful as a warning indicator of low temperature in an elderly person's house? Explain your answer.

(*c*) Which circuit could be used to waken campers when daylight arrives? Explain your answer.

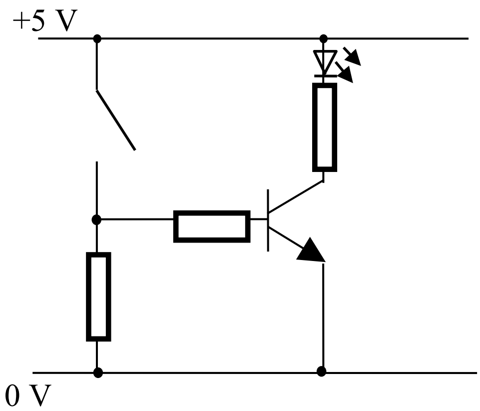
(*d*) Which circuit would be most suitable as a fire alarm?

5. For each of the following circuits state whether the output device is ON or OFF and explain your answer.

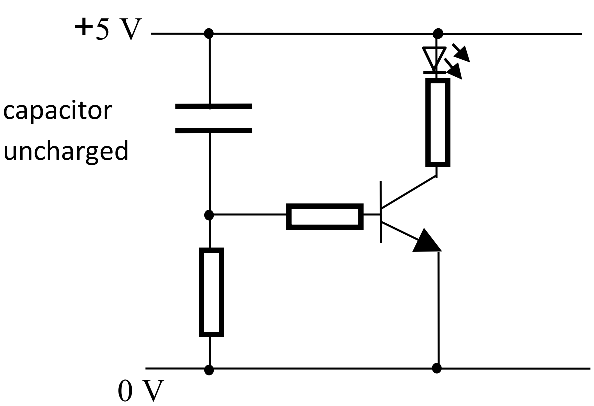
(*a*)



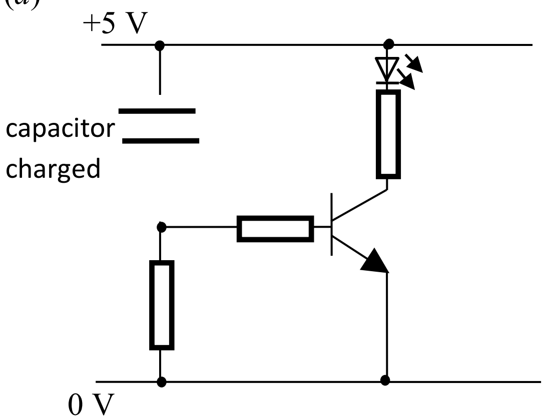
(*b*)



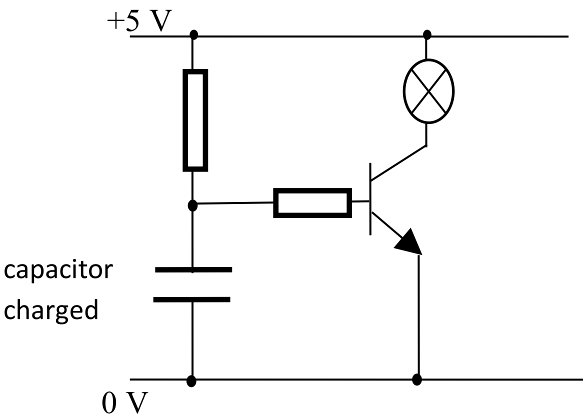
(*c*)



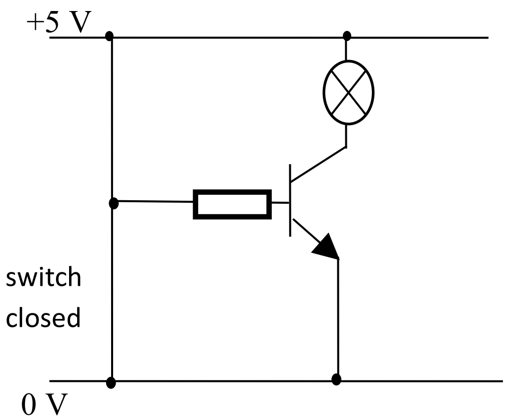
(*d*)



(*e*)



(*f*)



7. Pressure, Force and Area

National 5

In this section you can use the equation:

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

Where P = pressure in pascals (Pa) or newtons per square metre (Nm^{-2})
F = force in newtons (N)
A = area in square metres (m^2)

1. Find the missing values in the following table.

	Pressure (Pa)	*Force* (N)	*Area* (m^2)
(a)		120	1.6
(b)		4000	0.5
(c)	1.1×10^5		2.0
(d)	9000		8.0×10^{-2}
(e)	12 000	7.2×10^5	
(f)	1.4×10^4	4.9×10^4	

2. An elephant can exert a force of 5000 N by pressing his foot on the ground. If the area of his foot is 0.02 m^2, calculate the pressure exerted by his foot.

3. A water tank has a weight of 9 800 N and a base area of 20 m^2. It sits on a floor. Calculate the pressure exerted by the tank on the surface of the floor.

4. A syringe has a piston with a cross-sectional area of 2×10^{-4} m^2. The piston is pushed with a force of 12 N. Calculate the pressure.

5. A drawing pin has a sharp point with an area of 1×10^{-8} m^2. Calculate the pressure exerted by the point when the head is pushed with a force of 8 N.

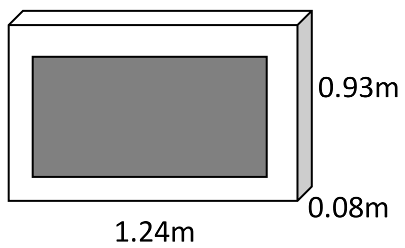
6. Explain why the use of large tyres helps to prevent a tractor from sinking into soft ground.

7. If you want to rescue someone who has fallen through ice on a pond, would it be easier to walk or crawl across the ice towards him? Explain why.

8. A 0.48 kg tin of baked beans is a cylinder with a radius of 3.2×10^{-2} m. It is placed on a kitchen counter.

(a) Calculate the weight of the tin. This is the force it exerts on the counter.
(b) Calculate the area of the tin in contact with the counter.
(c) Calculate the pressure on the counter caused by the tin.

9. A television has a length of 1.24 m, a height of 0.93 m and a depth of 0.08 m.



The mass of the television is 30 kg and it sits on a table.

(a) Calculate the weight of the television. This is the force it exerts on the table.
(b) Calculate the area of the television in contact with the table.
(c) Calculate the pressure on the table caused by the television.

10. A car of mass 1250 kg is driven on to a bridge. The pressure on the surface of the bridge when all four tyres are on the ground is 39.0 kPa.

(a) Calculate the weight of the car.
(b) Calculate the total contact area of the car's tyres on the bridge.
(c) Determine the contact area of one tyre.

11. A 50 kg ballerina can exert a pressure of 2.2×10^6 Pa when she stands on one pointed foot. Determine the area of the point of her ballet shoe. (Remember to calculate the weight of the ballerina first!)

12.

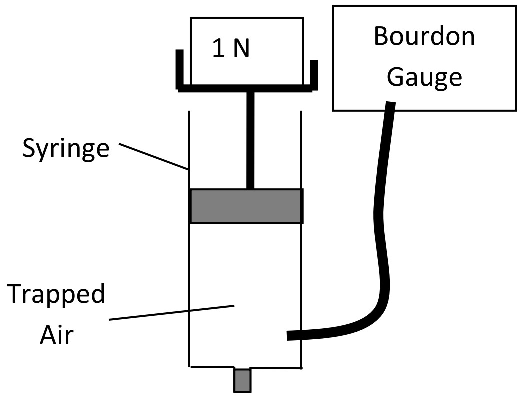
A tank exerts a pressure of only 3.675×10^4 Pa on the ground due to the large surface area of its tracks which is 8 m^2.

(a) Calculate the weight of the tank. This is the force it exerts on the ground.
(b) Calculate the mass of the tank.

13. The surface area of a person's head is approximately 0.5 m^2. Calculate the force exerted by the air on the person's head, given that air pressure is 1 x 10^5 Pa.

14. Measuring the total weight of yourself and your lab stool then measure the contact area of one leg of the stool in "swinging position". Calculate the pressure that is exerted on the floor when you swing on your stool.

15. In an experiment, weights are placed on top of a syringe filled with trapped air. A Bourdon Gauge is used to measure the air pressure inside the syringe. This is then repeated for different weights. The results are shown in the table.



***Force* (N)**	***Total Pressure* (x 10^5 Pa)**	***Pressure due to added weight* (x 10^3 Pa)**
0	1.01	0
1	1.03	2
2	1.05	4
3	1.07	6
4	1.09	8
5	1.11	10

Use this data to construct a line graph of force against pressure due to the added weight, and use the gradient of the straight line to calculate the surface area of the plunger inside the syringe.

8. The Gas Laws

National 5

In this section you can use the gas equations:

$P_1V_1 = P_2V_2$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

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

Together these equations form the General Gas Equation:

$$\frac{PV}{T} = \text{constant} \quad \text{or} \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Where P = pressure in pascals (Pa) or atmospheres (atm)
V = volume in cubic metres (m^3) or litres (l) … or any suitable unit
T = temperature in KELVIN (K)

Kelvin temperatures must be used in these calculations.
REMEMBER:

- **KELVIN is ALWAYS GREATER by 273.**
- **KELVIN temperatures are ALWAYS POSITIVE.**
- **A <u>change in temperature</u> in Kelvin is the same as a <u>change in temperature</u> in degrees Celsius.**

1. Convert the following temperatures from °C to Kelvin.
   (a) 27°C (b) 100°C (c) 0°C (d) -50°C

2. Convert the following temperatures from Kelvin to °C.
   (a) 400K (b) 10K (c) 273K (d) 97K

3. The temperature of water in a beaker rises from 20 °C to 80 °C.
   (a) Calculate this change in temperature in °C.
   (b) Calculate this change in temperature in K.

Pressure & Volume

4. A sealed syringe contains 100 cm^3 of gas. The gas in the syringe has a pressure of 105 kPa. The syringe plunger is pushed in to a new volume of 50 cm^3.
   Calculate the new pressure of the gas.

5. In an experiment the temperature of a fixed mass of gas is kept constant. The volume is altered and various readings of pressure and volume are taken. These are shown below.

Without drawing a graph, but buy using all of the data, what conclusion can you make from these results?

Volume (cm^3)	45	39	37	34	25	22	18
Pressure (kPa)	101	116	122	135	180	210	250

6. A fixed mass of gas is kept at constant temperature but the pressure is increased from 1.01×10^5 Pa to 3.00×10^5 Pa.
The initial volume was 0.2 m^3. Determine the final volume.

7. A weather balloon contains 100 m^3 of helium when atmospheric pressure is 90 kPa. If the atmospheric pressure changes to 100 kPa calculate the new volume of helium at the same temperature.

8. A 5 cm^3 syringe is filled with air and the pressure of the air is found to be 1.01×10^5 Pa. The syringe plunger is then pushed until there is 3 cm^3 of air. Calculate the new air pressure.

9. A scuba diving air tank has a volume of 7.5 litres and is filled with air at a pressure of 1.21×10^7 Pa. Determine the volume this air would occupy at atmospheric pressure (1.01×10^5 Pa).

Pressure & Temperature

10. A glass flask contains a fixed volume of gas. The pressure of the gas is 114 kPa when the temperature is 27°C.
Calculate the new pressure of the gas when the temperature is reduced to 0 °C.
Remember to change your temperatures to Kelvin!

11. The pressure of a fixed mass of gas is 200 kPa at 40 ºC and the volume is 1.5 m^3. The temperature is increased to 100 ºC but the volume remains the same. Calculate the new pressure.

12. The pressure of air in a car tyre is 2.5×10^5 Pa at a temperature of 27 ºC. After a motorway journey the pressure has risen to 3.0×10^5 Pa. Assuming the volume of air in the tyre has not changed, calculate the resulting temperature of air in the tyre.

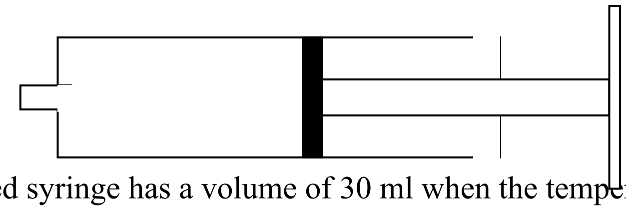
13. At a temperature of 20 °C, the pressure of a fixed mass of gas in a sealed container is found to be 104 kPa. The gas is heated to a uniform temperature of 90 °C using a heat bath. Calculate the pressure of the gas at a temperature of 90 °C.

14. The pressure of the air in a lorry tyre is found to be 2.58×10^5 Pa at the end of a journey. Once the tyre has cooled down, the temperature of the air inside the tyre is found to be 10 °C with the pressure decreasing to 2.41×10^5 Pa.

Calculate the temperature of the air in the tyre at the end of the journey.

Temperature & Volume

15.



A sealed syringe has a volume of 30 ml when the temperature of the gas in the syringe is 15°C.
Calculate the new volume of the gas when the temperature is changed to 30°C.

16. The volume of a fixed mass of gas is 40.0 cm^3 at 20 °C. The temperature of the gas is increased to 40 °C without changing the pressure.
A student makes this statement:

'*As the temperature of the gas has doubled, the volume of the gas will also double. Therefore, the volume of the gas at 40 °C will be 80.0 cm^3.*'

(a) Explain why this statement is incorrect.
(b) Calculate what the volume of the gas would actually be at 40 °C.

17. Air is trapped in a glass capillary tube by a bead of mercury. The volume of air is found to be 0.15 cm^3 at a temperature of 27 °C.
Assuming that the pressure of the air remains constant, what is the volume of the air at a temperature of 87 °C?

Pressure, Temperature & Volume

18. A fixed mass of gas is trapped in a syringe. The gas has a pressure of 1.63×10^5 Pa when it has a volume of 3.0 cm^3 and a temperature of 22 °C.
The gas is then heated until it has a uniform temperature of 57 °C and a volume of 5.0 cm^3.
Calculate the new pressure of the gas.

9. Kinetic Theory of Gases

National 5

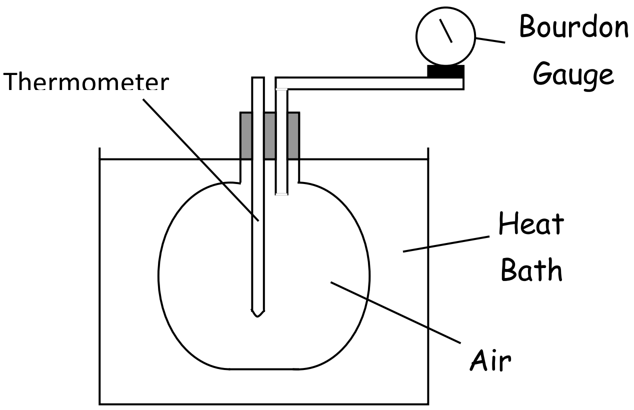
1. Explain what is meant by the following terms, in relation to a gas:

   (a) volume

   (b) temperature

   (c) pressure

2. Air is trapped inside a conical flask, as shown below, and the flask is heated.
   The temperature and the pressure of the trapped air are monitored as the air is heated.
   The results are shown in the table.



***Temperature* (°C)**	***Pressure* (x 10^5 Pa)**
20	1.01
30	1.04
40	1.08
50	1.11
60	1.15
70	1.18

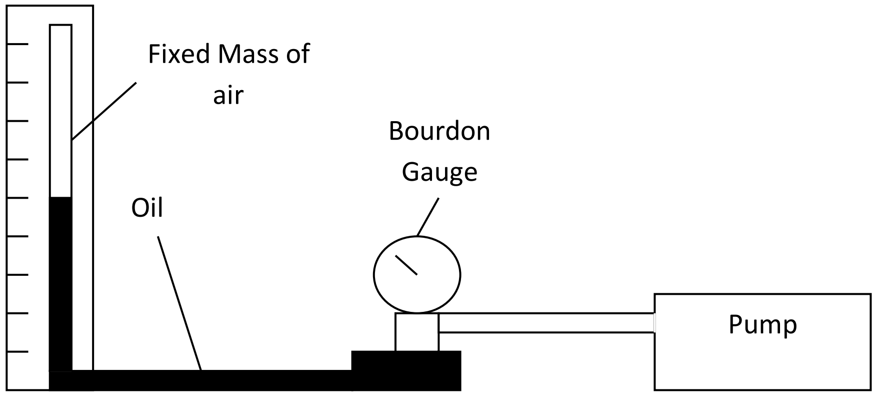
(a) Using the data, draw a line graph of pressure against temperature (in degrees Celsius). Make sure that your temperature axis goes from -300 °C to 70 °C.

(b) On your graph from part (a), continue your straight line back until it crosses through the x-axis. At what temperature would the pressure of the gas reach zero?

(c) Explain why the temperature you determined in part (b) is known as "absolute zero".

(d) Explain, using the kinetic theory of gases, why the air pressure increases as the temperature increases.

3. The following apparatus is designed to investigate how changing the volume of trapped air will affect the pressure of the trapped air.
Air is trapped above a pillar of oil and its volume can be measured using a scale on the pillar. The pressure of the air can be measured with the Bourdon Gauge.



The pump is used to raise the level of oil and reduce the volume of air.

It is observed that, as the volume of trapped air decreases, the pressure increases.

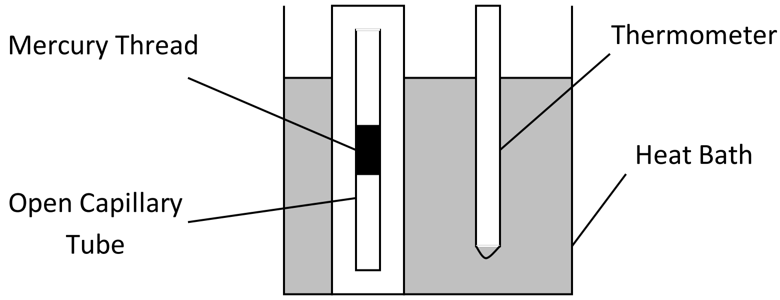
In fact, it is found that, provided the temperature remains constant, the presure is inversely proportional to the volume.

$$P \propto 1/V$$

Use the kinetic theory of gases to explain this result.

4. Explain, using the appropriate gas law, why a balloon will burst if you squeeze it.

5. In an experiment, an open capillary tube with a mercury thread is placed in to a heat bath.
As the temperature of the gas increases, the mercury thread moves up the capillary tube.
The pressure of the gas remains constant because the capillary tube is open.
The temperature of the gas is measured with a thermometer and the volume of the gas is measured using a scale next to the open capillary tube. The results of the experiment are shown.



Temperature (°C)	***Temperature (K)***	***Volume* (cm³)**
20		1.50
25		1.88
30		2.25
35		2.63
40		3.00
45		3.38

(a) Copy the table and complete it to show the temperatures in Kelvin.

(b) Draw a line graph of volume against temperature (in Kelvin).

(c) What conclusion can you make from this graph?

(d) Explain this result in terms of the kinetic theory of gases.

10. Applications of The Kinetic Model of a Gas

National 4

1. Explain why the pressure in car tyres increases as more air is pumped in.

2. Explain why car tyres are marked with a maximum pressure limit.

3. The air pressure decreases, the higher we go from the surface of Earth.

   (a) Explain why aircraft cabins must contain pressurised air.

   (b) Predict and explain what might happen if an explosion happened on an aeroplane at 40 000 feet, blowing open a door.

4. The summit of Mount Everest is at 8848 m. At this height the air pressure is approximately one third of the air pressure at sea level. In addition, the temperature at the summit of Everest averages around – 19^{o}C in summer, dropping to -36^{o}C in winter.

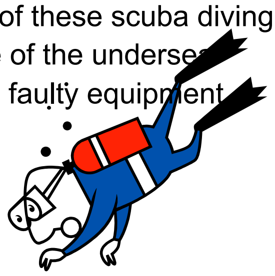
   (a) Use your knowledge of temperature and pressure to explain why you think it is very difficult to survive for very long at this altitude.

   (b) Research what the main health risks are for high altitude climbers, due to the drop in air pressure.

5. Read the information below and overleaf and use it to answer the questions that follow:

The Dangers of Scuba Diving

As scuba diving is a popular recreational sport, beautiful coral reefs and eerie shipwrecks around the world have become major tourist draws in their own right. However, it should not be forgotten that scuba diving is an extreme sport with its own peculiar injuries and potentially life-threatening hazards. Most of these scuba diving dangers stem from the effects of the increased water pressure of the undersea environment, but there are also dangers posed by sea life and faulty equipment.



Barotrauma

Barotrauma is caused by the damage done by increased underwater pressure on the air pocket in the middle ear. Divers usually "equalize" during a dive by pinching their nose shut and blowing, by chewing or by swallowing to push more air into the middle air. However, a descent that is too fast can result in severe pain and even injury to the middle ear.

Decompression Sickness

Often called "the bends," decompression sickness is caused by increased underwater pressure causing the body's tissues to absorb more nitrogen. If that pressure is suddenly reduced, this extra nitrogen forms potentially harmful bubbles. Deep divers return to the surface in carefully monitored stages so as to control the rate at which this absorbed nitrogen is released. A case of the bends can range from aching joints or a skin rash to paralysis and death.

Nitrogen Narcosis

Another nitrogen-related danger is the narcotic effect of all that extra nitrogen in the body. Nitrogen narcosis is a danger because it impairs judgement and sensory perception. As with the bends, the degree of nitrogen narcosis is related to how deep a diver goes and how much nitrogen they absorb.

Oxygen Toxicity

Oxygen toxicity is usually a problem only encountered by deep divers who go below 135 feet. The body absorbs extra oxygen under increased underwater pressure. For most divers this is not a problem, but at extreme depths so much extra oxygen is absorbed that this life-giving gas becomes a poison. The effects range from tunnel vision and/or nausea to twitching to loss of consciousness and/or seizures.

Pulmonary Embolism

Another risk facing a diver who rapidly ascends to the surface is pulmonary embolism. The increased pressure of the undersea environment results in extra gas being crammed into the same lung space. A rapid rise to the surface can cause the lungs to swell and even pop like a balloon because the water pressure decreases. Scuba divers guard against pulmonary embolism by making slow, controlled ascents to the surface and by never holding their breath.

Sea Life

Divers should never forget that each dive is the equivalent of entering an untamed wilderness. While most sea creatures are not aggressive towards divers and attacks are extremely rare, incidents do happen and a diver cannot afford to forget that she is surrounded by wild animals. The famed TV wildlife host "Crocodile Hunter" Steve Irwin was killed in 2006 when he was stung through the chest by a stingray, a frequently encountered and usually harmless sea creature. Divers should always treat sea life with great care and respect.

Defective Equipment

Many casual scuba divers do not own their own equipment, and are therefore reliant on renting equipment from the scuba diving operator who is conducting their dive trip. A broken depth gauge could lead to a mild case of decompression sickness, while a bad regulator might result in drowning. A diver should always thoroughly check rented scuba diving equipment, and never be shy about asking for a new piece of gear if they suspect something is wrong with what they have.

Questions

1. Which part of the body can be damaged by "barotrauma"?

2. How can a diver prevent or reduce the effect of barotrauma?

3. What is the scientific term for "The Bends"?

4. "The Bends" is caused by the body absorbing which gas?

5. What other condition can be caused by the body absorbing too much of the gas in Q. 4?

6. In high pressure environments, like deep sea, the body can absorb too much oxygen. What are the effects of this?

7. If a diver gets into difficulty underwater, should the diver swim to the surface as quickly as possible? Explain your answer.

8. Apart from the dangers due to the change in water pressure, name two other hazards that might face a diver.

11. Specific Heat Capacity

National 5

In this section you can use the equation:

heat energy = specific heat capacity x mass x temperature change

also written as

$$E_h = c\, m\, \Delta T$$

Where **E_h** = heat energy in joules (J)
c = specific heat capacity in joules per kilogram per degree Celsius ($Jkg^{-1}\ {}^oC^{-1}$)
m = mass in kilograms (kg)
ΔT = change in temperature (°C).

Helpful Hint
You will need to look up values for the specific heat capacity of different materials These values can be found on the data sheet on page 1.

1. Find the missing values in the following table.

	***Heat energy* (J)**	***Specific heat capacity* ($Jkg^{-1}\ {}^oC^{-1}$)**	***Mass* (kg)**	***Temperature change* (°C)**
(a)		4 200	2	65
(b)		902	5·5	15
(c)	$2·4 \times 10^3$	386	1·6	
(d)	4 250		17	0·5
(e)	$1·6 \times 10^3$		1·5	2
(f)		128	50×10^{-3}	30

2. How much heat energy is required to raise the temperature of 3 kg of aluminium by 10°C?

3. 3 kJ of heat is supplied to a 4 kg block of lead. What would be the rise in temperature of the block?

4. In an experiment on specific heat capacity an electric heater supplied 14 475 J of heat energy to a block of copper and raised its temperature by 15°C . What mass of copper was used in the experiment?

5. 6900 J of heat is supplied to 0.5 kg of methylated spirit in a plastic beaker and raises its temperature by 1.5°C. What is the specific heat capacity of methylated spirit?

6. How much heat energy would be required to raise the temperature of 2 kg of alcohol from 20°C to 65°C?

7. A 0.25 kg block of copper is allowed to cool down from 80°C to 42°C. How much heat energy will it give out?

8. 254 400 J of energy are required to heat 2 kg of glycerol from 12 °C to 65 °C. What is the specific heat capacity of glycerol?

9. Which of the following would give out more heat energy:

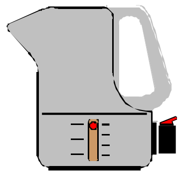
   A - a 2 kg block of aluminium as it cools from 54 °C to 20°C
   or
   B - a 4 kg block of copper as it cools from 83°C to 40°C?

10. 2500 J of heat is supplied to a quantity of alcohol and raises its temperature from 22°C to 45°C. What mass of alcohol was being heated?

11. Each concrete block in a storage heater has a mass of 1·4 kg. The blocks are heated to 85°C at night when the electricity is cheaper and cool down during the day to 20°C. If each block releases 77 000 J of energy during the day calculate the specific heat capacity of the concrete.

12. An immersion heater is used to heat 30 kg of water at 12°C. The immersion heater supplies 8 600 000 J of heat. Ignoring heat losses to the surroundings calculate the final temperature of the water.

13. A kettle supplies 262 **kJ** of energy to 800 **g** of water in order to heat it to 90 °C. What was the temperature of the water before the kettle was switched on?



14. 

A cup containing 140 **g** of water is heated in a microwave oven. The microwave supplies $4{\cdot}9 \times 10^4$ J of heat to the water which was originally at 10°C.
What is the final temperature of the water?

15. A 400 **g** block of lead is heated to 45°C by an electric heater which supplies 1·2 **kJ** of heat. What was the initial temperature of the lead block?

12. Specific Latent Heat

National 5

In this section you can use the equation:

heat energy = mass x specific latent heat

also written as

$$E_h = m\,L$$

where E_h = heat energy in joules (J)
m = mass in kilograms (kg)
L = specific latent heat in joules per kilogram ($J\ kg^{-1}$).

Helpful Hint

Value for 'L' described above can be found in the data sheet on page 1.

When you are solving a problem using this formula it is important to use the **correct value of 'L'** from the data sheet.

To do this:

Read the question carefully.

If the question is about the change of state: **liquid to gas** or **gas to liquid** then

'L' = latent heat of vaporisation

If the question is about the change of state : **liquid to solid** or **solid to liquid** then

'L' = latent heat of fusion.

1. Find the missing values in the following table.

	Energy (J)	*Mass* (kg)	*Specific latent heat* ($J\ kg^{-1}$)
(a)		2·0	$0{\cdot}99 \times 10^5$
(b)		35·5	$8{\cdot}3 \times 10^5$
(c)	$1{\cdot}08 \times 10^6$	6·0	
(d)	$4{\cdot}032 \times 10^5$		$11{\cdot}2 \times 10^5$
(e)	$22{\cdot}6 \times 10^5$		$22{\cdot}6 \times 10^5$
(f)	$1{\cdot}837 \times 10^8$	550	

2. Calculate the heat energy released when 2 kg of ice melts into 2 kg of water without a change in temperature.

3. How much heat energy is released when 56 kg liquid carbon dioxide changes into solid form without a change in temperature?

4. What mass of steam is produced when 7 232 000 J is supplied to water at 100°C?

5. What mass of turpentine condenses when 168 200 J of heat energy is removed from a supply of gaseous turpentine at its boiling point?

6. Calculate the specific latent heat of fusion of aluminium given that 10·27 **MJ** is required to change 26 kg of it from molten form into solid form.

7. How much heat energy is required to change 40 kg of solid carbon dioxide into liquid form with no change in temperature?

8. How much heat energy is required to evaporate 0.6 kg of water at 100 °C ?

9. The melting point of a certain chemical substance is 137°C. How much heat is required to melt 0·7 kg of this substance if it is known to have a specific latent heat of fusion of 1 300 J kg^{-1}?

10. How much water would evaporate at 100 °C if you supplied it with 28 500 J of heat energy?

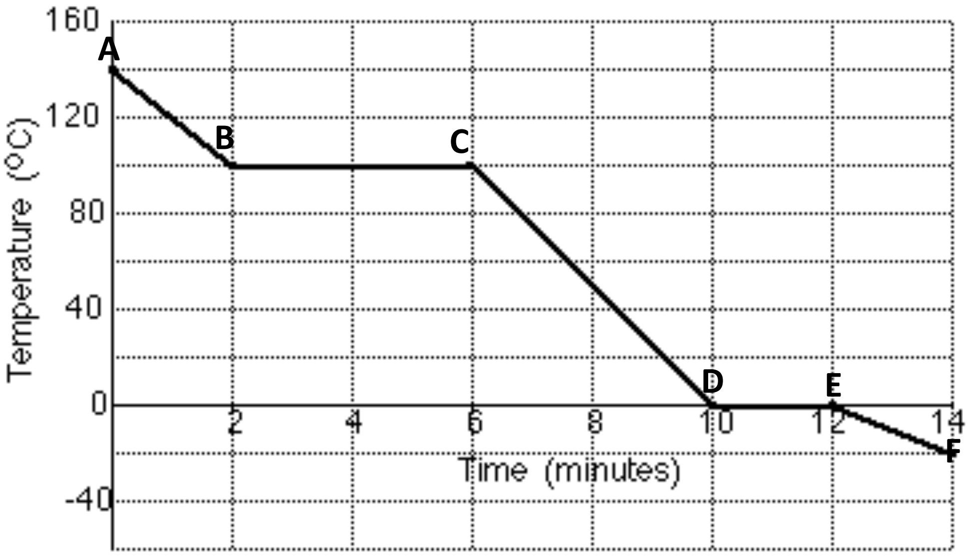
11. Liquid alcohol vaporises when used to make flambees. Calculate the heat energy required to change 0·5 kg of liquid alcohol into its gaseous form without a change in temperature.

12. Calculate the specific latent heat of fusion of lead if it takes 500 000 J of heat to convert 20 kg of solid lead into molten form at its melting point.

13. What mass of liquid glycerol is converted to vapour when 8 300 000 J of heat energy is supplied to it at its boiling point?

14. A steam wallpaper stripper can be used to help with the tedious task of preparing walls before decorating. The stripper contains 15 kg of water which turns to steam when boiled. Assuming the stripper is 100 % efficient, how much boiling water is converted to steam, if 100 x 10^{5} J of energy is supplied to it?

15. During an experiment 0·02 kg of steam was converted to ice. The temperature was recorded at various times throughout the experiment and plotted on a graph. The graph of results is shown below.



(a) Between which 2 letters on the graph is the steam changing to water?

(b) How much heat energy does the steam lose at 100 °C to become water at 100 °C?

(c) How much heat energy does the water lose at 100 °C to become water at 0 °C?

(d) How much heat energy does the water at 0 °C lose to become ice?

13. Re-Entry

National 5

In this section you can use the following equations:

$$E_k = \frac{1}{2} m v^2$$

$$E_h = c\, m\, \Delta T$$

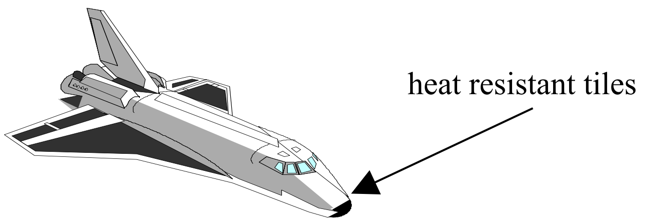
$$E_h = m L$$

$$E_w = F\, d$$

Where
- **E_k** = kinetic energy (J)
- **E_h** = heat energy (J)
- **E_w** = work done (J)
- **m** = mass (kg)
- **v** = velocity (ms^{-1})
- **c** = specific heat capacity ($J\ kg^{-1}\ {}^oC^{-1}$)
- **L** = specific latent heat ($J\ kg^{-1}$)
- **ΔT** = change in temperature (^oC)
- **F** = force (N)
- **d** = distance (m).

Helpful Hint

Energy cannot be created or destroyed. It can be changed from one form into another. When an object re-enters the Earth's atmosphere it heats up. **Some or all of its kinetic energy changes to heat energy as work is done against friction**. The shuttle has heat resistant tiles covering its body to stop it burning up as it re-enters the atmosphere.



In order to stop the shuttle when it touches down, work must be done by frictional forces. This changes its kinetic energy into heat energy.

1. A small piece of metal of mass 2 kg falls from a satellite and re-enters the Earth's atmosphere at a velocity of 4 000 ms^{-1}. If all its kinetic energy changes to heat calculate how much heat is produced.

2. How much work must be done by the brakes on a shuttle of mass 2×10^6 kg to bring it to rest if it lands with a touch down velocity of 90 ms^{-1}?

3. The space shuttle Columbia re-entered the Earth's atmosphere at a speed of 8 000 ms^{-1} and slowed down to a speed of 200 ms^{-1}. The shuttle's mass was 2 $x10^6$ kg.

(a) How much kinetic energy did the shuttle lose?
(b) How much heat energy was produced during this process?

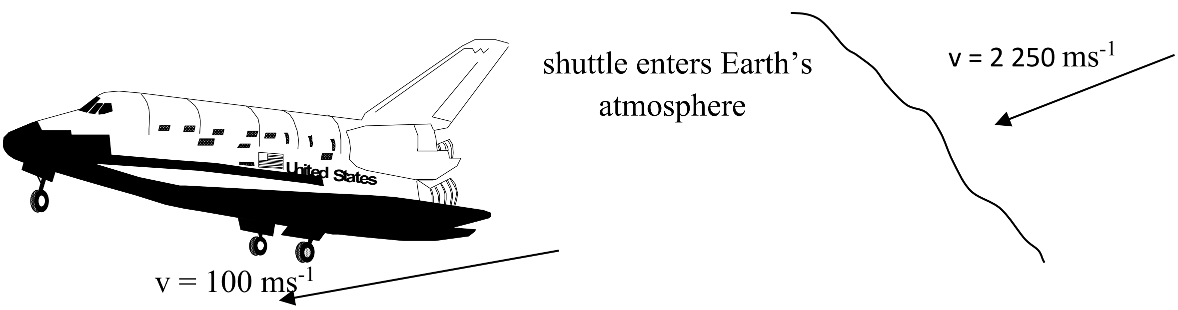
4. A ' shooting star' is a meteoroid that enters the Earth's atmosphere and is heated by the force of friction which causes it to glow. A certain meteoroid has a mass of 30 kg and enters the atmosphere at a velocity of 4 000 ms^{-1}.

Calculate the heat energy produced if all of the meteoroid's kinetic energy is converted to heat.

5. A small spy satellite of mass 70 kg is constructed from a metal alloy. The satellite has a short lifetime of two weeks before it re-enters the Earth's atmosphere at a speed of 5 000 ms^{-1}.

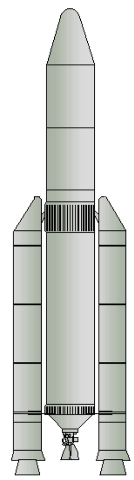
Calculate how much heat energy is produced when all of the satellite's kinetic energy changes to heat energy.

6. The nose section of a shuttle is covered with 250 kg of heat resistant tiles which experience a rise in temperature of 1 400 ^{o}C during the shuttle's journey back through the Earth's atmosphere.
The shuttle is slowed from 2 250 ms^{-1} to 100 ms^{-1} during this part of the journey.



(a) How much kinetic energy do the tiles on the nose of the shuttle lose?
(b) How much heat energy is produced at the nose during re-entry?
(c) Calculate the specific heat capacity of the material used to make the nose tiles.

7. A multistage rocket jettisons its third stage fuel tank when it is empty. The fuel tank is made of aluminium and has a mass of 4 000 kg.
(specific heat capacity of aluminium is 900 J kg^{-1} $^{o}C^{-1}$)



(a) Calculate the kinetic energy lost by the fuel tank as it slows down from 5 000 ms^{-1} to 1 000 ms^{-1} during its journey through the Earth's atmosphere.

(b) How much heat energy is produced?

8. In 1969 Apollo 11 returned to Earth with a velocity of 11 200 ms^{-1} on entering the Earth's atmosphere. It had a mass of 5 500 kg and slowed down over a distance of 10 000 000 m in the atmosphere, before splashing into the ocean .

(a) Calculate the kinetic energy of Apollo 11 as it entered the Earth's atmosphere.
(b) How much work was done by the frictional forces which brought it to rest?
(c) Calculate the average force it experienced as it slowed down over 10 000 000 m in the atmosphere.

9. Re-entry for a certain shuttle begins 75 miles above the Earth's surface at a speed of 10 **km s^{-1}**. It is slowed to a speed of 100 ms^{-1} by frictional forces during which time it has covered a distance of 4 x10^{7} m. The mass of the shuttle and its payload is 2·4 x 10^{6} kg.

(a) Calculate the loss in kinetic energy of the shuttle.
(b) How much work is done by friction?
(c) Calculate the average size of the frictional forces exerted by the atmosphere on the shuttle as it slows down.

10. At touch down a shuttle is travelling at 90 ms^{-1}. The brakes apply an average force of 4 x 10^{6} N in total to bring the shuttle to a stand still. The mass of the shuttle is 2 x 10^{6}kg .

(a) How much kinetic energy does the shuttle have at touch down?
(b) How much work must be done by the brakes to stop the shuttle?
(c) Calculate the length of runway required to stop the shuttle.