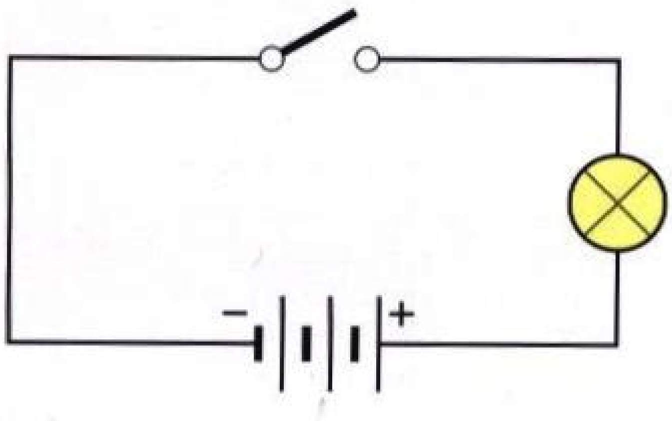
3 ELECTRIC CIRCUITS

Videos & questions on the CD ROM

Circuit diagrams

When people started using electricity, they quickly found that it was not convenient to draw accurate pictures of the circuits that they made. It was much easier to understand how the circuit worked, and to correct faults, if they used standard symbols for the parts. It was also much easier if the wires were drawn in straight lines, rather than trying to copy the exact route taken.

Study the circuits used in this chapter and learn the symbols and what they represent.



THE FLASHLIGHT

This simple circuit shows how a flashlight is powered by a **battery** consisting of three 1.5 V **cells**, giving a total e.m.f. of 4.5 V. In the case of a flashlight, the cells are put in separately, but in the case of a 9 V battery, for example, the six cells are pre-assembled by the manufacturer. The word 'battery' means an assembly of several cells, but people often use the word to refer to a single cell.

The '+' terminal of the cell is indicated by the long thin line, and the '-' terminal by the short thick line. It may help you to remember this if you imagine yourself cutting the long thin line into two shorter pieces and turning them into a + sign.

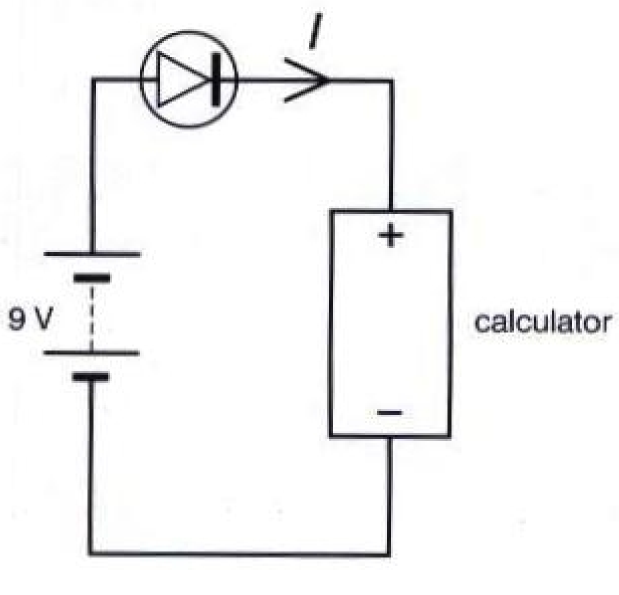
The other symbols in the circuit are the **normally open switch**, and the **lamp**.

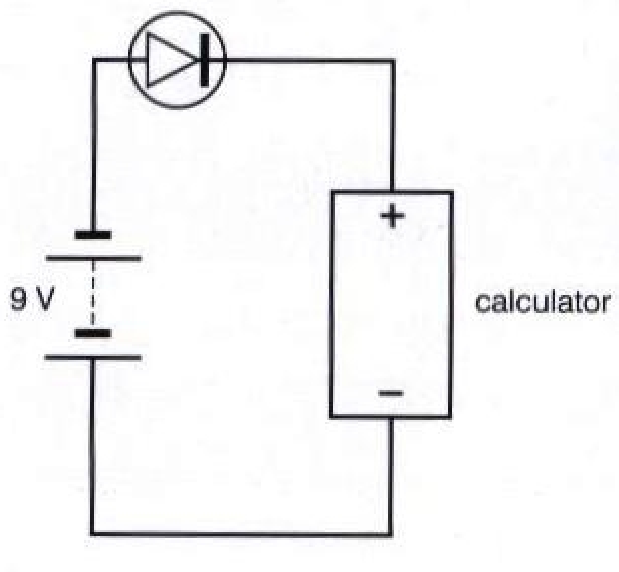
THE DIODE

It does not matter which way the charge flows through a lamp, but a pocket calculator, say, could be destroyed if the battery is not inserted correctly. One way to prevent this is to add a diode to the circuit.

In this circuit the calculator is represented as a resistor. A calculator is far more complicated than that, but it does behave to the battery *as if* it were a resistor, drawing a small current *I* out of the battery.

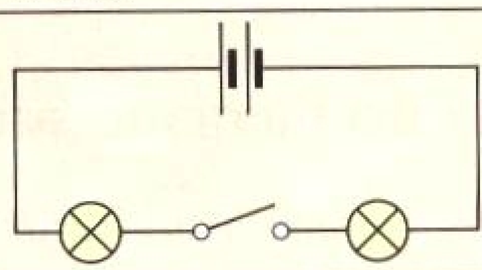
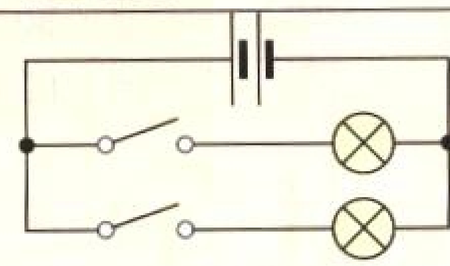
As you can see, the arrow on the diode shows the way that conventional current flows. When the battery is inserted the wrong way round, no charge can flow.





Series and parallel circuits

There are two different ways of connecting two lamps to the same battery. Two very different kinds of circuit can be made. These circuits are called **series** and **parallel** circuits.

	Series	**Parallel**
Circuit diagram		
Appearance of lamps	The brightness or dimness of the lamp depends on the voltage rating and the e.m.f. of the battery. Both lamps appear to have the same brightness, both lamps are dim.	The brightness or dimness of the lamp depends on the voltage rating and the e.m.f. of the battery. Both lamps appear to have the same brightness, both lamps are bright.
Battery	The battery is having a hard time pushing the same charge first through one bulb, then another. This means less charge flows each second, so there is a low current and energy is slowly transferred from the battery.	The battery pushes the charge along two alternative paths. This means more charge can flow around the circuit each second, so energy is quickly transferred from the battery.
Switches	The lamps cannot be switched on and off independently.	The lamps can be switched on and off independently by putting switches in the parallel branches.
Advantages/ disadvantages	A very simple circuit to make. The battery will last longer. If one lamp 'blows' then the circuit is broken so the other one goes out too.	The battery will not last as long. If one lamp 'blows' the other one will keep working.
Examples	Christmas tree lights are often connected in series.	Electric lights in the home are connected in parallel.

COMBINING RESISTORS

Two resistors can be replaced by a single resistor that has the same effect in the circuit. Calculating the value of the resistor needed depends on whether the original resistors are connected in series or parallel.

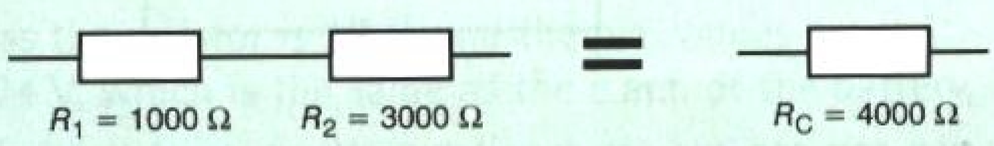
If the resistors R_1 and R_2 are in ...	**Then the combined resistance, R_C, is ...**
series	$R_C = R_1 + R_2$
parallel	$R_C = \dfrac{R_1 \times R_2}{R_1 + R_2}$

WORKED EXAMPLES

1 If the two resistors are 1000 ohms and 3000 ohms and they are in series, then

R_C = (1000 + 3000) ohms

= 4000 ohms



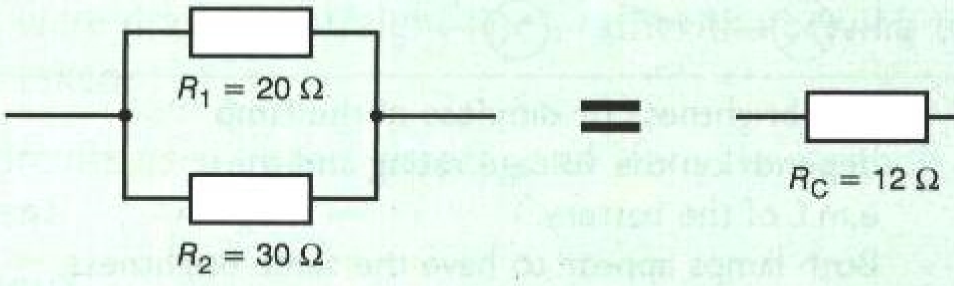
Note that the combined resistance is greater than the value of either of the two resistors.

2 If the two resistors are 20 ohms and 30 ohms, and they are in parallel then

$$R_C = \frac{20 \times 30}{(20 + 30)} \text{ ohms}$$

$$= \frac{600}{50} \text{ ohms}$$

$$= 12 \text{ ohms}$$



Note that the combined resistance is less than the value of either of the two resistors.

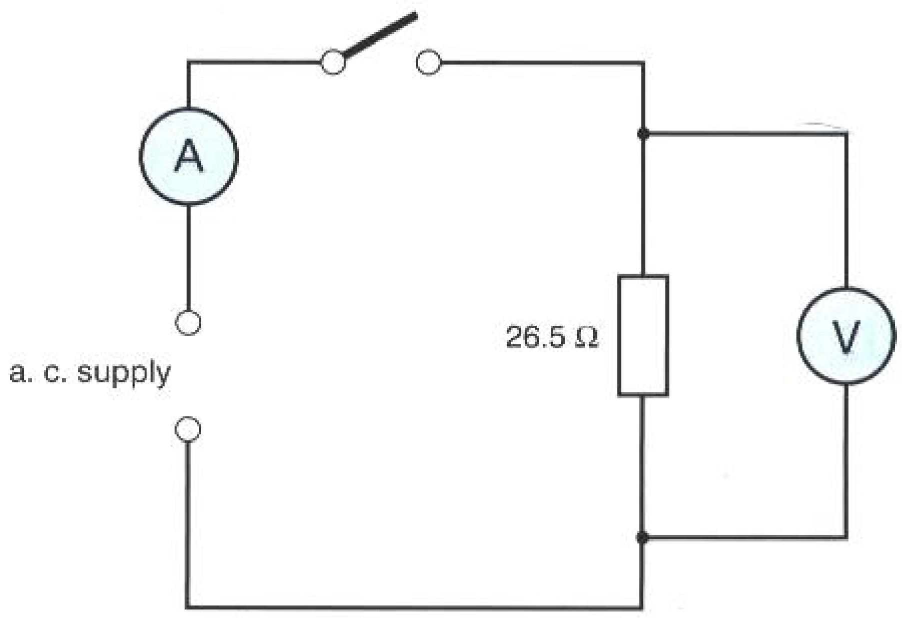
DIRECT AND ALTERNATING CURRENTS

A battery produces a steady current. The electrons are constantly flowing from the negative terminal of the battery round the circuit and back to the positive terminal. This produces a **direct current** (d.c.).

The mains electricity used in the home is quite different. The electrons in the circuit move backwards and forwards. This kind of current is called **alternating current** (a.c.). In some countries mains electricity moves forwards and backwards 50 times each second, that is, with a frequency of 50 hertz (Hz). The frequency chosen varies from country to country.

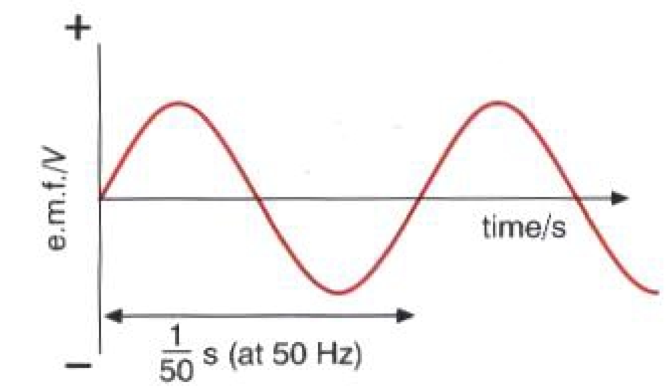
The advantage of using an a.c. source of electricity rather than a d.c. source is that it can be transmitted from power stations to the home at very high voltages, which reduces the amount of energy that is lost in the overhead cables.

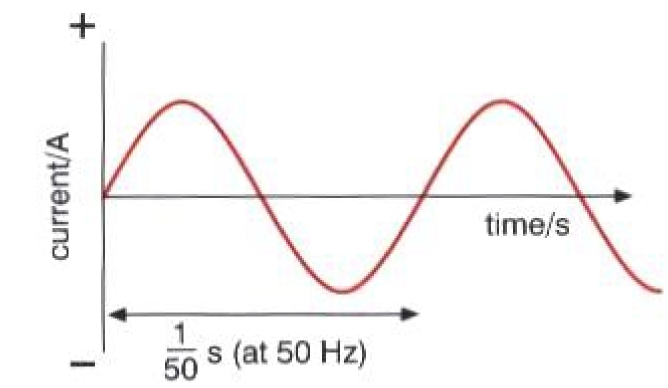
Here is a circuit where the current in and the p.d. across an electric kettle are being monitored.



As you can see, we are monitoring the current through the 26.5 ohm heater in the kettle, and the potential difference across it. In this circuit, the p.d. across the heater will have the same value as the e.m.f. of the a.c. supply that it is connected to.

When the normally open switch is closed, the p.d. and the current will have the waveforms shown right. They will both alternate positive and negative at the same time.



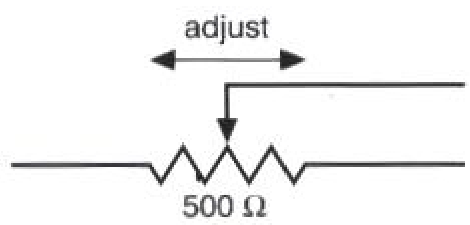


To drive the current back and forth, the e.m.f. has to repeatedly change direction. It is almost as if the circuit is being driven by a battery, but the wires to the two terminals on the battery are swapped over a hundred times per second.

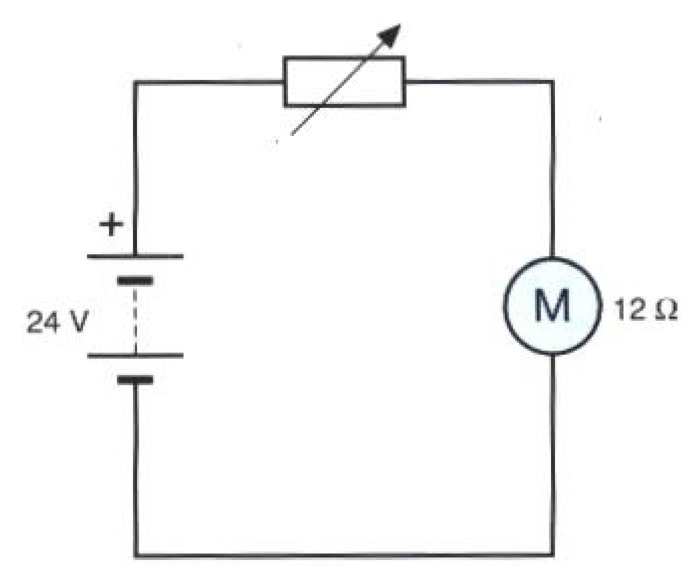
Action and use of circuit components

THE VARIABLE RESISTOR

A variable resistor contains a length of resistance wire and an adjustable sliding contact. One end of the wire and the contact are connected into the circuit. As the contact can be moved from one end of the wire to the other, the resistance of the variable resistor can be set to any value from approximately zero to the whole resistance of the resistance wire inside the device. In the case of the variable resistor here, the value can be set to any value between 0 ohms and 500 ohms.



In this circuit, we are using a variable resistor to control the speed of an electric motor. If it is a 24 V electric motor, and a battery with e.m.f. of 24 V, then with the variable resistor set to 0 ohms, the p.d. across the motor will be 24 V, and the motor will run at full speed. The p.d. across the variable resistor will be 0 V. The resistance of the whole circuit is 12 ohms and so the current through the motor will be 2.0 A.



If the variable resistor is set to 12 ohms, then the total resistance in the circuit is now 24 ohms, and the total current can be calculated:

$$I = \frac{V}{R}$$
$$= \frac{24}{24}$$
$$= 1.0\ \text{A}$$

The current through the motor will have halved, and the motor will run slower. Note that we can now work out the p.d. across the motor.

current through the motor = 1.0 A

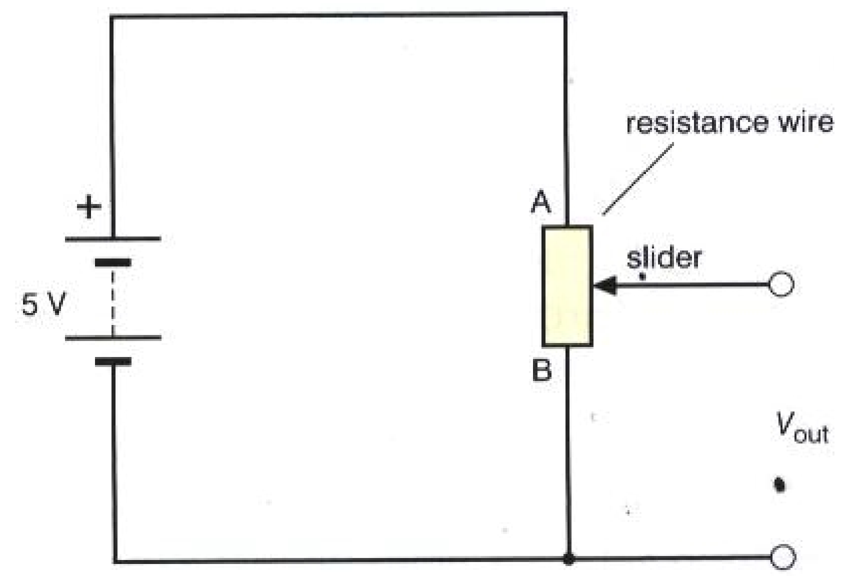
its resistance = 12 ohms

$$\text{p.d.} = I \times R$$
$$= 1.0 \times 12$$
$$= 12\ \text{V}$$

Likewise, the p.d. across the resistor is 12 V, and the p.d. values around the circuit add up to 24 V, which is the same as the e.m.f. of the battery, as always.

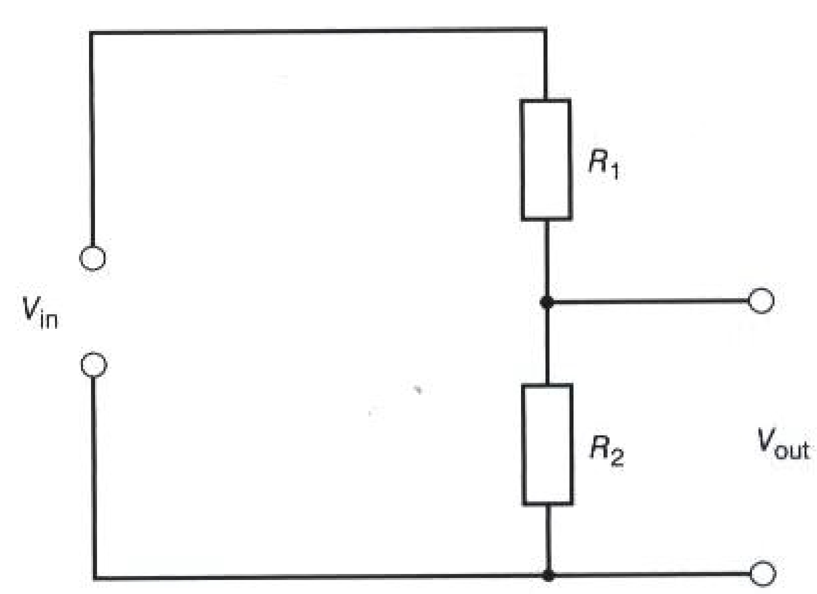
THE POTENTIOMETER AND THE POTENTIAL DIVIDER

The potentiometer is very similar in its design to a variable resistor, and in fact the same component can usually be used as either device. In the potentiometer, both ends of the resistance wire and the adjustable contact, all three points, are connected into the circuit. The two ends of the resistance wire are connected to both ends of the battery or power supply. So if the battery is 5 V, then the p.d. across the potentiometer is 5 V. If the slider is set to the top, then the p.d. V_{out} across the two output wires will again be 5 V. But if the slider is set to minimum, the two output wires are connected to the same point and the p.d. will be 0 V. This is a major difference between a potentiometer and a variable resistor: the output of the potentiometer can be set to zero. This is one reason why the volume control on most audio equipment is a potentiometer, as it gives full control over the output volume.



The potentiometer acts as a potential divider: it divides up the p.d. supplied by the power source.

It is also possible to make a potential divider using two resistors as shown in this circuit.



If $R_1 = R_2$, then the output p.d. V_{out} will be just half the input p.d. V_{in}. Note that it does not really matter what value R_1 and R_2 have; it is more important to note their *relative* values. So if R_1 is very small compared with R_2, then the output will be high, it will be approaching the value of V_{in}. If R_2 is very small compared with R_1, then the output will be close to zero, because the two output wires will almost be joined together.

THE THERMISTOR AND THE LDR

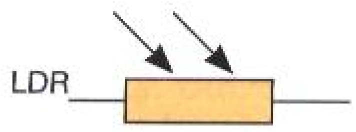
In some substances, increasing the temperature actually **lowers** the resistance. This is the case with **semiconductors** such as silicon. Silicon has few free electrons and so behaves more like an insulator than a conductor. But if silicon is heated, more electrons are removed from the outer electron shells of the atoms producing an increased electron cloud. The released electrons can move throughout the structure, creating an electric current. This effect is large enough to outweigh the increase in resistance that might be expected from the increased movement of the silicon ions in the structure as the temperature increases.

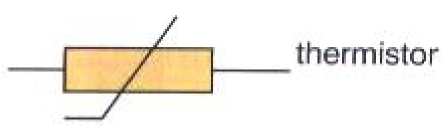
Semiconductors are used to make **thermistors**, which are used as temperature sensors, and **light-dependent resistors** (LDRs), which are used as light sensors.

In LDRs it is light energy that removes electrons from the semiconductor atoms, increasing the electron cloud.

A* EXTRA

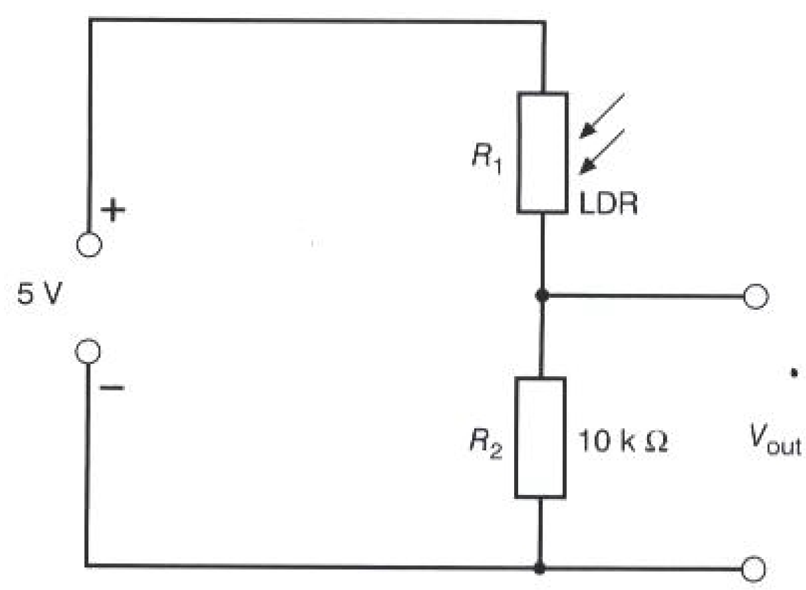
- In a thermistor, increasing temperature actually reduces the resistance. This is the opposite effect to that in a normal resistor.
- In a light-dependent resistor (LDR) an increase in brightness reduces the resistance.





INPUT TRANSDUCERS

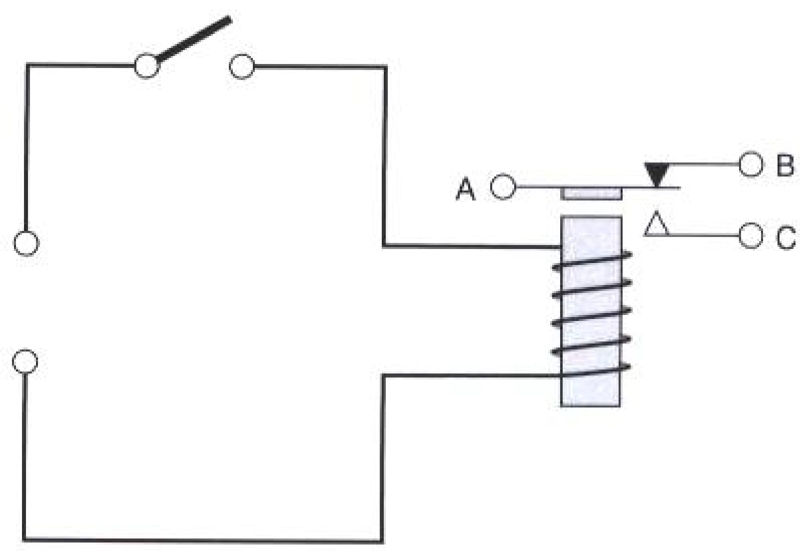
A transducer is a device that transfers energy from one form to another. An input transducer may be needed to transfer, for example, heat or light energy to electrical energy. Many machines have to take action if exposed to light or heat or some other input. The controls of a boiler will light the flame if the water is too cold; the computer controlling the house will close the curtains when it gets dark. The LDR and the thermistor are suitable electrical transducers for giving an electrical signal for this purpose. They are best used as part of a potentiometer.



In this circuit (right), the LDR has a resistance of about 200 kΩ in the dark. This means that R_2 is much smaller than R_1, and the output will be small, (about 0.2 V). When the LDR is in the light, its resistance drops to about 3 kΩ, and so the output voltage rises to something near to the input voltage (about 3.8 V).

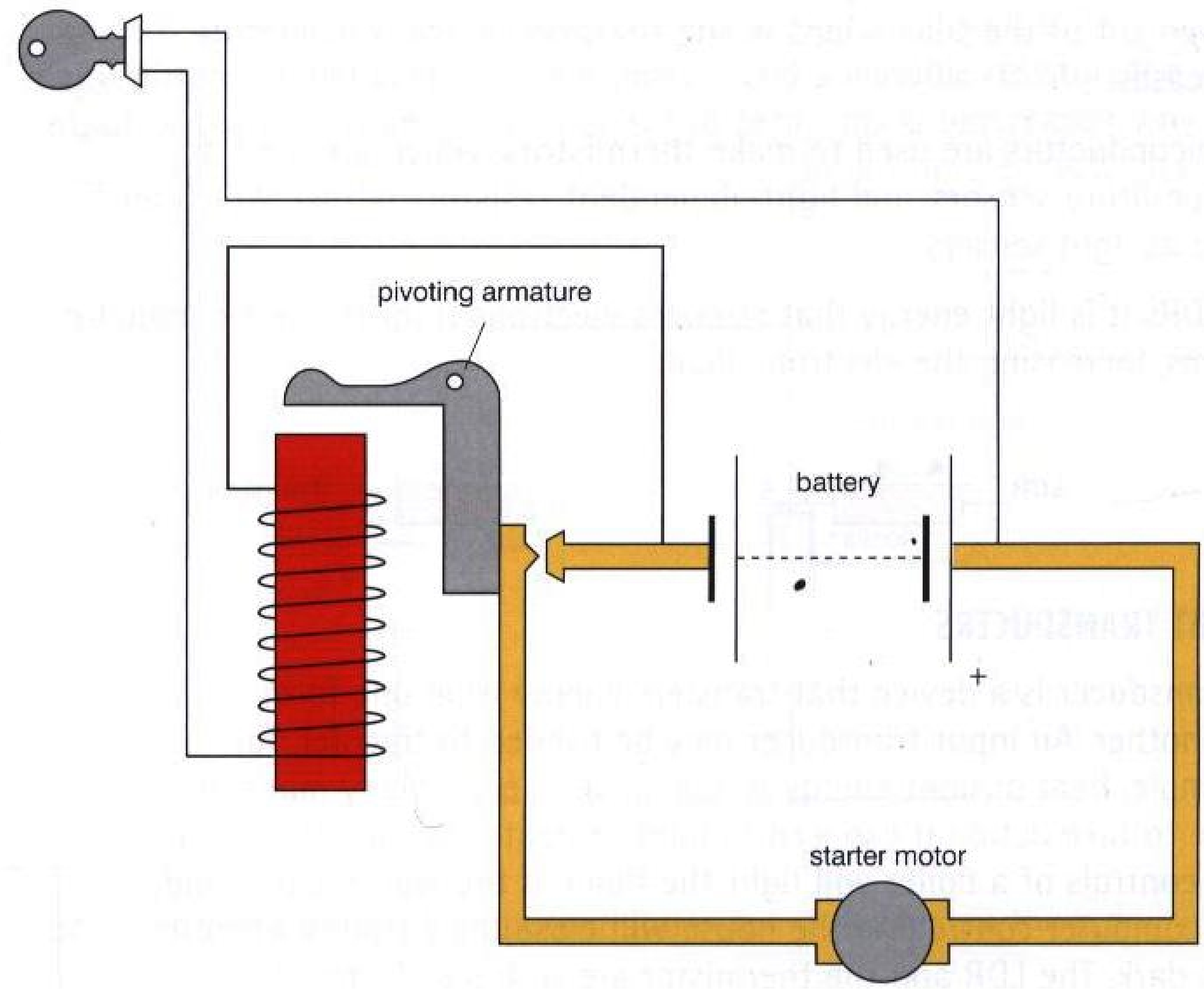
So with this circuit, light is detected by the output going from **low** to **high**. If the LDR had been put in the lower position, with a resistor above, then light would be detected by the output going from high to low.

THE RELAY



The relay is an electromagnet that can operate one or more switch contacts. For example, the contacts in this relay (right) join points A and B when the switch is open. When the electromagnet is energised it attracts a piece of soft iron and joins points A and C. Points B and C are never joined. A relay like this can be used as an output transducer, as you can choose a relay that operates at a particular voltage. The relay transfers electrical energy to mechanical energy.

Another application for the relay is to allow you to use a small current in the control circuit to close the contacts for a very large current in a second circuit. For example the starter motor in a car is connected to the battery by wires that are about 10 mm in diameter, so high is the current that flows to the starter motor. It would be completely impractical to have wires of this size to the switch operated by the car's key, so the key controls only the current to the coil, and the relay contacts control the current to the motor.



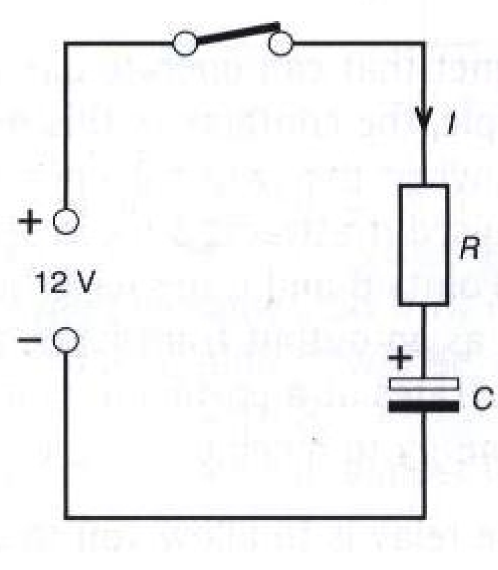
A relay circuit used to switch on a starter motor.

THE CAPACITOR

The capacitor is designed to store electric charge (and hence electrical energy) temporarily. The energy is stored as an electric field between two plates. The space between the plates is filled with an insulator, so current cannot flow through a capacitor. In some applications it is only stored for a fraction of a second, but be warned that large capacitors can hold on for many days to quantities of electricity that can kill. The following experiment must not be done with more than 12 V.

The following experiment shows how the capacitor can store energy.

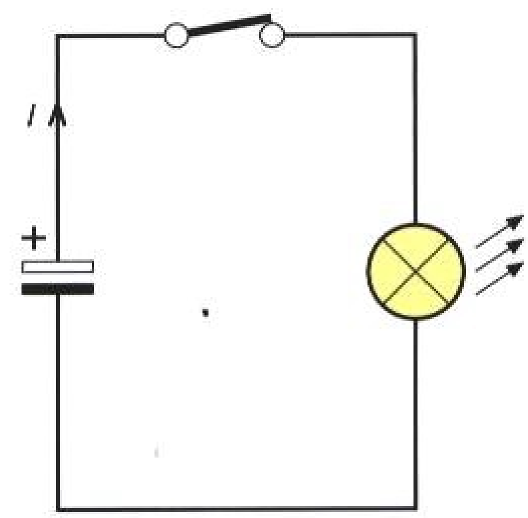
In the first step (below) connect a 12 V d.c. power supply to the capacitor.



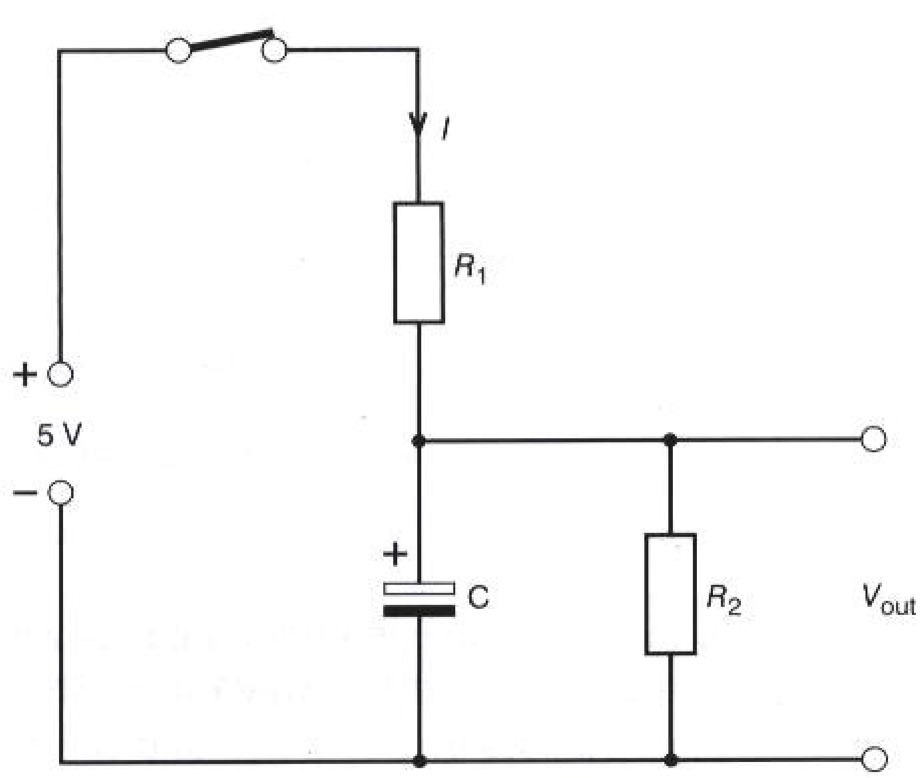
Note that many capacitors are marked with + and – terminals. The symbol for a capacitor of this type has a rectangular box shape for the + terminal. If the terminals are connected the wrong way round the capacitor will be damaged or destroyed. Capacitors also have a voltage rating. This one must be rated for 12 V or higher.

When, in the first step, the switch is closed, current flows *into* the capacitor as shown. A resistor *R* should be fitted to prevent too strong a surge of current. Initially, the p.d. across the capacitor is 0 V, and the full 12 V is across the resistor. So if the resistor is 12 ohms, for example, the initial current will be 1 A. As the capacitor stores charge, the p.d. across it increases to 12 V. If the capacitor has a large value, then the current will flow for longer and more energy will be stored. Remember that a current of 1 amp for 1 second into the capacitor will store a charge of 1 coulomb. When it is fully charged, the p.d. across the capacitor will be 12 V, the p.d. across the resistor will be 0 V, and the current will have died to zero.

In the second step (right) the charged capacitor is connected to a 12 V lamp. Then when the switch is closed, the lamp will have 12 V of p.d. across it, and it will be lit with maximum brightness as the current flows out of the capacitor. But the voltage of the capacitor will steadily drop and the lamp will get dimmer and dimmer until the current stops completely.



The capacitor can be used in a time-delay circuit.

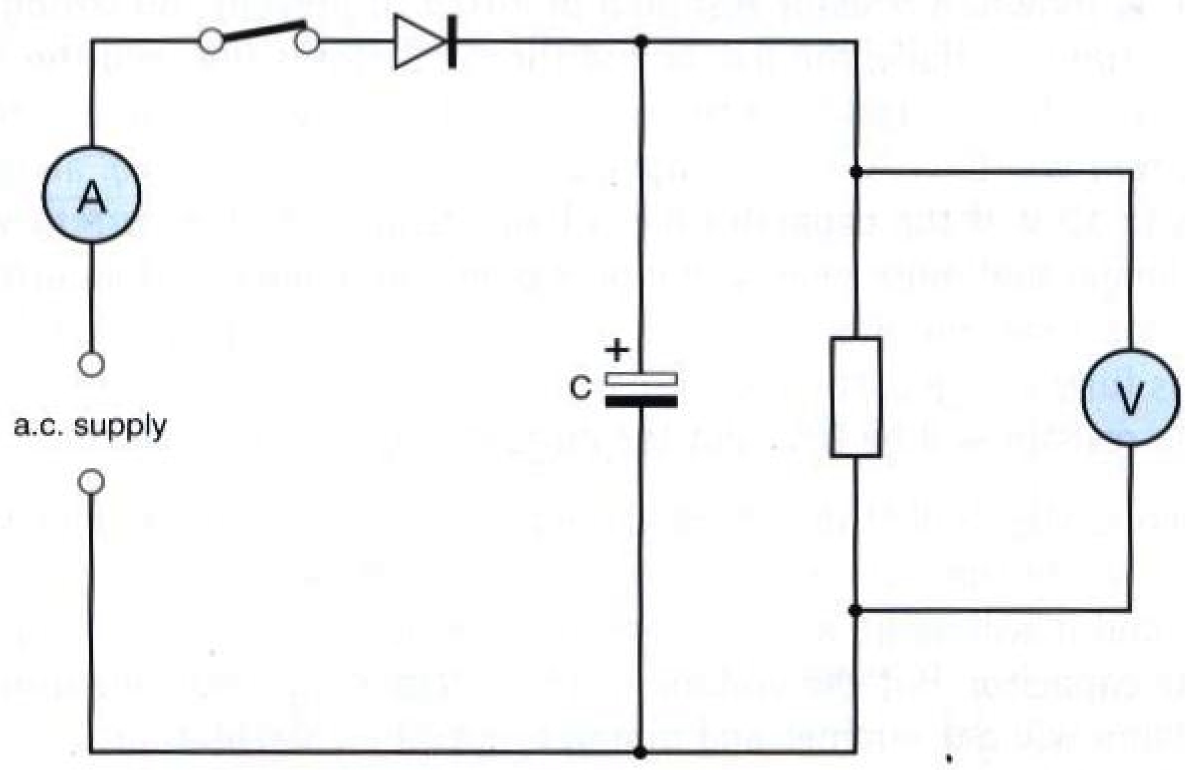


In this circuit, when the switch is closed, the p.d. across the capacitor C will increase from zero. If the output is connected to an output transducer, such as a relay, that operates when the output voltage reaches, say, 3 V, then there will be a time delay between the switch closing and the relay operating. This delay could be a fraction of a second or many minutes, depending on the resistance of R_1 and the capacitance of the capacitor C. For a long delay you want a high value of R_1 (to give a low current *I*) and a large capacitor C (to make it charge up more slowly).

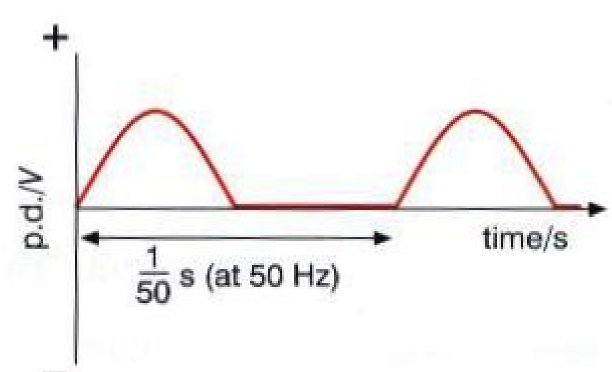
You may need to add a resistor R_2 so that the p.d. across the output is returned to zero when the switch is opened. R_2 must have a high resistance, or the capacitor will never be able to charge up (because the current would just flow through R_2 instead).

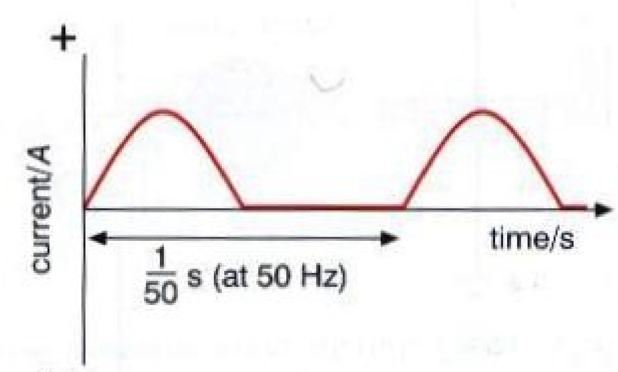
THE DIODE AS RECTIFIER

If you change the power source in the circuit on page 131 to a.c., the current will keep on changing direction. If a diode is added to the a.c circuit then, although the e.m.f. will stay as before, current will only flow in one direction. Conventional current can flow in the direction of the arrow in the diode symbol.



The graphs below show what you will measure across the resistor if the capacitor is *not* fitted. Only the positive p.d. will appear across the resistor. We say that the diode has rectified the alternating current. However, the p.d. and current fluctuate – they do not have a steady value.





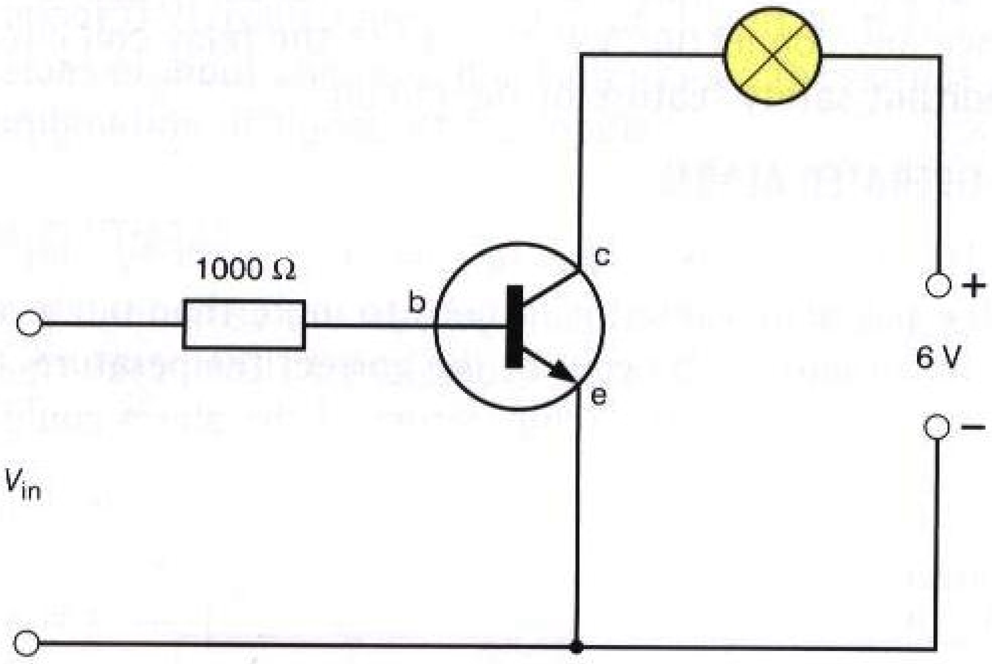
If you fit a capacitor C as well, then you have in effect a d.c. power supply. Note that the capacitor must be fitted this way round. The capacitor will be charged up by the pulses of electricity, and will be able to deliver a steady forward current through the resistor even when the e.m.f. is backwards.

THE TRANSISTOR AS SWITCH

The transistor is another output transducer. It is a semiconductor device made of silicon. It is the building block of electronics, and the processor of a computer contains millions of them. Most transistors are small and run at a few volts, but modern electric trains are started and stopped by semiconductor devices that control thousands of volts and thousands of amps.

The transistor has three wires coming out of it. These are labelled:
b = base
c = collector
e = emitter.

This type of transistor is known as a NPN transistor, with the arrow pointing out of the emitter.

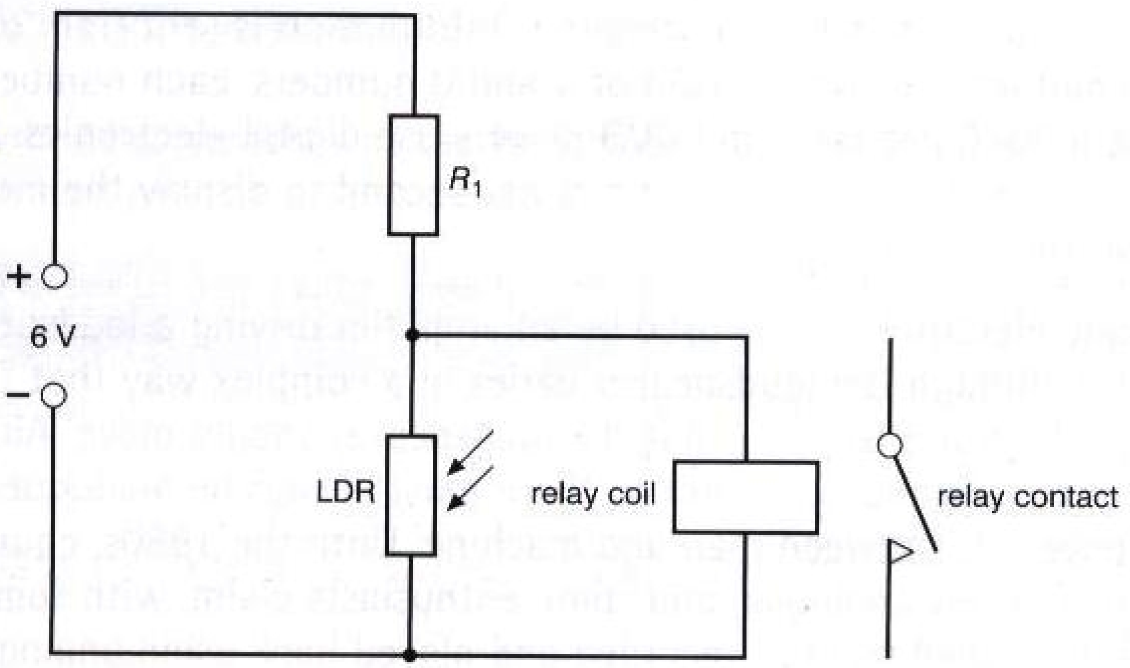


There are really two circuits here, one with the base and the emitter, which are in the input circuit, and one with the collector and the emitter, which are in the output circuit. (This overall circuit is known as a common-emitter circuit.)

In this circuit, if no voltage is applied to the base, or if the two input connections are joined together, then almost no current will flow through the output circuit, and the lamp will not light. If the input to the base is raised above 0.6 V, then the lamp will switch on. The 1000 ohm resistor is there to protect the input of the transistor, and allows the input to be set higher than 0.6 V, to 5 V or more without harming the transistor. Very little current is needed in the input circuit (and some transistors require no current at all). The output circuit can handle much higher currents, the exact current depending on the transistor chosen.

LIGHT-SENSITIVE SWITCH

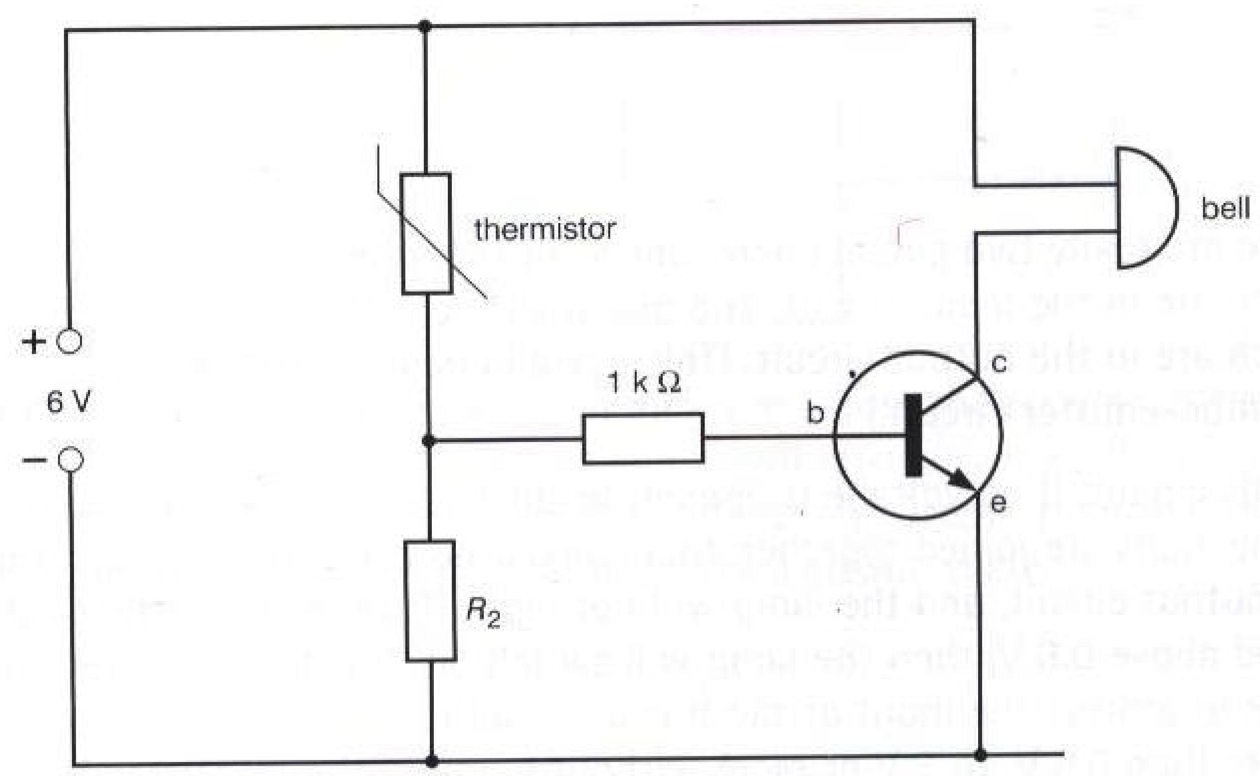
Here is the circuit of the light-sensitive switch, using a relay output.



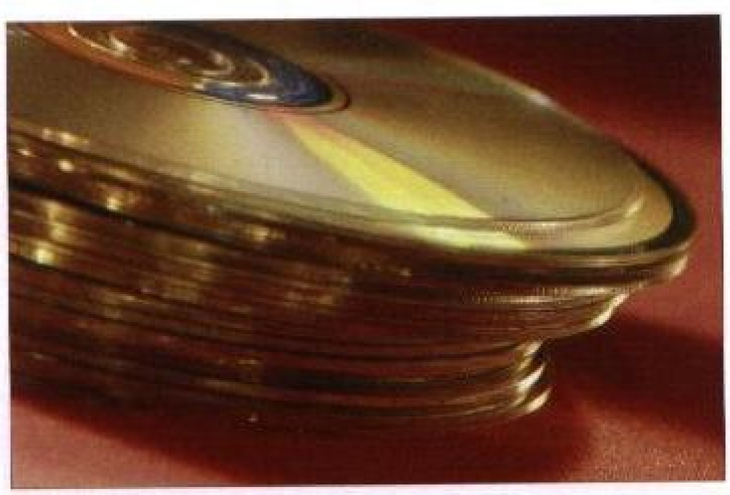
The relay is not energised so long as the resistance of the LDR stays low. If the illumination reduces, the resistance of the LDR increases and the p.d. across the coil goes up. When the illumination is sufficiently low, the relay will close the contact. Note that the circuit controlled by the relay does not need to have any connection whatsoever to the relay coil circuit. This can be an important safety feature of the circuit.

TEMPERATURE-OPERATED ALARM

In this circuit, the transistor will start to conduct electricity, and the bell will sound, if the p.d. across resistor R_2 goes to more than 0.6 V. The value of R_2 must be set to make this occur at the correct temperature. If R_2 was made a variable resistor, then the temperature of the alarm could be adjusted.



Some DJs still prefer vinyl records. If you look at the record you can see the analogue signal. The loudspeaker cone accurately follows these sideways movements of the groove.



Each DVD contains about 4.7 gigabytes of data in the form of the numbers 1 and 0. If the numbers out of one DVD were printed in paper books, you would need over 3000 books, each of 1000 pages.

Digital electronics

In digital electronics, the circuit is only allowed to be in one of two states: on or off. These two states represent the numbers 1 and 0. In practice, to make the circuit reliable, any low voltage is taken to indicate zero, and any high voltage is taken to represent 1. Information is sent from one place to another as a long stream of 1 and 0 numbers. Each number is known as a bit. Computers and DVD players use digital electronics. A DVD player has to read about 5 million bits per second to display the movie picture on the screen.

In analogue electronics, as is used by an amplifier driving a loudspeaker, the current through the loudspeaker varies in a complex way that accurately describes the way that the loudspeaker should move. All of the human senses are analogue, and so there must always be analogue-to-digital converters between man and machine. Until the 1980s, equipment used to be entirely analogue, and some enthusiasts claim, with some evidence, that vinyl records, recorded and played back using analogue equipment, sound best. However, most equipment is now digital, as it gives good quality and the ability to add many extra features at low cost.

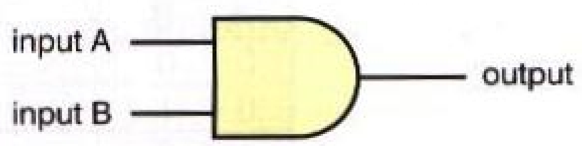
WHAT ARE LOGIC GATES?

A logic gate is an electronic circuit that has one or more **input** signals and one **output** signal. These signals are voltages that can be HIGH (about 5 V) or LOW (about 0 V). Logic gates are **digital** circuits as they can only have certain values of input and output – high or low. The output signal depends on the combination of signals at the inputs.

WHAT ARE TRUTH TABLES?

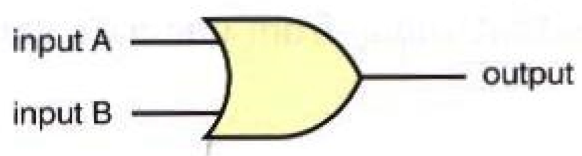
Truth tables summarise the way in which a logic gate operates. Truth tables usually use 1 for a HIGH signal and 0 for a LOW signal.

AND gate
The output is high only when input A **AND** input B are high.



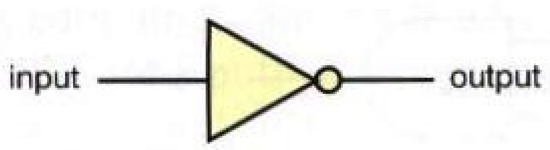
Inputs A	Inputs B	Output
0	0	0
0	1	0
1	0	0
1	1	1

OR gate
The output is high when input A **OR** input B is high, OR both.



Inputs A	Inputs B	Output
0	0	0
0	1	1
1	0	1
1	1	1

NOT gate
This gate is also called an **inverter**. It has only one input.
The output is high when the input is **NOT** high.



Input	Output
0	1
1	0

WORKED EXAMPLES

1 For safety, a car engine will not start unless the door is closed and the seat belt is fastened. Which type of logic gate is needed?

For the engine to start, both input conditions must be met. This circuit will need an AND gate.

2 A doorbell has switches at the front door and the back door of a house. Which type of logic gate is needed?

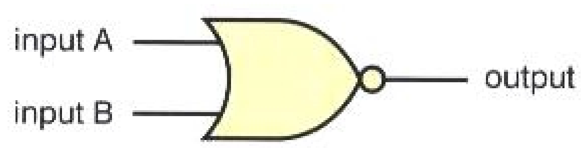
The bell needs to ring if either switch is pressed (or both). This circuit will need an OR gate.

MORE LOGIC GATES

A **NOR** gate combines an OR gate and a NOT gate.
The output is high when *neither* A NOR B are high.

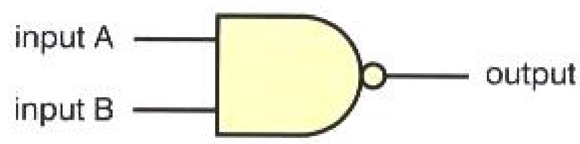
A* EXTRA

- Logic gates have a threshold value – usually between 2 V and 3 V. Input voltages below the threshold value are treated as low (0 V) and voltages above the threshold are treated as high (5 V).



Inputs A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

A **NAND** gate combines an AND gate and a NOT gate.
The output is high when *both* inputs are *not* high.



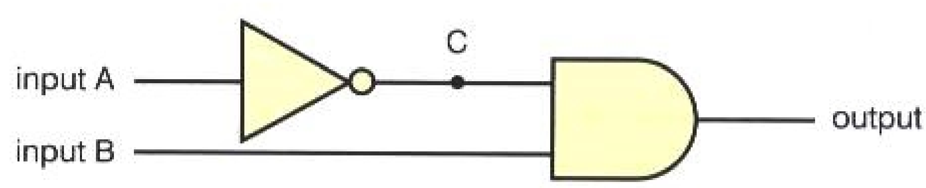
Inputs A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

LOGIC GATE CIRCUITS

Logic gates can be combined – the output signal from one gate can be used as the input signal to another.

WORKED EXAMPLE

Draw the truth table for this combination.



The key is to mark C on the diagram and work out this value first.

The value at C is NOT input A.

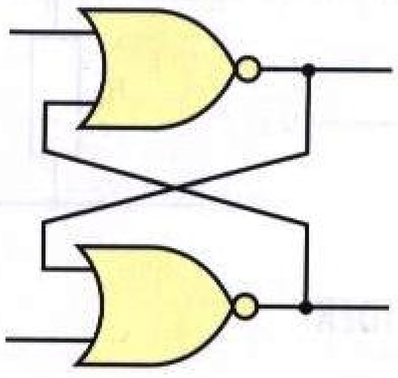
Inputs A	B	C	Output
0	0	1	
0	1	1	
1	0	0	
1	1	0	

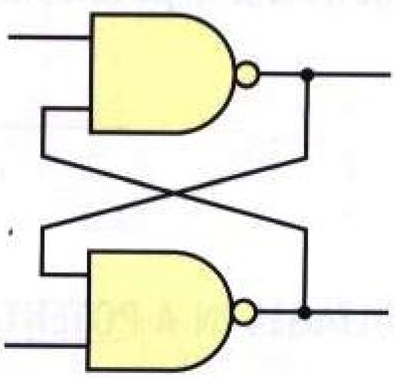
The final output is input B AND the value at C.

Inputs A	B	C	Output
0	0	1	0
0	1	1	1
1	0	0	0
1	1	0	0

BISTABLE CIRCUITS

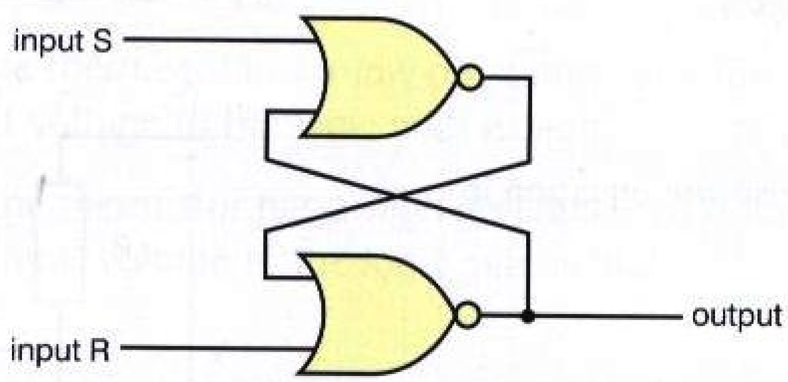
These circuits are made by cross-linking NOR gates or NAND gates.





The output depends on the **sequence** of changes at the inputs – the circuits act as a simple 'memory'. If only one output is used, the circuit is called a **latch**.

In a NOR gate latch:



- Initially, both inputs are low and the output is low.
- Input S (the **set** input) goes high, so the output goes high.
- Input S returns to low, but the output stays high – it is **latched on.**
- Input R (the **reset** input) goes high, so the output returns to low.
- Input R returns to low and the output stays low – it is **latched off.**

This is useful in circuits such as burglar alarms where the input sensor may only send a signal for a short time. The latch circuit keeps the alarm on until the reset is used.

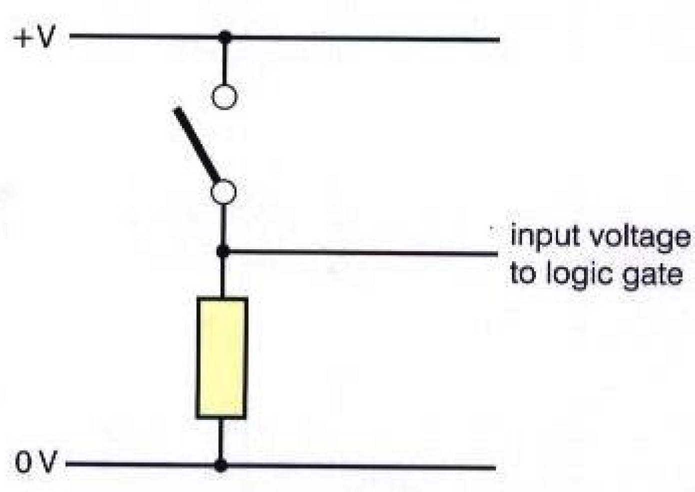
In a NAND gate latch, the sequence is the same except that:

- Both inputs and the output are *high* at the start.
- Moving the set input briefly to *low* changes the output to low.
- Moving the reset input briefly to *low* returns the output to high.

HOW DO WE PROVIDE SIGNALS FOR LOGIC GATES?

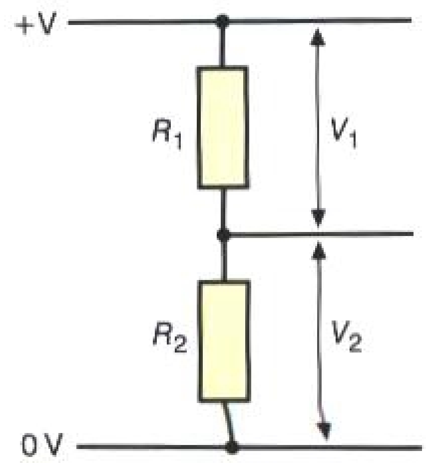
The simplest way to provide an input signal for a logic gate is to use a switch and a resistor.

Switch	Input voltage to logic gate
open	LOW
closed	HIGH



SENSORS USING POTENTIAL DIVIDERS

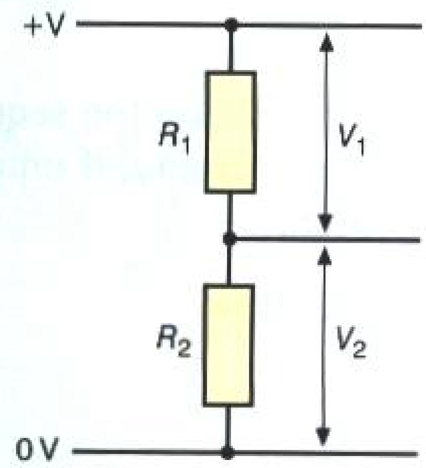
A sensor is a circuit in which a voltage changes as the environment changes. Most sensor circuits use a **potential divider**.



CALCULATING VOLTAGES IN A POTENTIAL DIVIDER

The current is the same in both resistors, so:

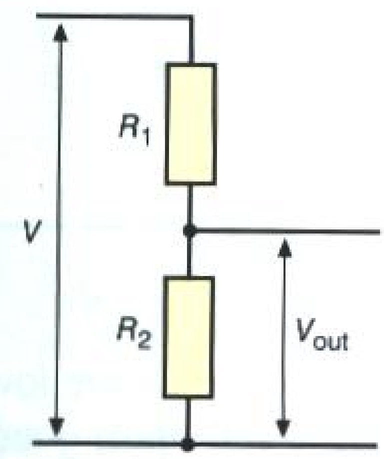
$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$



Often, we only need to work out the input voltage to the logic gate.

In this case, we can use the equation in this form:

$$V_{out} = \left(\frac{R_2}{R_1 + R_2}\right) V$$

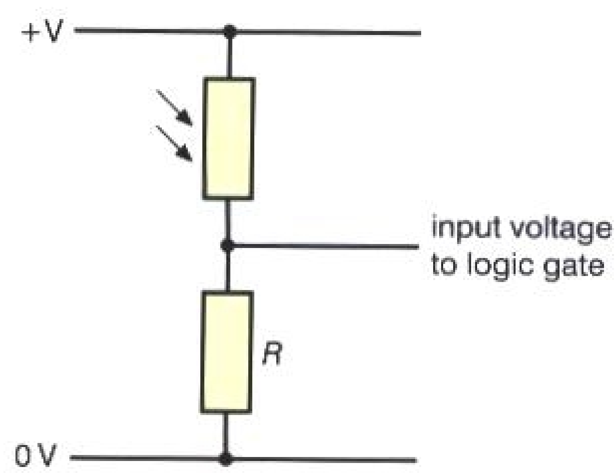


USING A LIGHT-DEPENDENT RESISTOR (LDR)

The resistance of an **LDR** is high in the dark and low in the light.

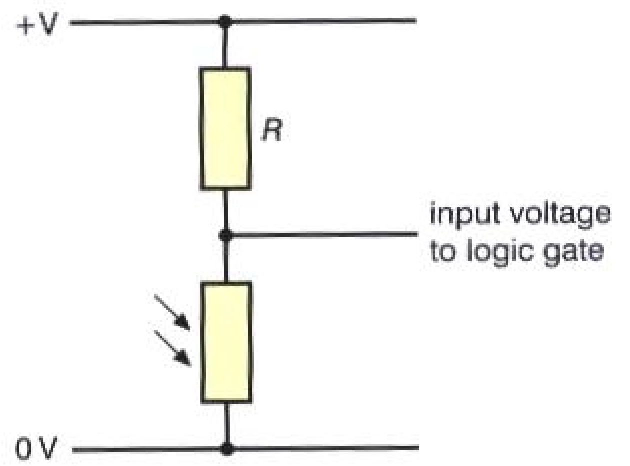
When it is *light*, the LDR has a *low* resistance, so it has a small share of the voltage. The input voltage to the logic gate is high.

When it is *dark*, the LDR has a *high* resistance, so it has a large share of the voltage. The input voltage to the logic gate is low.



This time the resistors have been switched round. The input voltage to the logic gate will be high when it is dark and low when it is light.

If the resistor R is changed to a variable resistor, then we can vary the light level at which the input voltage to the logic gate goes from low to high.

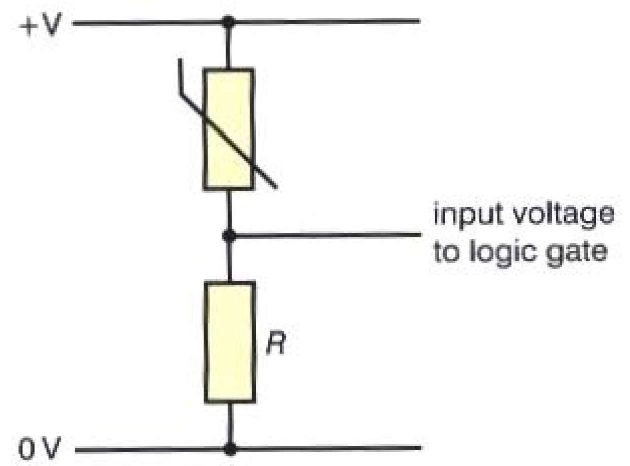


USING A THERMISTOR

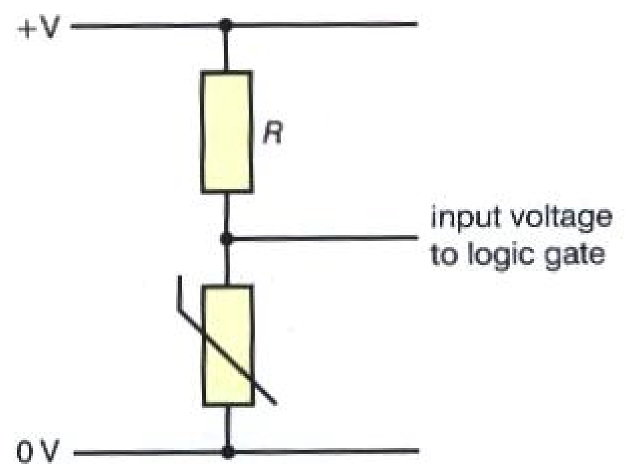
The resistance of a **thermistor** is high at low temperatures and low at high temperatures.

When it is *hot*, the thermistor has a *low* resistance, so it has a small share of the voltage. The input voltage to the logic gate is high.

When it is *cold*, the thermistor has a *high* resistance, so it has a large share of the voltage. The input voltage to the logic gate is low.



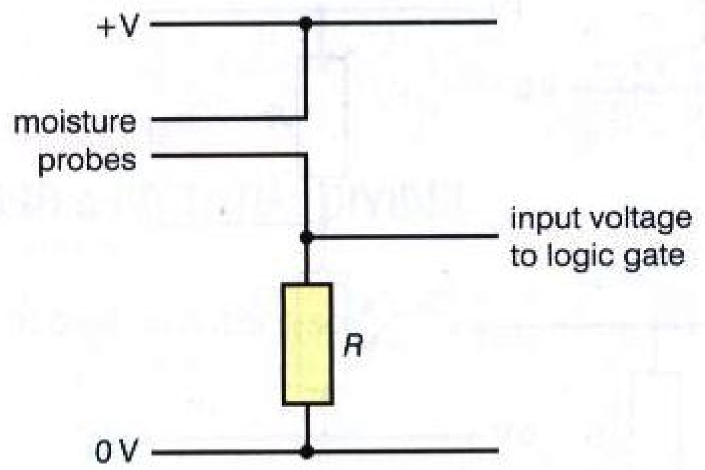
This time the resistors have been switched round. The input voltage to the logic gate will be high when it is cold and low when it is hot.



OTHER SENSORS

A moisture sensor has two wire probes separated by a small gap.

Moisture (water) conducts electricity better than the air, so the resistance of the gap changes when it is wet. This changes the input voltage to the logic gate.



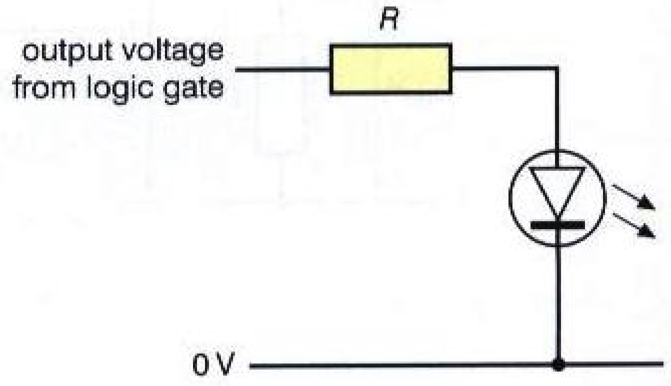
In a **tilt switch**, two contacts are only connected when the switch is turned in a particular direction. This changes the resistance, varying the input voltage to the logic gate.

Other sensors include:

- **magnetic sensors** – a change in magnetic field causes a change in the input voltage to the logic gate
- **pressure sensors** – the resistance of the sensor changes when the sensor is pressed in some way.

OUTPUT DEVICES

The output signal from a logic gate is large enough to drive devices such as **buzzers** and **LEDs (light-emitting diodes)**. When an LED is used, a resistor is used in series with it. This **protects** the LED against the current being too high.



The LED will light when the output from the logic gate is high (5 V).

WORKED EXAMPLE

When lit, an LED has a voltage of 1.8 V across it and a current of 10 mA. Work out a suitable value for the protective resistor, *R*.

voltage across resistor = output voltage from logic gate − voltage across LED

= 5 V − 1.8 V

= 3.2 V

Current through resistor = 10 mA = 0.01 A (because resistor and LED are in series)

Write Ohm's law in terms of *R*: $R = \frac{V}{I}$

Substitute the values for *V* and *I*: $R = \frac{3.2}{0.01}$

Work out the answer and write down the unit: $R = 320\ \Omega$

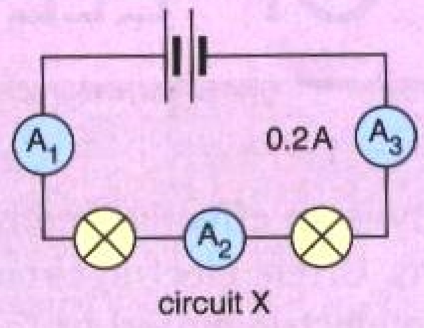
REVIEW QUESTIONS

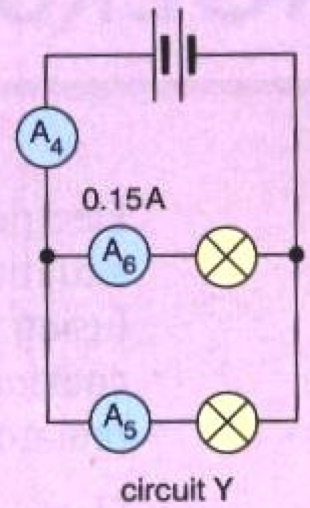
Q1 Look at the circuit diagrams on the right. They show a number of ammeters and in some cases the readings on these ammeters. All the lamps are identical.

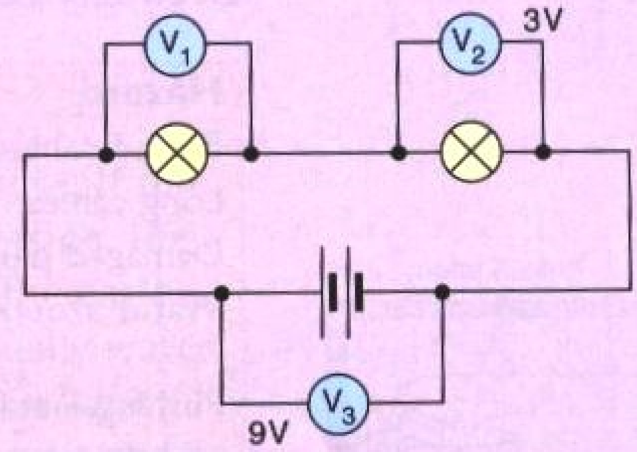
a For circuit X, what readings would you expect on ammeters A_1 and A_2?

b For circuit Y, what readings would you expect on ammeters A_4 and A_5?

c Look at the last circuit diagram. It shows how three voltmeters have been added to the circuit. What reading would you expect on V_1?

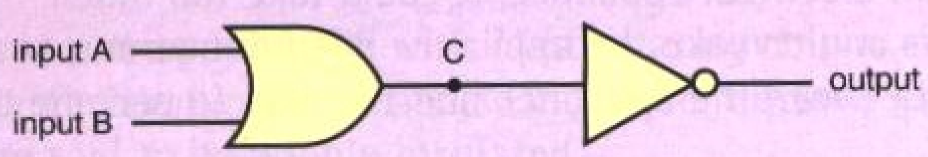






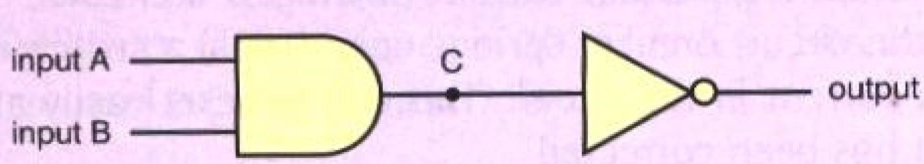
Q2 Complete the truth tables to show that:

a a NOR gate is the same as an OR gate followed by a NOT gate.



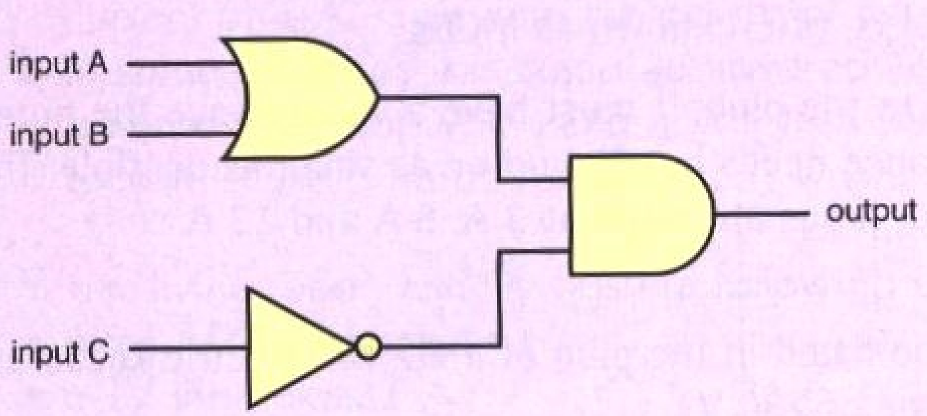
Inputs A	Inputs B	C	Output
0	0		
0	1		
1	0		
1	1		

b a NAND gate is the same as an AND gate followed by a NOT gate.



Inputs A	Inputs B	C	Output
0	0		
0	1		
1	0		
1	1		

Q3 Complete the truth table for this circuit.



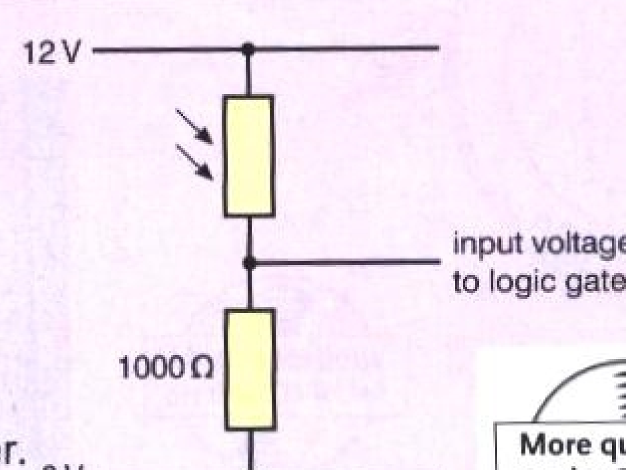
Inputs A	Inputs B	Inputs C	Output
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

Q4 Here is a light sensor circuit. It has to detect light and dark.

a At a particular light level, the resistance of the LDR is 500 Ω. Calculate the input voltage to the logic gate.

b In the dark the resistance of the LDR is 10 KΩ. What is the input voltage now?

c State two reasons why a relay must be used when the output from the logic gate needs to control a room heater.



More questions on the CD ROM

Examination questions are on page 156.