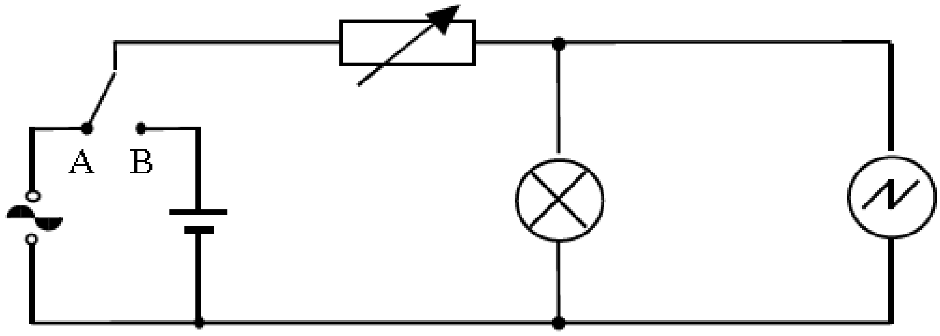
# A.C./D.C.

1. (a) What is the peak voltage of the 230 V mains supply?
   (b) The frequency of the mains supply is 50 Hz. How many times does the voltage fall to zero in 1 second?
2. The circuit below is used to compare a.c. and d.c. supplies.




The variable resistor is used to adjust the brightness of the lamp until the lamp has the same brightness when connected to either supply.

(a) Explain why the brightness of the lamp changes when the setting on the variable resistor is altered.
(b) What additional apparatus would you use to ensure the brightness of the lamp is the same when connected to either supply?
(c) The time-base of the oscilloscope is switched off. Diagram 1 shows the oscilloscope trace obtained when the switch is in position B. Diagram 2 shows the oscilloscope trace obtained when the switch is in position A.

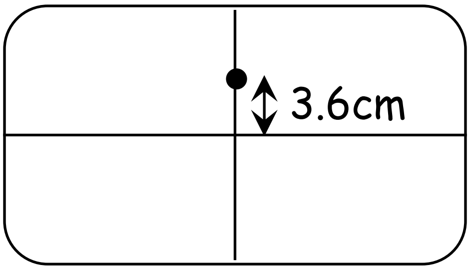



Diagram 1

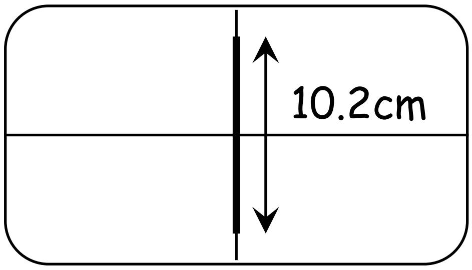


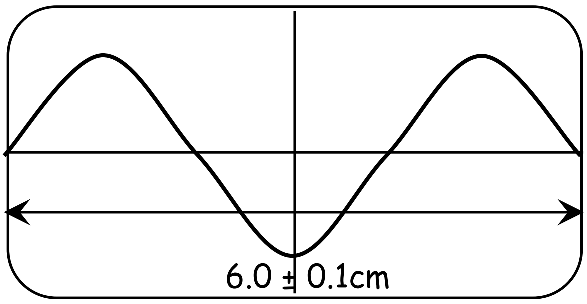

Diagram 2

Using information from the oscilloscope traces, find the relationship between the root mean square (r.m.s.) voltage and the peak voltage of a voltage supply.
(d) The time-base of the oscilloscope is now switched on. Redraw diagrams 1 and 2 to show what happens to the traces.

3. The root mean square voltage produced by a low voltage power supply is 10 V.
(a) Calculate the peak voltage of the supply.
(b) An oscilloscope, with its time-base switched off, is connected across the supply. The Y-gain of the oscilloscope is set to 5 $Vcm^{-1}$. Describe the trace seen on the oscilloscope screen.

4. A transformer has a peak output voltage of 12 V.
(a) Calculate the r.m.s. value of this voltage.
(b) An oscilloscope, with the time base switched off, is connected across another a.c. supply. The Y gain of the oscilloscope is set to 20 $Vcm^{-1}$. A vertical line 6 cm high appears on the oscilloscope screen.
Calculate:
(i) the peak voltage of the input
(ii) the r.m.s. voltage of the input.

5. An oscilloscope is connected across a signal generator. The time-base switch is set at 2·5 ms $cm^{-1}$.
The diagram shows the trace on the oscilloscope screen.




(a) (i) What is the frequency of the output from the signal generator?
(ii) What is the uncertainty in the frequency to the nearest Hz?
(b) The time base switch is now changed to:
(i) 5 ms $cm^{-1}$
(ii) 1·25 ms $cm^{-1}$
Sketch the new traces seen on the screen.

6. An a.c. signal of frequency 20 Hz is connected to an oscilloscope. The time-base switch on the oscilloscope is set at 0.01 $scm^{-1}$.
Calculate the distance between the neighbouring peaks of this waveform when viewed on the screen.

# Circuits

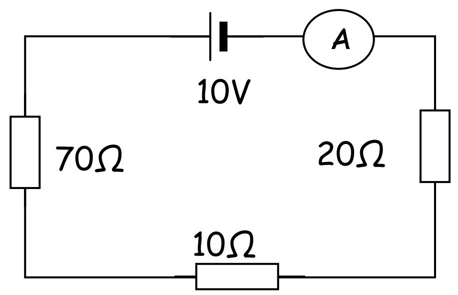
1. There is a current of 40 mA in a lamp for 16 s.
   Calculate the quantity of charge that passes any point in the circuit in this time.

2. A flash of lightning lasts for 1 ms. The charge transferred between the cloud and the ground in this time is 5 C.
   Calculate the value of the average current in this flash of lightning.

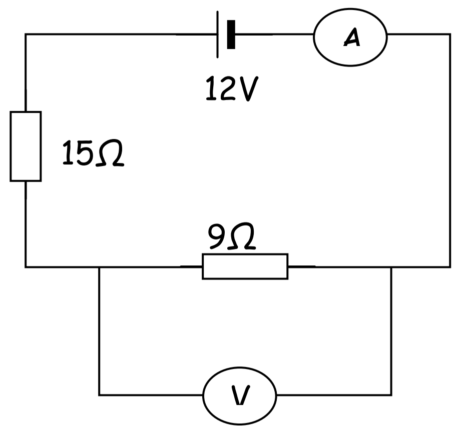
3. The current in a circuit is $2\ 5 \times 10^{-2}$ A. How long does it take for 500 C of charge to pass any given point in the circuit?

4. There is a current of 3 mA in a 2 kΩ resistor. Calculate the p.d. across the resistor.

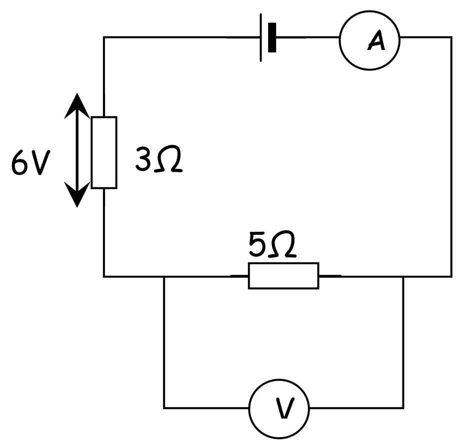
5. Calculate the values of the readings on the meters in the following circuits.



circuit 1

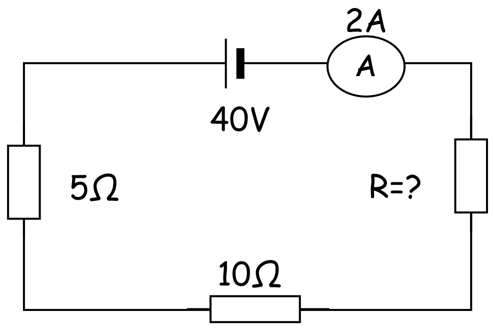


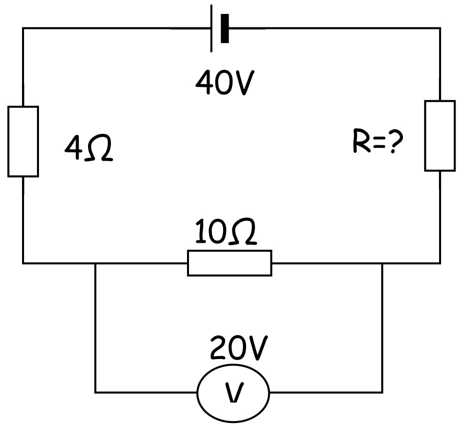
circuit 2



circuit 3

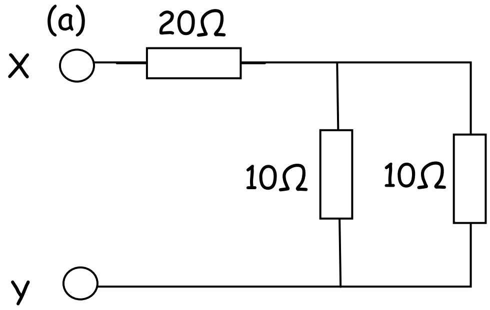
6. Calculate the unknown values R of the resistors in the following circuits.



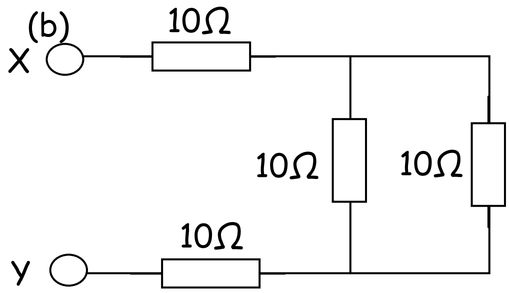




7. Calculate the total resistance between X and Y for the following combinations of resistors.

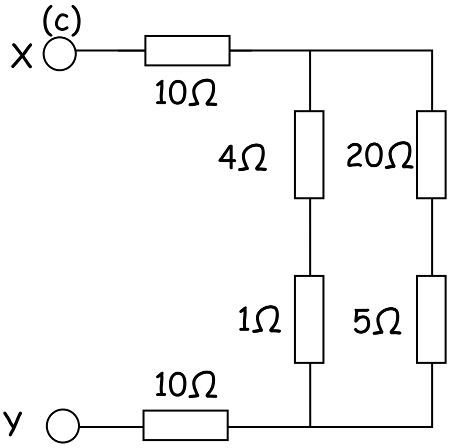
(a)



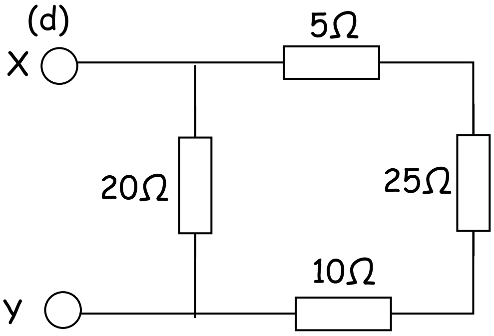

(b)



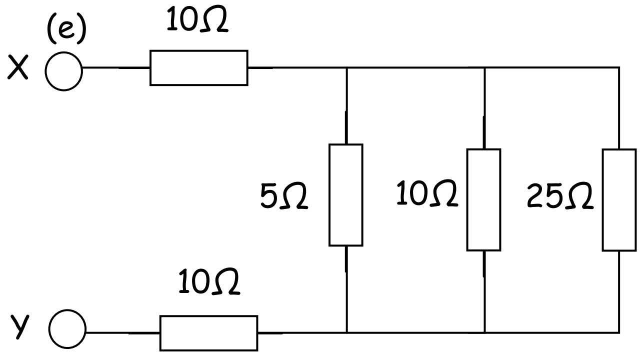

(c)



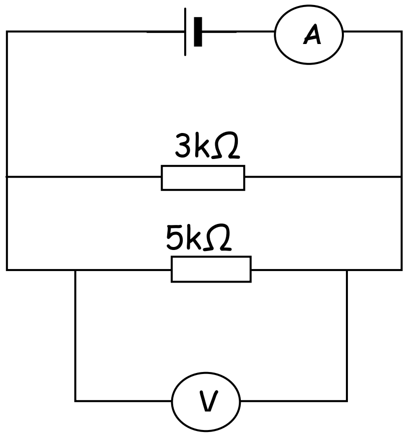

(d)




(e)



8. In the following circuit the reading on the ammeter is 2 mA.
Calculate the reading on the voltmeter.

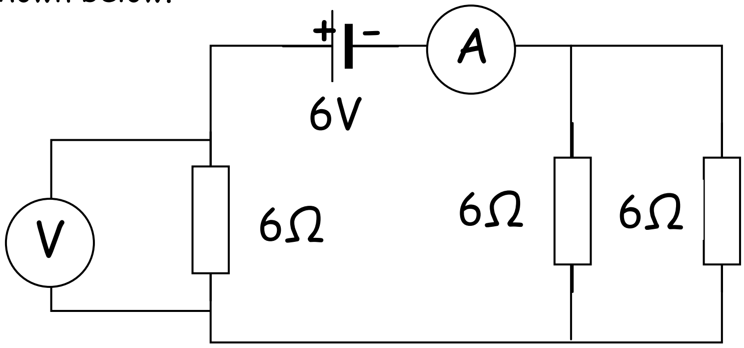



9. Calculate the power in each of the following situations.
(a) A 12 V battery is connected to a motor. There is a current of 5 A in the motor.
(b) A heater of resistance 60 Ω that is connected across a 140 V supply.
(c) A current of 5 A in a heater coil of resistance 20 Ω.

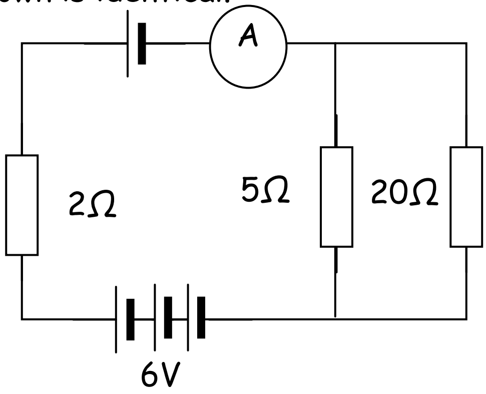
10. The heating element in an electric kettle has a resistance of 30 Ω.
(a) What is the current in the heating element when it is connected to a 230 V supply?
(b) Calculate the power rating of the element in the kettle.

11. A 15 V supply produces a current of 2 A in a lamp for 5 minutes.
Calculate the energy supplied in this time.

12. Calculate the readings on the ammeter and the voltmeter in the circuit shown below.



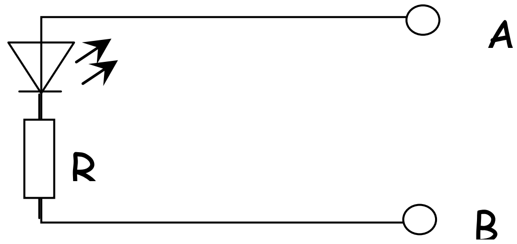
13. Each of the four cells in the circuit shown is identical.




Calculate
(a) the reading on the ammeter
(b) the current in the 20 Ω resistor
(c) the voltage across the 2 Ω resistor.

14. A voltage of 12 V is applied across a resistor. The current in the resistor is 50 mA. Calculate the resistance of the resistor.

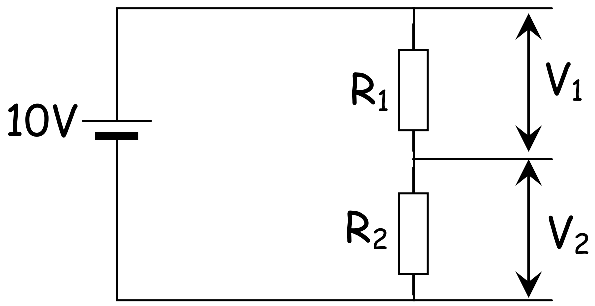
15. The LED in the circuit below is to emit light.




(a) What is the required polarity of A and B when connected to a 5 V supply so that the LED emits light?
(b) What is the purpose of the resistor R in the circuit?
(c) The LED rating is 20 mA at 1·5 V. Calculate the value of resistor R.

16. Write down the series and parallel circuit rules for
(a) potential differences (b) currents .

17. What is the name given to the circuit shown?



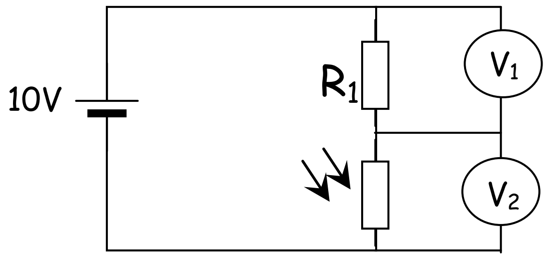

Write down the relationship between $V_1$, $V_2$, $R_1$ and $R_2$ .

18. Calculate the values of $V_1$ and $V_2$ of the circuit in question 17 when:

(a) $R_1$ = 1 kΩ  $R_2$ = 49 kΩ

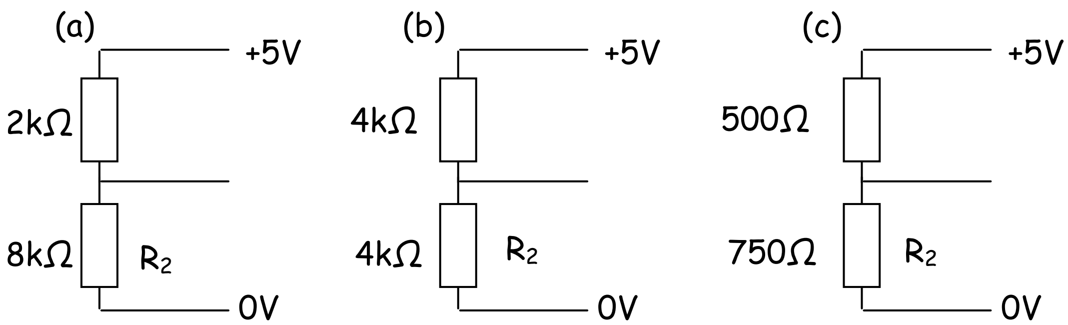
(b) $R_1$ = 5 kΩ  $R_2$ = 15 kΩ

19. The light dependent resistor in the circuit is in darkness.




Light is now shone on the LDR.
Explain what happens to the readings on $V_1$ and $V_2$

20. Calculate the p.d. across resistor $R_2$ in each of the following circuits.

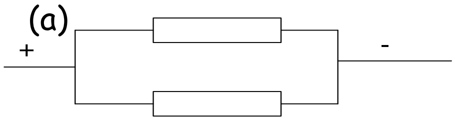


# Potential divider circuits

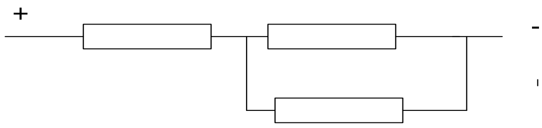
1. Prove from first principles the equation for
   (a) two resistors in series (b) Two resistors in parallel

2. Calculate the total resistance of the following circuits. All resistors are 2.2k

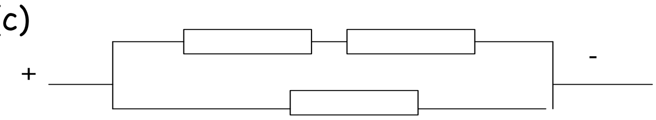
(a)




(b)



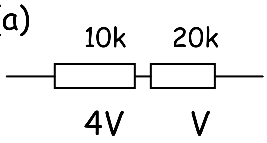

(c)



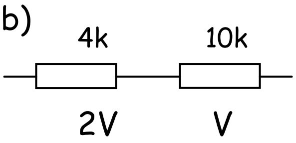

3. Calculate the limiting resistor required to operate a 12V 48W lamp from a 36V supply.

4. Calculate the unknown in each of the following circuits

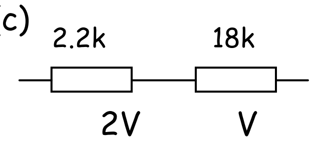
(a)




(b)

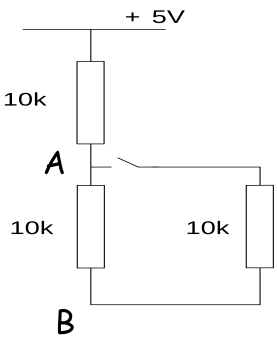



(c)

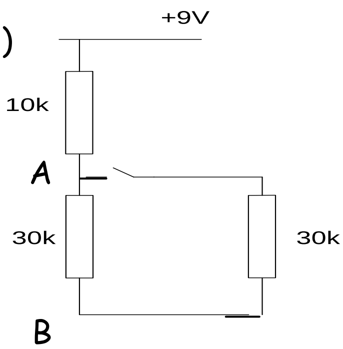



5. Consider the following circuits. Calculate the voltage across AB when (a) S is open and when (b) S is closed

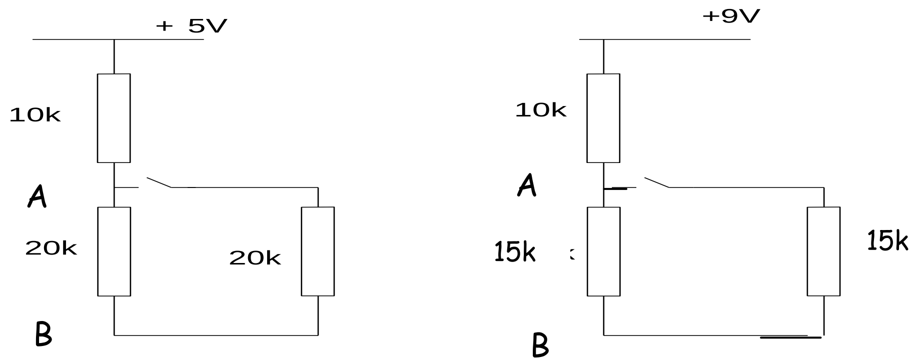
(i)




(ii)



6. Consider the following circuits. A current of 0.2A flows through the 10 ohm resistor when Switch is open



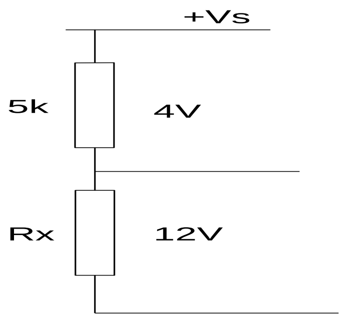

When Switch is open calculate

(a) the voltage across resistor AB in both diagrams

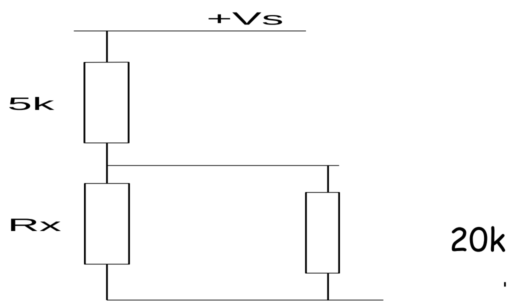
Switch S is now closed

(b) Calculate the new voltage across AB

7. Consider the following circuit.




a. Calculate the value of the unknown resistor
b. Calculate the supply voltage
c. Another resistor of value 20k is now put in parallel with the resistor $R_x$

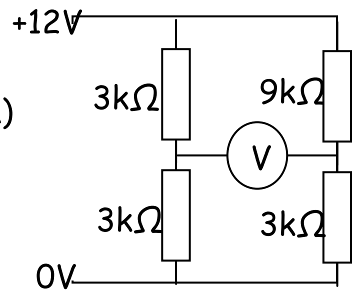



Calculate the new value of voltage across Rx

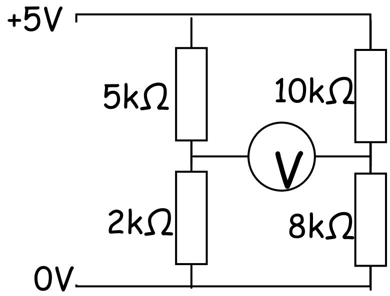
# Potential Dividers 2

1. Calculate the p.d. across AB (voltmeter reading) in each of the following circuits

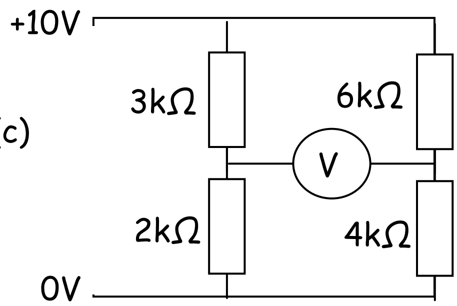
(a)



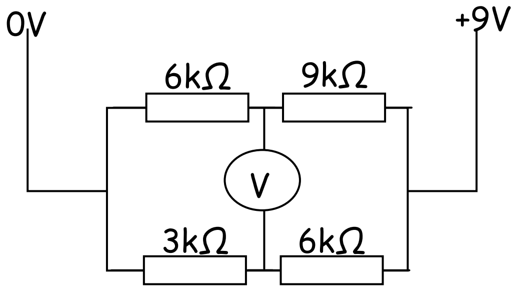

(b)




(c)




2. A circuit consisting of two potential dividers is set up as shown.



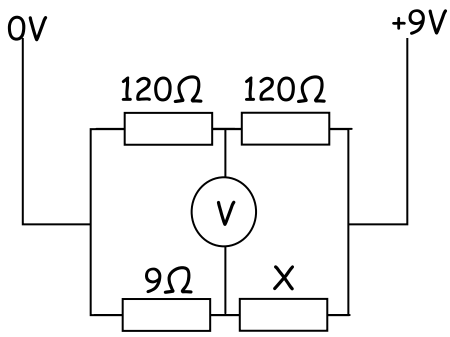

(a) Calculate the reading on the voltmeter.

(b) (i) Suggest a value of a resistor to replace the 9 kΩ resistor that would give a reading of 0 V on the voltmeter.

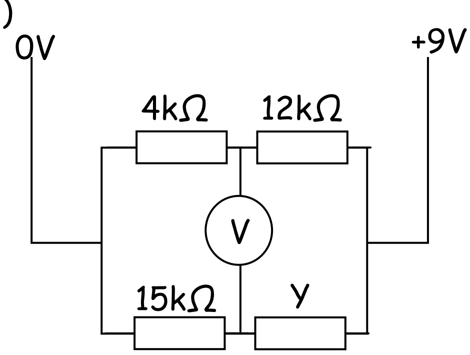
(ii) Suggest a value of resistor to replace the 3 kΩ resistor that would give a reading of 0 V on the voltmeter.

3. In the circuits shown the reading on the voltmeters is zero. Calculate the value of the unknown resistors X and Y in each of the circuits

(a)

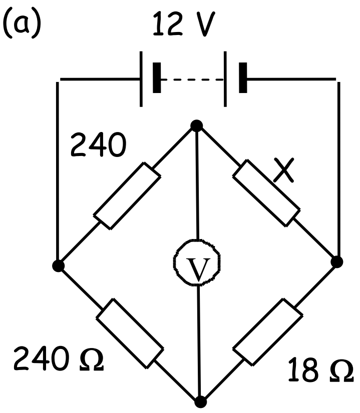



(b)

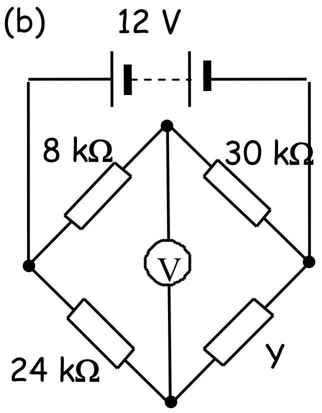



4. In the circuits shown the reading on the voltmeters is zero. Calculate the value of the unknown resistors X and Y in each of the circuits.

(a)



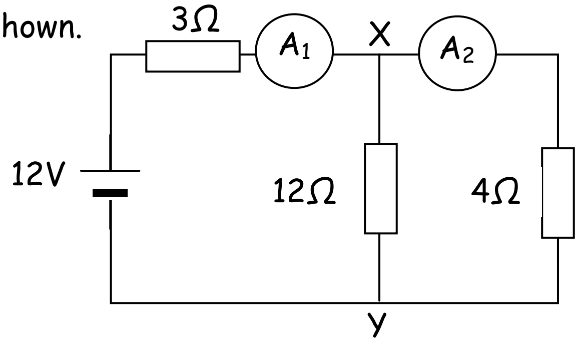

(b)



# Electrical sources and Internal Resistance

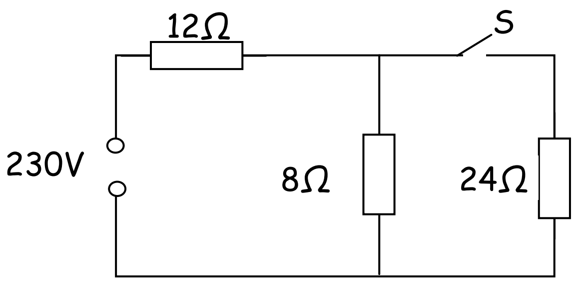
1. State what is meant by:
   (a) the e.m.f. of a cell
   (b) the p.d. between two points in a circuit.

2. A circuit is set up as shown.

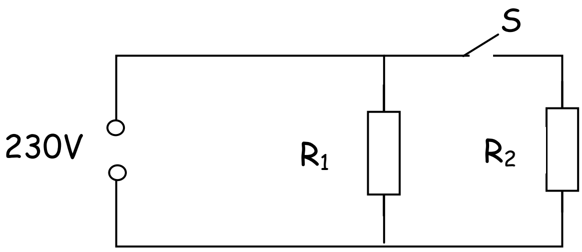



   (a) Calculate the total resistance of the circuit.
   (b) Calculate the readings on the ammeters.
   (c) What is the value of the p.d. between X and Y?
   (d) Calculate the power supplied by the battery.

3. The circuit shown uses a 230 V alternating mains supply.
   Calculate the current in each resistor when:
   (a) switch S is open
   (b) switch S is closed

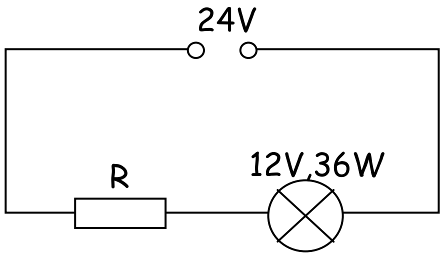



4. An electric cooker has two settings, high and low. This involves two heating elements, $R_1$ and $R_2$. On the low setting the current from the supply is 1 A. On the high setting the current from the supply is 3 A.



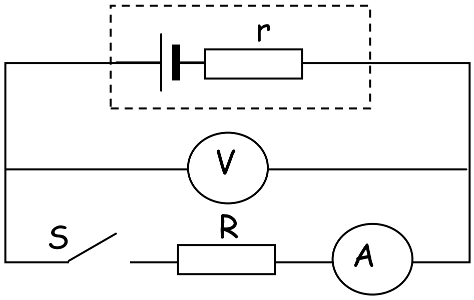

   (a) Calculate the resistance of $R_1$ and $R_2$.
   (b) What is the power consumption at each setting?

5. A lamp is rated at 12 V, 36 W. It is connected in a circuit as shown.




(a) Calculate the value of the resistor R that allows the lamp to operate at its normal rating.
(b) Calculate the power dissipated in the resistor.

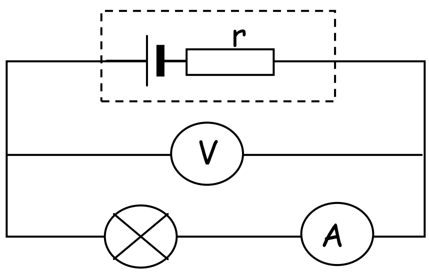
6. In the circuit shown, *r* represents the internal resistance of the cell and *R* represents the external resistance (or load resistance) of the circuit.




When S is open, the reading on the voltmeter is 2.0 V.
When S is closed, the reading on the voltmeter is 1.6 V and the reading on the ammeter is 0.8 A.

(a) What is the value of the e.m.f. of the cell?
(b) When S is closed what is the terminal potential difference across the cell?
(c) Calculate the values of *r* and *R*.
(d) The resistance *R* is now halved in value. Calculate the new readings on the ammeter and voltmeter.

7. The battery in the circuit shown has an e.m.f. of 5.0 V. The current in the lamp is 0.20 A and the reading on the voltmeter is 3.0 V.

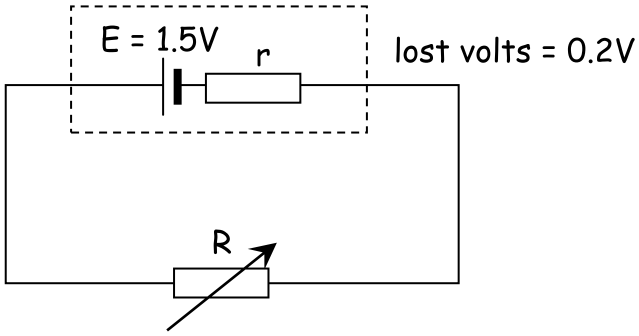



Calculate the internal resistance of the battery.

8. A battery of e.m.f. 4.0 V is connected to a load resistor with a resistance of 15 Ω. There is a current of 0.2 A in the load resistor. Calculate the internal resistance of the battery.

9. A signal generator has an e.m.f. of 8.0 V and an internal resistance of 4.0 Ω. A load resistor is connected across the terminals of the generator. The current in the load resistor is 0.50 A. Calculate the resistance of the load resistor.

10. A cell is connected in a circuit as shown below.



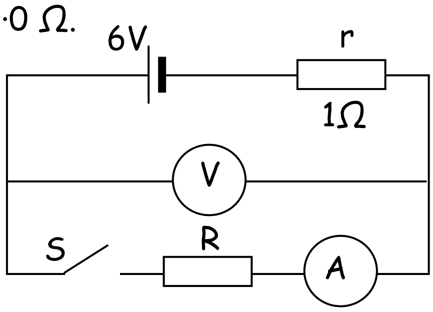

(a) Calculate the terminal p.d. across the cell.
(b) The resistance of the variable resistor R is now increased.
(i) Describe *and* explain what happens to the current in the circuit.
(ii) Describe *and* explain what happens to the p.d. across the terminals of the cell.

11. A cell has an e.m.f. 1·5 V and an internal resistance of 2·0 Ω. A 3·0 Ω resistor is connected across the terminals of the cell. Calculate the current in the circuit.

12. A student is given a voltmeter and a torch battery. When the voltmeter is connected across the terminals of the battery the reading on the voltmeter is 4·5 V.

When the battery is connected across a 6·0 Ω resistor the reading on the voltmeter decreases to 3·0 V.
(a) Calculate the internal resistance of the battery.
(b) What value of resistor is connected across the battery when the reading on the voltmeter reduces to 2·5 V?

13. In the circuit shown, the battery has an e.m.f. of 6·0 V and an internal resistance of 1·0 Ω.




When the switch is closed, the reading on the ammeter is 2·0 A. What is the corresponding reading on the voltmeter?

14. To find the internal resistance of a cell a load resistor is connected across the terminals of the cell. A voltmeter is used to measure $V_{tpd}$, the voltage measured across the terminals of the cell. An ammeter is used to measure I, the current in the variable resistor. The table below shows the results obtained as the resistance of the variable resistor is changed.

| | | | | | | |
|---|---|---|---|---|---|---|
| $V_{t.p.d}$ (V) | 1·02 | 0·94 | 0·85 | 0·78 | 0·69 | 0·60 |
| I (A) | 0·02 | 0·04 | 0·06 | 0·08 | 0·10 | 0·12 |

(a) Draw a diagram of the circuit used to produce these results.
(b) Plot a graph of the results and from it determine:
(i) the e.m.f. of the cell
(ii) the internal resistance of the cell
(iii) the short circuit current of the cell.

15. A variable resistor is connected across a power supply. A voltmeter is used to measure $V_{t.p.d.}$, the voltage measured across the terminals of the supply. An ammeter is used to measure I, the current in the variable resistor. The table below shows the results obtained as the resistance of the variable resistor is changed.

| $V_{t.p.d.}$(V) | 5·5 | 5·6 | 5·7 | 5·8 | 5·9 |
|---|---|---|---|---|---|
| I (A) | 5·0 | 4·0 | 3·0 | 2·0 | 1·0 |

Plot a graph of $V_{t.p.d}$. against I.

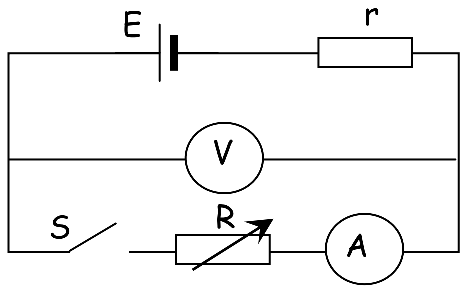
(a) What is the value of the open circuit p.d.?

(b) Calculate the internal resistance of the power supply.

(c) Calculate the short circuit current of the power supply.

(d) The variable resistor is now removed from the circuit and a lamp of resistance 1·5 Ω is connected across the terminals of the supply.
Calculate: (i) the terminal p.d.
(ii) the power delivered to the lamp.

16. A circuit is set up as shown to investigate the properties of a battery.




The variable resistor provides known values of resistance R.
For each value of resistance R, the switch is closed and the current I noted.
The table shows the results obtained.

| R(Ω) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|
| I(A) | 6.80 | 3.78 | 2.62 | 2.00 | 1.62 | 1.36 | 1.17 |
| 1/I($A^{-1}$) | | | | | | | |

(a) Show that the relationship E = I(R + r) can be put in the form:

$$R = \frac{E}{I} - r$$

(b) Complete the third row in the table.

(c) Use the values of *R* and 1/*I* to plot a graph.

(d) Use the information in the graph to find:

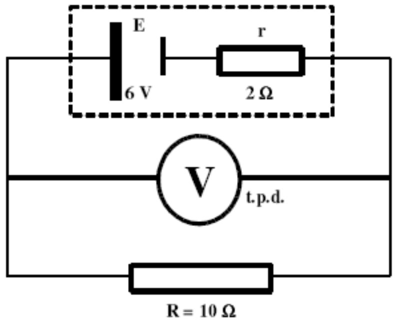
(i) the internal resistance of the battery

(ii) the e.m.f. of the battery.

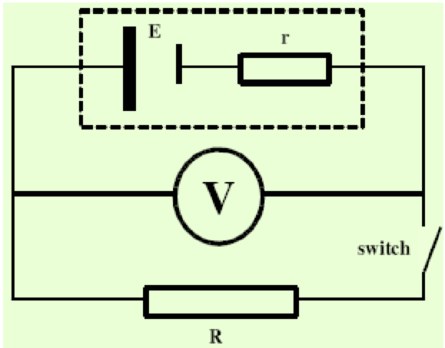
(e) The battery is now short circuited. Calculate the current in the battery when this happens.

# Internal Resistance

1. For the circuit shown, calculate;
(a) The current (I);
(b) The terminal potential difference (t.p.d.);
(c) The lost volts;
(d) The short circuit current (by connecting a wire across the terminals

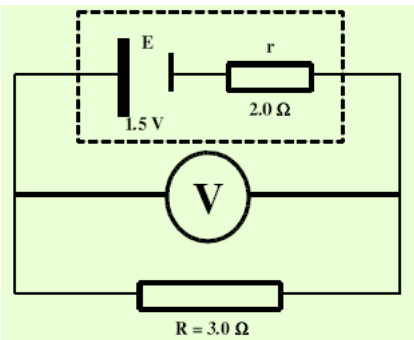



2. In this circuit, when the switch is open, the voltmeter reads 2.0 V. When the switch is closed, the voltmeter reading drops to 1.6 V and a current of 0.8 A flows through resistor R.
(a) State the value of the cell e.m.f.
(b) State the terminal potential difference across R when the switch is closed.
(c) Determine the "lost volts" across the cell.
(d) Calculate the resistance of resistor R.
(e) Calculate the internal resistance of the cell

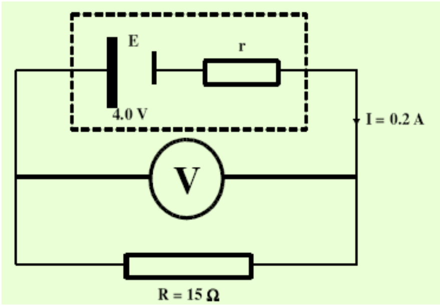



3. A pupil is given a voltmeter and a torch battery. When he connects the voltmeter across the battery terminals, it registers 4.5 V, but when he connects the battery across a 6.0 Ω resistor, the voltmeter reading decreases to 3.0 V.
(a) State the value of the battery e.m.f.
(b) State the value for the t.p.d. when the resistor is connected across the battery.
(c) Determine the "lost volts" across the battery.
(d) Calculate the current flowing through the 6.0 Ω resistor.
(e) Calculate the internal resistance of the battery.

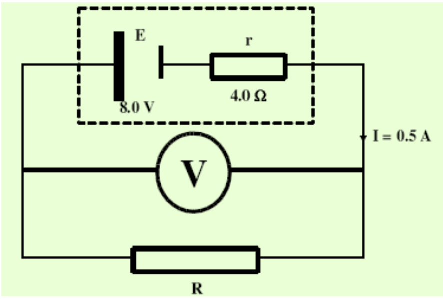
4. A cell with e.m.f. 1.5 V and internal resistance 2.0 Ω is connected to a 3.0 Ωresistor.
Calculate the current flowing round the circuit.



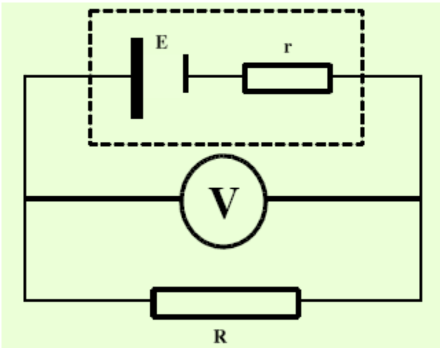
5. A cell of e.m.f. 4.0 V is connected to a load resistor of 15 Ω. If a current of 0.2 A flows round the circuit, what must be the internal resistance of the cell?



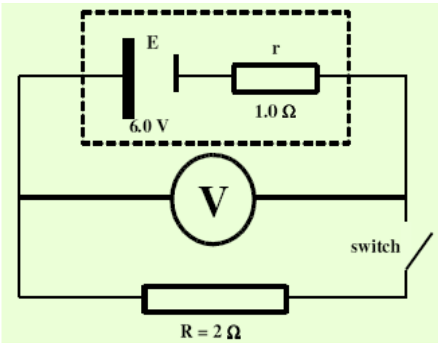

6. A power supply has an e.m.f. of 8.0 V and internal resistance of 4 Ω. When a load resistor is connected across the power supply terminals, a current of 0.5 A flows through the circuit.
   Calculate the load resistance.



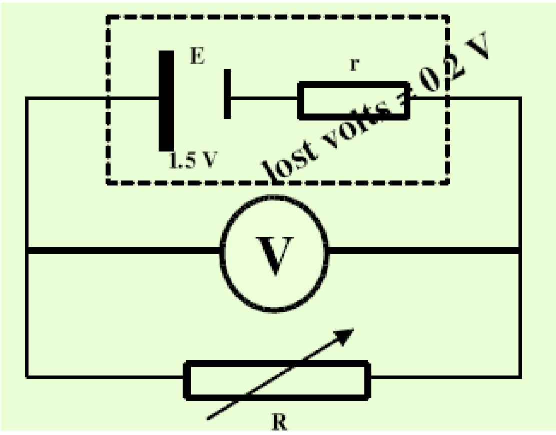

7. The cell in this circuit has an e.m.f. of 5.0 V. The current passing through resistor R is 0.2 A and the voltmeter reads 3.0 V.
   Calculate the cell's internal resistance.



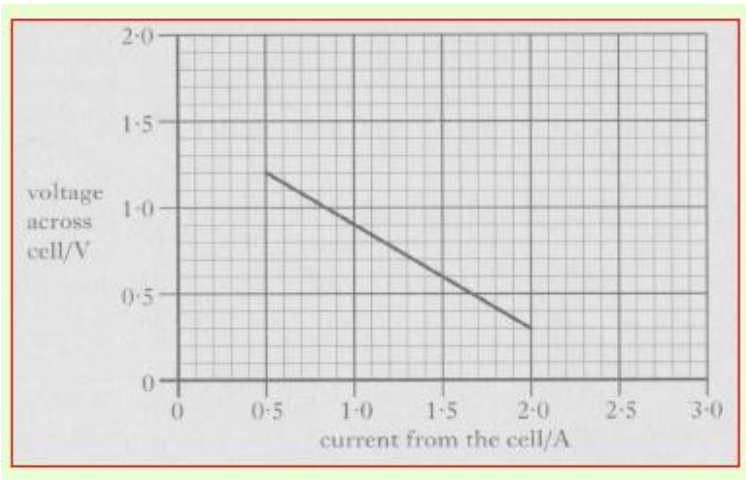

8. The cell has an e.m.f. of 6.0 V and an internal resistance of 1.0 Ω. When the switch is closed, a current of 2.0 A flows. Determine the t.p.d. (voltmeter reading



9. In the following circuit the emf of the cell is 1.5V and the lost volts amount to 0.2V
   (a) Determine the t.p.d.
   (b) (i) As the resistance of R increases, what happens to the value of the circuit current?
   (ii) As a result, explain whether the t.p.d. will increase or decrease.




10. During an experiment to find the internal resistance, emf and short circuit current the following graph was obtained
    (a) Draw the circuit that was used to obtain the results to plot the graph
    (b) From the graph find
    (i) The emf of the cell
    (ii) The internal resistance of the cell
    (iii) The short circuit current



# Capacitors

1. A 50 μF capacitor is charged until the p.d. across it is 100 V.
   (a) Calculate the charge on the capacitor when the p.d. across it is 100 V.
   (b) (i) The capacitor is now 'fully' discharged in a time of 4·0 ms. Calculate the average current during this time.
   (ii) Why is this average current?

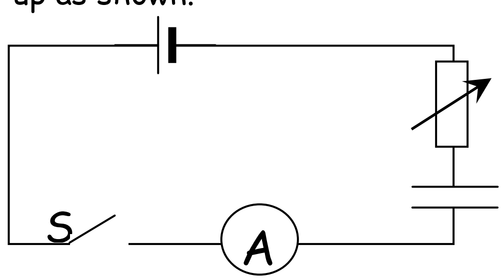
2. A capacitor stores a charge of $3{\cdot}0 \times 10^{-4}$ C when the p.d. across its terminals is 600 V.
   What is the capacitance of the capacitor?

3. A 30 μF capacitor stores a charge of $12 \times 10^{-4}$ C.
   (a) What is the p.d. across its terminals?
   (b) The tolerance of the capacitor is ± 0·5 μF. Express this uncertainty as a percentage.

4. A 15 μF capacitor is charged using a 1·5 V battery.
   Calculate the charge stored on the capacitor when it is fully charged.

5. (a) A capacitor stores a charge of $1{\cdot}2 \times 10^{-5}$ C when there is a p.d. of 12 V across it. Calculate the capacitance of the capacitor.
   (b) A 0·10 μF capacitor is connected to an 8·0 V d.c. supply. Calculate the charge stored on the capacitor when it is fully charged.

6. A circuit is set up as shown.



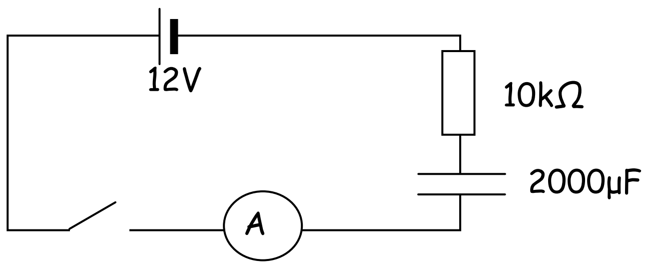

The capacitor is initially uncharged. The switch is now closed.
The capacitor is charged with a constant charging current of $2{\cdot}0 \times 10^{-5}$ A for 30 s. At the end of this time the p.d. across the capacitor is 12 V.

(a) What has to be done to the value of the variable resistor in order to maintain a current constant for the 30 s?
(b) Calculate the capacitance of the capacitor.

7. A 100 μF capacitor is charged using a 20 V supply.
   (a) How much charge is stored on the capacitor when it is fully charged?
   (b) Calculate the energy is stored in the capacitor when it is fully charged.

8. A 30 μF capacitor stores $6{\cdot}0 \times 10^{-3}$ C of charge. How much energy is stored in the capacitor?

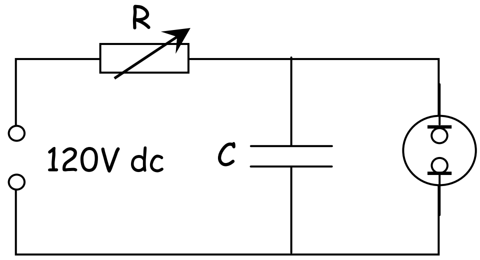
9. The circuit below is used to investigate the charging of a capacitor.




The battery has negligible internal resistance.
The capacitor is initially uncharged. The switch is now closed.

   (a) Describe what happens to the reading on the ammeter from the instant the switch is closed.
   (b) How can you tell when the capacitor is fully charged?
   (c) What would be a suitable range for the ammeter?
   (d) The 10 k Ω resistor is now replaced by a larger resistor and the investigation repeated.
   What is the maximum voltage across the capacitor now?

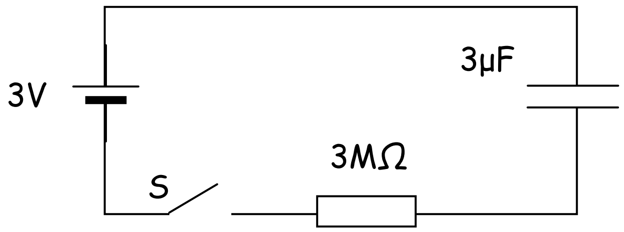
10. In the circuit below the neon lamp flashes at regular intervals.




The neon lamp requires a potential difference of 100 V across it before it conducts and flashes. It continues to glow until the potential difference across it drops to 80 V. While lit, its resistance is very small compared with the resistance of R.

   (a) Explain why the neon bulb flashes.
   (b) Suggest two methods of decreasing the flash rate.

11. A capacitor is connected in a circuit as shown.




The power supply has negligible internal resistance. The capacitor is initially uncharged. $V_R$ is the p.d. across the resistor and $V_C$ is the p.d. across the capacitor. The switch S is now closed.

(a) Sketch graphs of:

(i) $V_C$ against time during charging. Show numerical values for the maximum and minimum values of $V_C$.

(ii) $V_R$ against time during charging. Show numerical values for the maximum and minimum values of $V_R$.

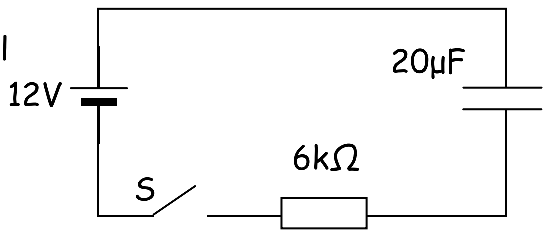
(b) (i) What is the p.d. across the capacitor when it is fully charged?

(ii) Calculate the charge stored by the capacitor when it is fully charged.

(c) Calculate the maximum energy stored by the capacitor.

12. A capacitor is connected in a circuit as shown.

The power supply has negligible internal resistance. The capacitor is initially uncharged. The switch S is now closed.

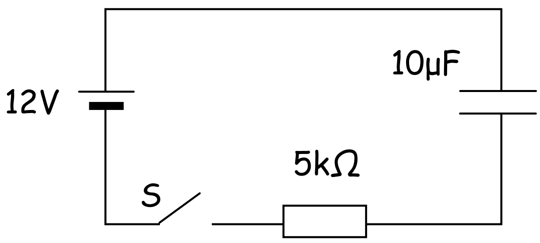



(a) Calculate the value of the initial current in the circuit.

(b) At a certain instant in time during charging the p.d. across the capacitor is 3 V. Calculate the current in the resistor at this time.

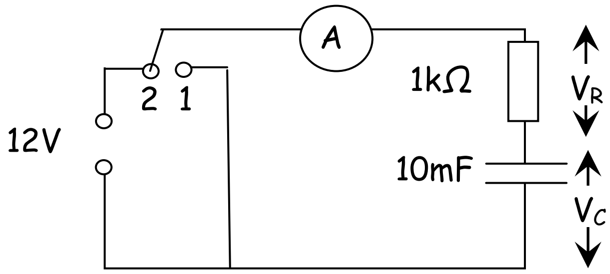
13. The circuit shown is used to charge a capacitor.

The power supply has negligible internal resistance.
The capacitor is initially uncharged.
The switch S is now closed.

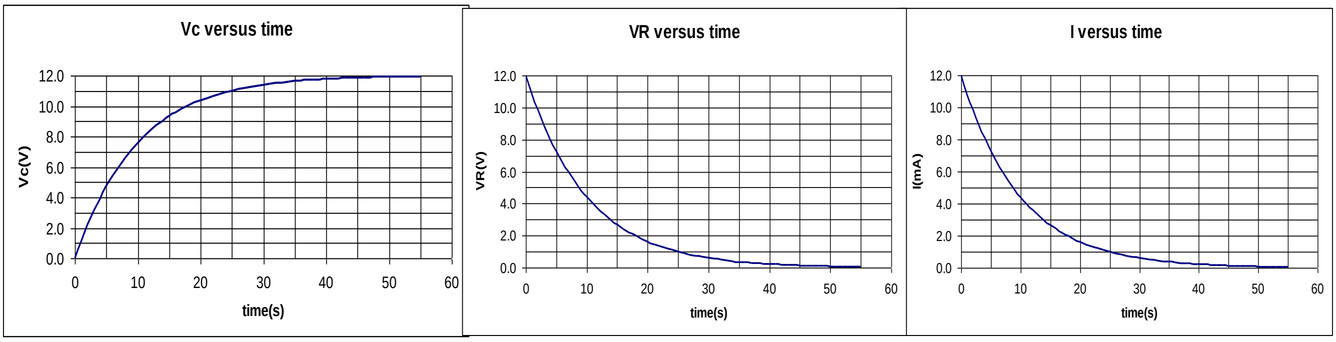



At a certain instant in time the charge on the capacitor is 20 μC. Calculate the current in the circuit at this time.

14. The circuit shown is used to investigate the charge and discharge of a capacitor.




The switch is in position 1 and the capacitor is uncharged.
The switch is now moved to position 2 and the capacitor charges.
The graphs show how $V_C$, the p.d. across the capacitor, $V_R$, the p.d. across the resistor, and $I$, the current in the circuit, vary with time.




(a) The experiment is repeated with the resistance changed to 2kΩ. Sketch the original graphs again and on each graph sketch the new lines which show how $V_C$, $V_R$ and $I$ vary with time.

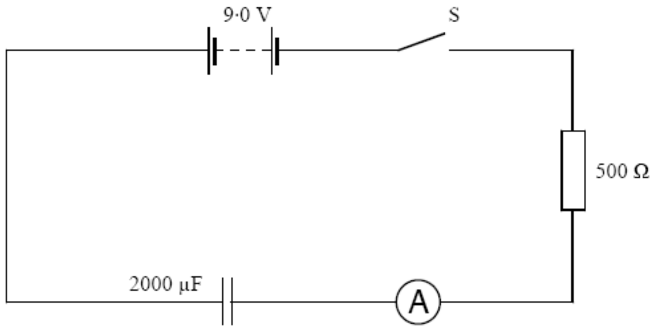
(b) The experiment is repeated with the resistance again at 1 kΩ but the capacitor replaced with one of capacitance 20 mF. Sketch the original graphs again and on each graph sketch the new lines which show how $V_C$, $V_R$ and $I$ vary with time.

(c) At any instant in time during the charging what should be the value of ($V_C$ + $V_R$)?

(d) The original values of resistance and capacitance are now used again and the capacitor fully charged. The switch is now moved to position 1 and the capacitor discharges. Sketch graphs of $V_C$, $V_R$ and $I$ from the instant the switch is moved until the capacitor is fully discharged.

# Capacitors 2

1. An uncharged 2000 μF capacitor and a 500 Ω resistor are connected to a 9·0 Vbattery as shown in Figure




The battery has negligible internal resistance.
The switch S is now closed.

(a) Sketch graphs (no values are required on any of the axes) to show how:

(i) The charging current varies with time

(ii) The potential difference across the capacitor varies with time

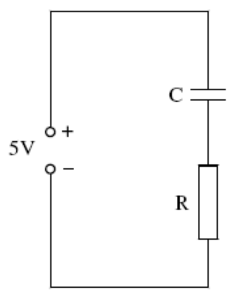
(iii) The potential difference across the capacitor varies with the charge stored on the capacitor.

(b) When the capacitor is fully charged, what is:

(i) The charge stored on the capacitor

(ii) The energy stored in the capacitor?

2. A circuit containing a 5 V supply and a resistor R is used to charge a capacitor C. The circuit diagram is shown below




(a) When the voltage across the capacitor is 5 V, there is a charge of $5 \times 10^{-5}$ C on the capacitor.
How much energy is stored in the capacitor?

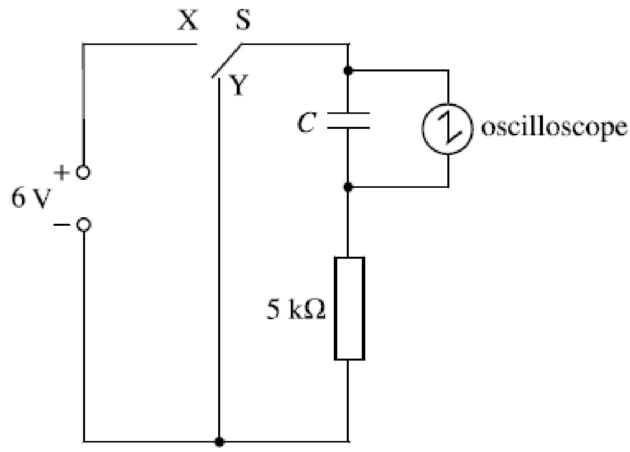
(b) If the resistance is increased what effect does this have on

(i) The maximum energy stored on the capacitor

(ii) The maximum current during the charging process

(iii) The time taken to charge

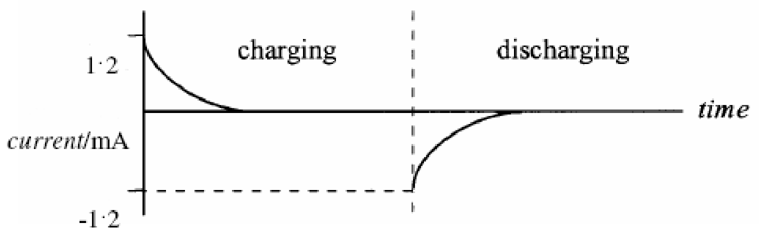
3. The charging and discharging of a capacitor of capacitance *C* are investigated using the circuit shown below




(a) What is the unit of capacitance?

(b) Switch S is connected to X and the capacitor is charged. S is now connected to Y and the capacitor is discharged.

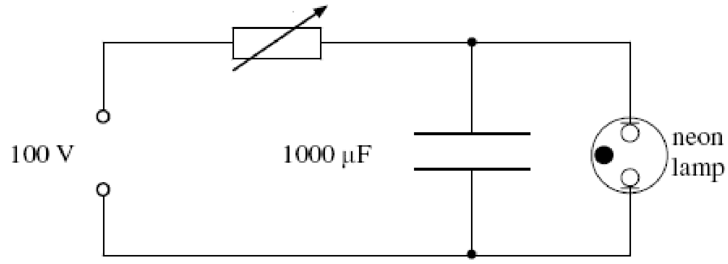
The graph below shows how the current varies with time during the charging and discharging processes.




The 5 k resistor is now replaced with a 2·5 k resistor.

Sketch a graph showing how the current now varies with time during the charging and discharging processes. Show clearly how this graph differs from the graph given in above.

4. The circuit shown below allows the neon lamp to flash on and off




The lamp is off when the voltage across it is less than 80 V.
The capacitor charges up.
When the potential difference across the capacitor reaches 80 V, a current is produced in the neon lamp and the lamp comes on. This current discharges the capacitor. The voltage across the capacitor falls below 80 V and the lamp goes off.
The capacitor then recharges and the process is repeated.

(a) What is meant by the statement:

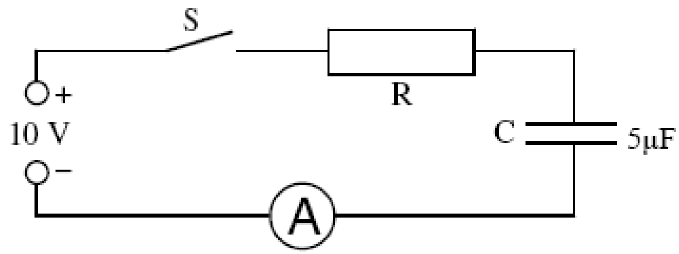
"A capacitor has a capacitance of 1000 μF"

(b) How much electrical charge is stored by the capacitor when the potential difference across the capacitor is 80 V?

(c) Calculate the energy stored in the capacitor just before it discharges.

(d) The resistance of the variable resistor is increased. What effect does this have on the rate at which the neon lamp flashes?
Explain your answer.

5. The circuit shown below is used to charge a 5μF capacitor




(a) The capacitor is initially uncharged.
Switch S is now closed and the capacitor begins to charge. What is the p.d. across C at the instant when the p.d. across R is 6·0 V?

(b) What is the p.d. across the capacitor when it is fully charged?

(c) When the capacitor is fully charged, switch S is opened. A lamp is then connected across the capacitor.

(i) Describe and explain what happens to the current in the lamp.

(ii) Calculate the energy transferred by the lamp.

# Electrons at work

1. In the following descriptions of energy levels in metals, insulators and semiconductors some words and phrases have been replaced by the letters A to N.

   In a metal the _**A**_ band is completely filled and the _**B**_ band is partially filled. The electrons in the _**C**_ band are free to move under the action of _**D**_ so the metal has a _**E**_ conductivity.

   In an insulator there are no free electrons in the _**F**_ band. The energy gap between the two bands is large and there is not enough energy at room temperature to move electrons from the _**G**_ band into the _**H**_ band.
   Insulators have a very _**I**_ conductivity.

   In a pure semiconductor the energy gap between the valence and conduction bands is _**J**_ than in a metal. At room temperature there is enough energy to move some electrons from the _**K**_ band into the _**L**_ band. As the temperature is increased the number of electrons in the conduction band _**M**_ so the conductivity of the semiconductor _**N**_.

   From the table below choose the correct words or phrases to replace the letters.

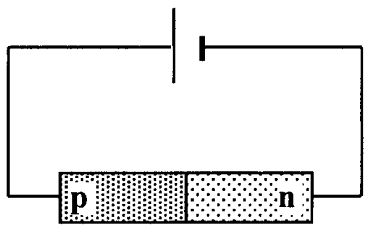
| *Letter* | *List of replacement word or phrase* |
|---|---|
| A, B, C, F, G, H, K, L | conduction, valence |
| D | an electric field, a magnetic field |
| E, I | low, high |
| J | bigger, smaller |
| M, N | decreases, increases |

2. The conductivity of a semiconductor material can be increased by 'doping'.
   (a) Explain what is meant by the 'conductivity' of a material.
   (b) Explain, giving an example, what is meant by 'doping' a semiconductor.
   (c) Why does 'doping' decrease the resistance of a semiconductor material?

3. (a) A sample of pure germanium (four electrons in the outershell) is doped with phosphorus (five electrons in the outer shell). What kind of semiconductor is formed?
   (b) Why does a sample of n-type semiconductor still have a neutral overall charge?

4. Describe the movement of the majority charge carriers when a current flows in:
   (a) an n-type semiconductor material
   (b) a p-type semiconductor material.

5. A p-n junction diode is connected across a d.c. supply as shown.




   (a) Is the diode connected in forward or reverse bias mode?
   (b) Describe the movement of the majority charge carriers across the p-n junction.
   (c) What kind of charge is the only one that actually moves across the junction?

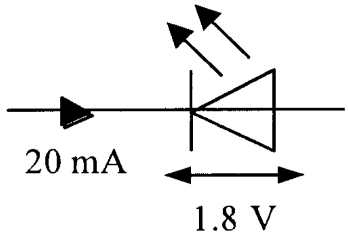
6. When positive and negative charge carriers recombine at the junction of ordinary diodes and LEDs, quanta of radiation are emitted from the junction.

   (a) Does the junction have to be forward biased or reverse biased for radiation to be emitted?
   (b) What form does this emitted energy take when emitted by:
      (i) an LED
      (ii) an ordinary junction diode?

7. A particular LED is measured as having a recombination energy of $3{\cdot}12 \times 10^{-19}$ J.

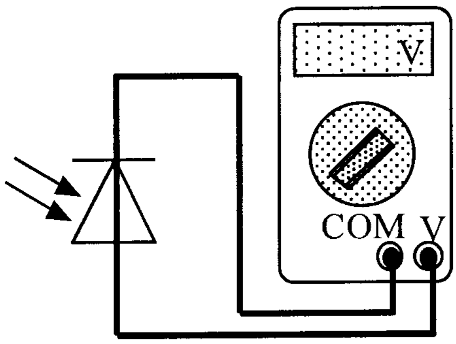
   (a) Calculate the wavelength of the light emitted by the LED.
   (b) What colour of light is emitted by the LED?
   (c) What factor about the construction of the LED determines the colour of the emitted light?

8. (a)State two advantages of an LED over an ordinary filament lamp.
   (b)An LED is rated as follows: operating p.d. 1·8 V, forward current 20 mA. The LED is to be operated from a 6 V d.c. power supply.



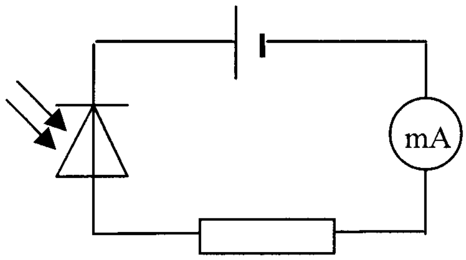

   (i) Draw a diagram of the circuit, including a protective resistor, which allows the LED to operate at its rated voltage.
   (ii) Calculate the resistance of the protective resistor that allows the LED to operate at its rated voltage.

9. The diagram shows a photodiode connected to a voltmeter.




(a) In which mode is the photodiode operating?
(b) Light is now incident on the photodiode.
   (i)Explain how an e.m.f. is created across the photodiode.
   (ii)The irradiance of the light incident on the photodiode is now increased. Explain why this increases the e.m.f. of the photodiode.

10. A photodiode is connected in reverse bias in a series circuit as shown.




(a) In which mode is the photodiode is operating?
(b) Why is the photodiode connected in reverse bias?
(c) What is the current in the circuit when the photodiode is in darkness? Explain your answer.
(d) The irradiance of the light on the photodiode is now increased.
(i)What is the effect on the current in the circuit?
(ii)What happens to the effective 'resistance' of the photodiode? Explain why this happens.

# Solutions

## Section 1: Electrons and energy

## a.c./d.c.

1. (a) 325 V
   (b) 100 times
2 (c) $V_{r.m.s.} = 0.71\ V_{peak}$
3. (a) 14 V
4. (a) 8.5 V
   (b) (i) 60 V
   (ii) 42 V
5. (a) (i) 100 Hz
   (ii) ±2 Hz
   (b) (i) 3 waves
   (ii) $\frac{3}{4}$ waves
6. 5 cm

## Circuits

1. 0.64 C
2. $5 \times 10^3$ A
3. $2{\cdot}0 \times 10^4$ s
4. 6 V
5. (a) $I = 0{\cdot}1$ A
   (b) $I = 0{\cdot}5$ A, $V = 4{\cdot}5$ V
   (c) $I = 2$ A, $V = 10$ V
6. (a) 5 Ω
   (b) 6 Ω

7. (a) 25 Ω
   (b) 25 Ω
   (c) 24·2 Ω
   (d) 13·3 Ω
   (e) 22·9 Ω
8. 3·75 V
9. (a) 60 W
   (b) 327 W
   (c) 500 W
10. (a) 7·7 A
    (b) 1763 W
11. 9000 J
12. $I$ = 0·67 A, $V$ = 4 V
13. (a) 0·67 A
    (b) 0·13 A
    (c) 1·34 V
14. 240 Ω
15. (a) B- negative, A -positive
    To limit the current and to protect the LED
    (c) 175 Ω
16. (a) series $V_1 + V_2 = V_s$ parallel $V_s = V_1 = V_2$
    (b) series $I_1 = I_2 = I_3$ parallel $I_s = I_1 + I_2$
17. (a) potential divider
    (b) $V_1/V_2 = R_1/R_2$
18. (a) $V_1$ = 0·2 V, $V_2$ = 9·8 V
    (b) $V_1$ = 2·5 V, $V_2$ = 7·5 V
19. (a)R decreases,$V_2$ decreases &$V_1$ increases
20. (a) 4 V
    (b) 2.5 V
    (c) 3 V

## Potential divider circuits

1. (a) $Rs = R_1 + R_2$
   (b) $1/Rp = 1/R_1 + 1/R_2$
2. (a) 1.1k
   (b) 3.3k
   (c) 1.47k
3. 6 Ω
4. (a) 8V
   (b) 5 V
   (c) 16.4 V
5. (a) (i) 2.5 V (ii) 6.75 V
   (b) (i) 1.67 V (ii) 5.4 V
6. (a) (i) 3.33 V (ii) 5.4 V
   (b) (i) 2.5 V (ii) 3.86 V
7. (a) 15kΩ
   (b) 16V
   (c) 10.1V

## Potential Divider 2

1. (a) 3V
   (b) -0.79V
   (c) 0V
2. (a) 0.6V
   (b) (i) replace 9k with 12k (ii) replace 3k with 4k
3. (a) 9Ω
   (b) 45kΩ
4. (a) 18Ω
   (b) 90kΩ

# Electrical sources and internal resistance

1. Emf is the amount of energy given to each coulomb of charge. This is the max voltage
2. (a) 6 Ω
   (b) $A_1$ = 2 A, $A_2$ = 1·5 A
   (c) 6 V
   (d) 24 W
3. (a) In 12Ω & 8 Ω current is 11·5A; in 24Ω current is 0A
   (b) In 12Ω current is 12·8A; in 24Ω current is 3·2A; in 8Ω current is 9·6A
4. (a) $R_1$ = 230 Ω $R_2$ = 115 Ω
   (b) Low 230 Ω high 690 Ω
5. (a) 4 Ω
   (b) 36 W
6. (a) 2·0 V
   (b) 1·6 V
   (c) $r$ = 0·5 Ω $R$ = 2 Ω
   (d) 1·3 A, 1·3 V
7. 10 Ω
8. 5 Ω
9. 12 Ω
10. (a) 1·3 V
    (b)(i) R increases I decreases since V=IR
    (ii) R increases I decreases , LV decrease, since LV = Ir, V increases since LV = E - V
11. 0·30 A
12. (a) 3·0 Ω
    (b) 3·7 Ω

13. 4·0 V
14. (b) (i) 1·1 V, the intercept on the *y*-axis
    (ii) 4·2 Ω the gradient of the line
    (iii) 0·26 A the intercept on the *x*-axis
15 (a) 6 V
   (b) 0·1 Ω
   (c) 60 A
   (d) (i) 5·6 V (ii) 21 W
16. (a). Teacher check – re-arrange equation
   (b) 0·147, 0·264,0·382, 0·.500, 0·617, 0·735, 0·855
   (c) Teacher Check- graph
   (d) (i) 2·5 Ω
       (ii) 17 V
   (e) 6·8 A

## Internal Resistance

1. (a) 0.5A
   (b) 5V
   (c) 1V
   (d) 3A
2. (a) 2V
   (b) 1.6V
   (c) 0.4V
   (d) 2 Ω
   (e) 0.5 Ω
3. (a) 4.5V
   (b) 3.0V
   (c) 1.5V
   (d) 0.5A
   (e) 3 Ω

4. 0.3A
5. 5 Ω
6. 12 Ω
7. 10 Ω
8. 4V
9. (a) 1.3V
   (b) (i)As R increases I decreases
   (ii)As I decreases then LV decreases, since LV = Ir and LV = E – V then V increases

10. (a) Teacher check - circuit
    (b) (i) 1.5V
    (ii) 0.6 Ω
    (iii) 2.5A

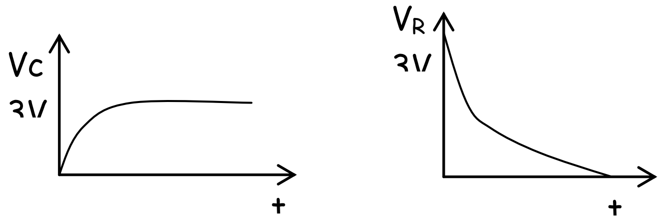
## Capacitors

1. (a) $5{\cdot}0 \times 10^{-3}$ C
   (b) (i) 1·25 A
   (ii) I is a max then falls to zero
2. 0·5 μF
3 (a) 40 V
  (b) 1·7%
4. $2{\cdot}25 \times 10^{-5}$ C
5. (a) 1·0 μF
   (b) 0·8 μC
6. (a) Rv decreased
   (b) 50 μF
7. (a) $2{\cdot}0 \times 10^{-3}$ C
   (b) 0·020 J
8. 0·60 J

9. (a) Max I falls to zero
   (b) Reading on ammeter is 0 A
   (c) 0 to 2 mA (max. current 1·2 mA)
   (d) 12 V

10. (a) C is fully charged and discharges through neon bulb (making it light) when it reaches 80V the C starts to charge back up and bulb is off, when it reaches 100V the process repeats.
    (b) increase R or C

11. (a)

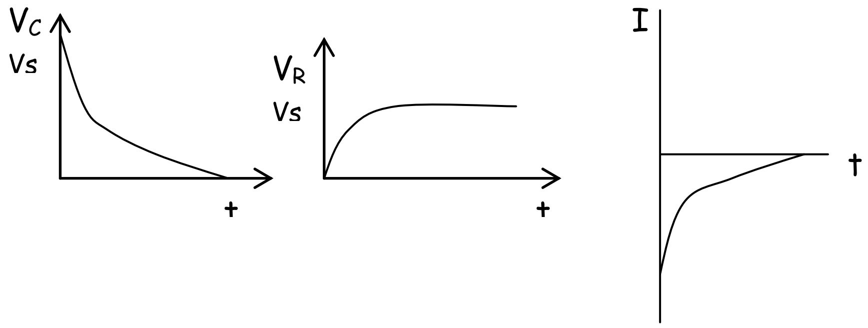



(b) (i) 3V
    (ii) 9 μC
(c) $1.35 \times 10^{-5}$J

12. (a) 2 mA
    (b) 1·5 mA

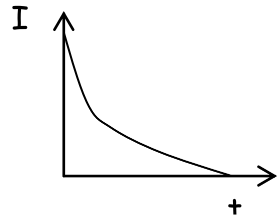
13. 2 mA

14. (a)(b) Same shape graphs but time to max or zero value is longer.
    (c) $V_C + V_R = V_S$
    (d)

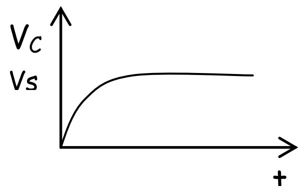


# Capacitors 2

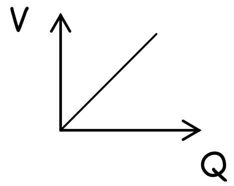
1. (a) (i)




(ii)




(iii)




(b) (i) 0.018C
(ii) 0.08J

2. (a) $1.25 \times 10^{-4}$J
(b)(i) no change
(ii) R increases then initial I decreases
(iii) R increases time taken to charge increases

3 (a) farad
(b) Same shape graph but longer time to reach zero

4. (a) $1000 \times 10^{-6}$ coulombs of charge stored for every Volt
(b) 0.08C
(c) 3.2J
(d) R increases time taken increases, flashes less frequent

5. (a) 4V
(b) 10V
(c)(i) lamp lights then dims to off
(ii) $2.5 \times 10^{-4}$ J

# Electrons at work

1. A = valence; B = conduction; C = conduction; D = an electric field; E = high; F = conduction; G = valence; H = conduction; I = low; J = smaller; K = valence; L = conduction; M = increases; N = increases.
2. (a) The ability to allow charges to flow
   (b) adding an impurity, eg Arsenic (valency 5) to silicon (valency 4)
   (c) Increases the no. of charge carriers per unit volume
3. (a) n - type
   (b) for every electron there is a proton
4. (a) negative electrons move
   (b) positive holes move
5. (a) forward bias
   (b) barrier is broken down, electrons and holes migrate towards each other
   (c) electrons
6. (a) forward bias
   (b)(i) light energy in the visible spectrum range
   (ii) heat energy
7. (a) 638 nm
   (b) Red
   (c) Colour of light emitted depends on the band gap
8. (a) lasts longer, all electrical energy is changed to light energy
   (b) (i) Teacher Check – circuit (ii) 210 Ω

9. (a) Photovoltaic
   (b) (i) When a photon of light enters the junction an electron hole pair is produced
   (ii) Increasing the irradiance, increases the no. of photons entering the junction per second thereby increasing the no. of electron hole pairs produced, pd increases
10. (a) Photoconductive
   (b) No I flows unless light falls on it
   (c) In Dark no photons hitting junction, no electron hole pairs produced, I = 0A
   (d)(i) Irradiance inreases, I increases
   (ii) Effective R decreases