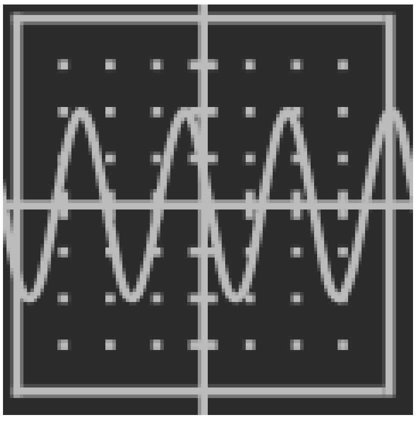
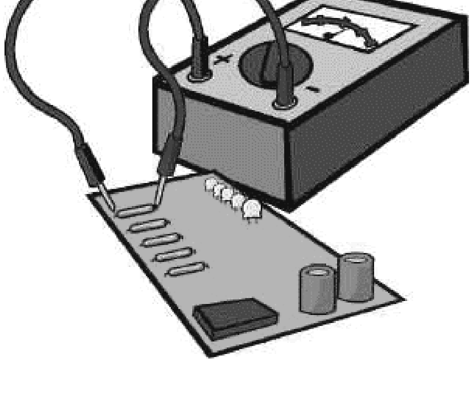
HIGHER PHYSICS

UNIT 3 — ELECTRICITY

WRITTEN QUESTIONS

2000—2019





Unit 3 Homework

1. **Monitoring & Measuring A.C.**

   2000 Qu 26, 2003 Qu 25a, 2004 Qu 22b

2. **Circuits**

   2001 Qu 24, 2002 Qu 24, 2009 Qu 24, 2015 Qu 25

3. **Capacitors**

   2001 Qu 25a, 2004 Qu 25, 2009 Qu 26

4. **Semiconductors**

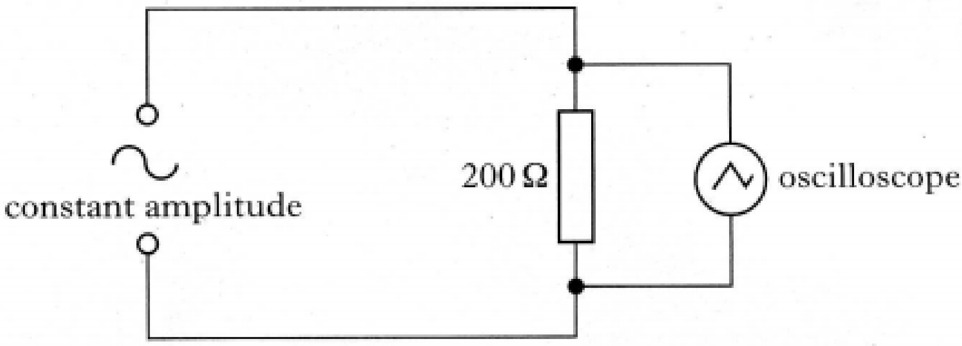
   2000 Qu 25a, 2002 Qu 29a,b(i), 2005 Qu 21b, 2013 Qu 31a

Monitoring & Measuring A.C.

Monitoring & Measuring A.C.

2000 Q.26

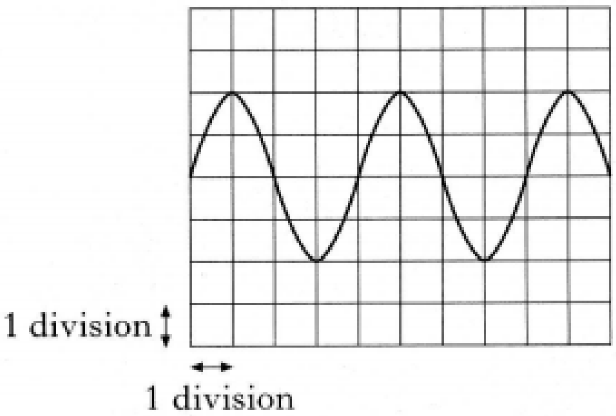
A circuit is set up as shown below. The amplitude of the output voltage of the a.c. supply is kept constant.



The settings of the controls on the oscilloscope are as follows:

y-gain setting = 5 V/division
time-base setting = 2·5 ms/division

The following trace is displayed on the oscilloscope screen.

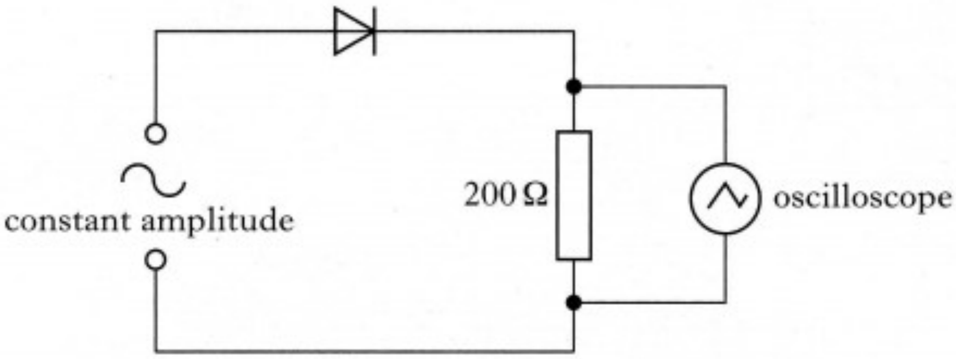


(*a*) (i) Calculate the frequency of the output from the a.c. supply.

(ii) Calculate the **r.m.s. current** in the 200 Ω resistor. **5**

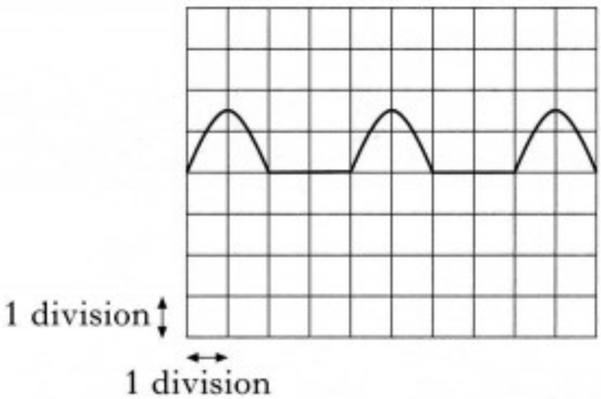
Return to Monitoring and Measuring AC Contents

(*b*) A diode is now connected in the circuit as shown below.



The settings on the controls of the oscilloscope remain unchanged.

Connecting the diode in the circuit causes **changes** to the original trace displayed on the oscilloscope screen. The new trace is shown below.



Describe and explain the changes to the original trace. **2**

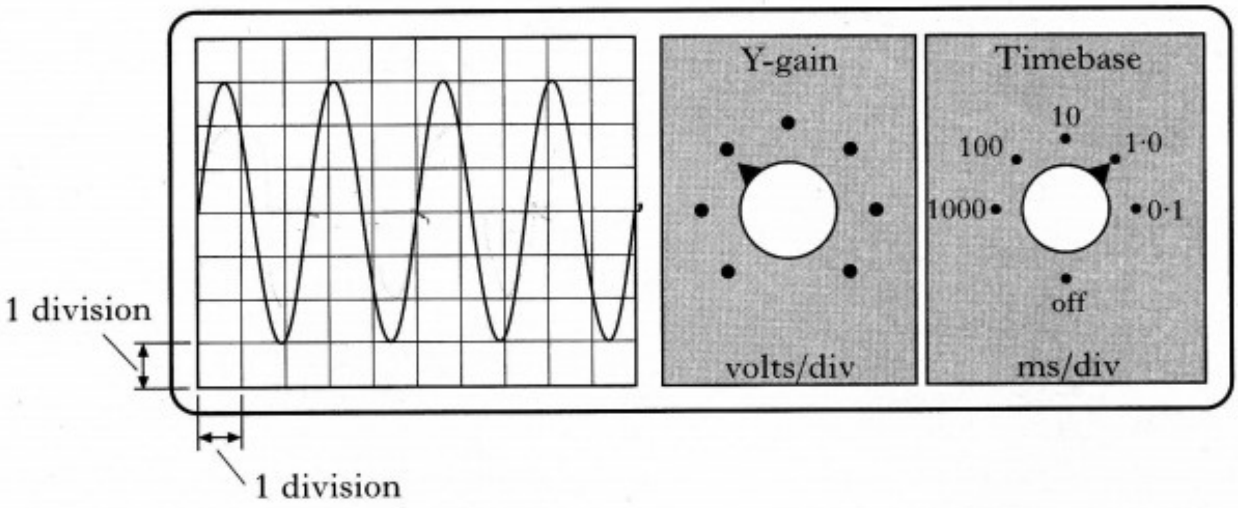
(7)

Return to Monitoring and Measuring AC Contents

2003 Q.25 a

(*a*) A signal generator is connected to an oscilloscope. The output of the signal generator is set to a peak voltage of 15 V.

The following diagram shows the trace obtained, the Y-gain and the timebase controls on the oscilloscope. The scale for the Y-gain has been omitted.



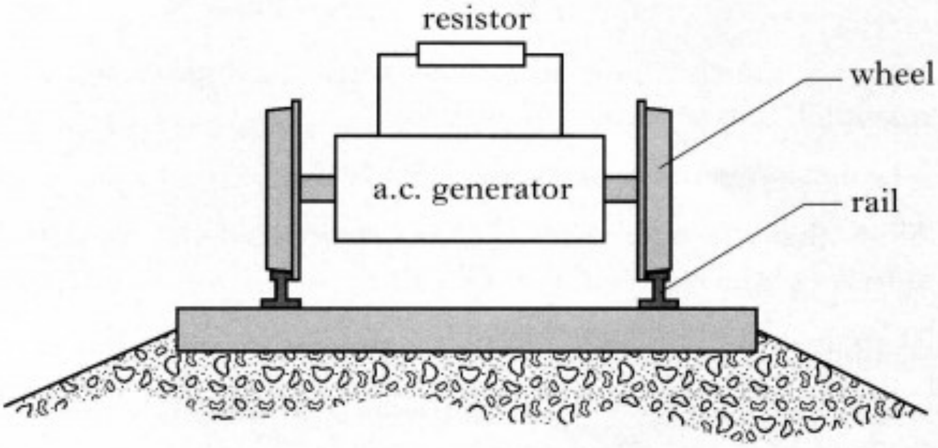
Calculate:

(i) the Y-gain setting of the oscilloscope;

(ii) the frequency of the signal in hertz. **3**

2004 Q.22 b

(*b*) Part of the train's braking system consists of an electrical circuit as shown in the diagram.



While the train is braking, the wheels drive an a.c. generator which changes kinetic energy into electrical energy. This electrical energy is changed into heat in a resistor. The r.m.s. current in the resistor is $2{\cdot}5 \times 10^3$ A and the resistor produces 8·5 MJ of heat each second.

Calculate the peak voltage across the resistor. **3**

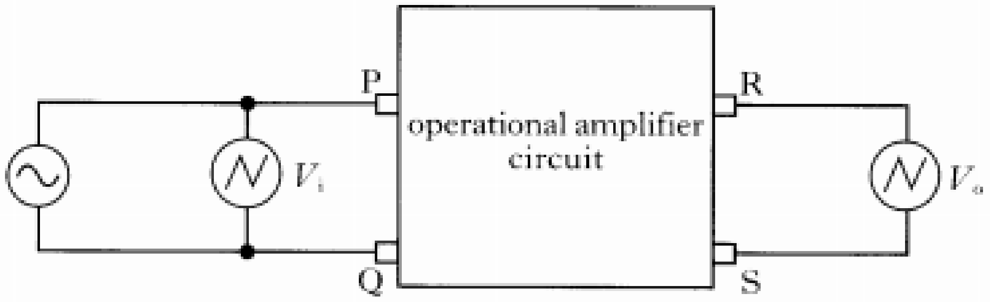
Return to Monitoring and Measuring AC Contents

2006 Q.26 a

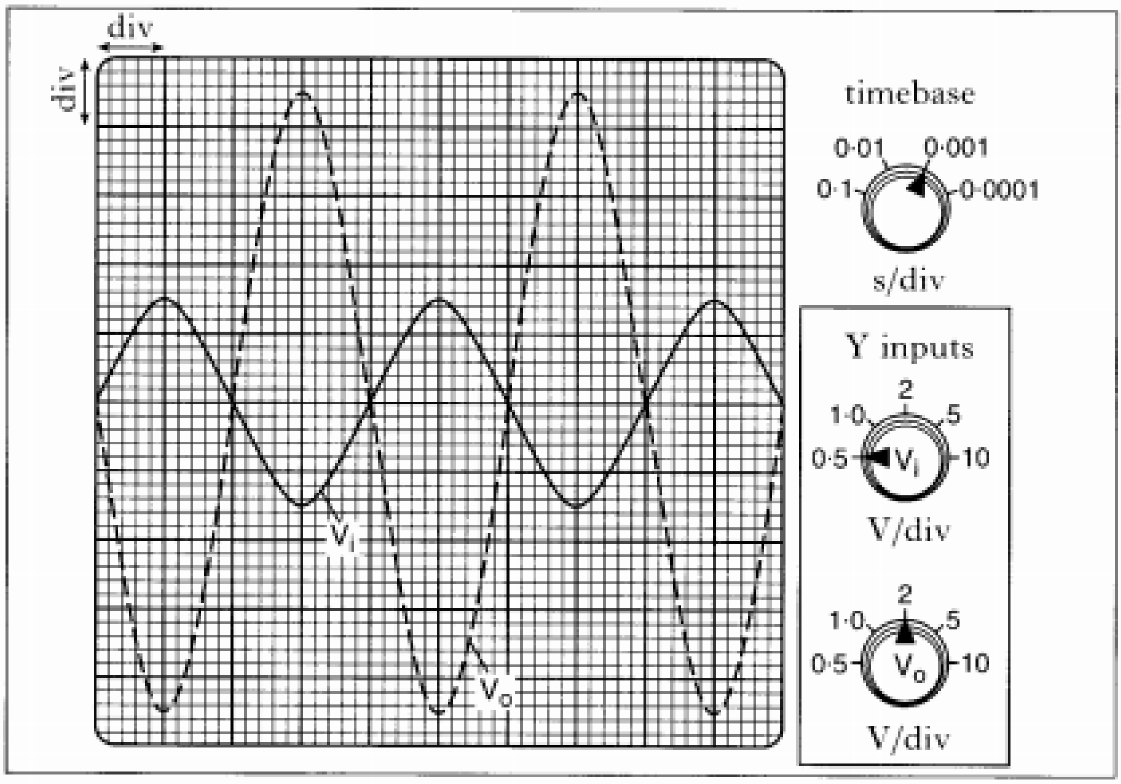
A double beam oscilloscope has two inputs which allows two signals to be viewed on the screen at the same time.

A double beam oscilloscope is connected to the input terminals **P** and **Q** and the output terminals **R** and **S** of a box containing an operational amplifier circuit.

The operational amplifier is operating in the inverting mode.



(*a*) The oscilloscope control settings and the two traces displayed on its screen are shown in the diagram.



(i) Calculate the frequency of the a.c. supply. **2**

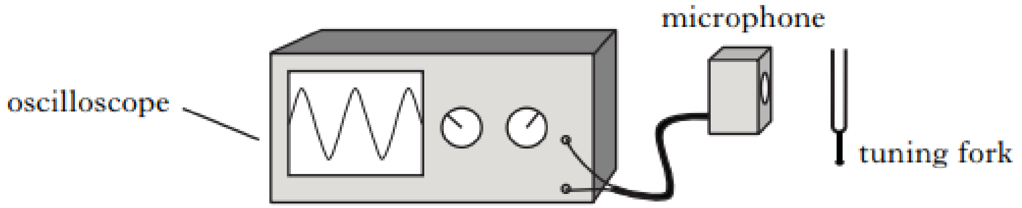
(ii) Calculate the voltage gain of the amplifier circuit. **2**

(iii) Calculate the r.m.s. value of the output voltage of the amplifier circuit. **2**

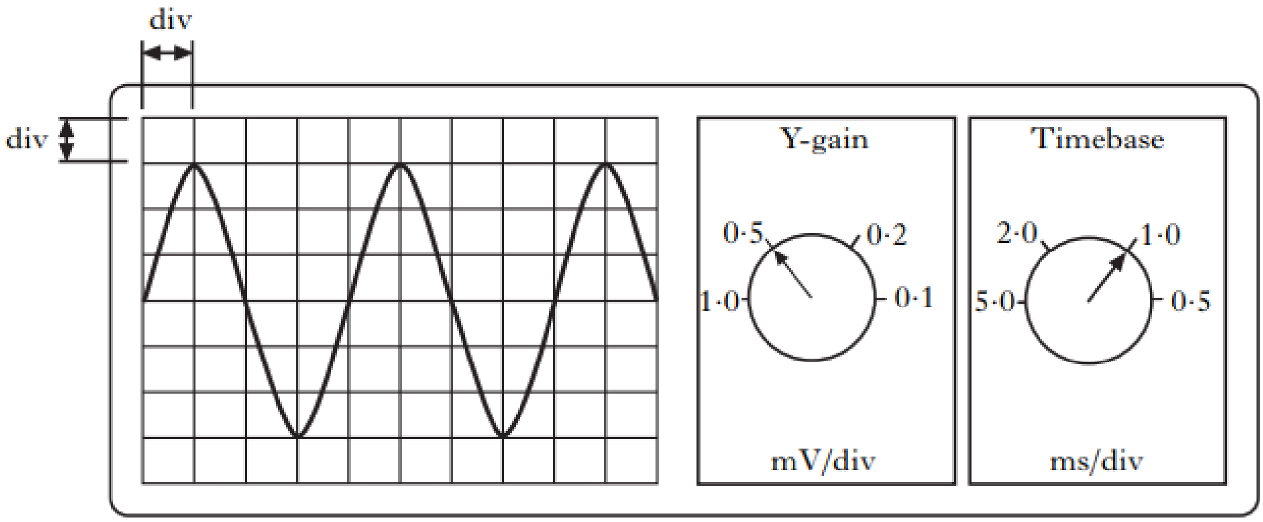
Return to Monitoring and Measuring AC Contents

2009 Q.25 a

(*a*) A microphone is connected to the input terminals of an oscilloscope. A tuning fork is made to vibrate and held close to the microphone as shown.



The following diagram shows the trace obtained and the settings on the oscilloscope.



Calculate:

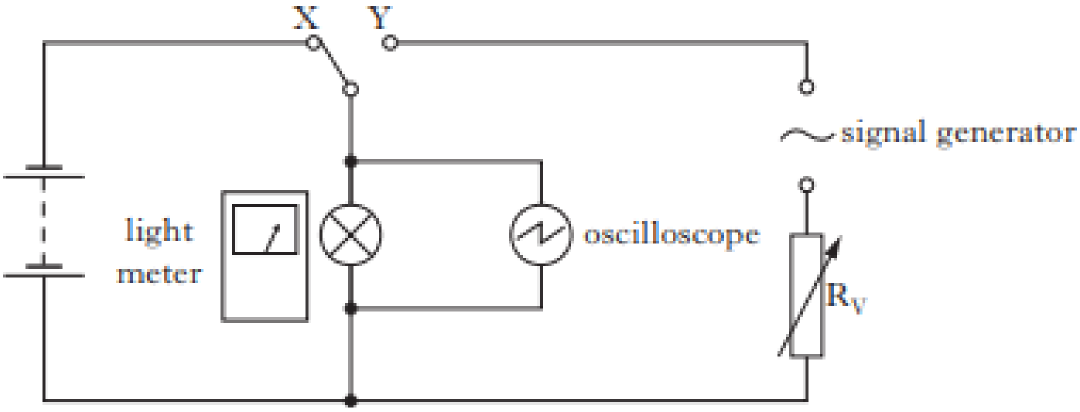
(i) the peak voltage of the signal; **1**

(ii) the frequency of the signal. **2**

Return to Monitoring and Measuring AC Contents

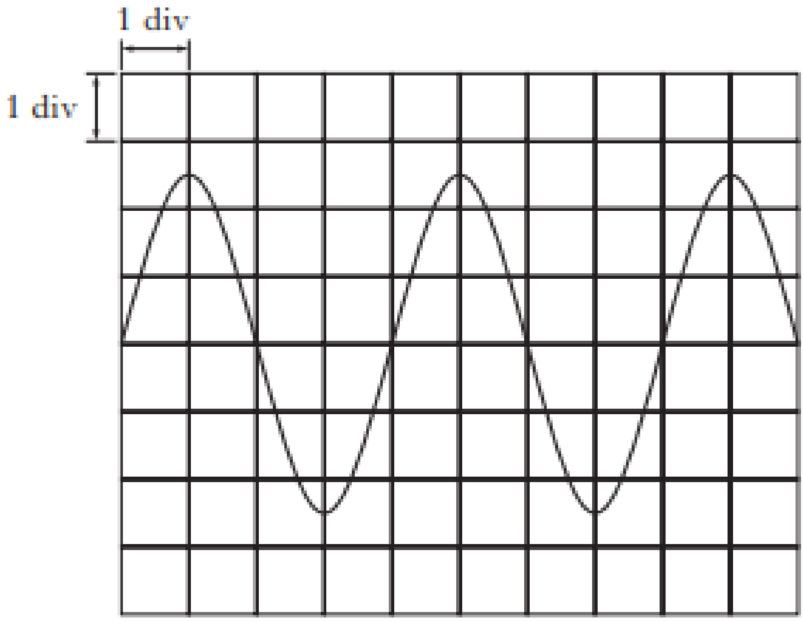
2013 Q.26

The circuit shown is used to compare the voltage from a battery and the voltage produced by a signal generator.



The switch is connected to X and the voltage across the lamp is 2·30 V. The reading on the light meter is recorded.

The switch is now connected to Y. The resistance of R_V is adjusted until the light meter reading is the same as before. The trace on the oscilloscope screen is shown.



(*a*) The timebase setting is 0·01 s/div.

Calculate the frequency of the output voltage of the signal generator. **2**

(*b*) Calculate the peak value of the voltage displayed on the oscilloscope. **2**

(*c*) With the switch still connected to Y, the signal generator frequency is now doubled without altering the output voltage.

State what happens to the reading on the light meter.

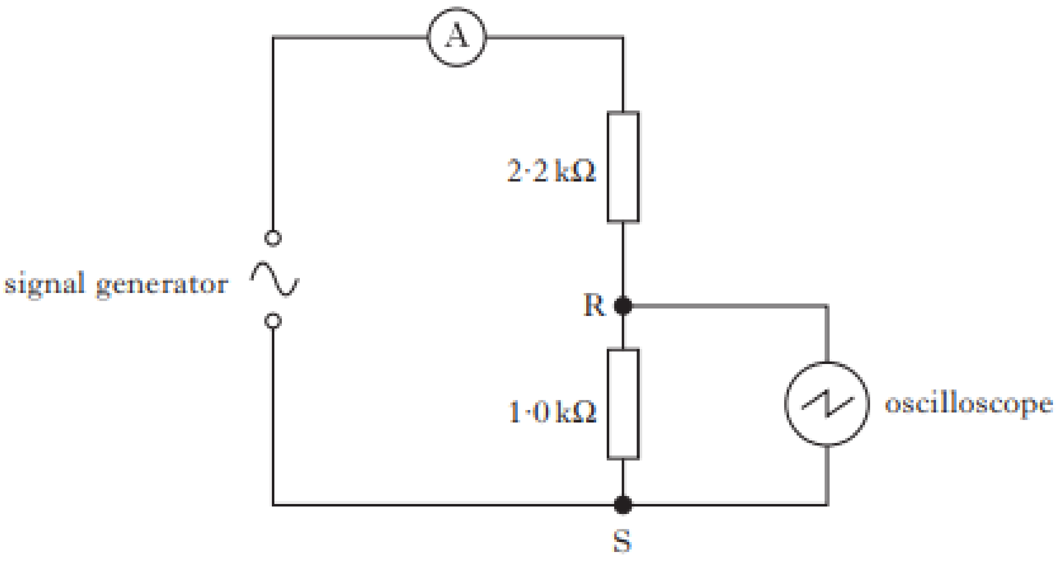
Justify your answer. **1**

(5)

Return to Monitoring and Measuring AC Contents

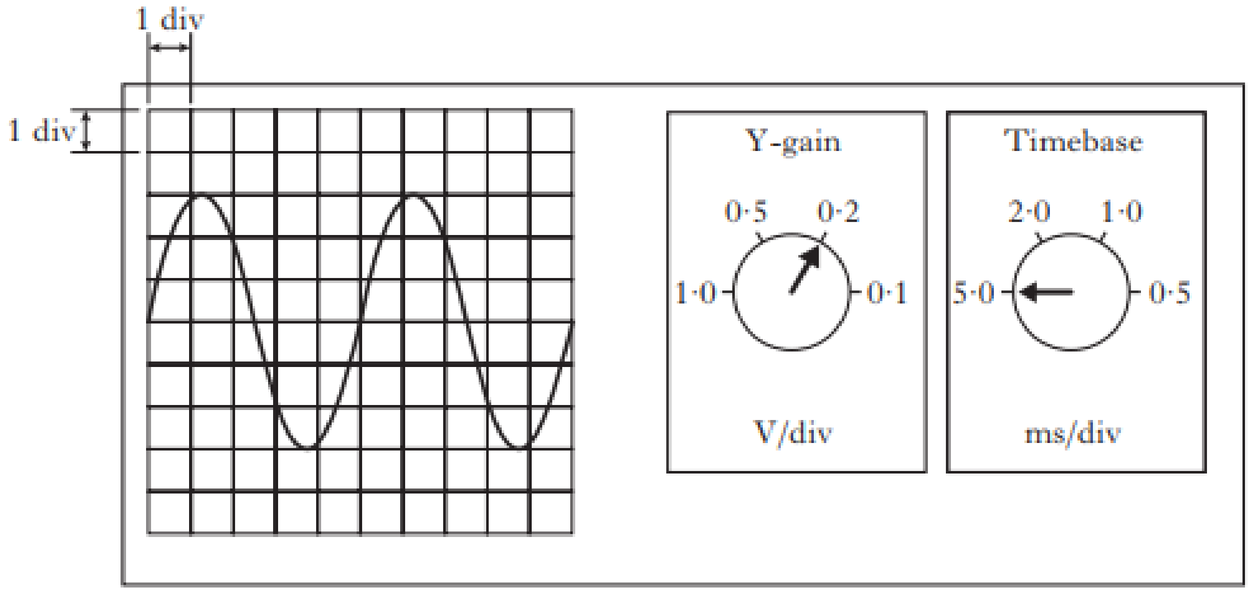
2014 Q.27 a

A student sets up the following circuit to investigate alternating current.



(*a*) An oscilloscope is connected across the 1·0 kΩ resistor.

The oscilloscope control settings and the trace displayed on its screen are shown.



(i) Determine the peak voltage across the 1·0 kΩ resistor. **1**

(ii) Calculate the r.m.s. current in the 1·0 kΩ resistor. **3**

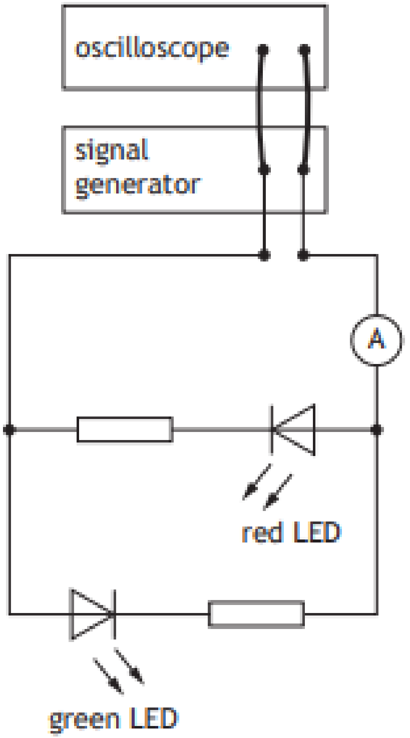
(iii) Calculate the r.m.s. output voltage of the signal generator. **2**

Return to Monitoring and Measuring AC Contents

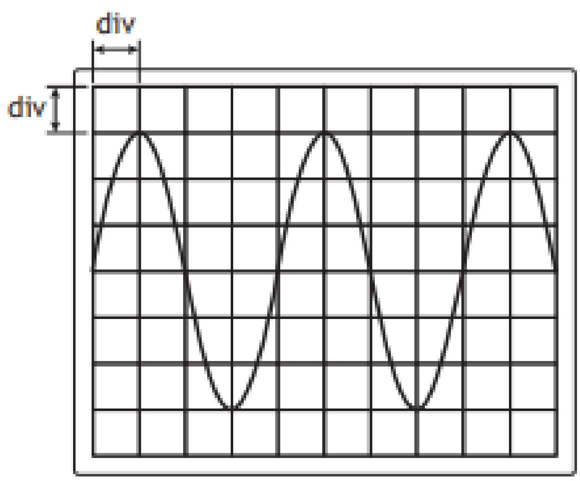
2018 Q.12 a

A student carries out a series of experiments to investigate alternating current.

(a) A signal generator is connected to an oscilloscope and a circuit as shown.



The output of the signal generator is displayed on the oscilloscope.



The Y-gain setting on the oscilloscope is 1·0 V/div.

The timebase setting on the oscilloscope is 0·5 s/div.

(i) Determine the peak voltage of the output of the signal generator. **1**

Space for working and answer

Return to Monitoring and Measuring AC Contents

2018 Q.12 a cont.

(ii) Determine the frequency of the output of the signal generator. **3**

Space for working and answer

(iii) The student observes that the red LED is only lit when the ammeter gives a positive reading and the green LED is only lit when the ammeter gives a negative reading.

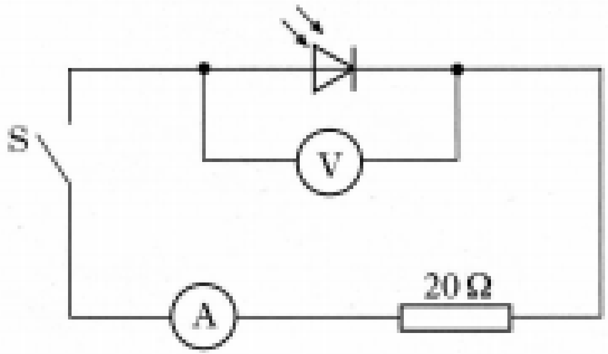
Explain these observations. **2**

Circuits

Return to Homework Contents

2000 Q.25 b,c

A photodiode is connected in a circuit as shown below.



Switch S is open.

Light is shone on to the photodiode.

A reading is obtained on the voltmeter.

(*a*) (i) State the mode in which the photodiode is operating.

(ii) Describe the effect of light on the material of which the photodiode is made.

(iii) The intensity of the light on the photodiode is increased.

What happens to the reading on the voltmeter? **3**

(*b*) Light of a constant intensity is shone on to the photodiode in the circuit shown above.

The following measurements are obtained with S open and then with S closed.

	S open	S closed
reading on voltmeter/V	0·508	0·040
reading on ammeter/mA	0·00	1·08

(i) What is the value of the e.m.f. produced by the photodiode for this light intensity?

(ii) Calculate the internal resistance of the photodiode for this light intensity. **3**

Return to Circuits Contents

2000 Q.25 b,c cont.

(*c*) In the circuit above, the 20 Ω resistor is now replaced with a 10 Ω resistor.

The intensity of the light is unchanged.

The following measurements are obtained.

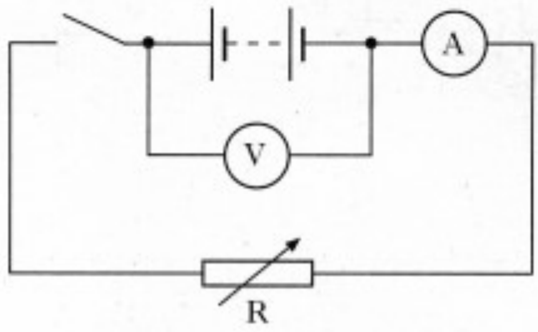
	S open	S closed
reading on voltmeter/V	0·508	0·011

Explain why the reading on the voltmeter, when S is closed, is smaller than the corresponding reading in part (*b*). **2**

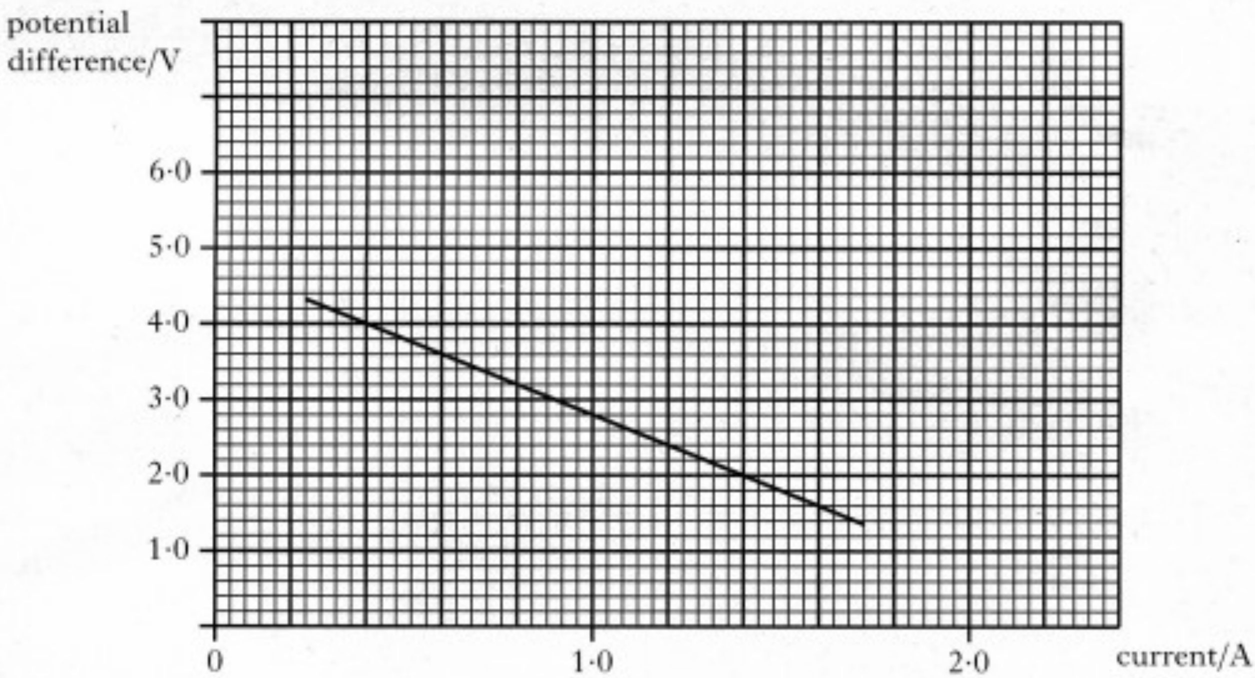
Return to Circuits Contents

2001 Q.24

(*a*) The following circuit is used to measure the e.m.f. and the internal resistance of a battery.



Readings of current and potential difference from this circuit are used to produce the following graph.



Use information from the graph to find:

(i) the e.m.f. of the battery, in volts;

(ii) the internal resistance of the battery. **3**

(*b*) A car battery has an e.m.f. of 12 V and an internal resistance of 0·050 Ω.

(i) Calculate the short circuit current for this battery.

(ii) The battery is now connected in series with a lamp. The resistance of the lamp is 2·5 Ω. Calculate the power dissipated in the lamp. **5**

(8)

Return to Circuits Contents

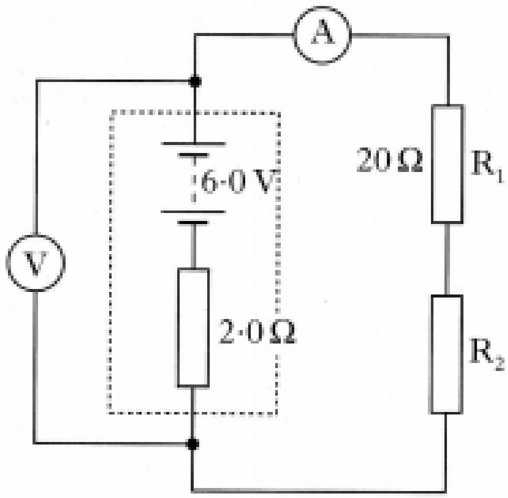
2002 Q.24

A battery has an e.m.f. of 6·0 V and internal resistance of 2·0 Ω.

(*a*) What is meant by an *e.m.f. of 6·0 V*? **1**

(*b*) The battery is connected in series with two resistors, R_1 and R_2. Resistor R_1 has a resistance of 20 Ω.

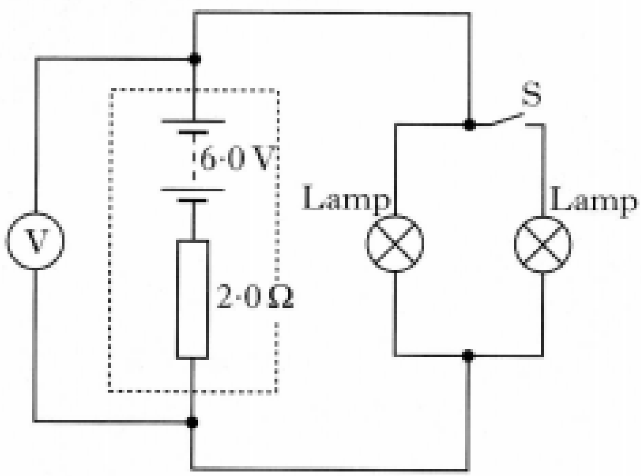
The reading on the ammeter is 200 mA.



(i) Show by calculation that R_2 has a resistance of 8·0 Ω.

(ii) Calculate the reading on the voltmeter. **4**

(*c*) The battery is now connected to two identical lamps as shown below.



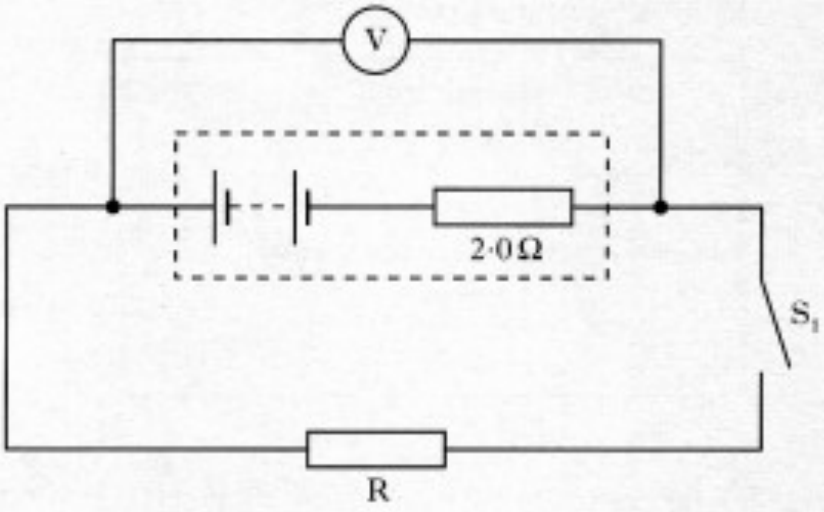
Describe and explain what happens to the reading on the voltmeter when switch S is closed. **2**

(7)

Return to Circuits Contents

2004 Q.24

A student sets up the circuit shown.



The internal resistance of the battery is 2·0 Ω.

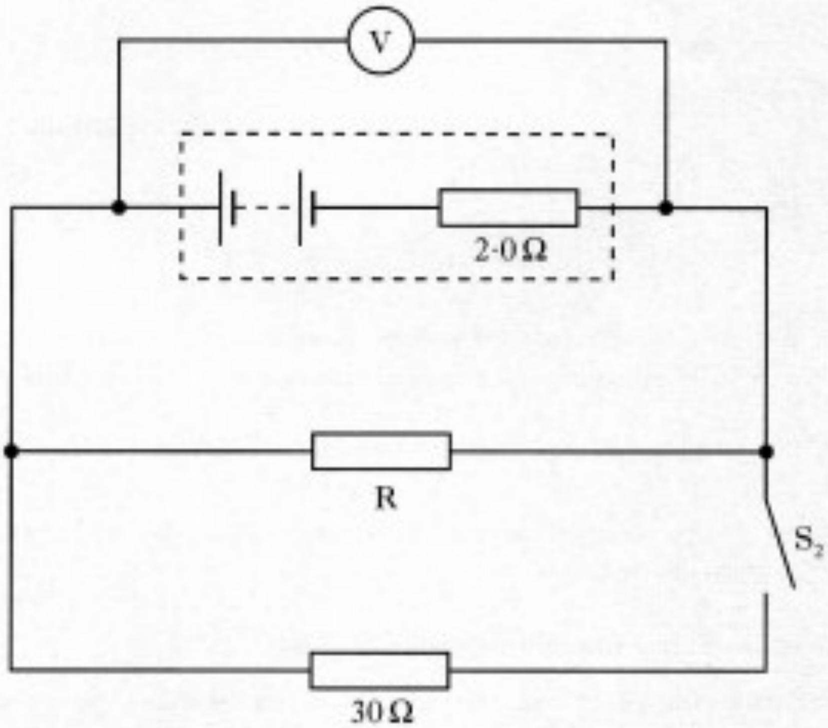
With S_1 open, the student notes that the reading on the voltmeter is 9·0 V.

The student closes S_1 and notes that the reading on the voltmeter is now 7·8 V.

(*a*) (i) Calculate the resistance of resistor R.

(ii) Explain why the reading on the voltmeter decreases when S_1 is closed. **4**

(*b*) The student adds a 30 Ω resistor and a switch S_2 to the circuit as shown.



The student now closes S_2.

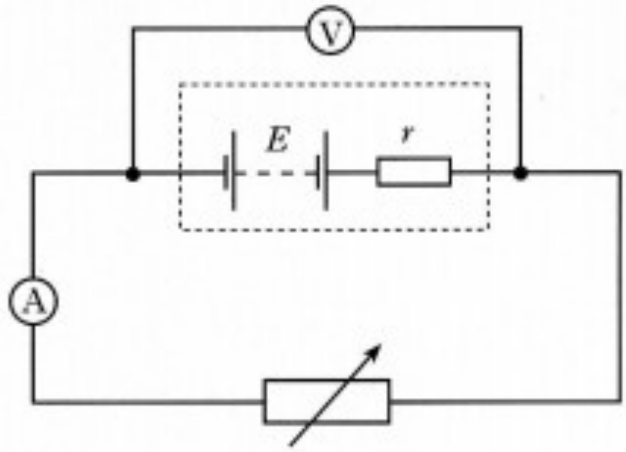
Explain what happens to the reading on the voltmeter. **2**

(6)

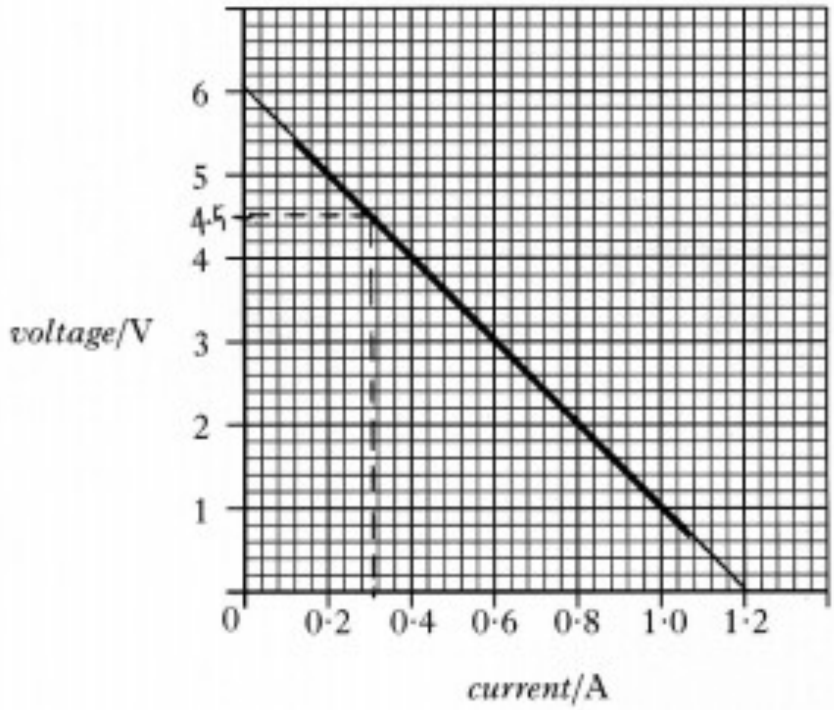
Return to Circuits Contents

2005 Q.25

A student sets up the following circuit to find the e.m.f. E and the internal resistance r of a battery.



Readings from the voltmeter and ammeter are used to plot the following graph.



(*a*) What is meant by the term *e.m.f.*? **1**

(*b*) (i) Use the graph to determine:

(A) the e.m.f.; **1**

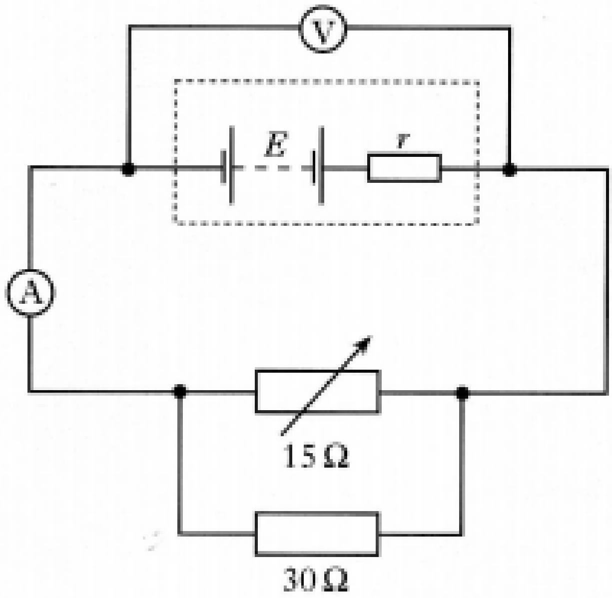
(B) the internal resistance of the battery. **2**

(ii) Show that the variable resistor has a value of 15 Ω when the current is 0·30 A. **1**

Return to Circuits Contents

2005 Q.25 cont.

(c) Without adjusting the variable resistor, a 30 Ω resistor is connected in parallel with it.



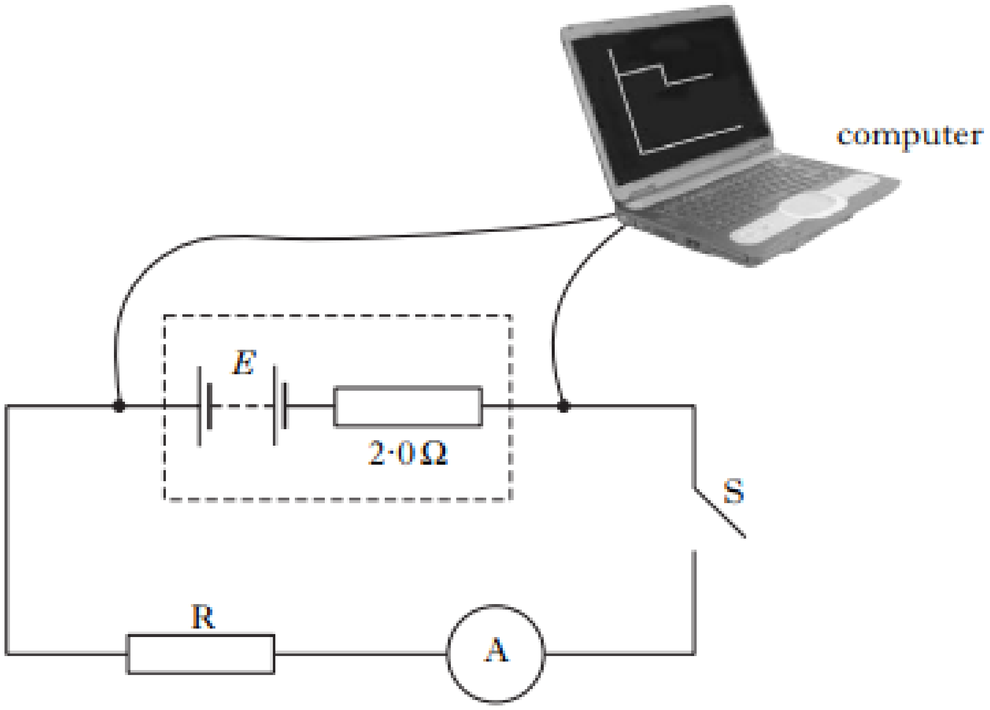
Calculate the new reading on the ammeter. **2**

(7)

Return to Circuits Contents

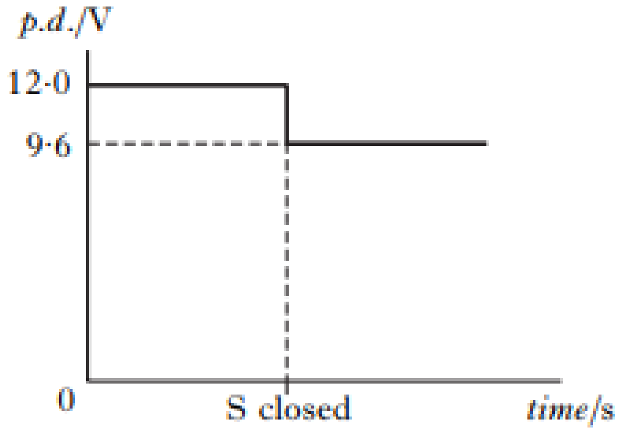
2007 Q.25

A power supply of e.m.f. E and internal resistance $2{\cdot}0\,\Omega$ is connected as shown.



The computer connected to the apparatus displays a graph of potential difference against time.

The graph shows the potential difference across the terminals of the power supply for a short time before and after switch S is closed.



(*a*) State the e.m.f. of the power supply. **1**

(*b*) Calculate:

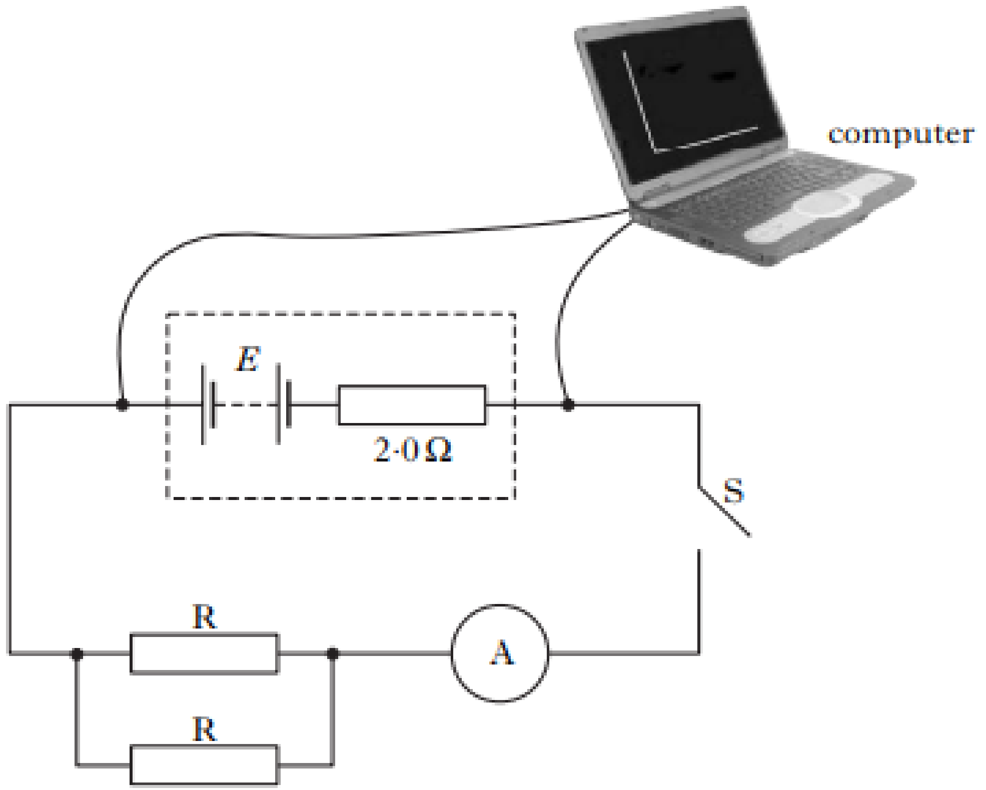
(i) the reading on the ammeter after switch S is closed; **2**

(ii) the resistance of resistor R. **1**

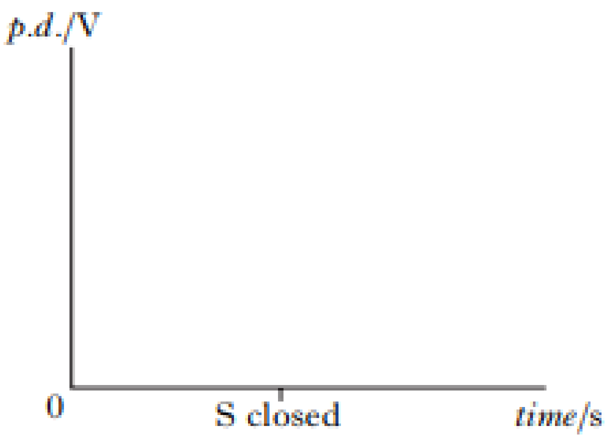
Return to Circuits Contents

2007 Q.25 cont.

(*c*) Switch S is opened. A second identical resistor is now connected in parallel with R as shown.



The computer is again connected in order to display a graph of potential difference against time.



Copy and complete the new graph of potential difference against time showing the values of potential difference before and after switch S is closed. **2**

(6)

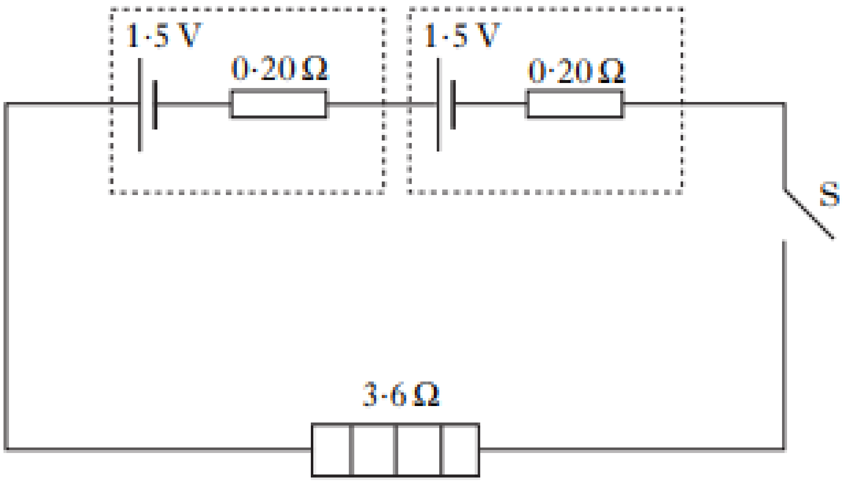
Return to Circuits Contents

2008 Q.24

Electrically heated gloves are used by skiers and climbers to provide extra warmth.

(*a*) Each glove has a heating element of resistance 3·6 Ω.

Two cells, each of e.m.f. 1·5 V and internal resistance 0·20 Ω, are used to operate the heating element.



Switch S is closed.

(i) Determine the value of the total circuit resistance. **1**

(ii) Calculate the current in the heating element. **2**

(iii) Calculate the power output of the heating element. **2**

(*b*) When in use, the internal resistance of each cell gradually increases.

What effect, if any, does this have on the power output of the heating element?

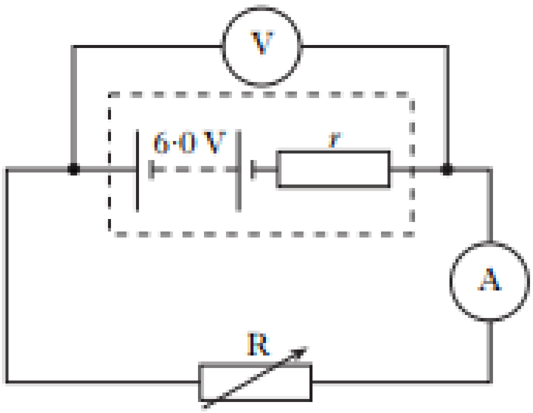
Justify your answer. **2**

(7)

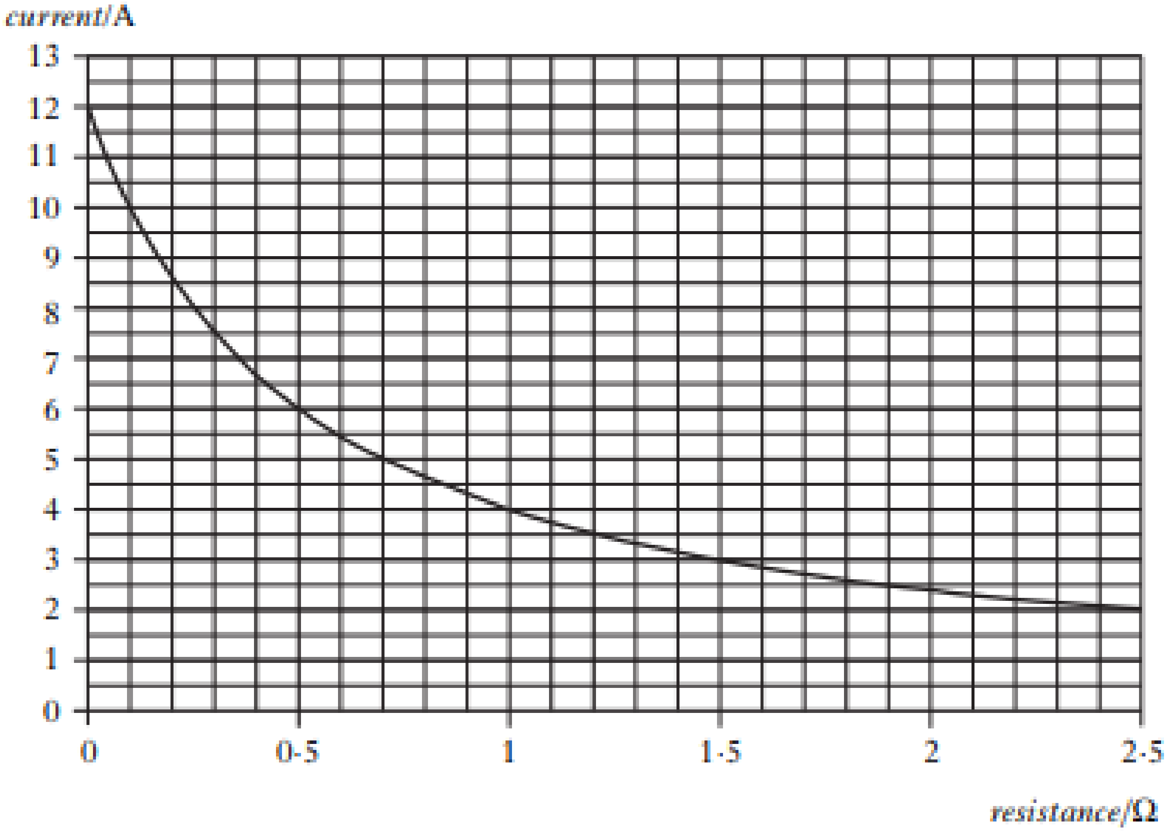
Return to Circuits Contents

2009 Q.24

A battery of e.m.f. 6·0 V and internal resistance, *r*, is connected to a variable resistor R as shown.



The graph shows how the current in the circuit changes as the resistance of R increases.



(*a*) Use information from the graph to calculate:

(i) the lost volts in the circuit when the resistance of R is 1·5 Ω; **2**

(ii) the internal resistance, *r*, of the battery. **2**

(*b*) The resistance of R is now increased.

What effect, if any, does this have on the lost volts?

You must justify your answer. **2**

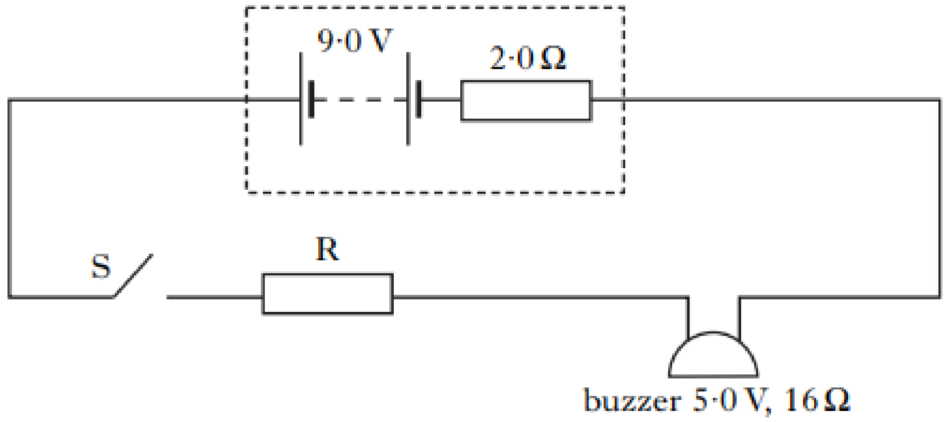
(6)

Return to Circuits Contents

2010 Q.30 d

(*d*) The alarm circuit in the smoke detector contains a battery of e.m.f. 9·0 V and internal resistance 2·0 Ω.

This circuit is shown.



When smoke is detected, switch S closes and the buzzer operates. The buzzer has a resistance of 16 Ω and an operating voltage of 5·0 V.

Calculate the value of resistor R required in this circuit. **3**

Return to Circuits Contents

2011 Q.24

(*a*) A supply of e.m.f. 10·0 V and internal resistance *r* is connected in a circuit as shown in Figure 1.

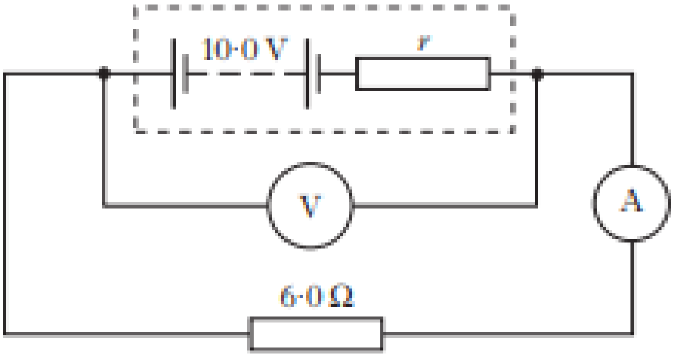


Figure 1

The meters display the following readings.

Reading on ammeter = 1·25 A

Reading on voltmeter = 7·50 V

(i) What is meant by an *e.m.f. of 10·0 V*? **1**

(ii) Show that the internal resistance, *r*, of the supply is 2·0 Ω. **1**

(*b*) A resistor R is connected to the circuit as shown in Figure 2.

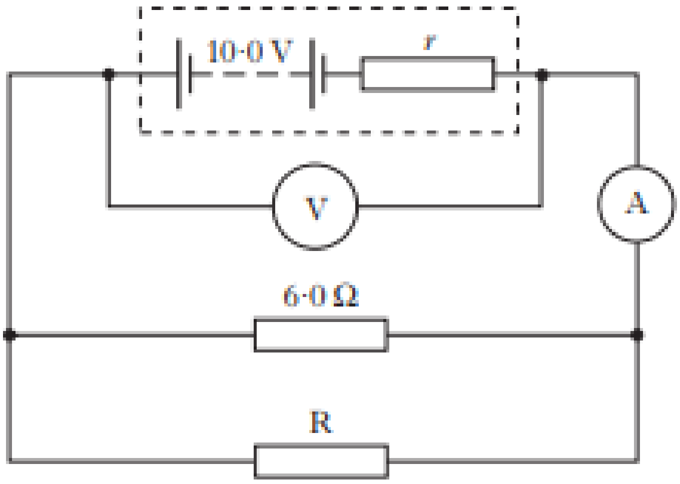


Figure 2

The meters now display the following readings.

Reading on ammeter = 2·0 A

Reading on voltmeter = 6·0 V

(i) Explain why the reading on the voltmeter has decreased. **2**

(ii) Calculate the resistance of resistor R. **3**

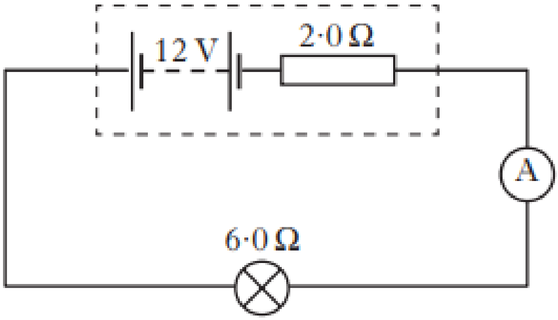
(7)

Return to Circuits Contents

2012 Q.25

A student carries out two experiments using different power supplies connected to a lamp of resistance 6·0 Ω.

(*a*) In the first experiment the lamp is connected to a power supply of e.m.f. 12 V and internal resistance 2·0 Ω as shown.



Calculate:

(i) the reading on the ammeter; **2**

(ii) the lost volts; **1**

(iii) the output power of the lamp. **2**

(*b*) In the second experiment the lamp is connected to a different power supply. This supply has the same e.m.f. as the supply in part (*a*) but a different value of internal resistance.

The output power of the lamp is now greater.

Assuming the resistance of the lamp has not changed, is the internal resistance of the new power supply less than, equal to, or greater than the internal resistance of the original supply?

Justify your answer. **2**

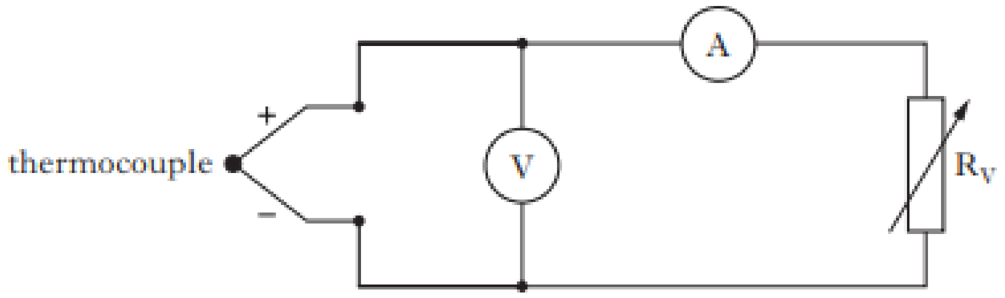
(7)

Return to Circuits Contents

2013 Q.30

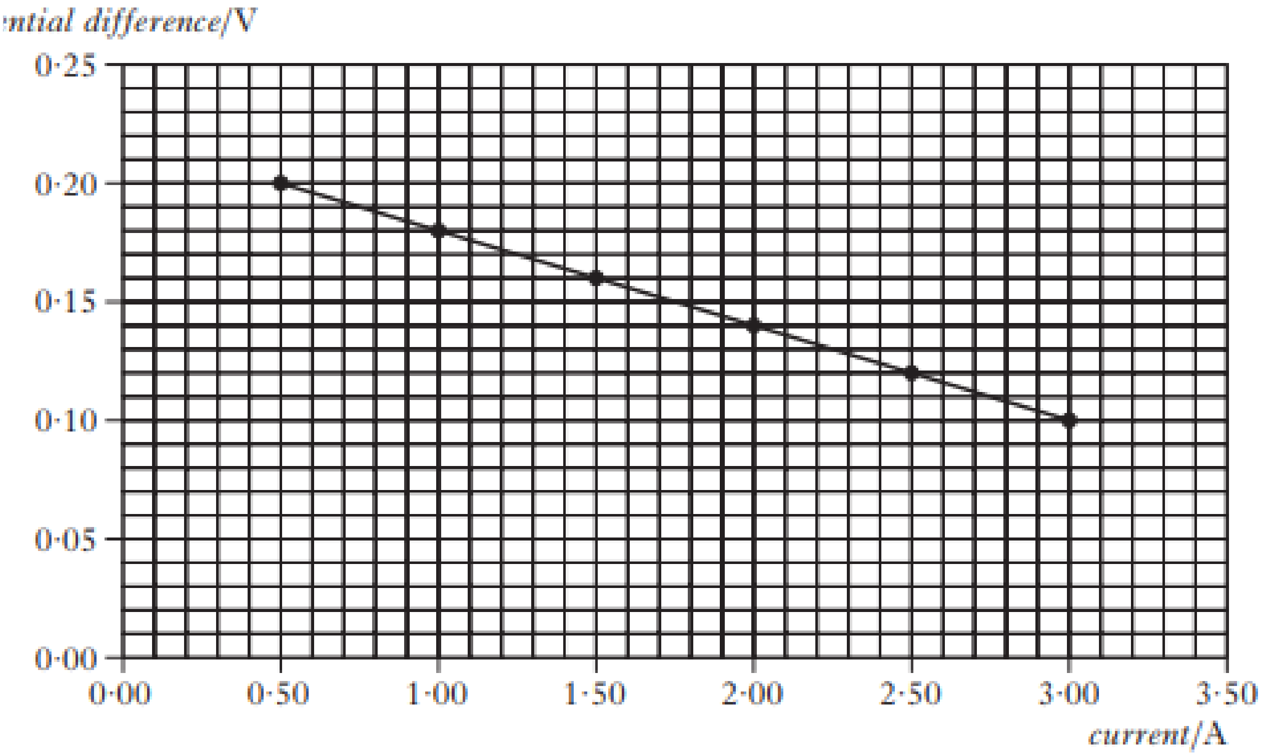
A thermocouple is a device that produces an e.m.f. when heated.

(*a*) A technician uses the circuit shown to investigate the operation of a thermocouple when heated in a flame.



Readings of current and potential difference (p.d.) are recorded for different settings of the variable resistor R_V.

The graph of p.d. against current is shown.



Use information from the graph to find:

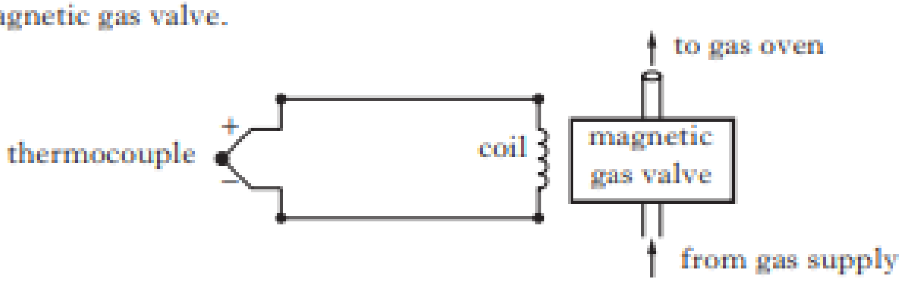
(i) the e.m.f. produced by the thermocouple; **1**

(ii) the internal resistance of the thermocouple. **2**

Return to Circuits Contents

2013 Q.30 cont.

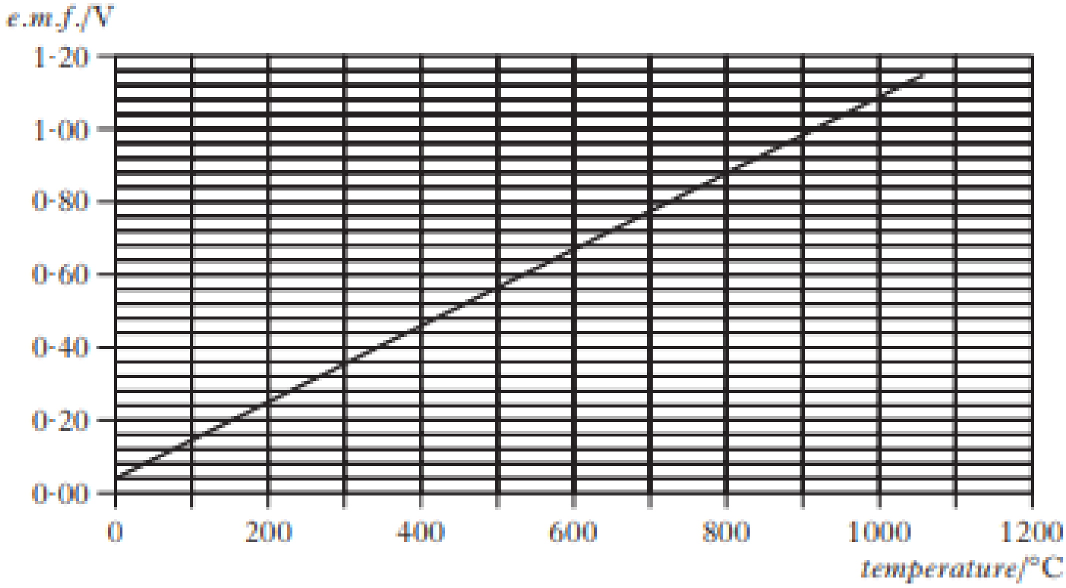
(*b*) A **different** thermocouple is to be used as part of a safety device in a gas oven. The safety device turns off the gas supply to the oven if the flame goes out. The thermocouple is connected to a coil of resistance 0·12 Ω which operates a magnetic gas valve.

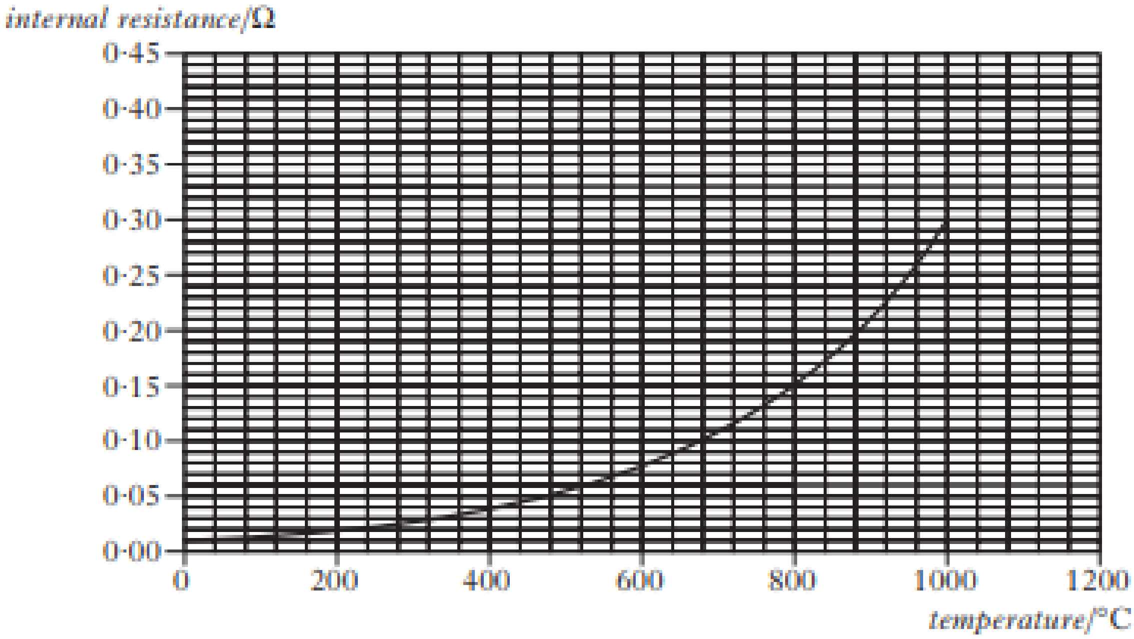


When the current in the coil is less than 2·5 A, the gas valve is closed.

The temperature of the flame in the gas oven is 800 °C.

The manufacturer's data for this thermocouple is shown in the two graphs.





Is this thermocouple suitable as a source of e.m.f. for the gas valve to be open at a temperature of 800 °C?

You must justify your answer. **3**

(6)

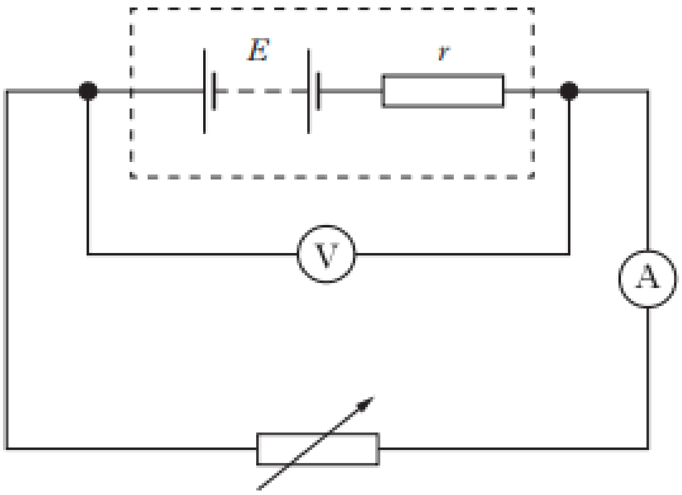
Return to Circuits Contents

2014 Q.30

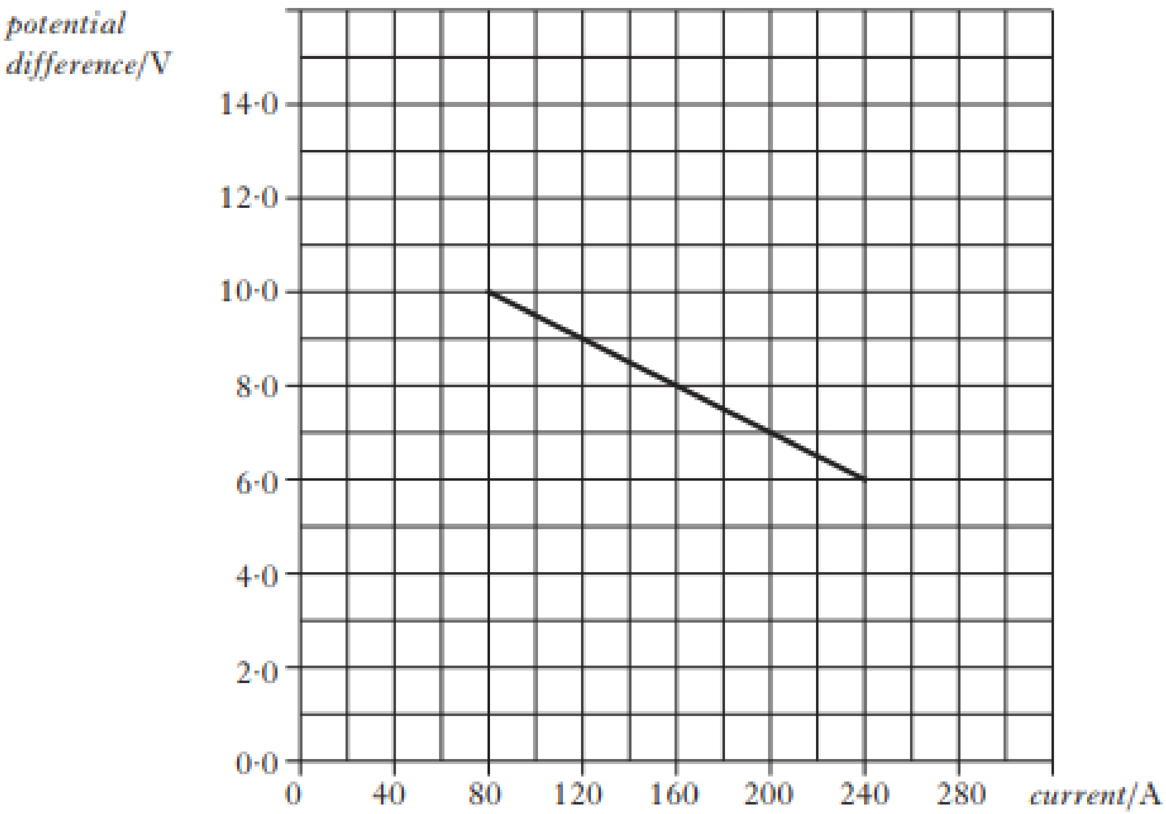
A technician is testing a new design of car battery.

The battery has an e.m.f. E and internal resistance r.

(*a*) In one test, the technician uses this battery in the following circuit.



Readings from the voltmeter and ammeter are used to plot the following graph.



(i) Use information from the graph to determine the e.m.f. of the car battery. **1**

(ii) Calculate the internal resistance of the car battery. **2**

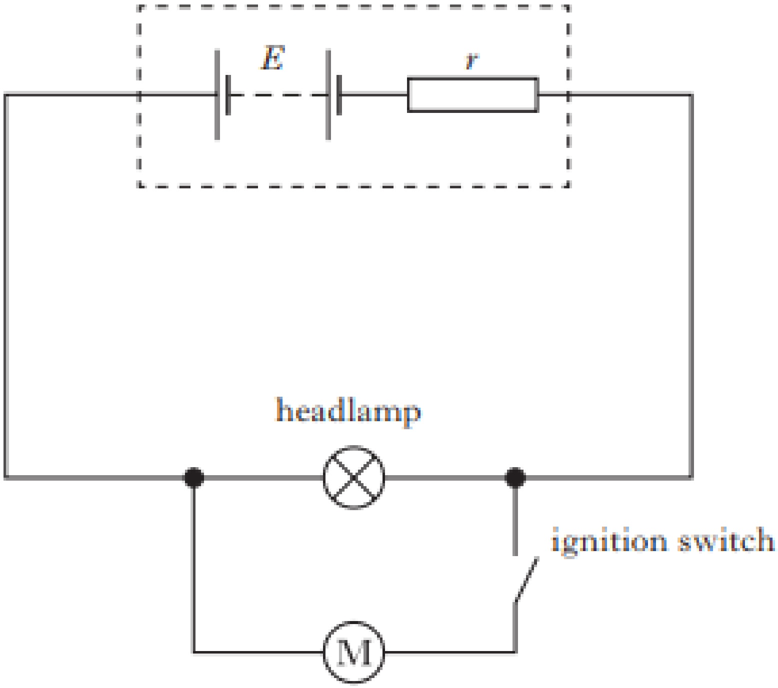
(iii) The technician accidently drops a metal spanner across the terminals of the battery. This causes a short circuit.

Calculate the short circuit current. **2**

Return to Circuits Contents

2014 Q.30 cont.

(*b*) In a second test, the technician connects the battery to a headlamp in parallel with a starter motor as shown.



The technician notices that the headlamp becomes dimmer when the ignition switch is closed and the starter motor operates.

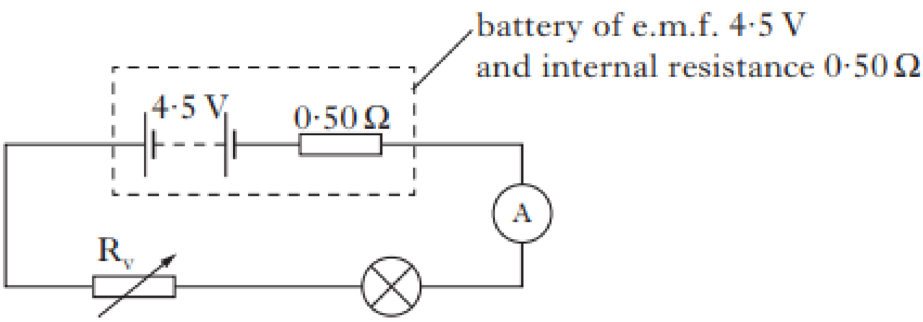
Explain why this happens. **2**

(7)

2015 Q. 30 a

A technician investigates the use of different light sources for torches.

The following circuit is set up.



(*a*) The resistance of variable resistor R_v is set to 2·5 Ω. The reading on the ammeter is 0·30 A.

(i) Show that the resistance of the lamp is 12 Ω at this current. **2**

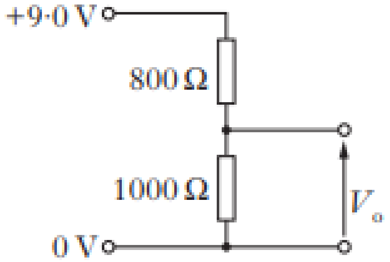
(ii) Calculate the power output of the lamp at this current. **2**

Return to Circuits Contents

2015 Q.25

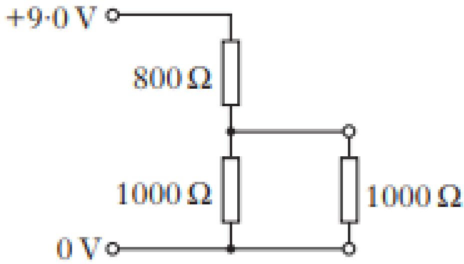
Two students are each given the task of designing an arrangement of resistors to provide an output voltage of 5·0 V from a 9·0 V supply.

(*a*) (i) Student **A** designs the circuit shown.



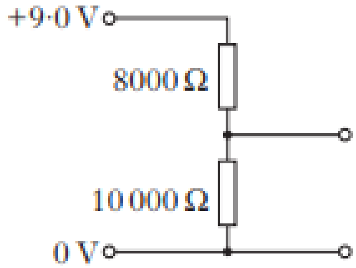
Show that the output voltage V_o is 5·0 V. **1**

(ii) Student **A** now connects a load resistor of resistance 1000 Ω across the output terminals as shown.

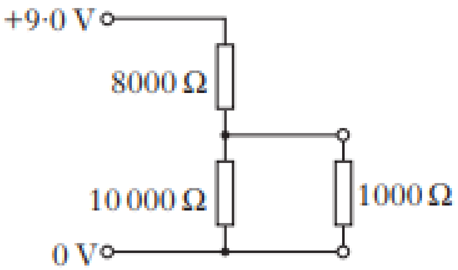


Calculate the potential difference across the load resistor. **2**

(*b*) Student **B** designs the circuit shown below.



Student **B** now connects the same load resistor as shown.



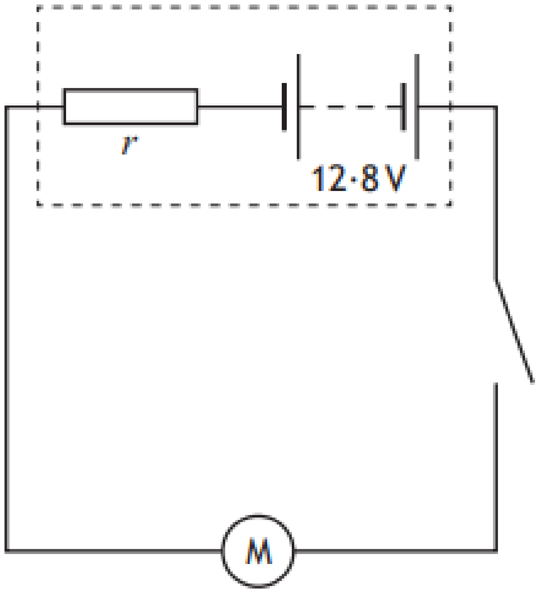
State which student's design achieves a potential difference closer to 5·0 V across the 1000 Ω load resistor.

You must justify your answer. **2**

Return to Circuits Contents

2015 Q.10

A car battery is connected to an electric motor as shown.



The electric motor requires a large current to operate.

(a) The car battery has an e.m.f. of 12·8 V and an internal resistance r of $6{\cdot}0 \times 10^{-3}\,\Omega$. The motor has a resistance of 0·050 Ω.

(i) State what is meant by an *e.m.f. of 12·8 V*. **1**

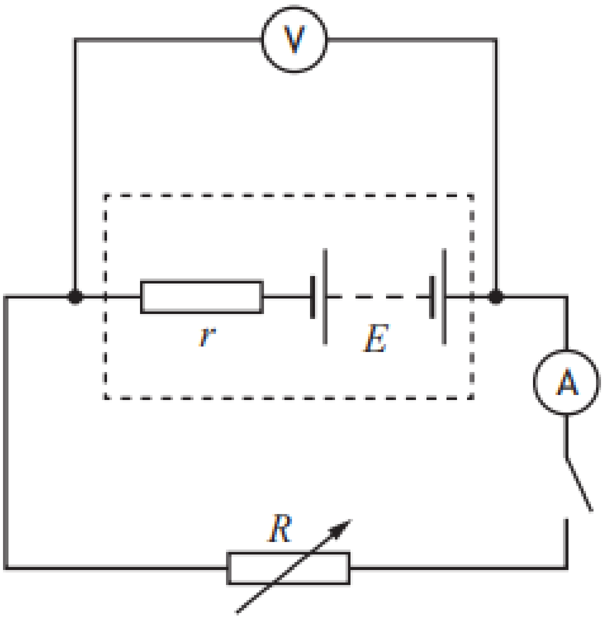
(ii) Calculate the current in the circuit when the motor is operating. **3**

Space for working and answer

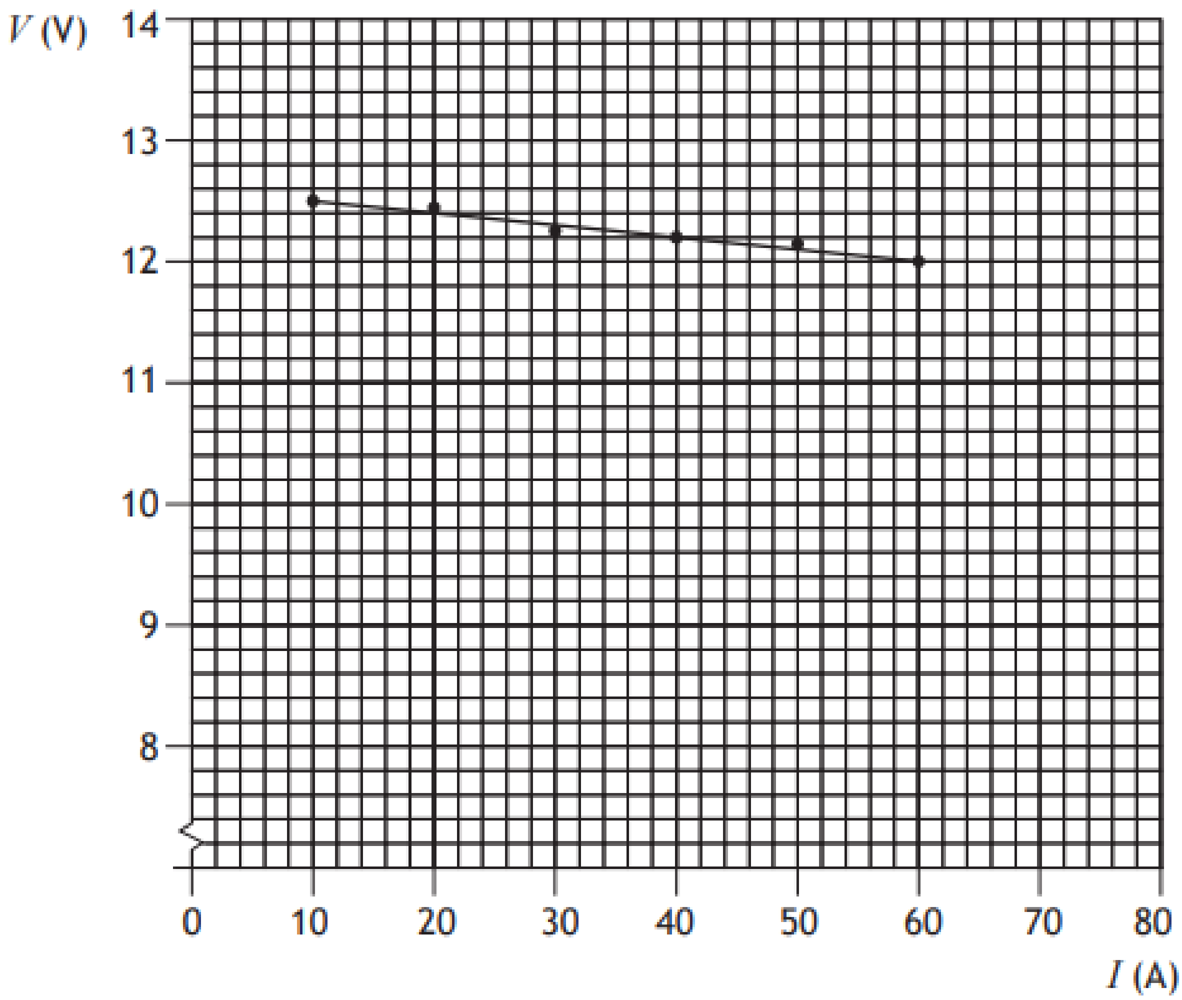
(iii) Suggest why the connecting wires used in this circuit have a large diameter. **1**

2015 Q.10 cont.

(b) A technician sets up the following circuit with a different car ba connected to a variable resistor R.



Readings of current I and terminal potential difference V from this circuit are used to produce the following graph.

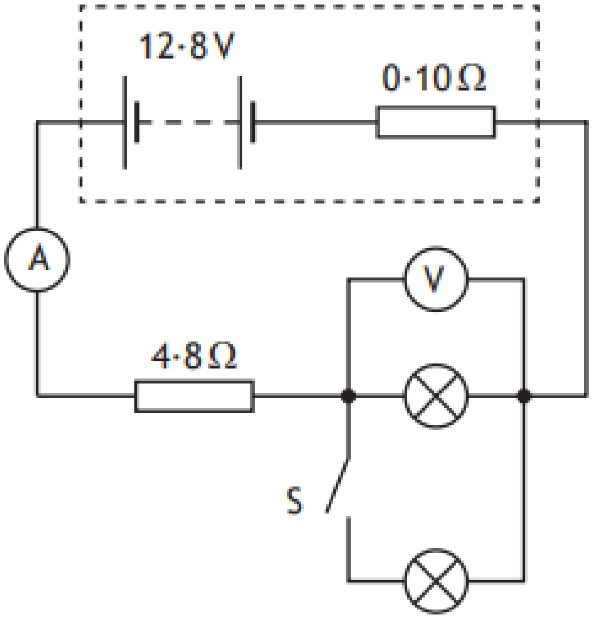


Return to Circuits Contents

2016 Q.12 a

A technician sets up a circuit as shown, using a car battery and two identical lamps.

The battery has an e.m.f. of 12·8 V and an internal resistance of 0·10 Ω.



(a) Switch S is open. The reading on the ammeter is 1·80 A.

(i) Determine the reading on the voltmeter. **4**

Space for working and answer

(ii) Switch S is now closed.

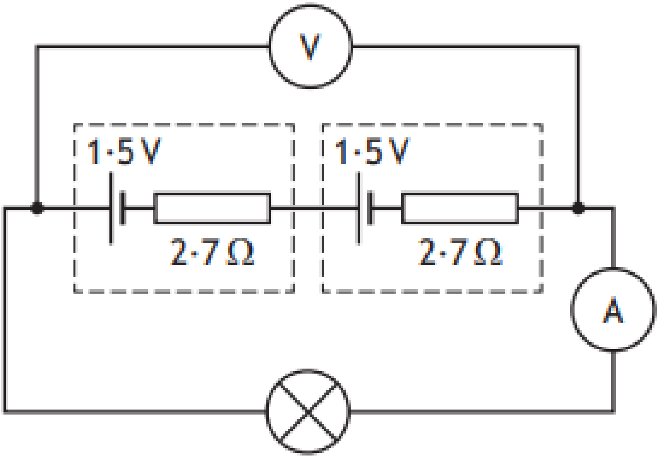
State the effect this has on the reading on the voltmeter.

Justify your answer. **3**

Return to Circuits Contents

2017 Q.12

A lamp is connected to a battery containing two cells as shown.



The e.m.f. of each cell is 1·5 V and the internal resistance of each cell is 2·7 Ω.

The reading on the ammeter is 64 mA.

(a) State what is meant by *an e.m.f. of 1·5 V.* **1**

(b) (i) Show that the lost volts in the battery is 0·35 V. **2**

Space for working and answer

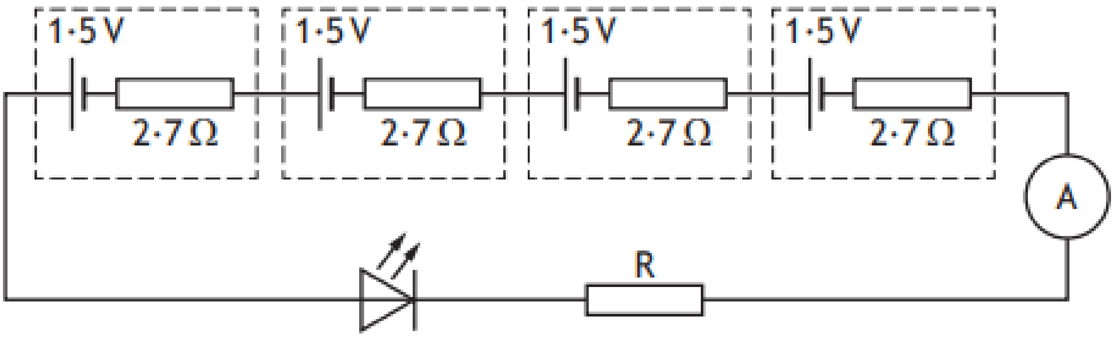
(ii) Determine the reading on the voltmeter. **1**

Space for working and answer

(iii) Calculate the power dissipated by the lamp. **3**

Space for working and answer

(c) In a different circuit, an LED is connected to a battery containing four cells.



The potential difference across the LED is 3·6 V when the current is 26 mA.

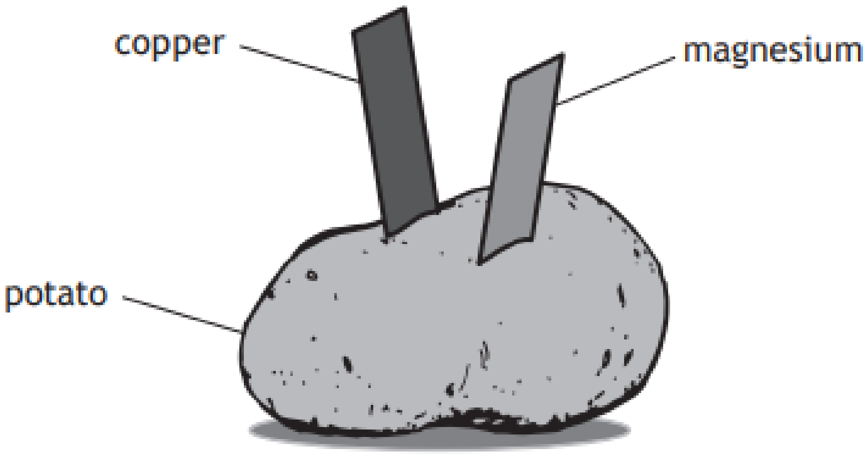
Determine the resistance of resistor R. **4**

Space for working and answer

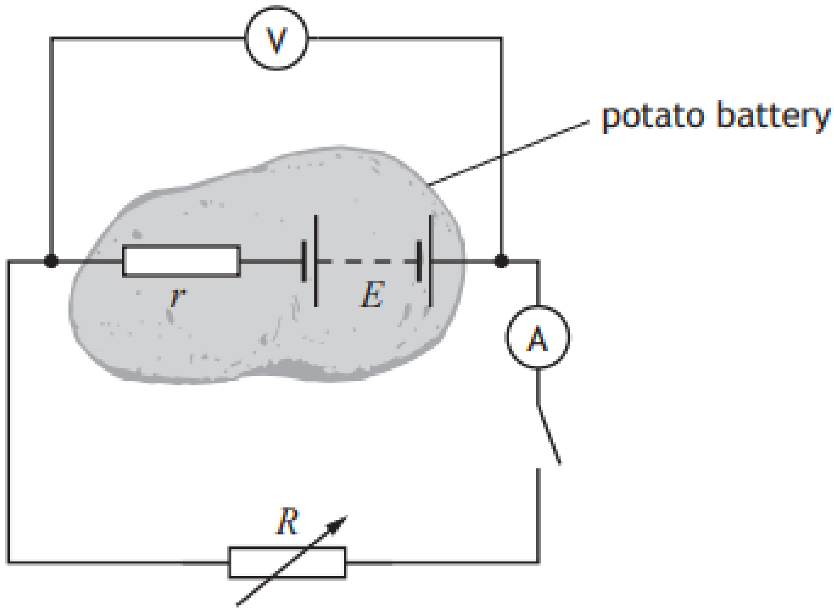
Return to Circuits Contents

2018 Q.11 a,b

A student constructs a battery using a potato, a strip of copper and a strip of magnesium.

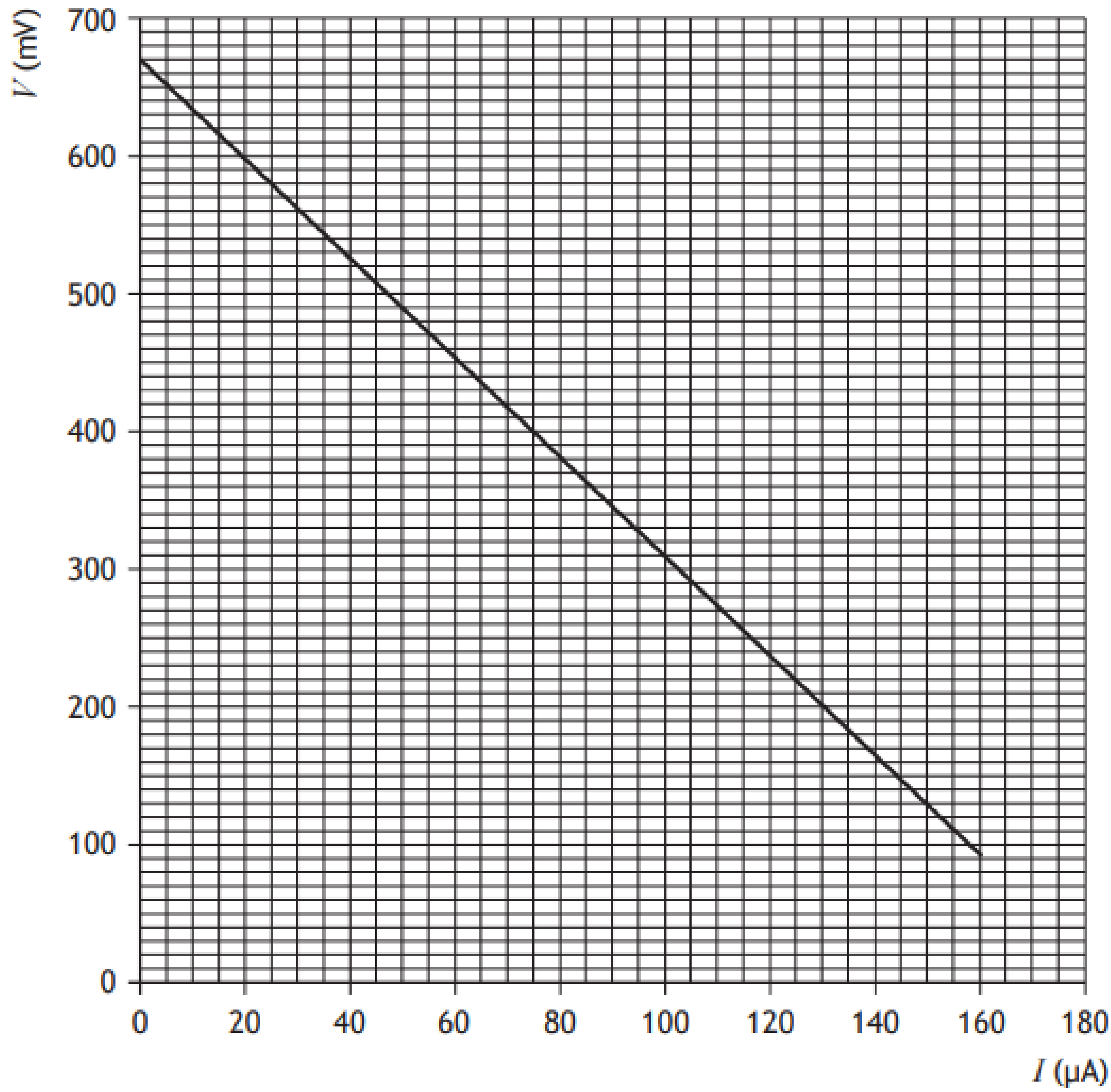


The student then sets up the following circuit with the potato battery connected to a variable resistor R, in order that the electromotive force (e.m.f.) and internal resistance of the battery may be determined.



(a) State what is meant by the term *electromotive force* (e.m.f.). **1**

(b) The student uses readings of current I and terminal potential difference V from this circuit to produce the graph shown.

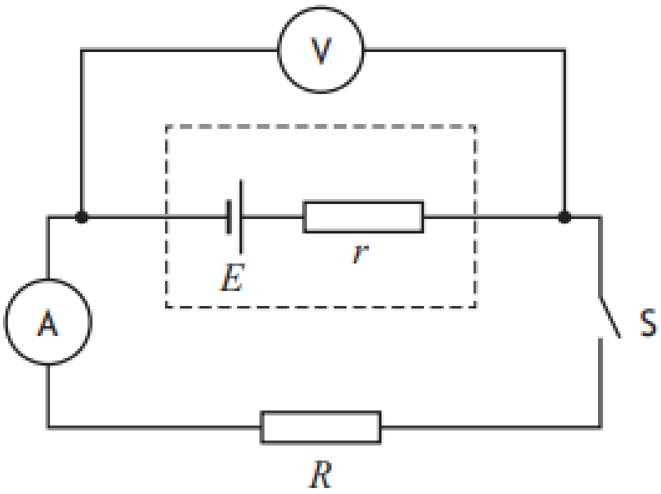


Determine the internal resistance of the potato battery. **3**

Space for working and answer

2019 Q.12

(a) A student sets up the circuit shown.



When switch S is open the reading on the voltmeter is 1·5 V.

Switch S is now closed.

The reading on the voltmeter is now 1·3 V and the reading on the ammeter is 0·88 A.

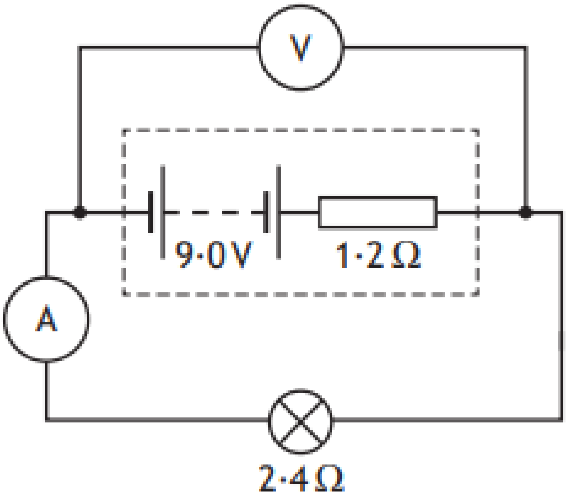
(i) State the EMF E of the cell. **1**

(ii) Calculate the internal resistance r of the cell. **3**

Space for working and answer

(iii) Explain why the reading on the voltmeter decreases when the switch is closed. **2**

(b) A battery of EMF 9·0 V and internal resistance 1·2 Ω is connected in series with a lamp. The lamp has a resistance of 2·4 Ω.



(i) Determine the current in the lamp. **3**

Space for working and answer

Return to Circuits Contents

2019 Q.12 cont.

(ii) Calculate the power dissipated in the lamp. **3**

Space for working and answer

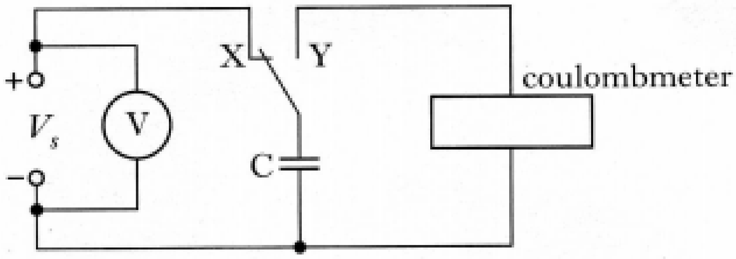
Return to Circuits Contents

Capacitors

Return to Homework Contents

2000 Q.24

24. (*a*) In an experiment to measure the capacitance of a capacitor, a student sets up the following circuit.



When the switch is in position X, the capacitor charges up to the supply voltage, V_s. When the switch is in position Y, the coulombmeter indicates the charge stored by the capacitor.

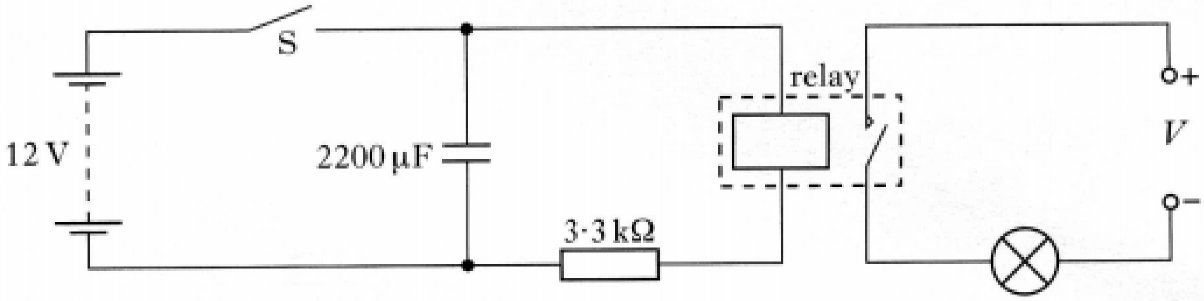
The student records the following measurements and uncertainties.

Reading on voltmeter = $(2 \cdot 56 \pm 0 \cdot 01)$ V
Reading on coulombmeter = (32 ± 1) μC

Calculate the value of the capacitance and the percentage uncertainty in this value. You must give the answer in the form

value ± percentage uncertainty. **3**

(*b*) The student designs the circuit shown below to switch off a lamp after a certain time.



The 12 V battery has negligible internal resistance.

The relay contacts are normally open. When there is a current in the relay coil the contacts close and complete the lamp circuit.

Switch S is initially closed and the lamp is on.

(i) What is the maximum energy stored in the capacitor?

(ii) (A) Switch S is now opened. Explain why the lamp stays lit for a few seconds.

(B) The 2200 μF capacitor is replaced with a 1000 μF capacitor.

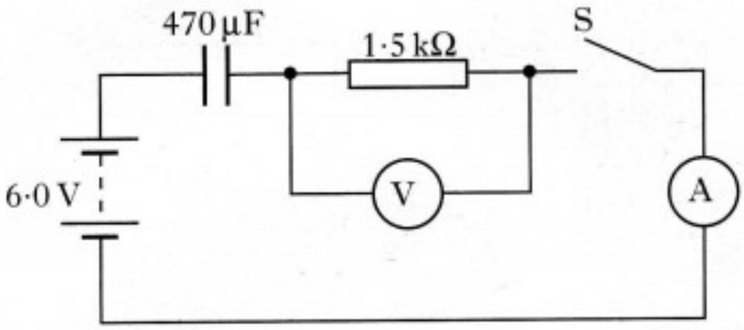
Describe and explain the effect of this change on the operation of the circuit. **6**

(9)

Return to Capacitors Contents

2001 Q.25 a

25. (*a*) The following diagram shows a circuit that is used to investigate the charging of a capacitor.



The capacitor is initially uncharged.

The capacitor has a capacitance of 470 μF and the resistor has a resistance of 1·5 kΩ.

The battery has an e.m.f. of 6·0 V and negligible internal resistance.

(i) Switch S is now closed. What is the initial current in the circuit?

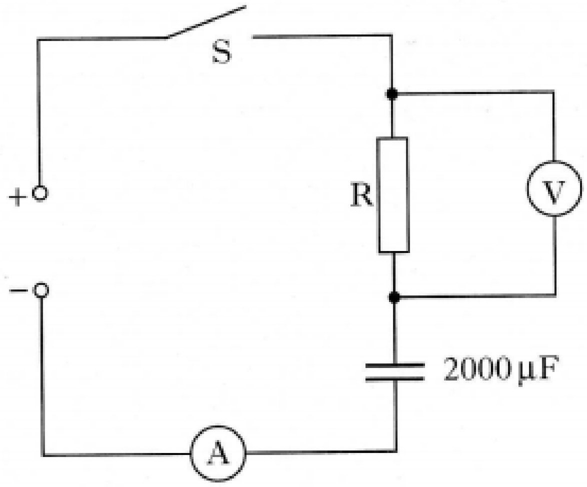
(ii) How much energy is stored in the capacitor when it is fully charged?

(iii) What change could be made to this circuit to ensure that the **same** capacitor stores **more** energy? **5**

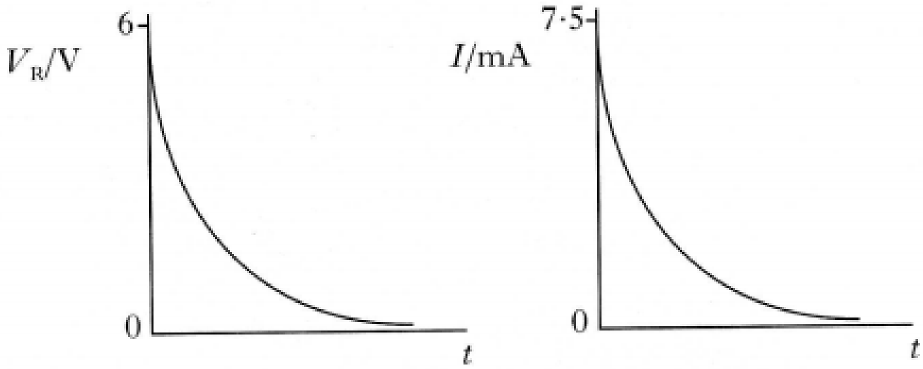
Return to Capacitors Contents

2002 Q.25

25. (*a*) The circuit below is used to investigate the charging of a 2000 μF capacitor. The d.c. supply has negligible internal resistance.



The graphs below show how the potential difference V_R across the **resistor** and the current I in the circuit vary with time from the instant switch S is closed.



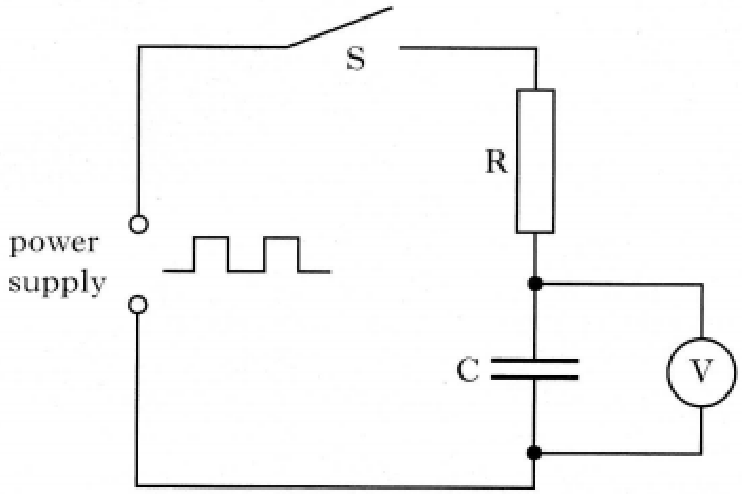
(i) What is the potential difference across the capacitor when it is fully charged?

(ii) Calculate the energy stored in the capacitor when it is fully charged.

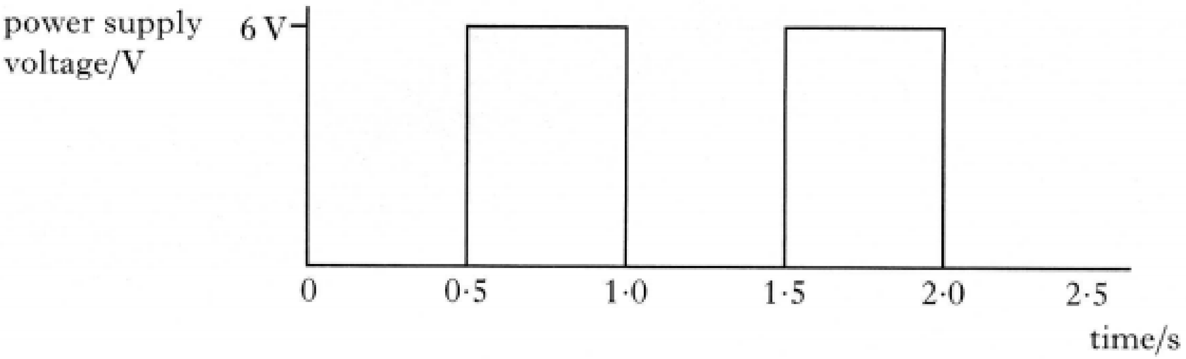
(iii) Calculate the resistance of R in the circuit above. **5**

Return to Capacitors Contents

(*b*) The circuit below is used to investigate the charging and discharging of a capacitor.



The graph below shows how the power supply voltage varies with time after switch S is closed.



The capacitor is initially uncharged.

The capacitor charges fully in 0·3 s and discharges fully in 0·3 s.

Sketch a graph of the reading on the voltmeter for the first 2·5 s after switch S is closed.

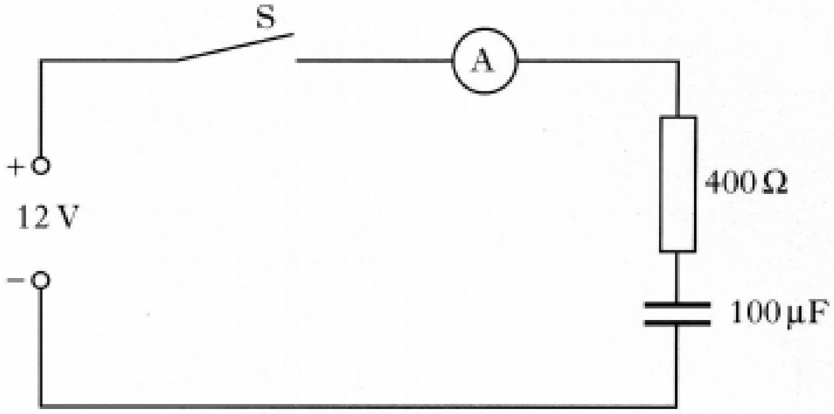
The axes on your graph must have the same numerical values as those in the above graph. **2**

(7)

Return to Capacitors Contents

2004 Q.25

25. In an experiment, the circuit shown is used to investigate the charging of a capacitor.



The power supply has an e.m.f. of 12 V and negligible internal resistance. The capacitor is initially uncharged.

Switch S is closed and the current measured during charging. The graph of charging current against time is shown in figure 1.

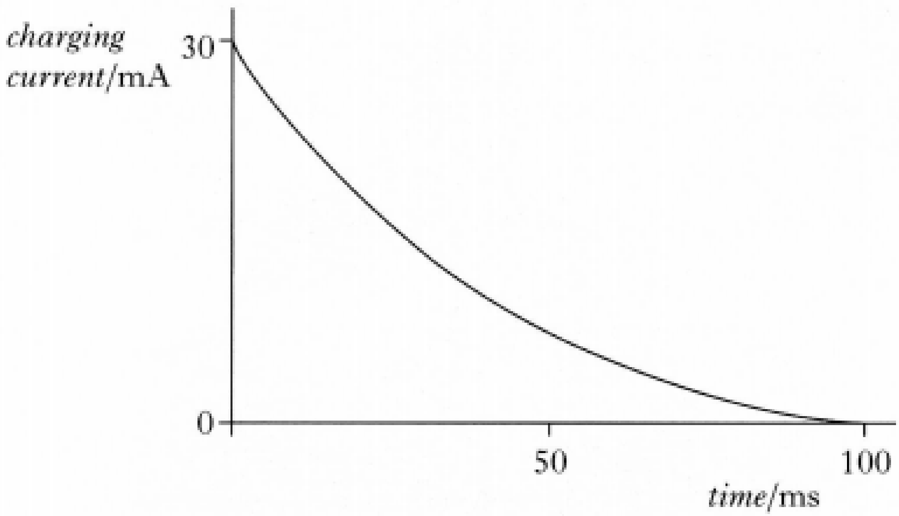


figure 1

(*a*) Sketch a graph of the voltage across the capacitor against time until the capacitor is fully charged. Numerical values are required on both axes. **2**

(*b*) (i) Calculate the voltage across the capacitor when the charging current is 20 mA.

(ii) How much energy is stored in the capacitor when the charging current is 20 mA? **4**

(*c*) The capacitor has a maximum working voltage of 12 V.

Suggest **one** change to this circuit which would allow an initial charging current of greater than 30 mA. **1**

Return to Capacitors Contents

(*d*) The 100 μF capacitor is now replaced by an uncharged capacitor of unknown capacitance and the experiment is repeated. The graph of charging current against time for this capacitor is shown in figure 2.

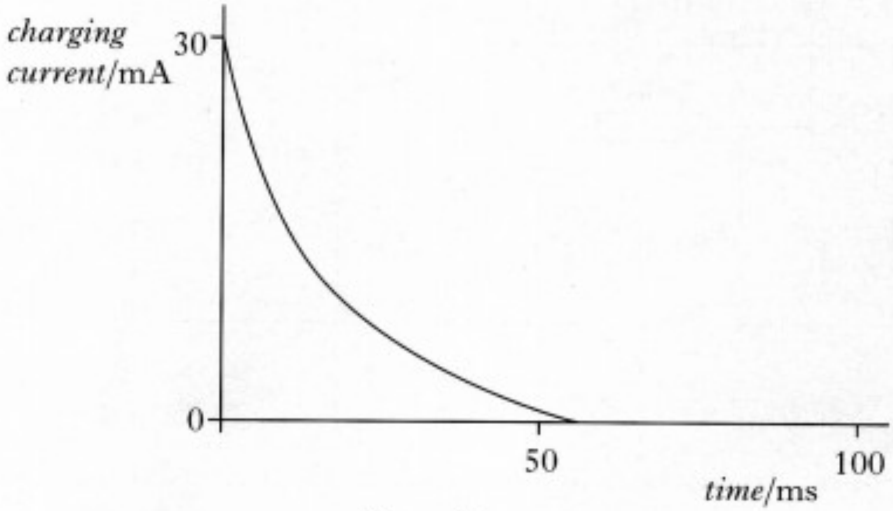


figure 2

By comparing figure 2 with figure 1, determine whether the capacitance of this capacitor is greater than, equal to or less than 100 μF.

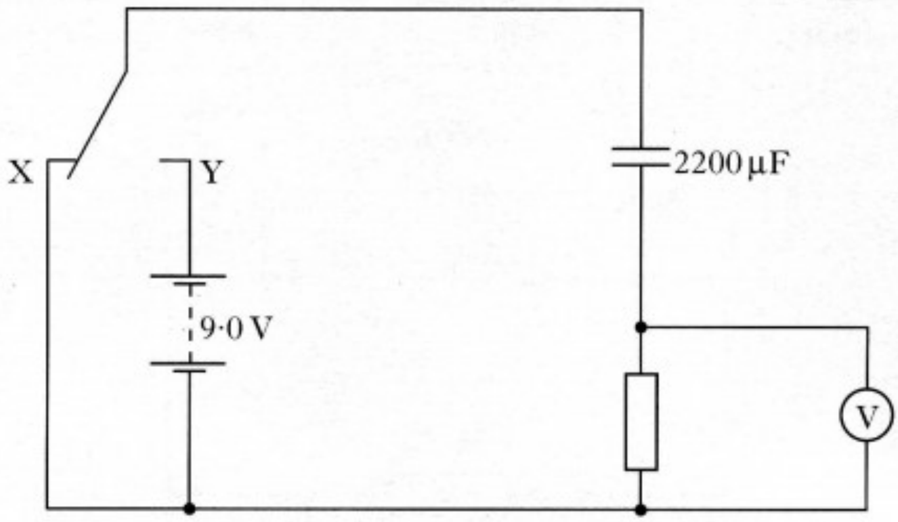
You must justify your answer. **2**

(9)

Return to Capacitors Contents

2005 Q.26

26. A student investigates the charging and discharging of a 2200 μF capacitor using the circuit shown.



The 9·0 V battery has negligible internal resistance.

Initially the capacitor is uncharged and the switch is at position X.

The switch is then moved to position Y and the capacitor charges fully in 1·5 s.

(*a*) (i) Sketch a graph of the p.d. across the **resistor** against time while the capacitor charges. Appropriate numerical values are required on both axes. **2**

(ii) The resistor is replaced with one of higher resistance.

Explain how this affects the time taken to fully charge the capacitor. **1**

(iii) At one instant during the charging of the capacitor the reading on the voltmeter is 4·0 V.

Calculate the charge stored by the capacitor at this instant. **3**

(*b*) Using the same circuit in a later investigation the resistor has a resistance of 100 kΩ. The switch is in **position Y** and the capacitor is fully charged.

(i) Calculate the maximum energy stored in the capacitor. **2**

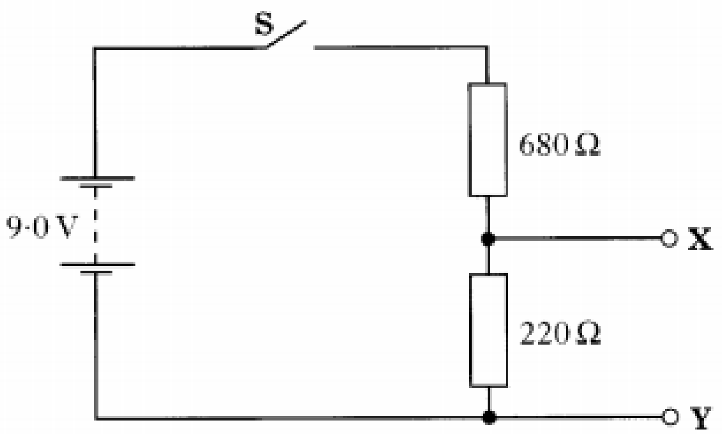
(ii) The switch is moved to position X. Calculate the maximum current in the resistor. **2**

(10)

Return to Capacitors Contents

2006 Q.25

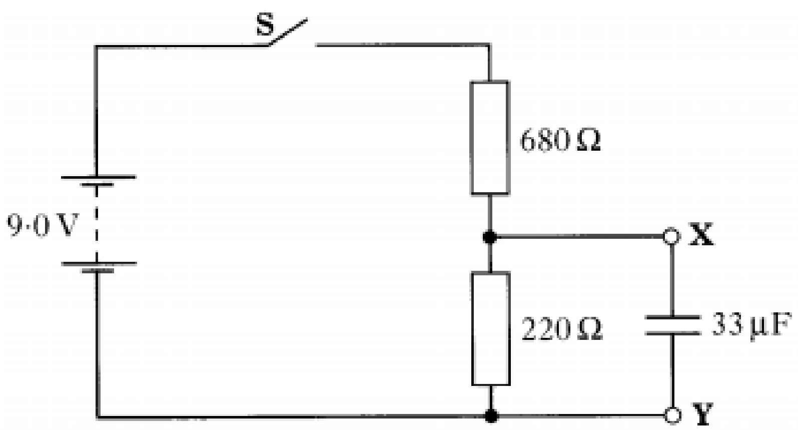
25. The 9·0 V battery in the circuit shown below has negligible internal resistance.



(*a*) Switch **S** is closed.
Calculate the potential difference between **X** and **Y**. **2**

(*b*) Switch **S** is opened.

An uncharged 33 μF capacitor is connected between **X** and **Y** as shown.



Switch **S** is then closed.

(i) Explain why work is done in charging the capacitor. **1**

(ii) State the value of the maximum potential difference across the capacitor in this circuit. **1**

(iii) Calculate the maximum energy stored in the capacitor. **2**

(iv) Switch **S** is now opened.

Sketch a graph to show how the current through the 220 Ω resistor varies with time from the moment the switch is opened.

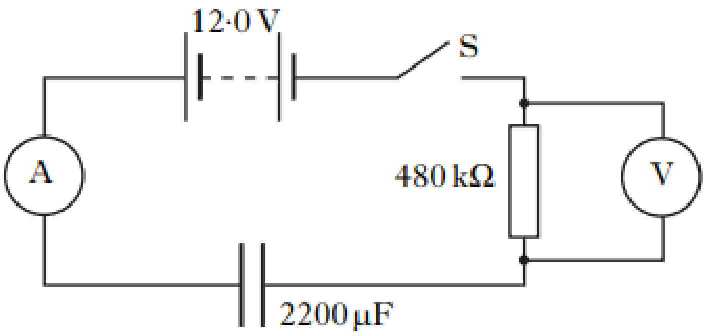
Numerical values are required only on the current axis. **2**

(8)

Return to Capacitors Contents

2007 Q.26

26. An uncharged $2200\,\mu F$ capacitor is connected in a circuit as shown.



The battery has negligible internal resistance.

(*a*) Switch S is closed. Calculate the initial charging current. **2**

(*b*) At one instant during the charging process the potential difference **across the resistor** is 3·8 V.

Calculate the charge stored in the capacitor at this instant. **3**

(*c*) Calculate the **maximum** energy the capacitor stores in this circuit. **2**

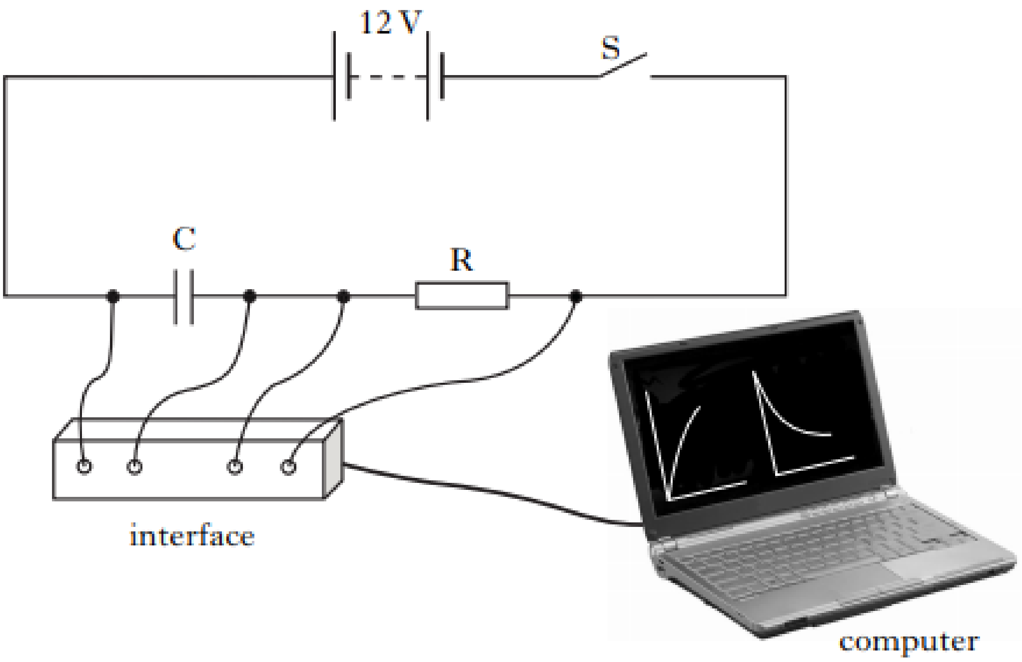
(7)

Return to Capacitors Contents

2008 Q.25

25. (*a*) State what is meant by the term *capacitance*. **1**

(*b*) An uncharged capacitor, C, is connected in a circuit as shown.



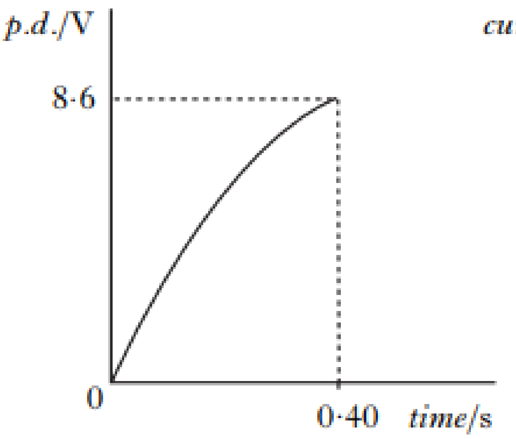
The 12 V battery has negligible internal resistance.

Switch S is closed and the capacitor begins to charge.

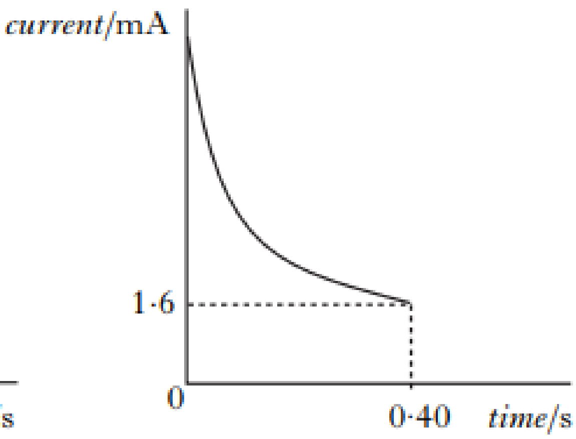
The interface measures the current in the circuit and the potential difference (p.d.) across the capacitor. These measurements are displayed as graphs on the computer.

Graph 1 shows the p.d. across the capacitor for the first 0·40 s of charging.

Graph 2 shows the current in the circuit for the first 0·40 s of charging.



Graph 1



Graph 2

Return to Capacitors Contents

(i) Determine the p.d. **across resistor R** at 0·40 s. **1**

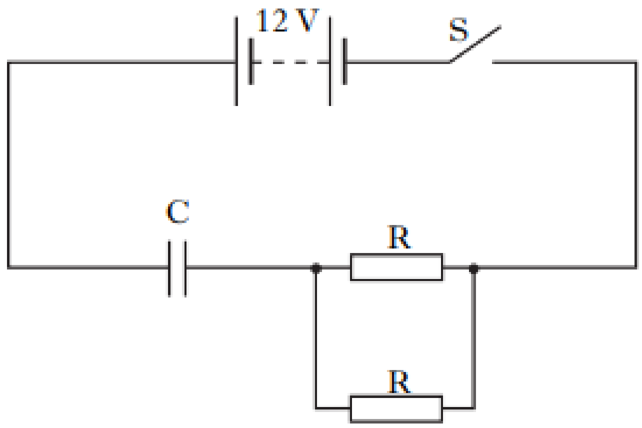
(ii) Calculate the resistance of R. **2**

(iii) The capacitor takes 2·2 seconds to charge fully.

At that time it stores 10·8 mJ of energy.

Calculate the capacitance of the capacitor. **3**

(*c*) The capacitor is now discharged.
A second, identical resistor is connected in the circuit as shown.



Switch S is closed.

Is the time taken for the capacitor to fully charge less than, equal to, or greater than the time taken to fully charge in part (*b*)?

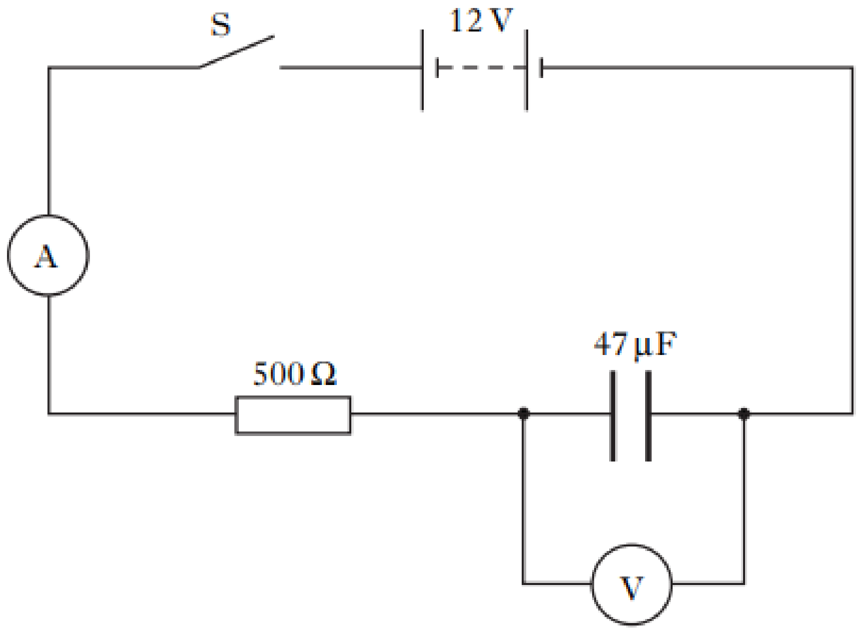
Justify your answer. **2**

(9)

Return to Capacitors Contents

2009 Q.26

26. A 12 volt battery of negligible internal resistance is connected in a circuit as shown.



The capacitor is initially uncharged. Switch S is then closed and the capacitor starts to charge.

(*a*) Sketch a graph of the current against time from the instant switch S is closed. Numerical values are not required. **1**

(*b*) At one instant during the charging of the capacitor the reading on the ammeter is 5·0 mA.

Calculate the reading on the voltmeter at this instant. **3**

(*c*) Calculate the **maximum** energy stored in the capacitor in this circuit. **2**

(*d*) The 500 Ω resistor is now replaced with a 2·0 kΩ resistor.

What effect, if any, does this have on the maximum energy stored in the capacitor?

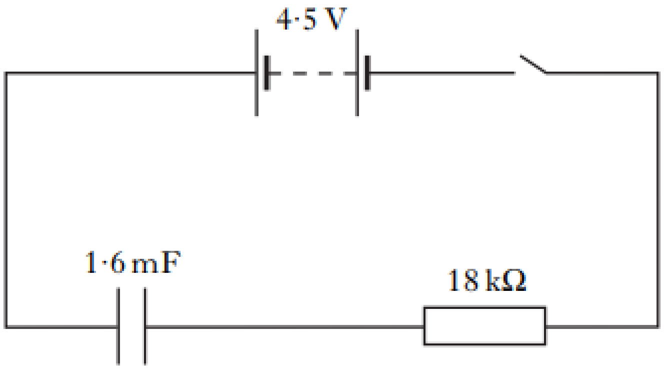
Justify your answer. **2**

(8)

Return to Capacitors Contents

2010 Q.24 b

(*b*) Part of the circuit in the electronic timer consists of a 1·6 mF capacitor and an 18 kΩ resistor connected to a switch and a 4·5 V supply.



(i) Calculate the charge on the capacitor when it is fully charged. **2**

(ii) Sketch the graph of the current in the resistor against time as the capacitor charges.

Numerical values are required on the current axis. **2**

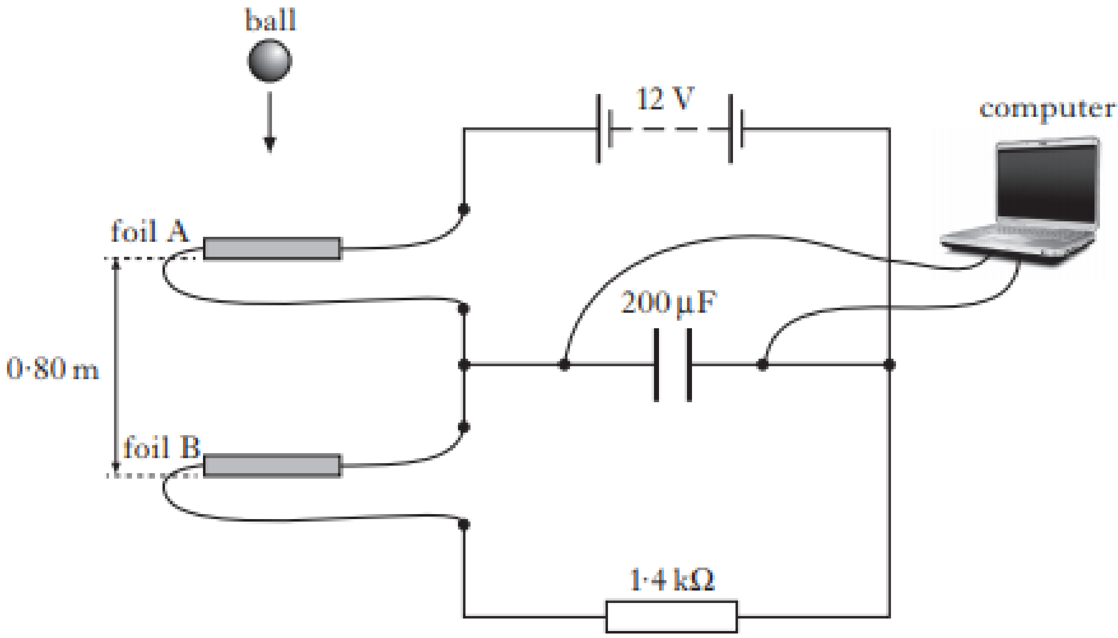
Return to Capacitors Contents

2011 Q.25 a, b

25. A student carries out an experiment using a circuit which includes a capacitor with a capacitance of 200 μF.

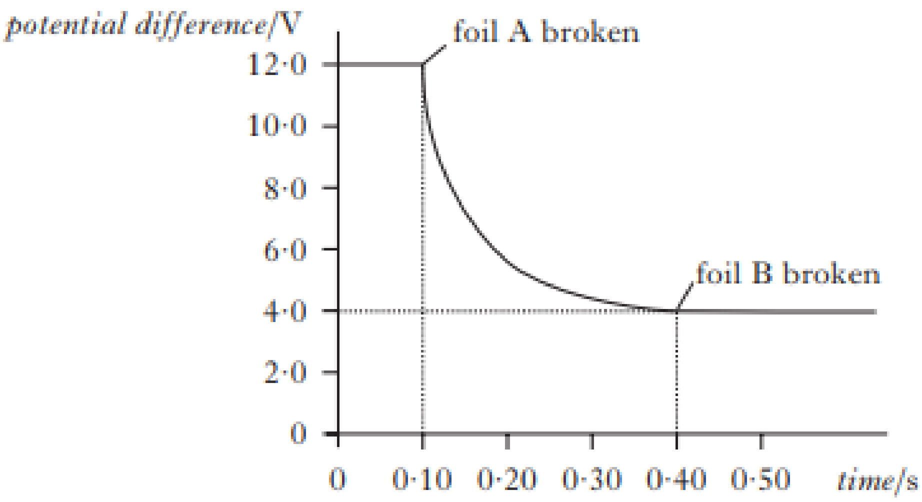
(*a*) Explain what is meant by a *capacitance of 200 μF*. **1**

(*b*) The capacitor is used in the circuit shown to measure the time taken for a ball to fall vertically between two strips of metal foil.



The ball is dropped from rest above foil A. It is travelling at $1{\cdot}5\,m\,s^{-1}$ when it reaches foil A. It breaks foil A, then a short time later breaks foil B. These strips of foil are 0·80 m apart.

The computer displays a graph of potential difference across the capacitor against time as shown.



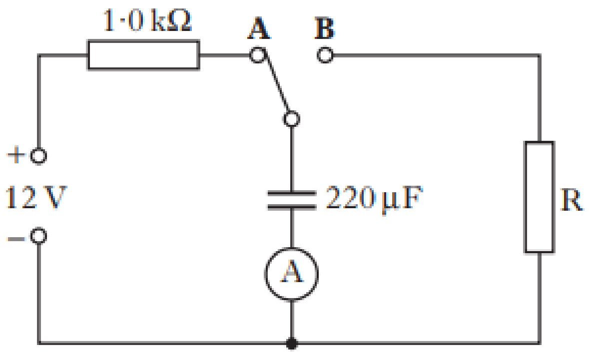
(i) Calculate the current in the 1·4 kΩ resistor at the moment foil A is broken. **2**

(ii) Calculate the **decrease** in the energy stored in the capacitor during the time taken for the ball to fall from foil A to foil B. **3**

Return to Capacitors Contents

2012 Q.26

26. The charging and discharging of a capacitor are investigated using the circuit shown.



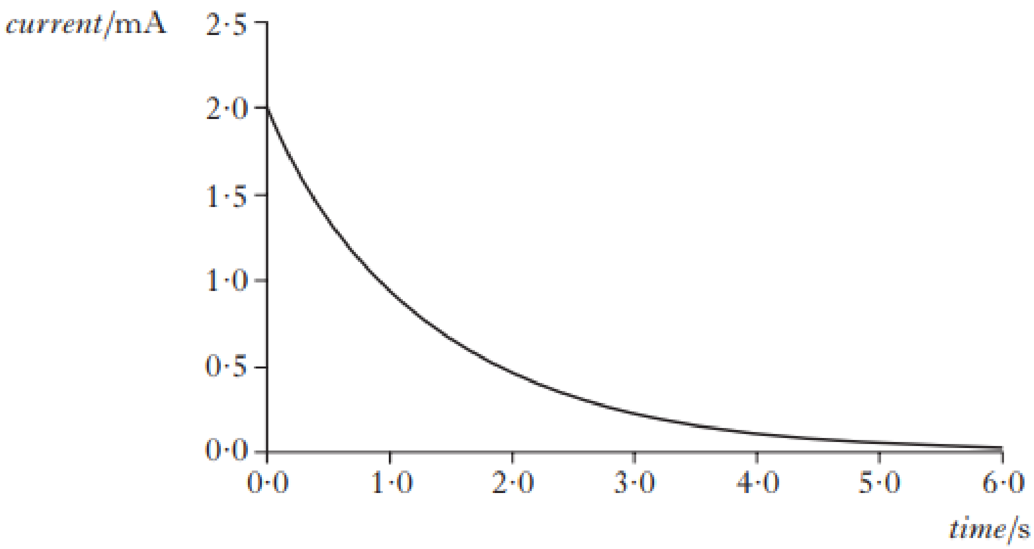
The power supply has an e.m.f. of 12 V and negligible internal resistance. The capacitor is initially uncharged.

(*a*) The switch is connected to **A** and the capacitor starts to charge. Sketch a graph showing how the voltage across the plates of the capacitor varies with time. Your graph should start from the moment the switch is connected to **A** until the capacitor is fully charged.

Numerical values are only required on the voltage axis. **2**

(*b*) The capacitor is now discharged by moving the switch to **B**.

The graph of current against time as the capacitor discharges is shown.



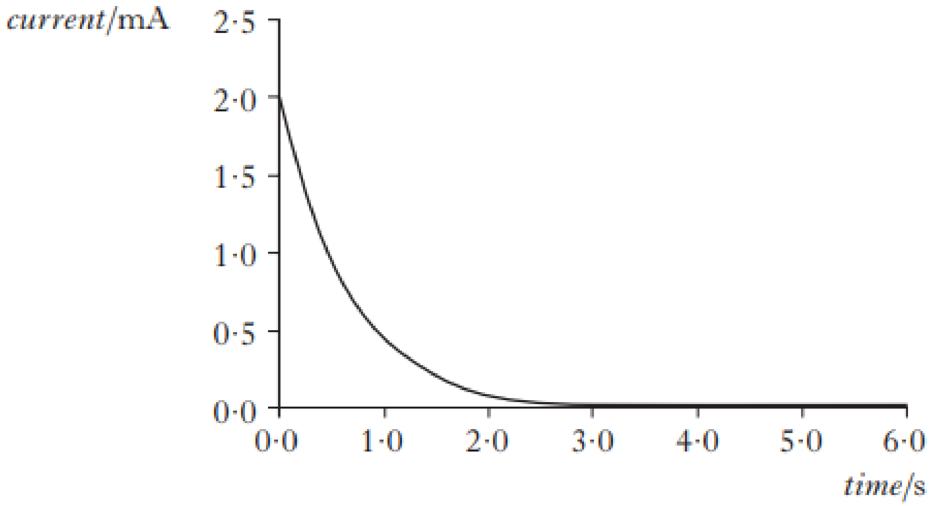
Calculate the resistance of R. **2**

Return to Capacitors Contents

2012 Q.26 cont.

(*c*) The 220 µF capacitor is now replaced with one of different value. This new capacitor is fully charged by moving the switch to **A**. It is then discharged by moving the switch to **B**.

The graph of current against time as this capacitor discharges is shown.



(i) Explain why the value of the initial discharging current remains the same as in part (*b*). **1**

(ii) How does the capacitance of this capacitor compare with the capacitance of the original 220 µF capacitor?

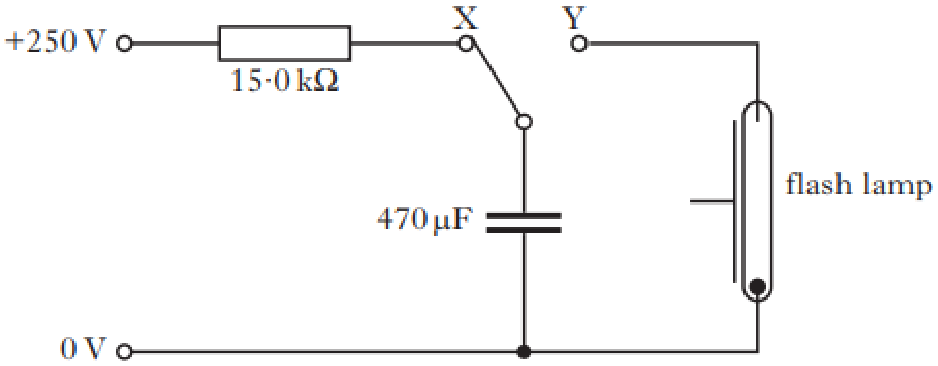
You must justify your answer. **2**

(7)

Return to Capacitors Contents

2013 Q.27

27. Part of a camera flash circuit operates at 250 V d.c. The circuit includes a 15·0 kΩ resistor and a 470 μF capacitor. The capacitor is initially uncharged.



(*a*) The capacitor is now charged by connecting the switch to X.

(i) Calculate the initial charging current. **2**

(ii) Sketch a graph to show how the voltage across the capacitor varies with time from the moment the switch is connected to X. Numerical values are required on the voltage axis. **1**

(iii) Show that the energy stored in the capacitor is 14·7 J when it is fully charged. **1**

(*b*) When a flash photograph is taken, the switch is connected to Y and the capacitor discharges through the flash lamp in a time of 200 μs.

Calculate the average power output of the flash lamp. **2**

(*c*) The flash cannot be fired again for another photograph until the capacitor has recharged. The time for this to happen is called the recycle time.

How could the circuit be modified to reduce the recycle time without altering the power output of the flash? **1**

(7)

2014 Q. 31

31. Recent innovations in capacitor technology have led to the development of "ultracapacitors". Ultracapacitors of a similar size to standard AA rechargeable cells are now available with ratings of around 100 F with a maximum working voltage of 2·7 V.

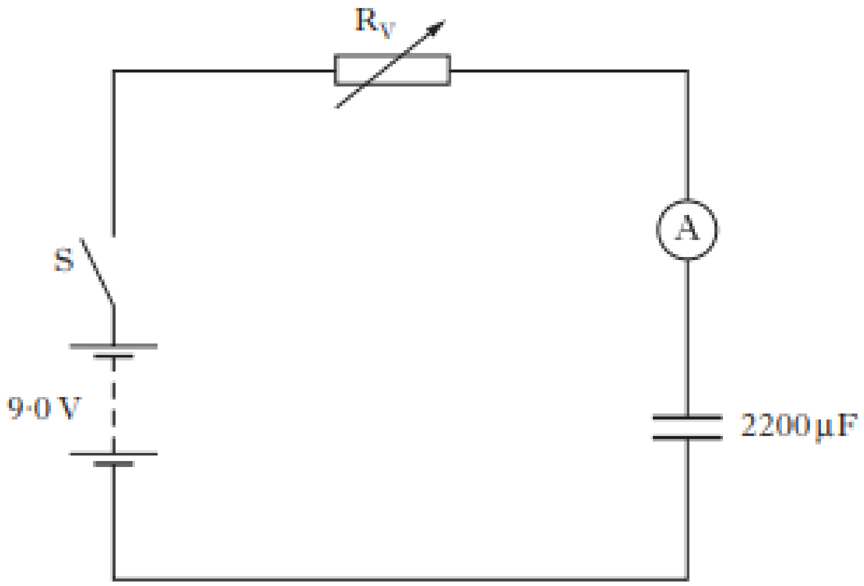
By comparison, AA rechargeable cells operate at 1·5 V and can store up to 3400 mA h of charge.
(*charge* in mA h = *current* in mA × *time* in hours)

Use your knowledge of physics to compare the advantages and/or disadvantages of using ultracapacitors and rechargeable cells. **(3)**

Return to Capacitors Contents

2014 Q.26

26. A student sets up the circuit shown to investigate the charging of a capacitor.



The battery has an e.m.f. of 9·0 V and negligible internal resistance.

Initially the capacitor is uncharged and the variable resistor R_V is set to 12 kΩ.

(*a*) Switch S is now closed and the capacitor charges.

Sketch a graph of the current in the circuit against time from the moment the switch is closed until the capacitor is fully charged.

Numerical values are only required on the current axis. **2**

(*b*) Capacitors have an insulator between their plates.

Explain why there is a current in the circuit during the charging process. **1**

(*c*) At one instant during the charging process, the current in the 12 kΩ resistor is $5{\cdot}0 \times 10^{-4}$ A.

Calculate the charge stored on the capacitor at this time. **3**

(*d*) Switch S is now opened and the capacitor is fully discharged. The variable resistor is adjusted to a greater resistance.

Switch S is closed and the capacitor charges again.

Explain what effect, if any, this increase in resistance has on:

(i) the maximum potential difference across the capacitor; **1**

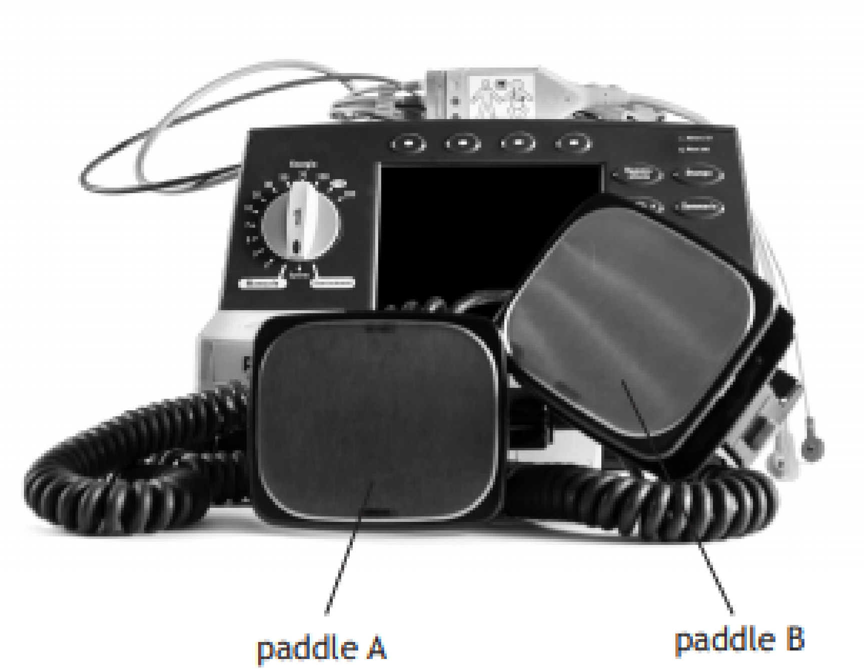
(ii) the maximum current in the circuit. **1**

(8)

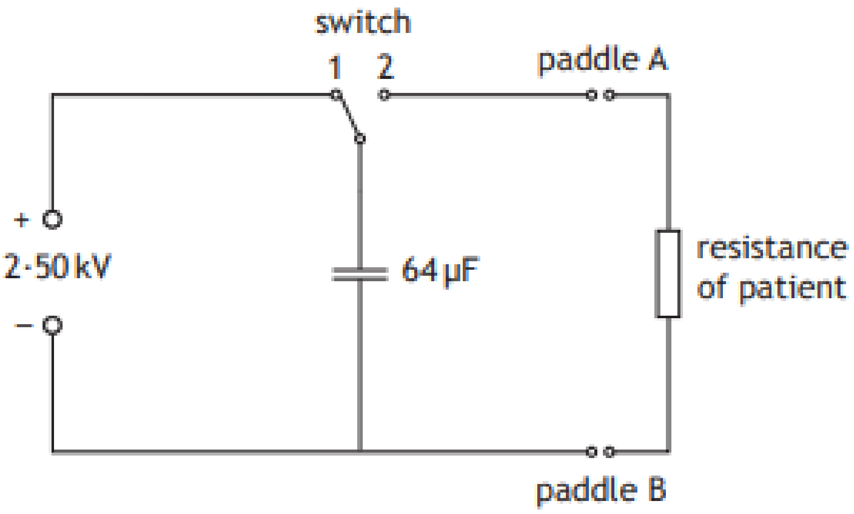
Return to Capacitors Contents

2015 Q.11

11. A defibrillator is a device that provides a high energy electrical impulse to correct abnormal heart beats. **MARK**



The diagram shows a simplified version of a defibrillator circuit.



The switch is set to position 1 and the capacitor charges.

(a) Show the charge on the capacitor when it is fully charged is 0·16 C. **2**

(b) Calculate the maximum energy stored by the capacitor. **3**

Return to Capacitors Contents

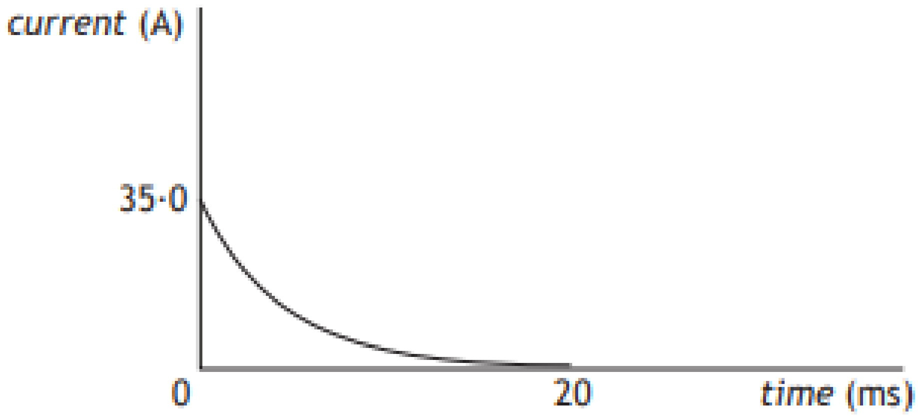
2015 Q.11 cont.

(c) To provide the electrical impulse required the capacitor is discharged through the person's chest using the paddles as shown

The initial discharge current through the person is 35·0 A.

(i) Calculate the effective resistance of the part of the person's body between the paddles. **3**

(ii) The graph shows how the current between the paddles varies with time during the discharge of the capacitor.



The effective resistance of the person remains the same during this time.

Explain why the current decreases with time. **1**

(iii) The defibrillator is used on a different person with larger effective resistance. The capacitor is again charged to 2·50 kV.

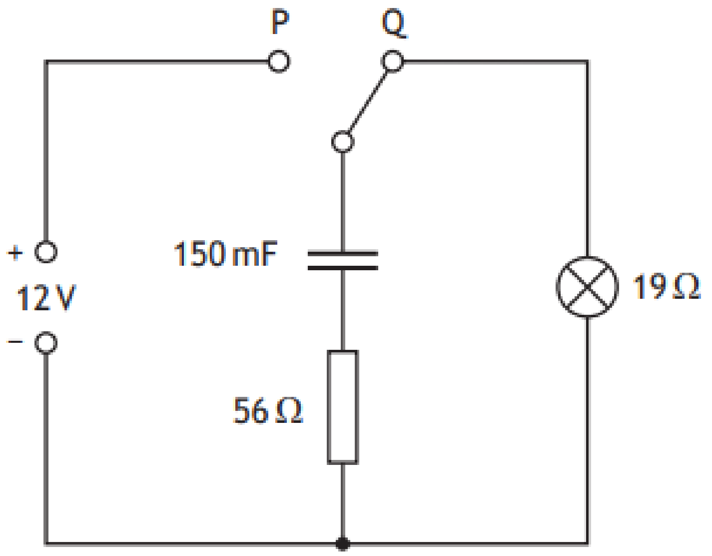
On the graph in (c)(ii) add a line to show how the current in this person varies with time.

(An additional graph, if required, can be found on *Page thirty-eight*). **2**

Return to Capacitors Contents

2016 Q.13

13. A technician sets up a circuit as shown.



The power supply has negligible internal resistance.

(a) The capacitor is initially uncharged.

The switch is moved to position P and the capacitor charges.

(i) State the potential difference across the capacitor when it is fully charged. **1**

(ii) Calculate the maximum energy stored by the capacitor. **3**

(b) The switch is now moved back to position Q.

Determine the maximum discharge current in the circuit. **3**

(c) The technician replaces the 150 mF capacitor with a capacitor of capacitance 47 mF.

The switch is moved to position P and the capacitor is fully charged.

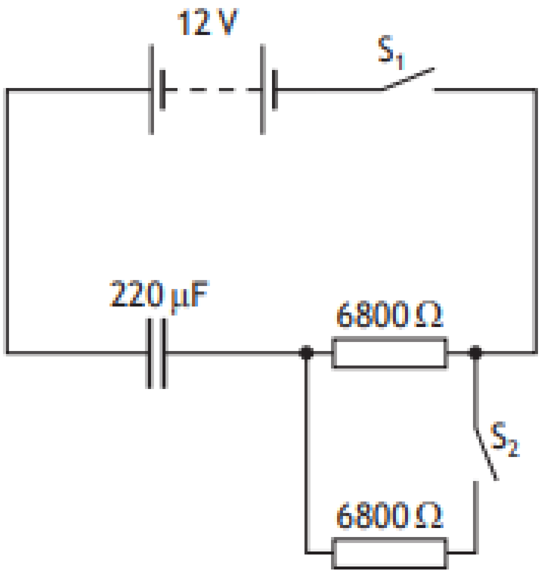
The switch is now moved to position Q.

State the effect that this change has on the time the lamp stays lit.

You must justify your answer. **2**

Return to Capacitors Contents

13. An uncharged 220 μF capacitor is connected in a circuit as shown. **MARK**



The 12 V battery has negligible internal resistance.

(a) Switch S_1 is closed and the capacitor charges in a time of 7·5 s.

Calculate the initial charging current. **3**

(b) Switch S_1 is opened.

The capacitor is discharged.

Switch S_2 is now closed and then switch S_1 is closed.

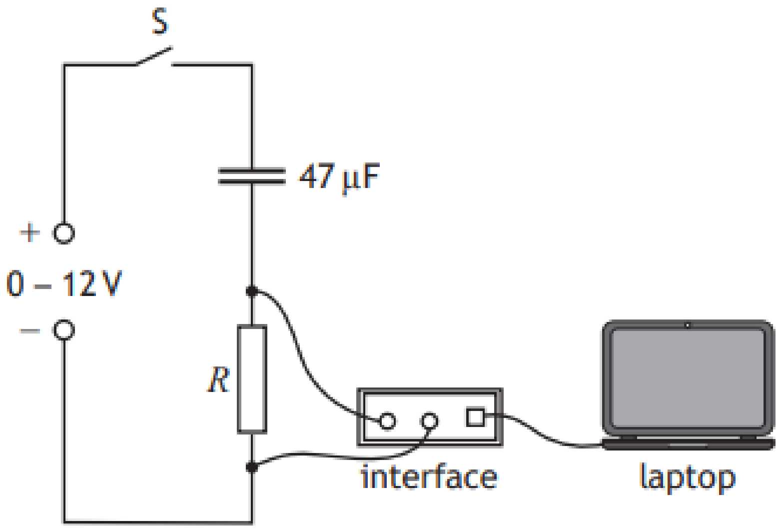
Explain why the time for the capacitor to fully charge is less than in part (a). **2**

Return to Capacitors Contents

2019 Q.13

13. A student investigates the charging of a capacitor.

The student sets up the circuit as shown using a 47 μF capacitor.



The capacitor is initially uncharged. The switch S is now closed. A laptop connected to an interface displays a graph of current against time as the capacitor charges.

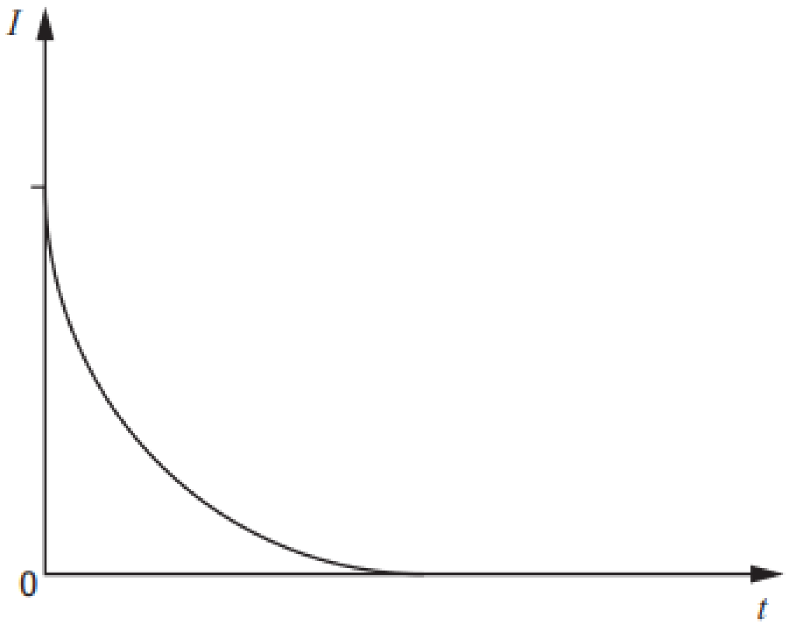
(a) The variable voltage supply is set at 6·0 V.

Calculate the maximum charge stored by the capacitor. **3**

Return to Capacitors Contents

2019 Q.13 cont.

(b) The graph shows how the current I varies with time t as the capac
charges.



Switch S is opened, and the capacitor is discharged.

The resistor is now replaced with one that has a greater resistance.

Switch S is again closed and the capacitor charges.

Add a line to the graph above to show how the current now varies with time as the capacitor charges. **2**

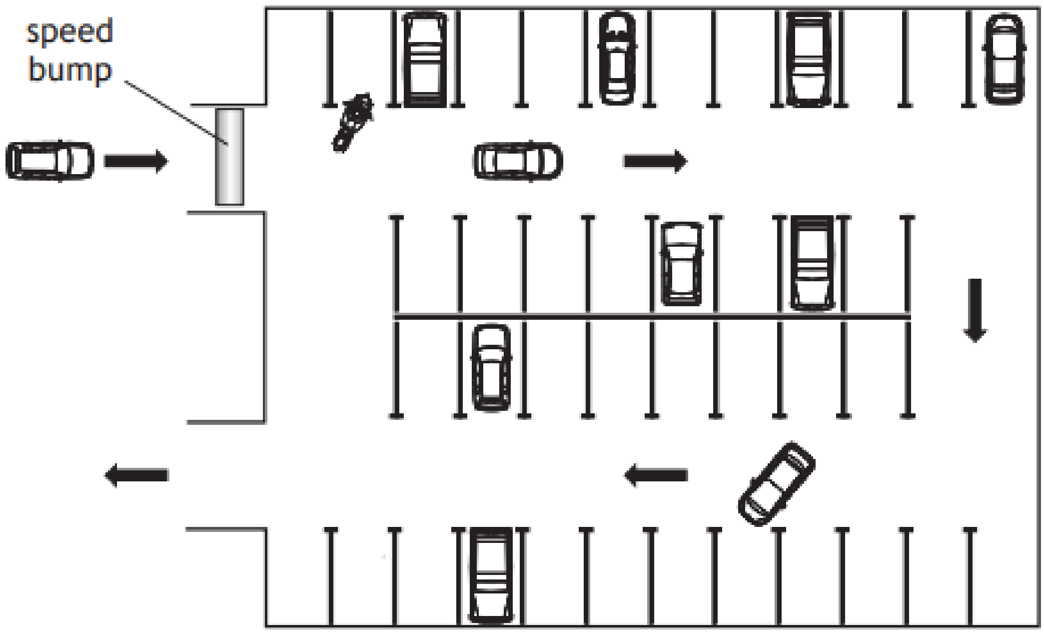
(An additional graph, if required, can be found on *page 45*.)

(c) Suggest an alteration the student could make to this circuit to increase the maximum energy stored by the 47 μF capacitor. **1**

Return to Capacitors Contents

(d) The use of analogies from everyday life can help improve understanding of physics concepts.

Vehicles using a car park may be taken as an analogy for the charging of a capacitor.

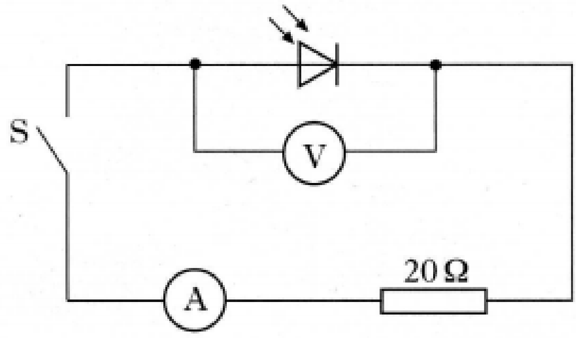


Use your knowledge of physics to comment on this analogy. **3**

Semiconductors

2000 Q.25 a

25. A photodiode is connected in a circuit as shown below.



Switch S is open.

Light is shone on to the photodiode.

A reading is obtained on the voltmeter.

(*a*) (i) State the mode in which the photodiode is operating.

(ii) Describe the effect of light on the material of which the photodiode is made.

(iii) The intensity of the light on the photodiode is increased.

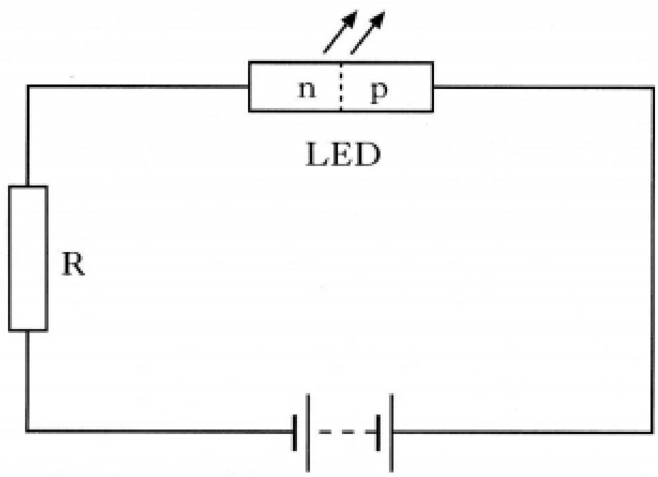
What happens to the reading on the voltmeter? **3**

2002 Q. 29 a, b(i)

29. (*a*) A sample of pure semiconducting material is doped by adding impurity atoms.

How does this addition affect the resistance of the semiconducting material? **1**

(*b*) The circuit below shows a p-n junction diode used as a light emitting diode (LED).

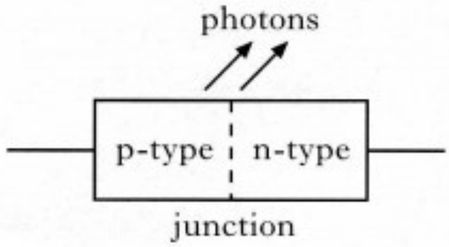


(i) Explain in terms of the charge carriers how the LED emits light.

Return to SemiConductors Contents

2004 Q.29 a,b

29. An LED consists of a p-n junction as shown.



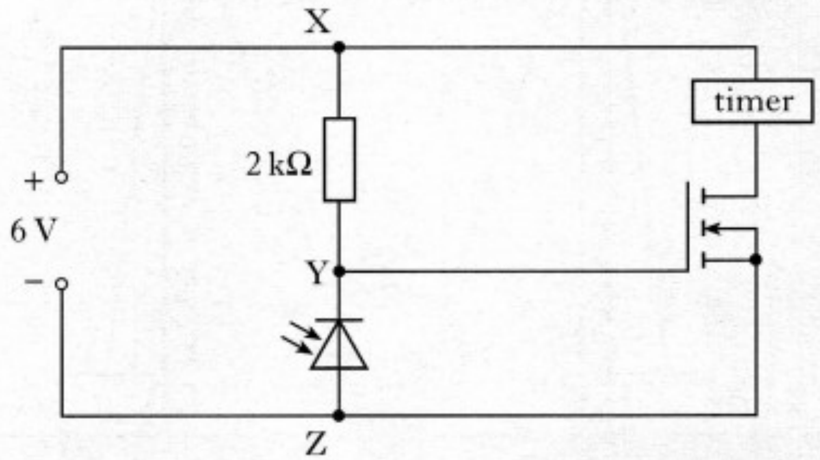
(*a*) Copy the diagram and add a battery so that the p-n junction is forward-biased. **1**

(*b*) Using the terms *electrons, holes* and *photons*, explain how light is produced at the p-n junction of the LED. **1**

2005 Q. 21 b

(*b*) The light gate consists of a lamp shining onto a photodiode.

The photodiode forms part of the circuit shown.



(i) In which mode is the photodiode operating? **1**

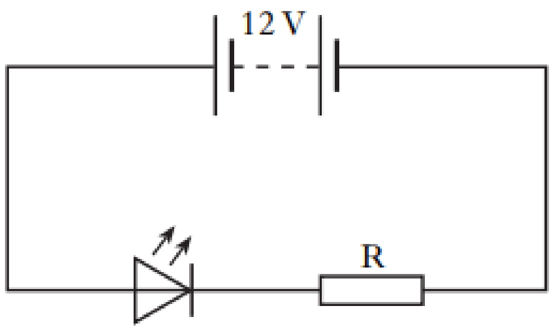
(ii) Explain why the timer only operates while the light beam is broken. **2**

Return to SemiConductors Contents

2008 Q. 21 c

(*c*) The brake lights of the car consist of a number of very bright LEDs.

An LED from the brake lights is forward biased by connecting it to a 12 V car battery as shown.



The battery has negligible internal resistance.

(i) Explain, in terms of charge carriers, how the LED emits light. **1**

(ii) The LED is operating at its rated values of 5·0 V and 2·2 W.

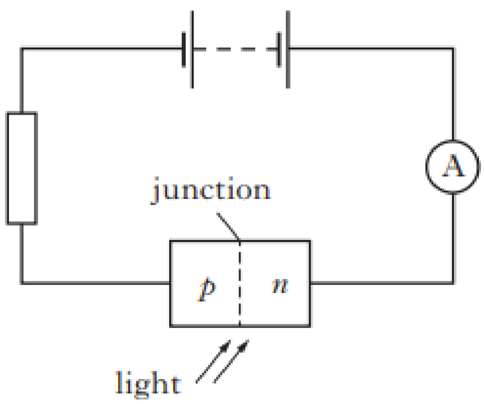
Calculate the value of resistor R. **3**

2012 Q. 30 a, b

30. (*a*) An n-type semiconductor is formed by adding impurity atoms to a sample of pure semiconductor material.

State the effect that the addition of the impurity atoms has on the resistance of the material. **1**

(*b*) A p-n junction is used as a photodiode as shown.



(i) In which mode is the photodiode operating? **1**

(ii) The irradiance of the light on the junction of the photodiode is now increased.

Explain what happens to the current in the circuit. **2**

Return to SemiConductors Contents

2013 Q. 31 a

31. (*a*) Use band theory to explain how electrical conduction takes place in a pure semiconductor such as silicon.

Your explanation should include the terms: *electrons*, *valence band* and *conduction band*. **2**

2015 Q. 28 a

28. A sample of pure semiconductor has a high resistance at room temperature. Doping this sample decreases its resistance and can create n-type or p-type semiconductors. Semiconductors are used to make many solid state devices such as the photodiode.

(*a*) State what is meant by the terms:

(i) *doping*; **1**

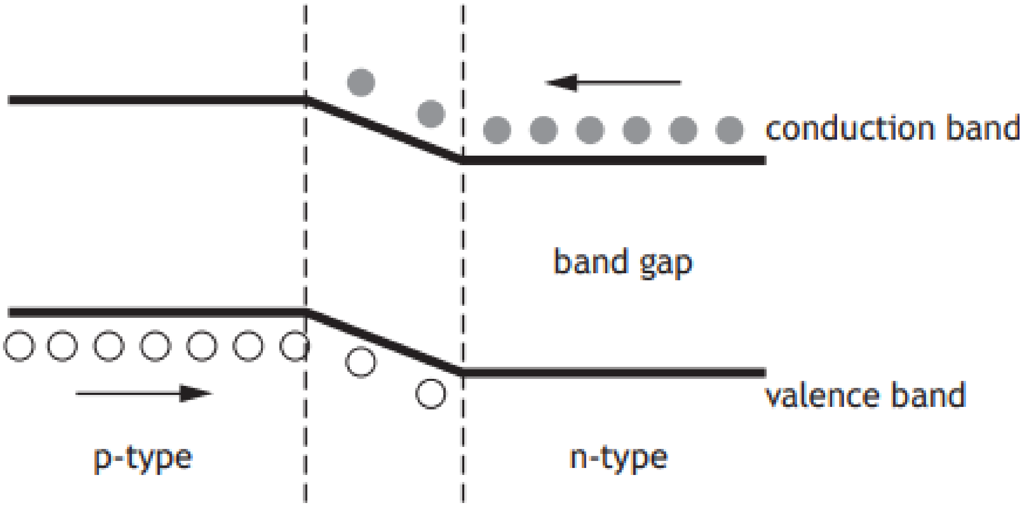
(ii) *n-type semiconductor*. **1**

2016 Q.12 b

(b) Some cars use LEDs in place of filament lamps.

An LED is made from semiconductor material that has been doped with impurities to create a p-n junction.

The diagram represents the band structure of an LED.



(i) A voltage is applied across an LED so that it is forward biased and emits light.

Using **band theory,** explain how the LED emits light. **3**

Return to SemiConductors Contents

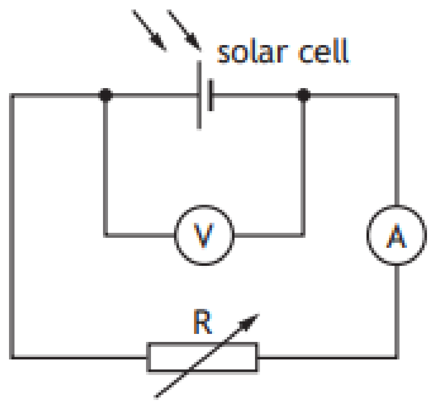
2017 Q.14

14. Solar cells are made by joining n-type and p-type semiconductor materials. A layer is formed at the junction between the materials.

(a) A potential difference is produced when photons enter the layer between the p-type and n-type materials.

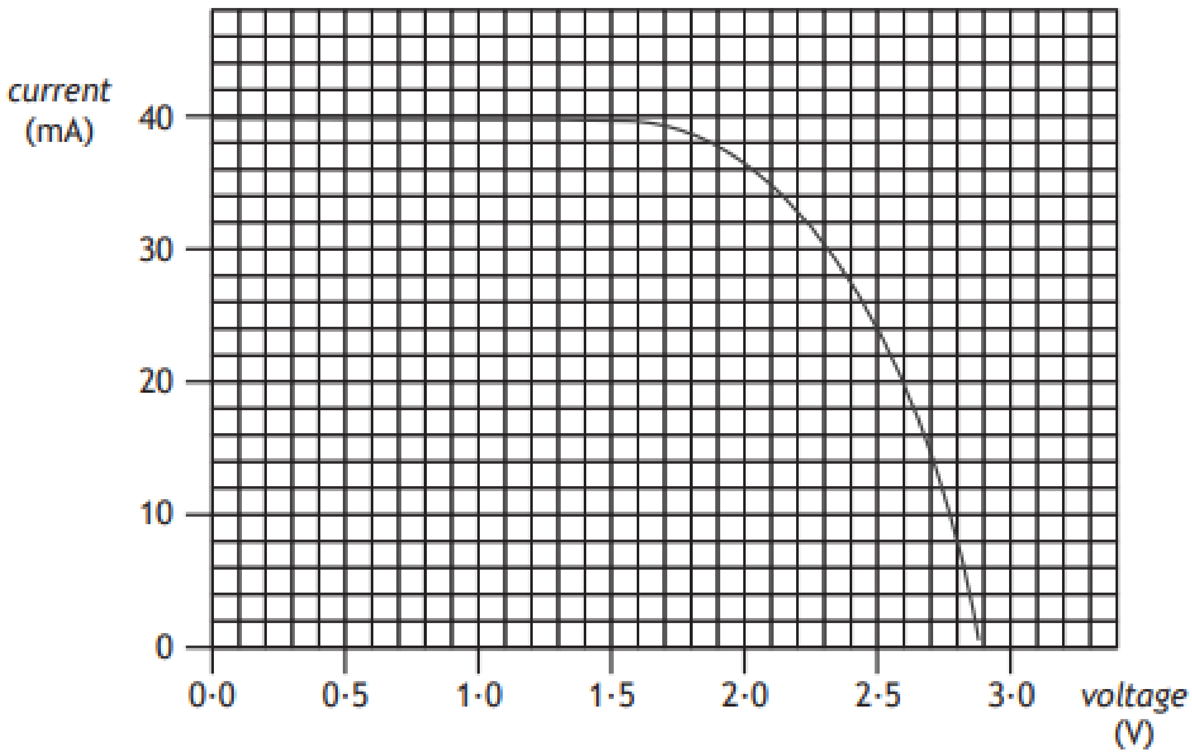
State the name of this effect. **1**

(b) A student carries out an experiment using a solar cell connected to a variable resistor R as shown.



A lamp is placed above the solar cell and switched on.

The variable resistor is altered and readings of current and voltage are taken. These readings are used to produce the following graph.



Return to SemiConductors Contents

2017 Q.14 cont.

(i) Solar cells have a maximum power output for a particular irradiance of light.

In this experiment, the maximum power output occurs when the voltage is 2·1 V.

Use information from the graph to estimate a value for the maximum power output from the solar cell. **3**

(ii) The lamp is now moved closer to the solar cell.

Explain, in terms of photons, why the maximum output power from the solar cell increases. **1**

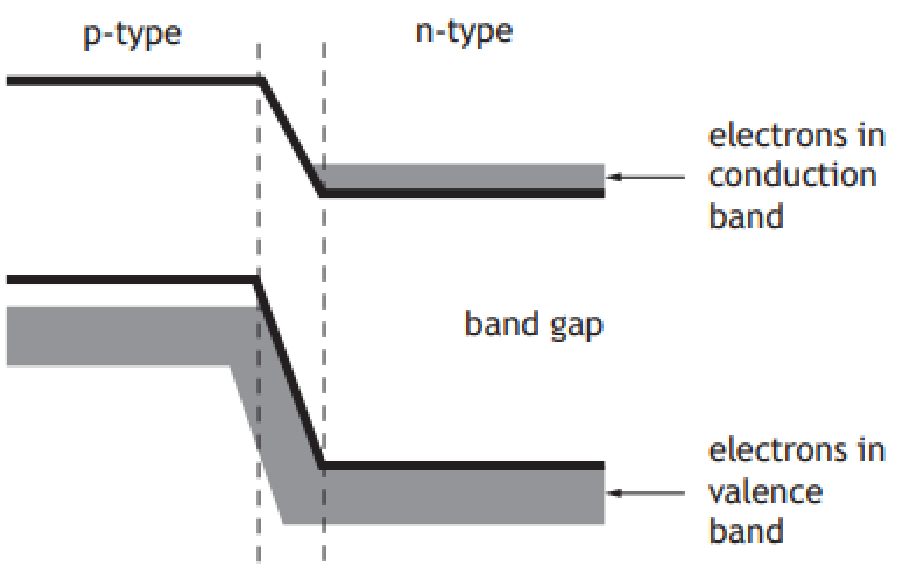
2018 Q. 11 c

(c) The student connects a red LED and a blue LED, in turn, to the battery.

The LEDs are forward biased when connected.

The student observes that the battery will operate the red LED but not the blue LED.

The diagram represents the band structure of the blue LED.



LEDs emit light when electrons fall from the conduction band into the valence band of the p-type semiconductor.

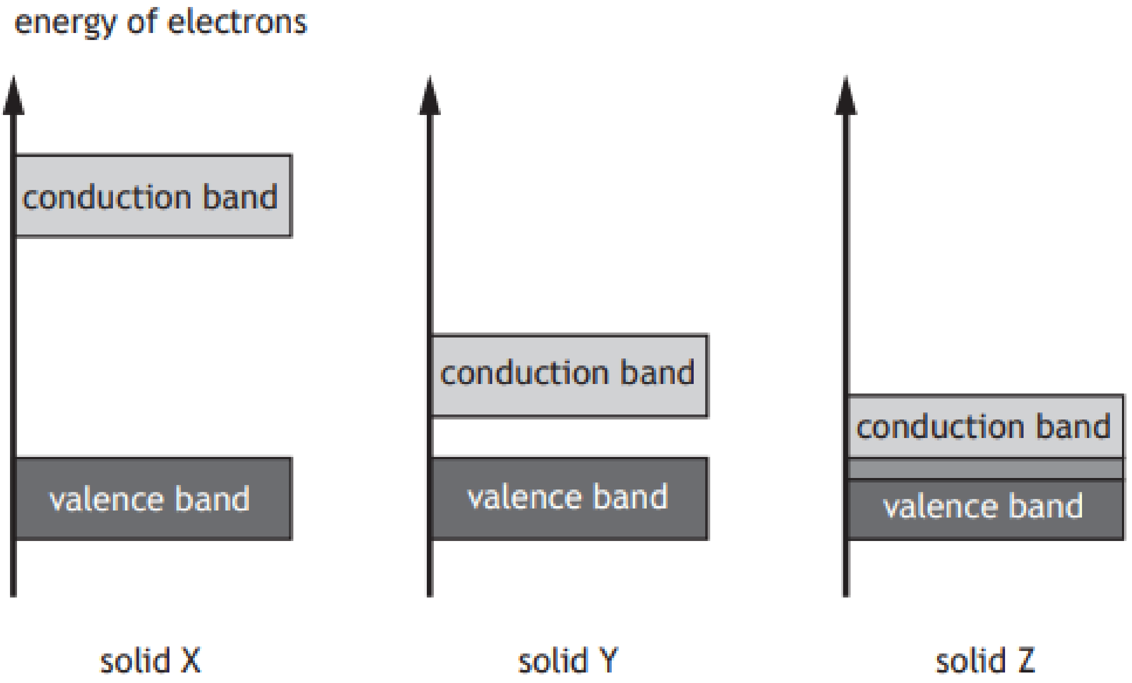
Explain, using **band theory**, why the blue LED will not operate with this battery. **1**

2019 Q.14 a, b, c

14. Solids can be categorised as conductors, insulators or semiconductors depending on their ability to conduct electricity. Their electrical conductivity can be explained using band theory.

The diagrams show the valence and conduction bands of three solids X, Y and Z.

One represents a conductor, one represents an insulator and one represents a semiconductor.



(a) Complete the table to show which solid represents a conductor, an insulator and a semiconductor. **1**

Solid	Category
X	
Y	
Z	

(b) Using **band theory**, explain why conduction can take place in a semiconductor at room temperature. **2**

(c) Silicon can be doped with arsenic to produce an n-type semiconductor.

State the effect that doping has on the conductivity of silicon. **1**

Return to SemiConductors Contents