H

Exam Question Practice

Section 2 — Extended Answer Questions for UNIT 2 -ELECTRICTY

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \mathrm{m\,s^{-1}}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \mathrm{J\,s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \mathrm{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \mathrm{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \mathrm{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \mathrm{m\,s^{-2}}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \mathrm{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ \mathrm{s^{-1}}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

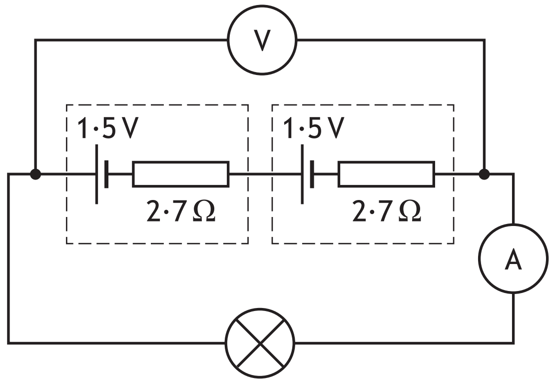
Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 } 10590 }	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

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**

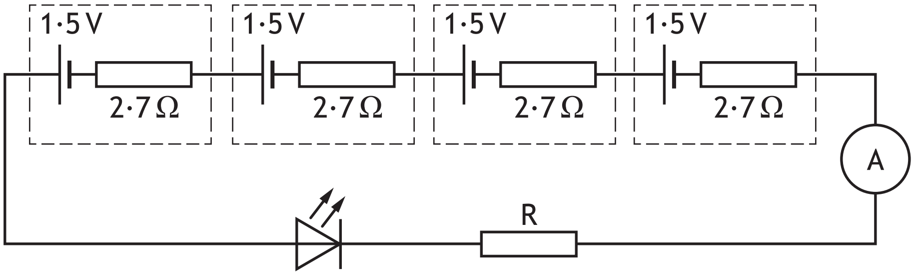
Space for working and answer

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

Space for working and answer

12. (continued)

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

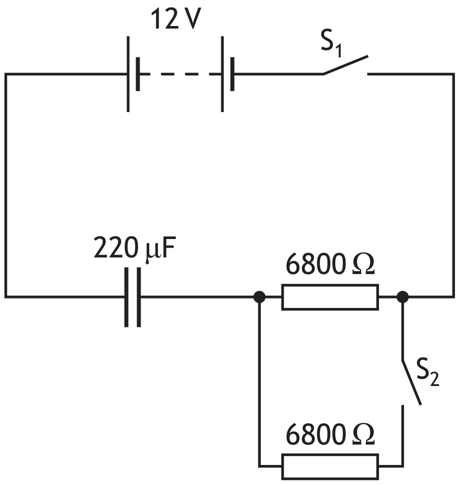


The potential difference across the LED is 3·6 V when the current is 26 mA.

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

Space for working and answer

13. An uncharged 220 μF capacitor is connected in a circuit as shown. **MARKS** DO NOT WRITE IN THIS MARGIN



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**

Space for working and answer

(b) Switch S_1 is opened.

The capacitor is discharged.

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

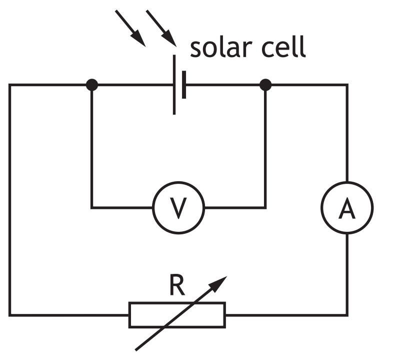
Explain why the time for the capacitor to fully charge is less than in part (a). **2**

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.

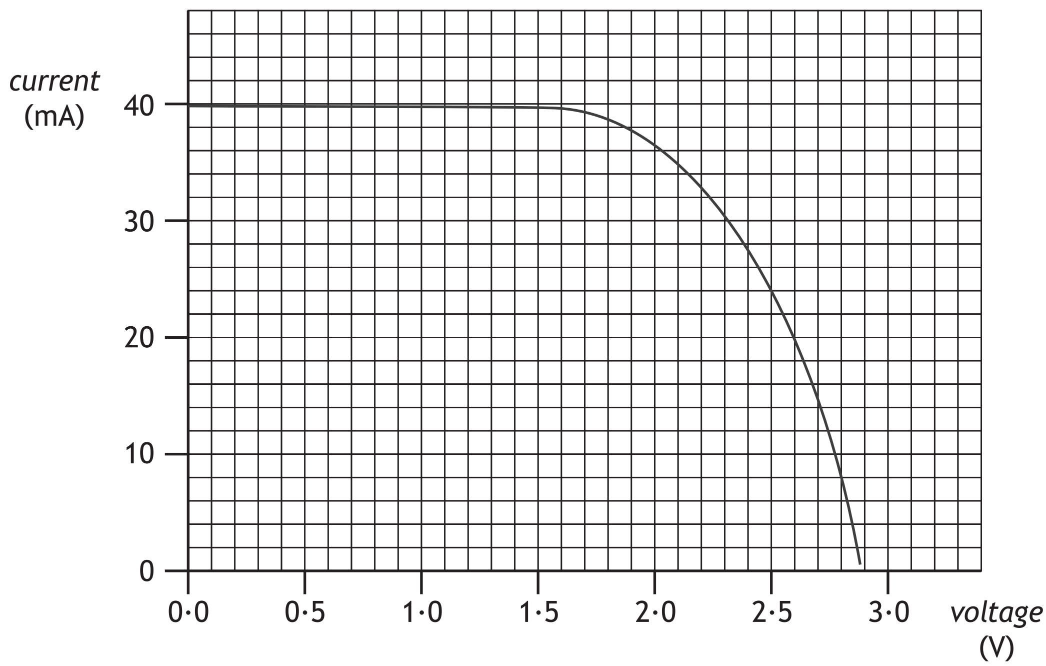
State the name of this effect. **1**

(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.



14. (b) (continued)

(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**

Space for working and answer

(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**

15. A wire of length L and cross-sectional area A is shown.

The resistance R of the wire is given by the relationship

$$R = \frac{\rho L}{A}$$

where ρ is the resistivity of the wire in $\Omega\,\text{m}$.

(a) The resistivity of aluminium is $2{\cdot}8 \times 10^{-8}\,\Omega\,\text{m}$.

Calculate the resistance of an aluminium wire of length $0{\cdot}82\,\text{m}$ and cross-sectional area $4{\cdot}0 \times 10^{-6}\,\text{m}^2$. **2**

Space for working and answer

(b) A student carries out an investigation to determine the resistivity of a cylindrical metal wire of cross-sectional area $4{\cdot}52 \times 10^{-6}\,m^2$.

The student varies the length L of the wire and measures the corresponding resistance R of the wire.

The results are shown in the table.

Length of wire L (m)	*Resistance of wire* R ($\times 10^{-3}\,\Omega$)
1·5	5·6
2·0	7·5
2·5	9·4
3·0	11·2
3·5	13·2

(i) Using the square-ruled paper on *Page 36*, draw a graph of R against L. **3**

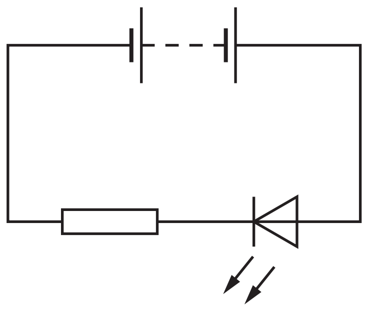
(ii) Calculate the gradient of your graph. **2**

Space for working and answer

(iii) Determine the resistivity of the metal wire. **3**

Space for working and answer

11. A student is describing how the following circuit works.



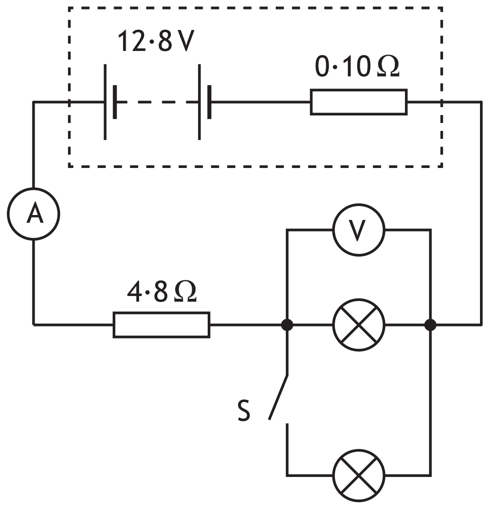
The student states:

"The electricity comes out of the battery with energy and flows through the resistor using up some of the energy, it then goes through the LED and the rest of the energy is changed into light waves."

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

12. 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.

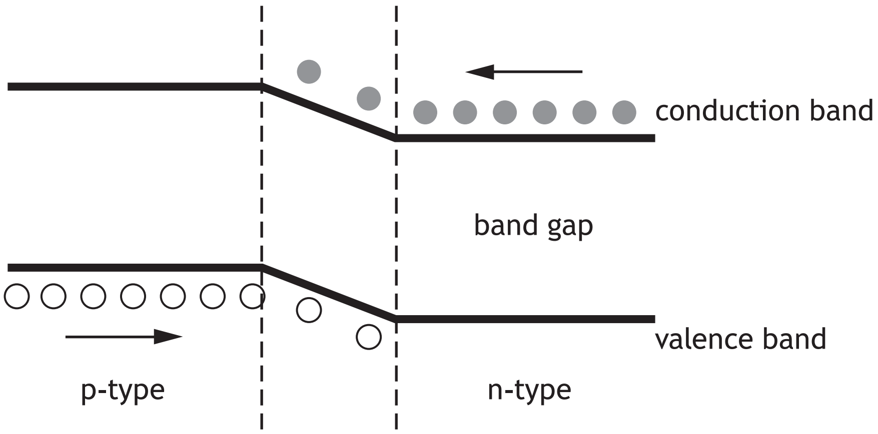
Justify your answer. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

(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**

(ii) The energy gap between the valence band and conduction band is known as the band gap.

The band gap for the LED is $3{\cdot}03 \times 10^{-19}$ J

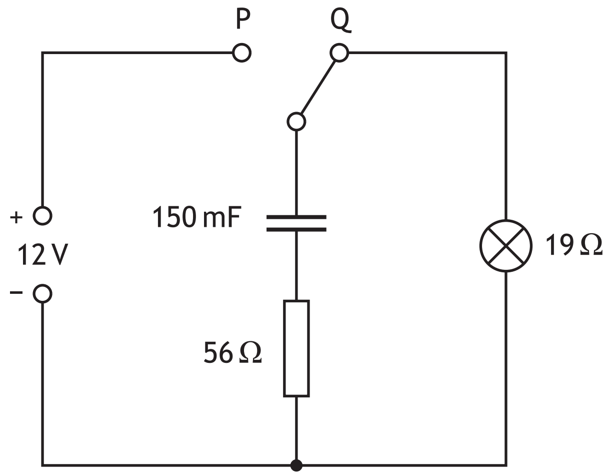
(A) Calculate the wavelength of the light emitted by the LED. **4**

Space for working and answer

(B) Determine the colour of the light emitted by the LED. **1**

MARKS | DO NOT WRITE IN THIS MARGIN

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**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

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

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

Space for working and answer

(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.

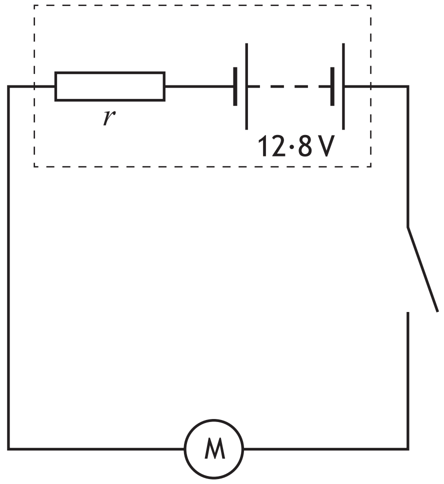
The switch is now moved to position Q.

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

You must justify your answer. **2**

[Turn over for next question

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 $0{\cdot}050\,\Omega$.

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

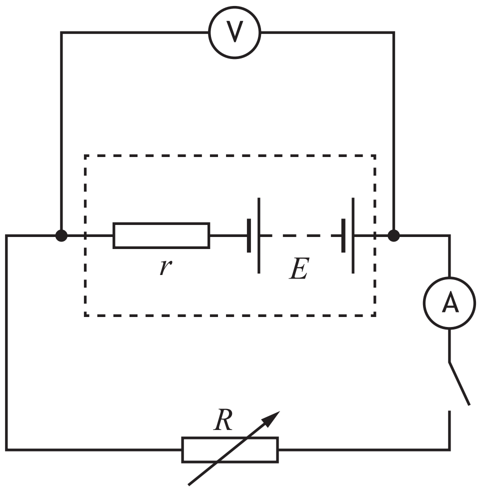
(ii) Calculate the current in the circuit when the motor is operating. **3**

Space for working and answer

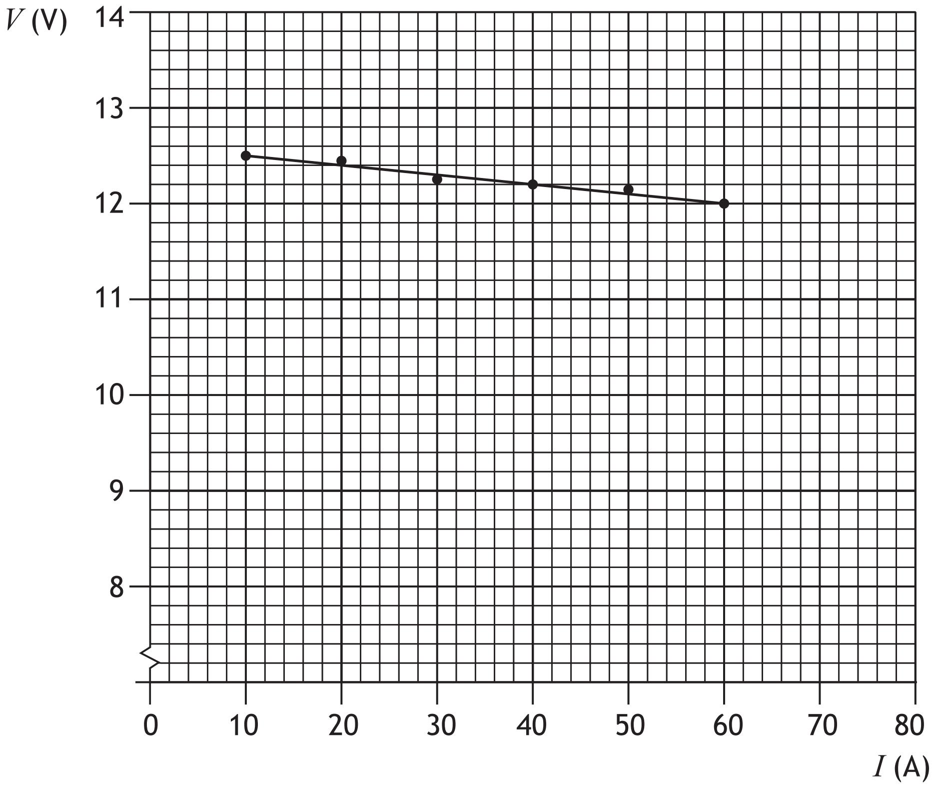
(iii) Suggest why the connecting wires used in this circuit have a large diameter. **1**

10. (continued)

(b) A technician sets up the following circuit with a different car battery 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.



MARKS DO NOT WRITE IN THIS MARGIN

10. (b) (continued)

Use information from the graph to determine:

(i) the e.m.f. of the battery; **1**

Space for working and answer

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

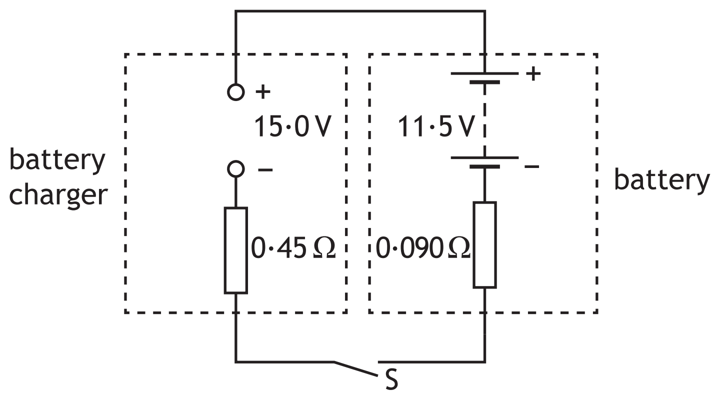
Space for working and answer

[Turn over

10. (b) (continued)

(iii) After being used for some time the e.m.f. of the battery decreases to 11·5 V and the internal resistance increases to 0·090 Ω.

The battery is connected to a battery charger of constant e.m.f. 15·0 V and internal resistance of 0·45 Ω as shown.



(A) Switch S is closed.

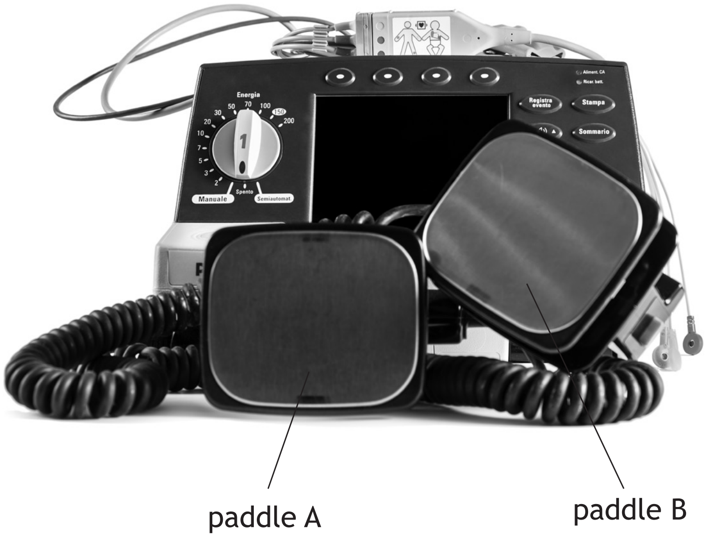
Calculate the initial charging current. **3**

Space for working and answer

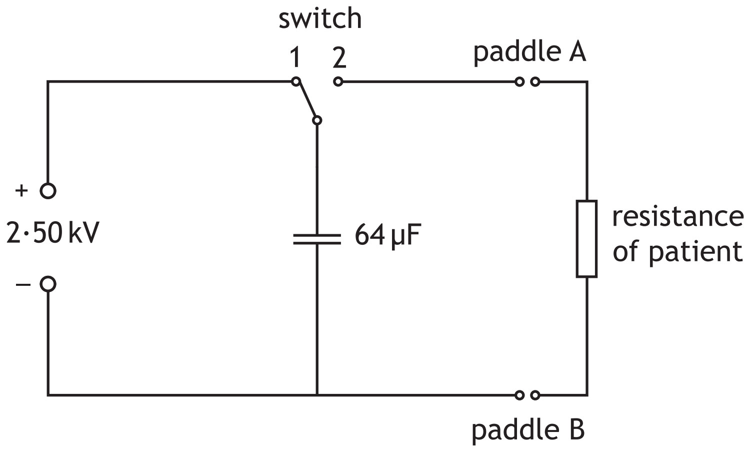
(B) Explain why the charging current decreases as the battery charges. **2**

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

MARKS | DO NOT WRITE IN THIS MARGIN



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**

Space for working and answer

MArKS DO NOT WRITE IN THIS MARGIN

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

Space for working and answer

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

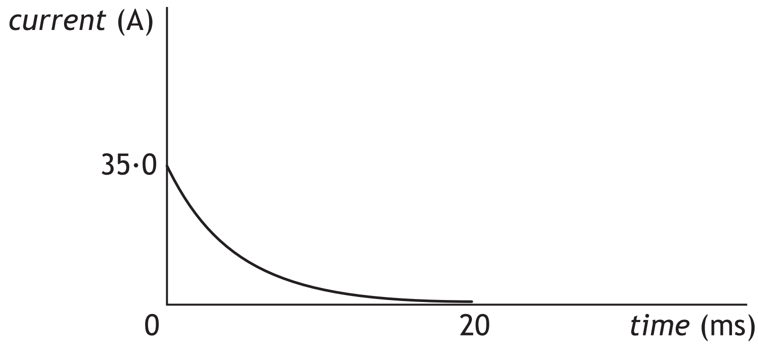
The initial discharge current through the person is 35·0 A.

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

Space for working and answer

11. (c) (continued)

(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.

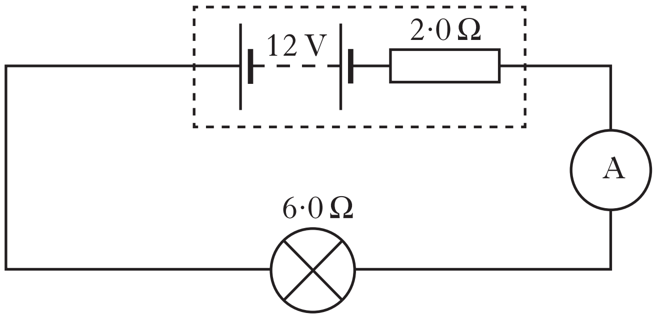
On the graph in (c)(ii) add a line to show how the current in this person varies with time.

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

Marks

31. A student carries out two experiments using different power supplies connected to a lamp of resistance $6{\cdot}0\,\Omega$.

(*a*) In the first experiment, the lamp is connected to a power supply of e.m.f. 12 V and internal resistance $2{\cdot}0\,\Omega$ 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.

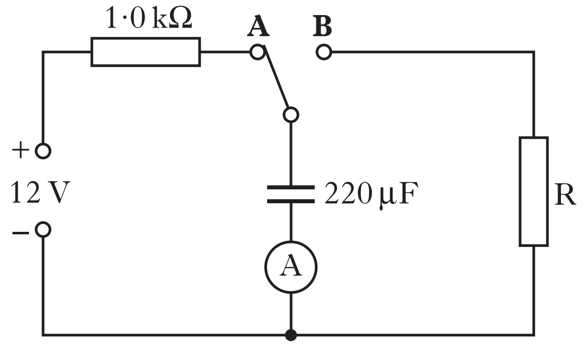
Assuming the resistance of the lamp has not changed, is the internal resistance of the new power supply less than, equal to, or greater than the internal resistance of the original supply?

Justify your answer. **2**

(7)

Marks

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



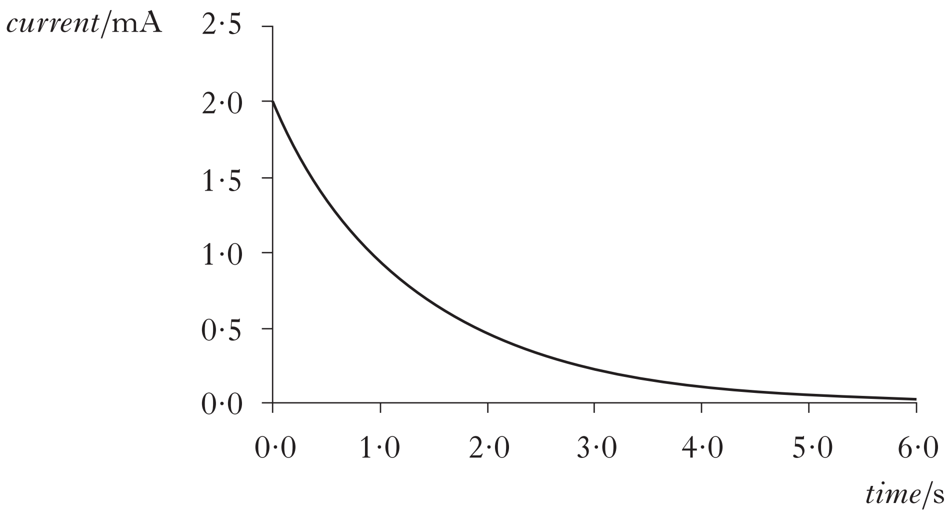
The power supply has an e.m.f. of 12 V and negligible internal resistance. The capacitor is initially uncharged.

(*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.



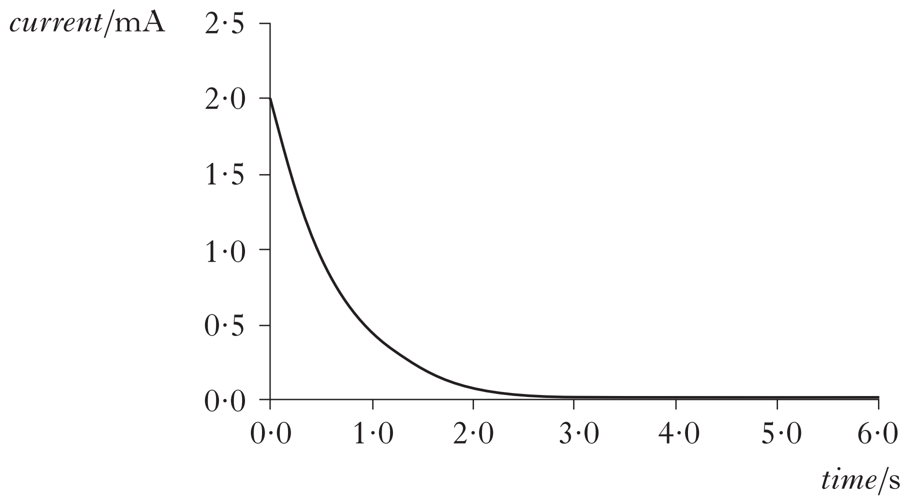
Calculate the resistance of R. **2**

Marks

32. (continued)

(*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?

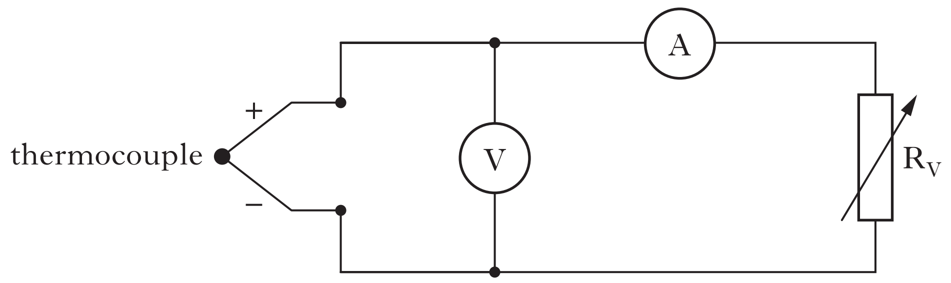
You must justify your answer. **2**

(7)

Marks

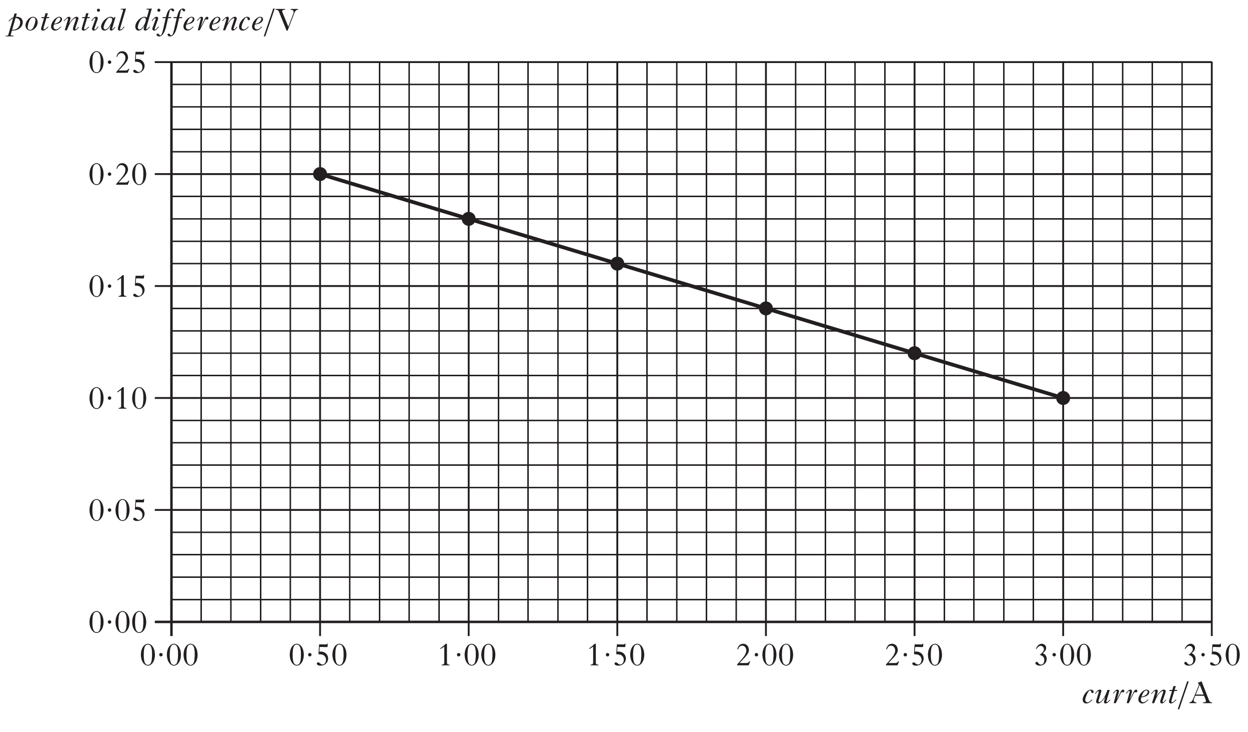
30. A thermocouple is a device that produces an e.m.f. when heated.

(*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.

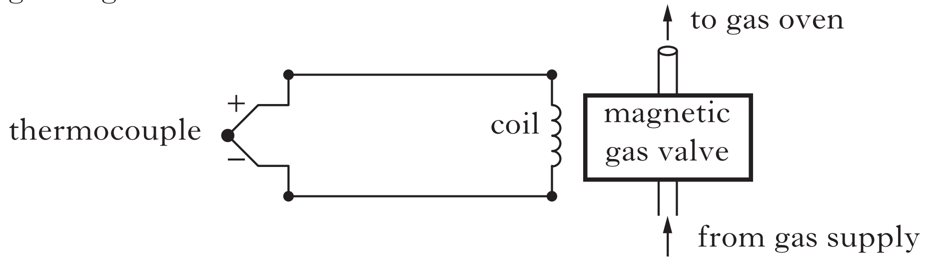
The graph of p.d. against current is shown.



Use information from the graph to find:

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

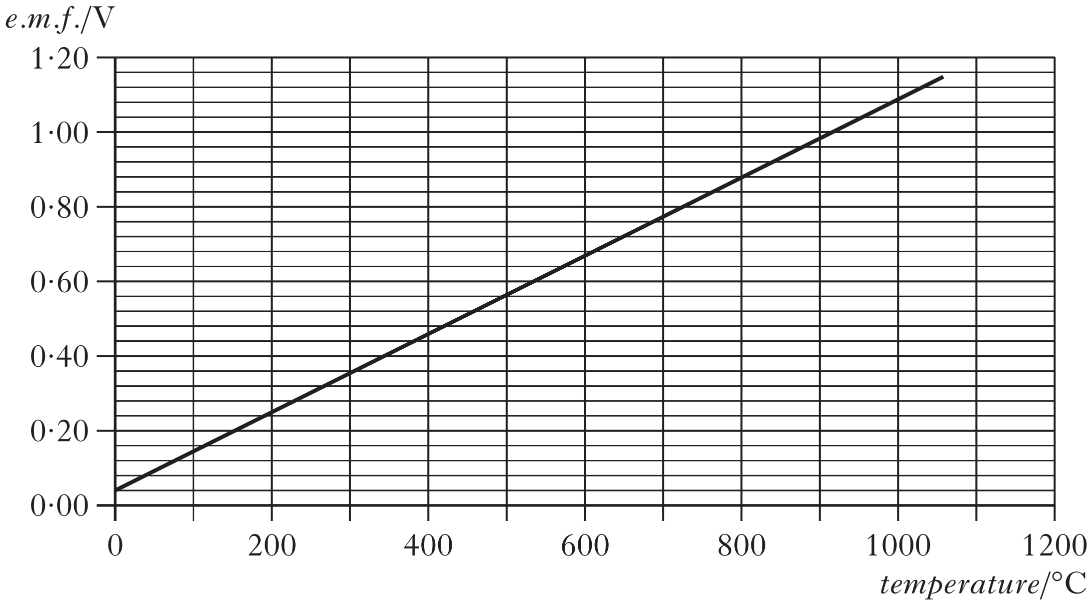
(ii) the internal resistance of the thermocouple. **2** (*b*) A **different** thermocouple is to be used as part of a safety device in a gas oven. The safety device turns off the gas supply to the oven if the flame goes out. The thermocouple is connected to a coil of resistance 0·12 Ω which operates a magnetic gas valve.

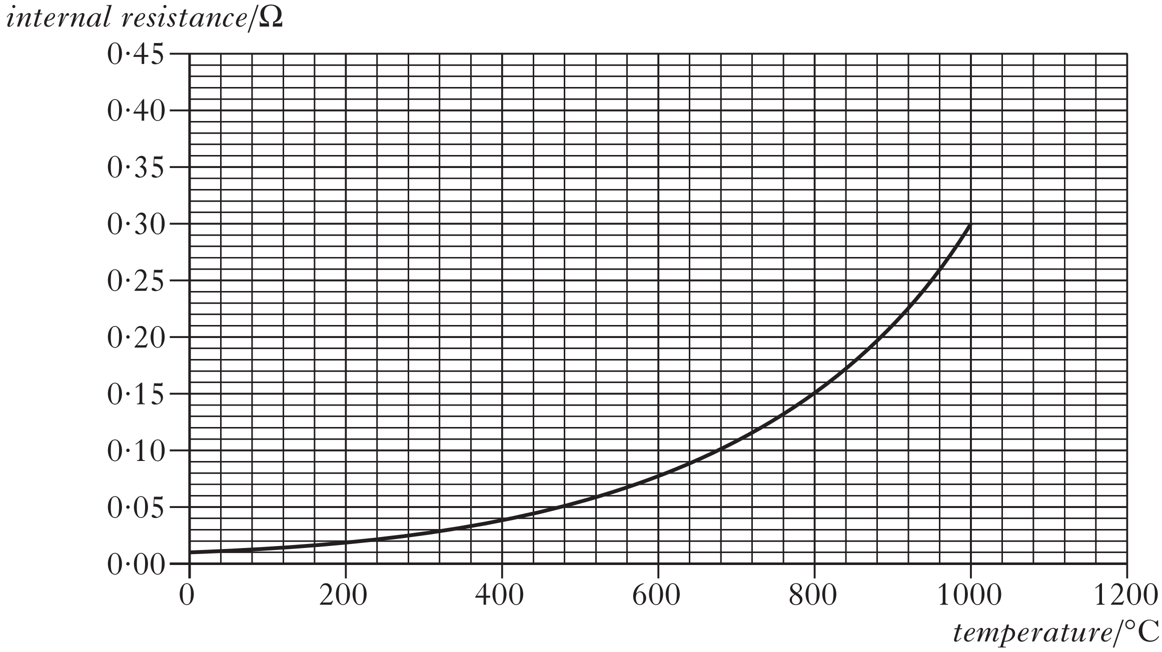


When the current in the coil is less than 2·5 A, the gas valve is closed.

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)

Marks

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**

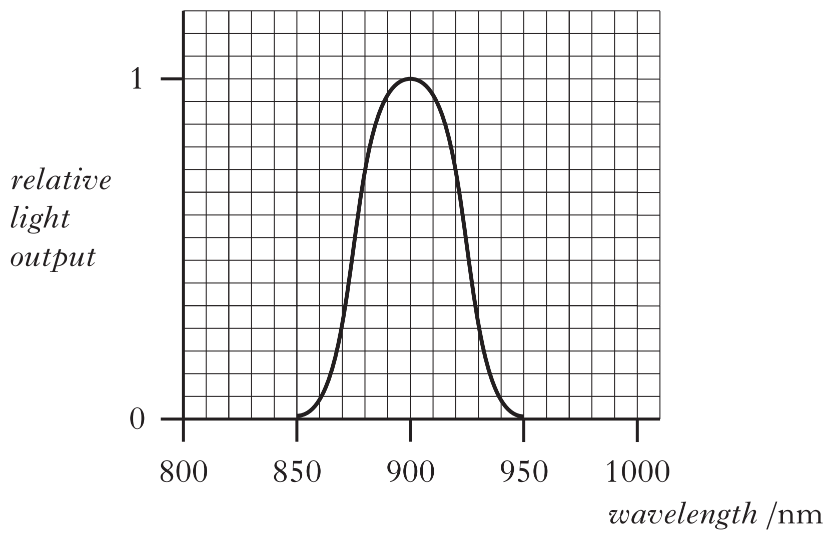
(*b*) A light emitting diode (LED) is a p-n junction which emits light. The table gives the colour of some LEDs and the voltage across the junction required to switch on the LED.

Colour of LED	*Switch on voltage*/V
Green	2·0
Red	1·4
Yellow	1·7

Using this data, suggest a possible value for the switch on voltage of an LED that emits blue light. **1**

(*c*) The remote control for a television contains an LED.

The graph shows the range of wavelengths emitted by the LED and the relative light output.



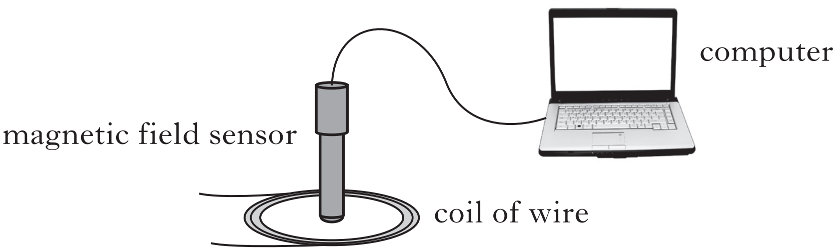
Calculate the maximum energy of a photon emitted from this LED. **3**

(6)

Marks

32. A student is investigating how the magnetic field strength at the centre of a coil of wire depends on the direct current in the coil.

The strength of the magnetic field is measured with a magnetic field sensor placed in the centre of the coil. The sensor is connected to a computer as shown.



The computer displays values of magnetic field strength. The unit of magnetic field strength is the tesla (T).

(*a*) The student designs a circuit to vary and measure the current in the coil of wire.

The circuit symbol for a coil of wire is shown.

Draw a circuit diagram to show how the current in the coil could be varied and measured. **2**

(*b*) The following results are obtained.

Current in coil/A	*Magnetic field strength*/T
0·20	$1{\cdot}4 \times 10^{-4}$
0·40	$2{\cdot}4 \times 10^{-4}$
0·60	$3{\cdot}0 \times 10^{-4}$
0·80	$3{\cdot}6 \times 10^{-4}$
1·00	$4{\cdot}6 \times 10^{-4}$

Using square ruled paper, plot a graph of magnetic field strength against current. **2**

(c) The student concludes that the results show that there is a systematic uncertainty in the measurements.

Suggest a reason why the student has come to this conclusion. **1**

Marks

32. (continued)

(*d*) The magnetic field strength B at the centre of a coil of wire is given by the relationship

$$B = 6{\cdot}3 \times 10^{-7}\,\frac{NI}{r}$$

where B is the magnetic field strength in tesla

N is the number of turns in the coil

I is the current in the coil in amperes

r is the radius of the coil in metres.

The number of turns in the coil used by the student is 30.

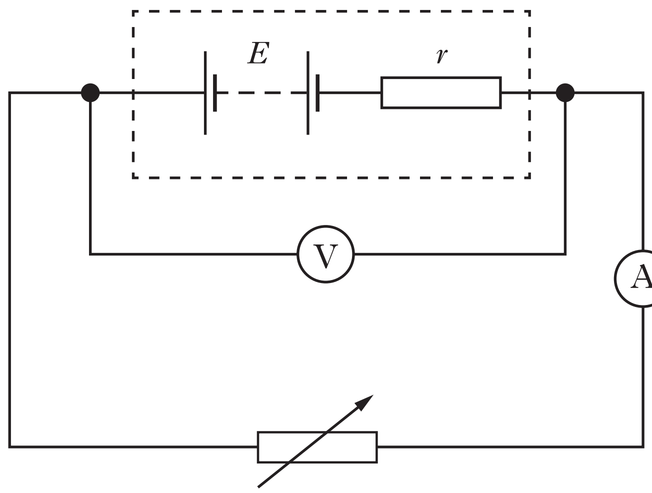
Use this relationship and the gradient of your graph to calculate the radius of the coil. **3**

(8)

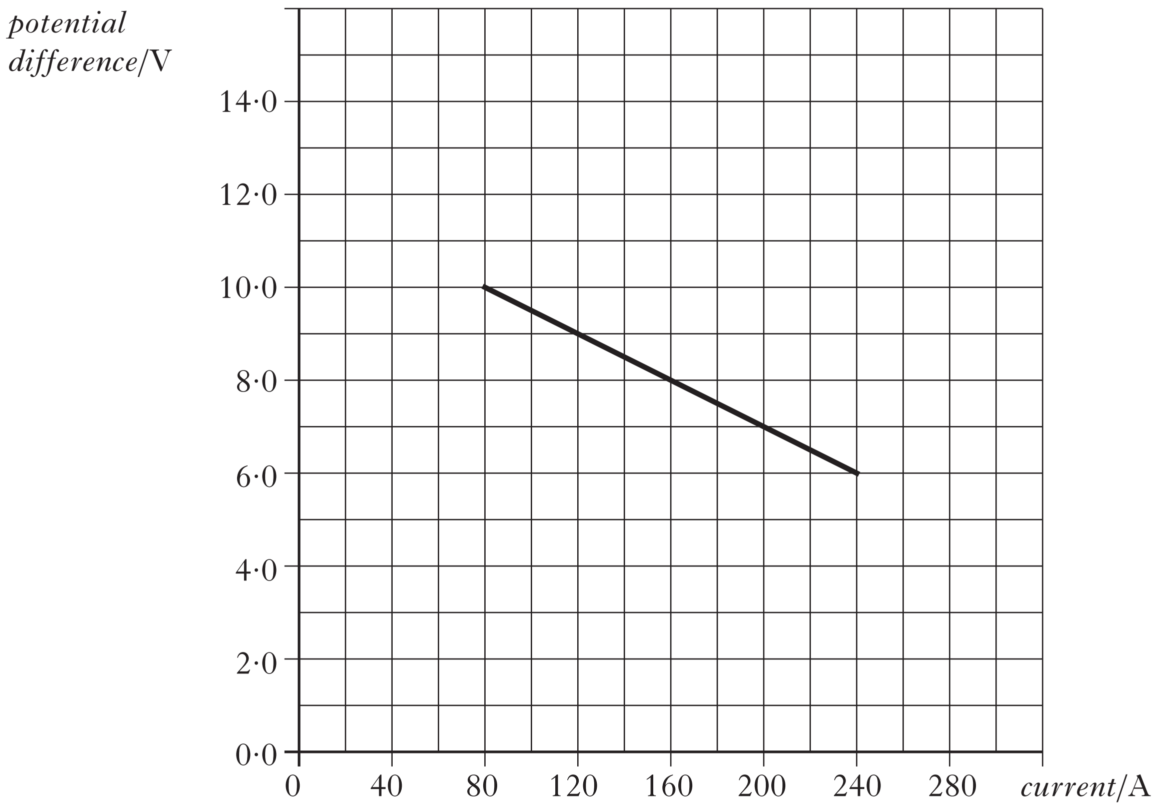
30. A technician is testing a new design of car battery. *Marks*

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**

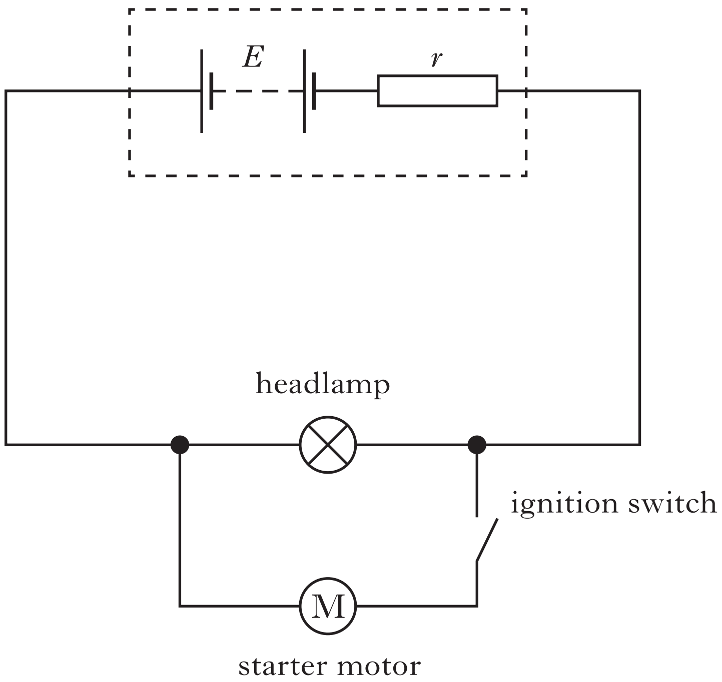
(ii) Calculate the internal resistance of the car battery. **2**

(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**

30. (continued)

(*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)

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.

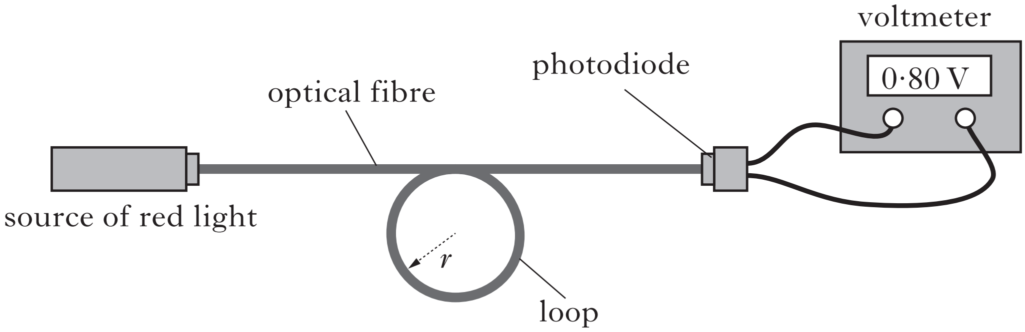
By comparison, AA rechargeable cells operate at 1·5 V and can store up to 3400 mA h of charge.
(*charge* in mA h = *current* in mA × *time* in hours)

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

Marks

32. A group of students carries out an experiment to investigate the transmission of light through an optical fibre.

Red light is transmitted through a loop of optical fibre and detected by a photodiode connected to a voltmeter as shown.



The photodiode produces a voltage proportional to the irradiance of light incident on it.

The students vary the radius, r, of the loop of optical fibre and measure the voltage produced by the photodiode.

The results are shown in the table.

Radius of loop/mm	*Voltage*/V
5	0·48
10	0·68
15	0·76
20	0·79
30	0·80
40	0·80

(*a*) Using the square ruled paper provided, draw a graph of these results. **2**

(*b*) For use in communication systems, the amount of light transmitted through a loop of optical fibre must be at least 75% of the value for the fibre with no loop.

With no loop in this fibre the reading on the voltmeter is 0·80 V.

Use your graph to estimate the minimum radius of loop when using this fibre in communication systems. **1**

(*c*) Using the same apparatus, the students now wish to determine more precisely the minimum radius of loop when using this fibre in communication systems.

Suggest **two** improvements to the experimental procedure that would achieve this. **2**

(*d*) Describe further experimental work that could be carried out to investigate another factor that may affect the transmission of light through an optical fibre. **2**

(7)