wqe | Wyggeston & Queen Elizabeth I College

A level Physics

Revision questions - Electricity

Worked answers

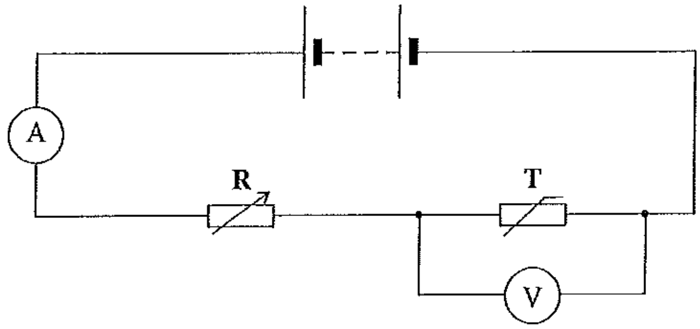
Name	Teacher

Task	Mark	Grade	Comment

1.

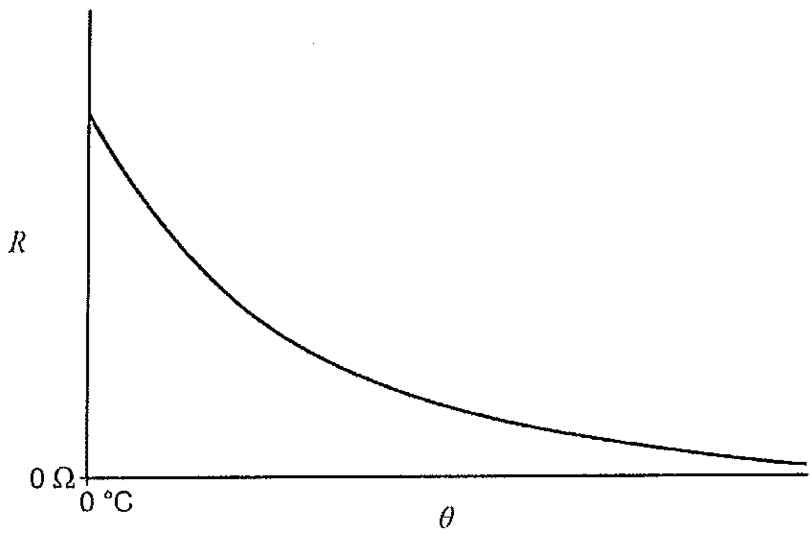
Figure 4 shows a circuit including a thermistor **T** in series with a variable resistor **R**. The battery has negligible internal resistance.

Figure 4



The resistance–temperature (R-θ) characteristic for **T** is shown in **Figure 5**.

Figure 5



a)

The resistor and thermistor in **Figure 4** make up a potential divider.

Explain what is meant by a potential divider.

[1 mark]

A combination of resistors in series across a voltage source, which splits the voltage b)

State and explain what happens to the voltmeter reading when the resistance of **R** is increased while the temperature is kept constant.

[3 marks]

Increasing R increases the voltage across R ✓
Voltage across R + voltage across thermistor
= supply voltage ✓
So voltage across T decreases ✓

c)

State and explain what happens to the ammeter reading when the temperature of the thermistor increases.

[2 marks]

The resistance of the thermistor decreases ✓

The total circuit resistance is lower, so the current (or ammeter reading) increases ✓

d)

The battery has an emf of 12.0 V. At a temperature of 0 °C the resistance of the thermistor is $2.5 \times 10^3\ \Omega$.

The voltmeter is replaced by an alarm that sounds when the voltage across it exceeds 3.0 V.

Calculate the resistance of R that would cause the alarm to sound when the temperature of the thermistor is lowered to 0 °C.

[2 marks]

Either

when $V_T = 3V$, $R_T = 2500\Omega$

so $I = \frac{V}{R} = \frac{3}{2500} = 1.2\times10^{-3}A$ ✓

$V_R = 12 - 3 = 9V$

and $R = \frac{V}{I}$, so $R = \frac{9}{1.2\times10^{-3}}$

$= 7500\Omega$ ✓

Or

$\frac{V_R}{V_T} = \frac{R_R}{R_T}$

$\frac{9}{3} = \frac{R_R}{2500}$ ✓

$R_R = 3 \times 2500 = 7500\Omega$ ✓

resistance = ______________ Ω

(Or Voltage across T will be ¼ of supply voltage, so resistance of R must be $3\times R_T$)

e) State **one** change that you would make to the circuit so that instead of the alarm coming on when the temperature falls, it comes on when the temperature rises above a certain value.

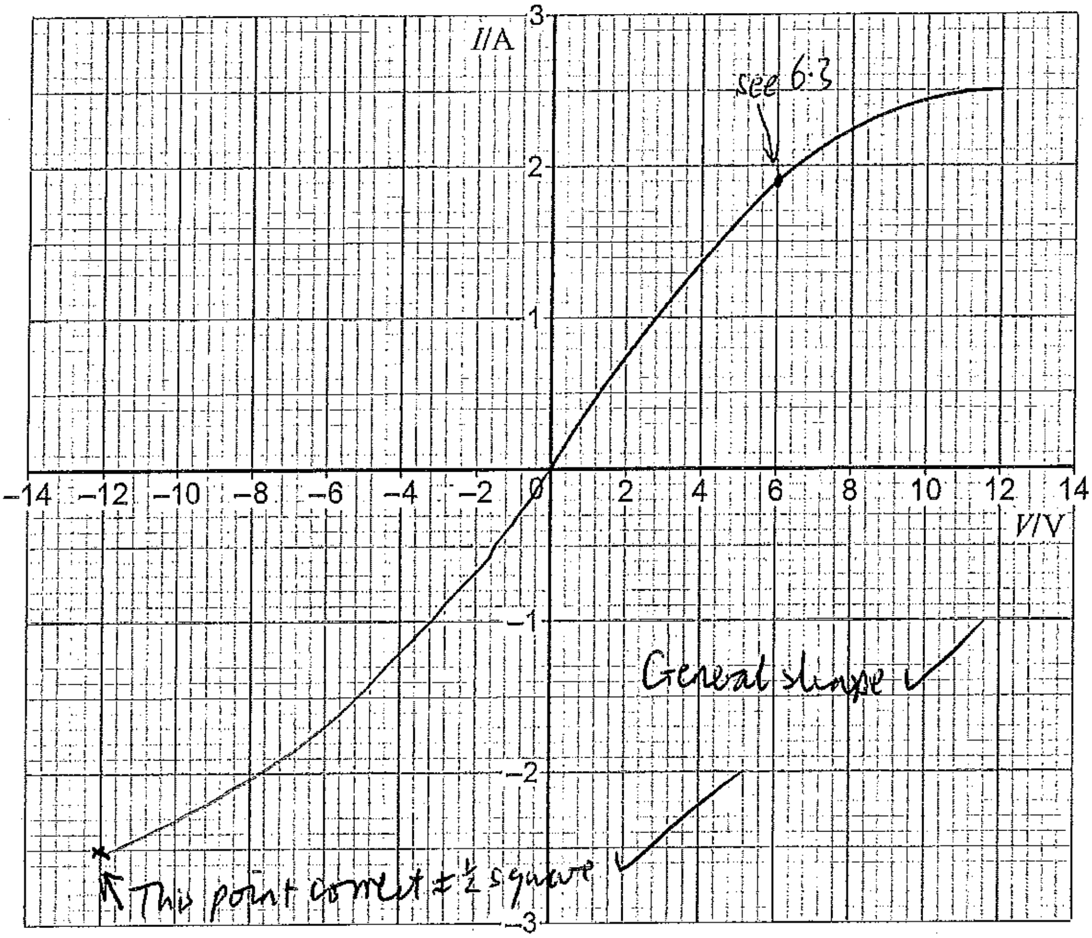
[1 mark]

Connect the alarm across R instead of T ✓

2.

Figure 5 shows the current–voltage (I–V) characteristic of the lamp used in a car headlight up to its working voltage.

Figure 5



a)

Draw on **Figure 5** the characteristic that would be obtained with the connections to the supply reversed.

[2 marks]

b)

0 3 . 2 Lamps are marked with their working voltage and the power used at this voltage. For example, a lamp for use in a torch may be marked 2.5 V 0.3 W.

Deduce the marking on the lamp for the car headlight.

[2 marks]

From question, maximum voltage = working voltage

Power = $IV = 2.5 \times 12$ (from graph)

lamp marking = 12 V 30 W

c)

Determine the resistance of the lamp when the potential difference (pd) across it is half the working voltage.

[1 mark]

$R = \frac{V}{I} = \frac{6}{1.9}$ ← from graph

Note Not the gradient or $\frac{1}{\text{gradient}}$

resistance = 3.2 Ω

d)

(Describe and..)

0 6 . 4 Explain, without further calculation, how the resistance of the lamp varies as the voltage across it is increased from zero to its working voltage.

[3 marks]

Resistance increases

Because temperature increases

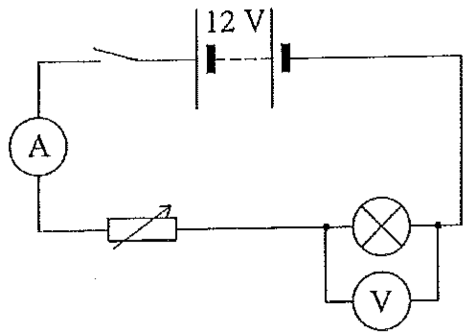
And there are more collisions of electrons with lattice ions

(use this phrase if you can - AQA like it)
(although "atoms" will probably get the mark)

Question 6 continues on the next page

e) A student suggests that the circuit shown in **Figure 6** is suitable for collecting data to draw the I–V characteristic of the lamp up to its working voltage.
The maximum resistance of the variable resistor is $6.0\ \Omega$ and the internal resistance of the power supply is $2.0\ \Omega$.
The resistance of the ammeter is negligible.

Figure 6



Discuss the limitations of this circuit when used to collect the data for the characteristic.

[2 marks]

Cannot gain either maximum (12V) or minimum (0V) voltage ✓

Either

When resistance of VR is 6 Ω, there is still a current in the bulb / a voltage across the bulb ✓

Or

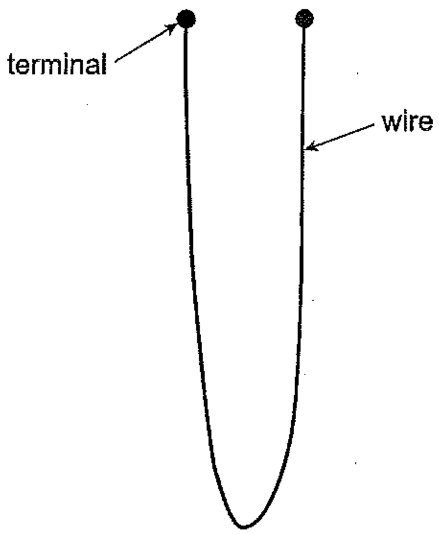
When resistance of VR is zero, the current flowing reduces the terminal voltage across the battery to less than 12 V

Do not write outside the box

0 3 3.

A wire probe is used to measure the rate of corrosion in a pipe carrying a corrosive liquid. The probe is made from the same metal as the pipe. **Figure 6** shows the probe. The rate of corrosion of the wire in the probe is the same as in the pipe.

Figure 6



0 3 . 1 The wire in an unused probe has a resistance of 0.070 Ω and a length of 0.50 m.

a) Calculate the diameter of the wire.

[3 marks]

resistivity of metal in the wire = $9.7 \times 10^{-8}\ \Omega\,m$

$R = \rho \, l / A$, $A = \frac{\rho l}{R}$

$= \frac{9.7 \times 10^{-8} \times 0.50}{0.070}$

$= \cancel{1.77 \times 10^{-8}}$

$= 6.929 \times 10^{-7}\ m^2$

diameter $= \sqrt{(A / 4\pi} \times 2 = 9.4 \times 10^{-4}$

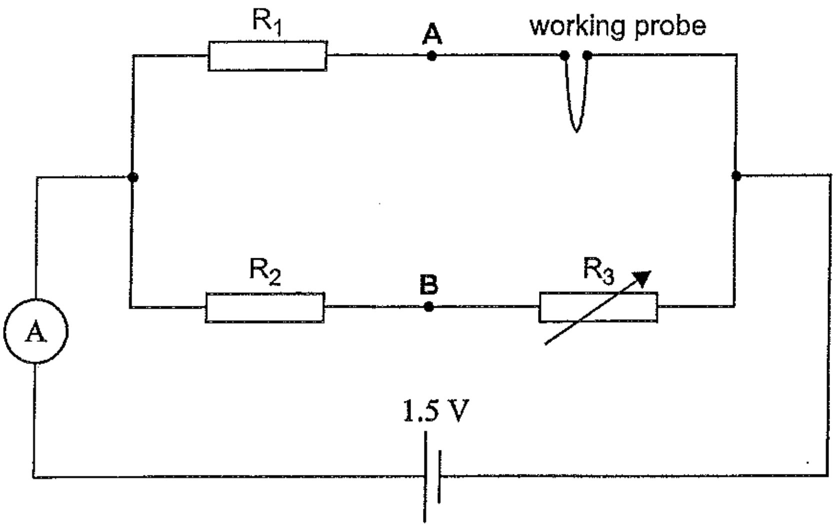
diameter = 9.4×10^{-4} m

Do not write outside the box

In order to measure the resistance of a used working probe, it is connected in the circuit shown in **Figure 7**.

b)

Figure 7



When R_3 is adjusted to a particular value the current in the cell is 0.66 A.

Calculate the total resistance of the circuit.
You may assume that the cell has a negligible internal resistance.

[1 mark]

$V = IR$, $R = V/I = \frac{1.5}{0.66} = 2.27$

✓

resistance = 2.3 Ω

0 4 . 3 The resistance of R_2 is 22 Ω and the resistance of R_3 is 1.2 Ω.

c) Calculate the current in R_3.

[1 mark]

$V = IR$, $I = \frac{V}{R}$ where $R = (22 + 1.2) = 23.2\,\Omega$

$I = \frac{1.5}{23.2} = 0.065$

✓

current = 0.065 A

Do not write outside the box

0 4 . 4 Calculate the resistance of the probe when the resistance of R_1 is 2.4 Ω.

[3 marks]

d)

Current in $R_1 = 0.66 - 0.0647 = 0.595A$

Total resistance of the branch $= \frac{V}{I} = \frac{1.5}{0.595}$

$= 2.52\Omega$

Resistance of probe $= 2.52 - 2.4 = 0.12\ \Omega$

resistance = 0.12 Ω

e)

0 4 . 5 Calculate the percentage change in the diameter of the probe when its resistance increases by 1.6 %.

[2 marks]

$R = \frac{\rho l}{A}$, $R \propto \frac{1}{A}$

For R to increase by 1.6%, A decreases by 1.6%

∴ Diameter must decrease by 0.8%

percentage change = 0.8 %

A voltmeter is connected between points **A** and **B** in the circuit and R_3 stays at 1.2 Ω.

f)

Explain, without calculation, why the reading on the voltmeter does not change when the cell in the circuit is replaced with another cell of the same emf but a significant internal resistance.

[2 marks]

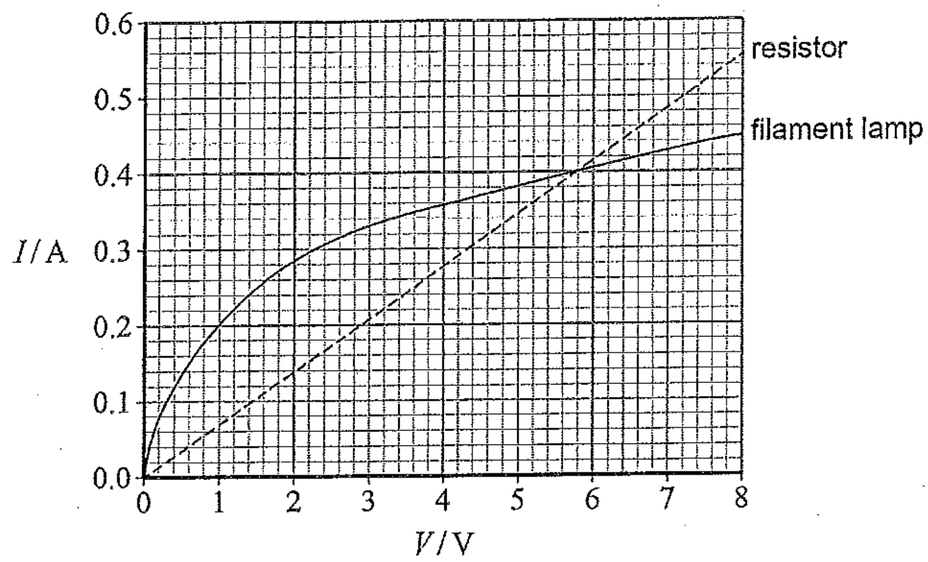
Voltmeter has infinite resistance so does not affect the circuit.

If a cell with internal resistance is used there will be reduced terminal pd, so reduced current but the resistors ratio does not change.

ANY 2

4. **Figure 2** shows the current–voltage (I–V) characteristics for a resistor and a filament lamp.

Figure 2



a) Explain, in terms of electron motion, why the I–V characteristic for the filament lamp is a curve.

[4 marks]

Current
Increase in voltage leads to increase in temperature ✓

Increase in movement of lattice ions atoms ✓

Increase in the rate of collisions between lattice (etc) and electrons ✓

So resistance increases + | $\frac{V}{I}$ changes or Non-proportional graph ✓

0 2 . 2 Determine the resistance of the resistor.

[1 mark]

b) As it is a straight line, can use $\frac{1}{\text{gradient}}$.

$R = \frac{8}{0.555}$

resistance = 14.3 ✓ Ω

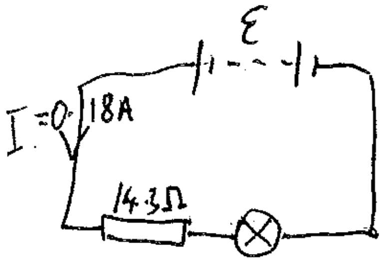
0 2 . 3 The resistor and the filament lamp are connected in series with a supply of variable emf and negligible internal resistance.

c)

Determine the emf that produces a current of 0.18 A in the circuit.

[3 marks]

From graph, voltage across bulb when $I = 0.18A = 0.8V$ ✓



$\mathcal{E} = 0.8 + 0.18 \times 14.3$ ✓

$= 0.8 + 2.6$

(see m/s for other methods)

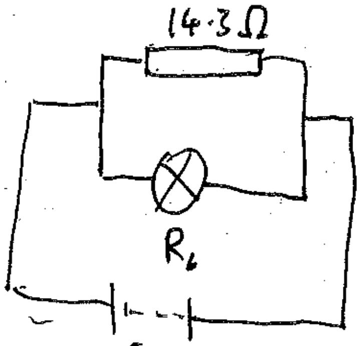
emf = 3.4 ✓ V

0 2 . 4 The resistor and filament lamp are now connected in parallel.

d)

Determine the resistance of the parallel combination when the emf of the supply is adjusted to be 4.0 V.

[3 marks]



From graph, $I_b = 0.36$ when $V = 4V$ ✓

$R_b = \frac{V}{I} = \frac{4}{0.36} = 11.1\Omega$

$\frac{1}{R_{tot}} = \frac{1}{14.3} + \frac{1}{11.1}$ ✓

resistance = 6.2 ✓ Ω

6.3

OR
From graph, $I_b = 0.36A$
$I_R = 0.28A$ ✓

Total current $= 0.36 + 0.28 = 0.64A$ ✓

$R = \frac{V}{I} = \frac{4.0}{0.64} = 6.2\Omega$ ✓

Question 2 continues on the next page

Turn over ►

Do not write outside the box

0 1 . 5

e)

The resistance of the filament lamp at its working temperature is $14\ \Omega$.
The filament has a length of $0.36\ \mathrm{m}$ and a diameter of $32\ \mu\mathrm{m}$.

Calculate the resistivity of the metal that is used for the filament when the lamp is at its working temperature.

Give an appropriate unit for your answer.

[3 marks]

$$A = \frac{\pi d^2}{4} = \frac{\pi \times (32 \times 10^{-6})^2}{4} \checkmark$$

$$= 8.0 \times 10^{-10}\ m^2$$

$$\rho = \frac{RA}{l} = \frac{14 \times 8.0 \times 10^{-10}}{0.36}$$

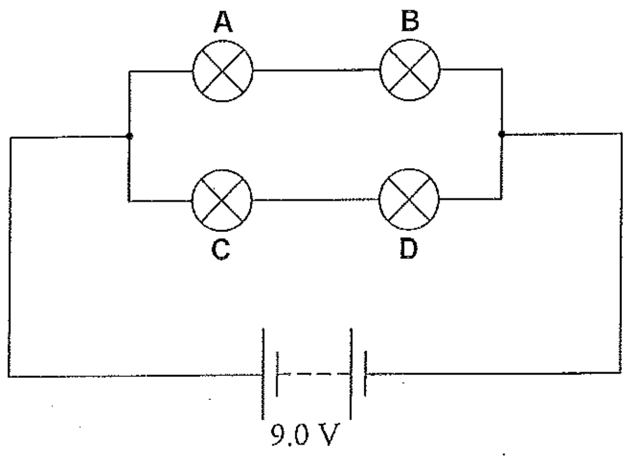
resistivity = 3.1×10^{-8} ✓ unit Ωm ✓

14

5.

A student connects four lamps **A**, **B**, **C** and **D** in the circuit shown in **Figure 6**.
The battery has an emf of 9.0 V and negligible internal resistance.

Figure 6



Do not write outside the box

Table 1 shows the operating conditions for the lamps when they are at normal brightness.

a)

Table 1

Lamps	Operating voltage / V	Power / W	R/Ω
A and **C**	6.0	6.0	6.0
B and **D**	3.5	4.1	3.0

The student observes that **two** of the lamps are at their normal brightness.
Assume that any changes in resistance of the lamps are negligible.

Determine which **two** lamps are at their normal brightness.

Use calculations to support your answer.

[4 marks]

$P = \frac{V^2}{R}$ $\therefore$ $R = \frac{P}{V^2}$ – see table.

Across either branch, the ratio of resistances is 2:1

So also the ratio of voltages is 2:1

As total voltage = 9 V, there must be 6 V across A and 3 V across B (same for C and D)

So A and C are at normal brightness

Question 6 continues on the next page

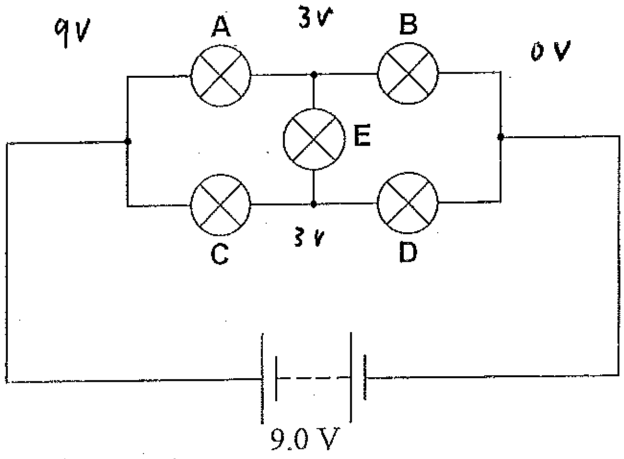
Do not write outside the box

0 6 . 2

b)

The student connects another lamp **E** in the circuit as shown in **Figure 7**.
Lamp **E** is identical to lamps **A** and **C**.

Figure 7



Explain what the student would observe regarding the brightness of the lamps.

Refer to potential differences across lamp **E** in your answer.

[3 marks]

(As A and C are identical, and B and D are identical, the potentials at the top and bottom of bulb E are the same)

Potential difference across E = 0 V ✓

So no current flows in E ✓

Other lamps are not affected ✓

Because the current in the other lamps does not change ✓

Max 3

0 6 . c)

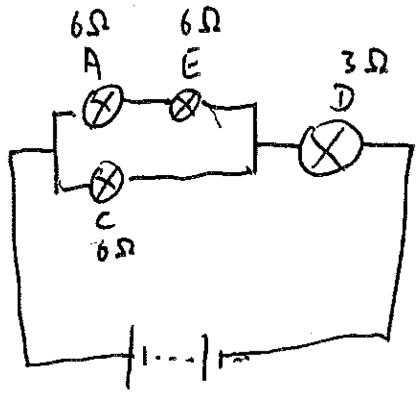
Lamp **B** in **Figure 7** fails so that it no longer conducts. This change does not affect the resistance of the other lamps.

Deduce the effect on the current in the battery.

Use calculations to support your answer.

[3 marks]

Circuit now becomes:



In first circuit, current through A+C = $\frac{V}{R} = \frac{9}{9} = 1A$

So current in battery = 2A ✓

In new circuit, resistance of ∥ arrangement: $\frac{1}{R} = \frac{1}{12} + \frac{1}{6} = \frac{3}{12}$

$R = 4\Omega$

∴ Total circuit resistance = 4+3 = 7Ω

Circuit current = $\frac{V}{R} = \frac{9}{7} = 1.29$ A ✓

Turn over for the next question

So current in battery decreases ✓

(see m/s for details)

10

(c) Lamp **B** in **Figure 2** fails so that it no longer conducts. This change does not affect the resistance of the other lamps.

Deduce the effect on the current in the battery.

Use calculations to support your answer.

(3)
(Total 10 marks)

Q6.

The current in a wire is 20 mA.

How many electrons pass a point in the wire in 2 minutes?

A	2.5×10^{17}	☐
B	1.5×10^{19}	☐
C	2.5×10^{20}	☐
D	1.5×10^{22}	☐

$Q = It = 20 \times 10^{-3} \times 2 \times 60$
$= 2.4\ C$

Charge on an electron $= 1.6 \times 10^{-19}\ C$

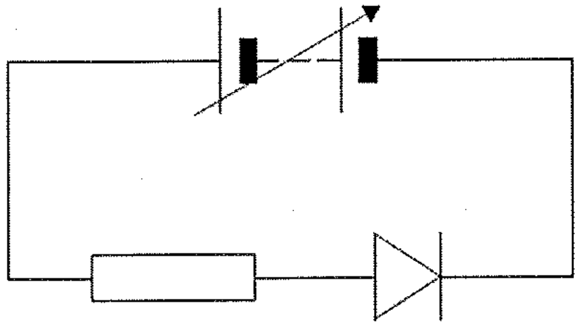
So number of electrons

$= \dfrac{2.4}{1.6 \times 10^{-19}}$

(Total 1 mark)

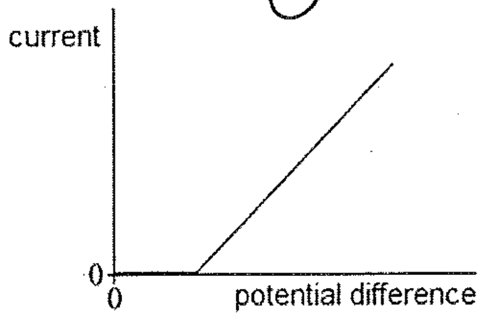
Q7.

A resistor and diode are connected in series with a variable power supply as shown in the diagram.

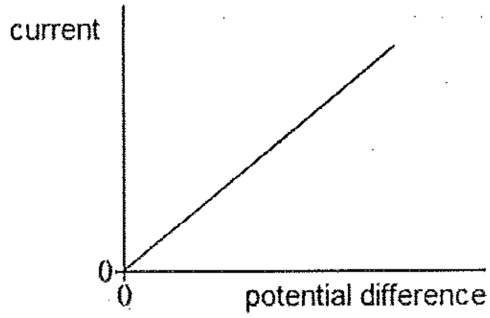


Which best shows the characteristic for the combination of the resistor and diode?

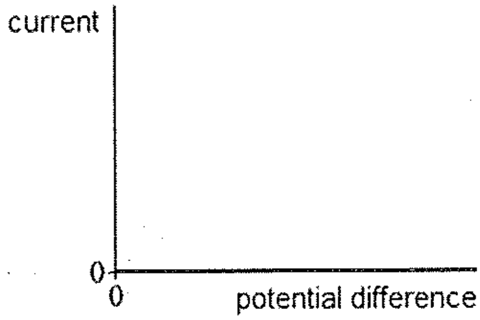
A



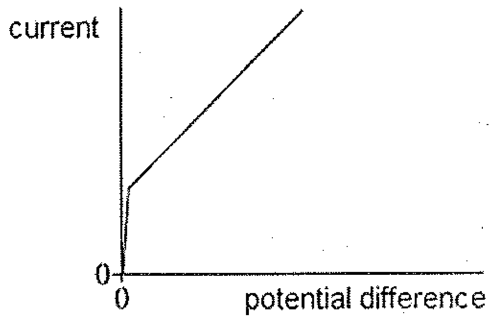
B



C



D



A ☐

B ☐

C ☐

D ☐

Knowledge

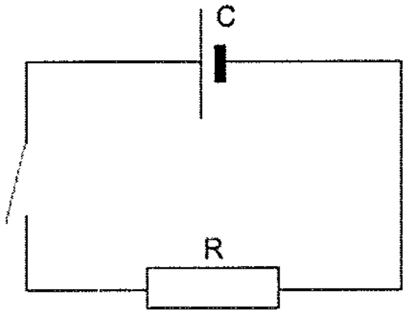
(Total 1 mark)

Q8.

A cell C of negligible resistance and a switch are in series with a resistor R. The switch is moved to the on (closed) position for a time t.

Which change reduces the amount of charge flowing through R in time t?

ie current



$I = \frac{V}{R}$

A	add an identical cell in parallel with C	☐	× V not affected
B	add an identical cell in series with C	☐	× V increase
C	add a second resistor in series with R	☐	✓ R increase
D	add a second resistor in parallel with R	☐	× R decreases

(Total 1 mark)

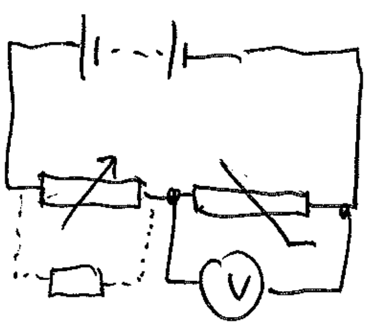
Q9.

A potential divider circuit consists of a battery connected across a thermistor and variable resistor in series.

Which of the following causes the potential difference (pd) across the thermistor to increase?

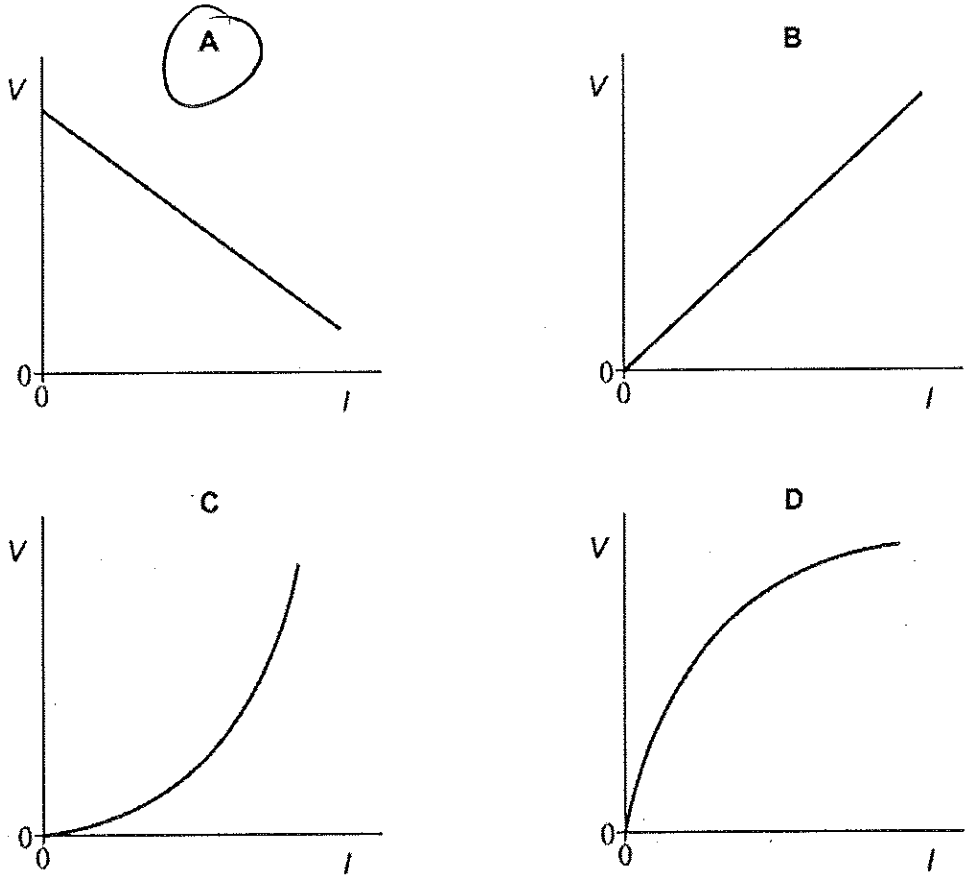
A	increasing the temperature of the thermistor	☐	× Resistance ↓ so proportion of voltage ↓
B	increasing the resistance of the variable resistor	☐	× Proportion of voltage across VR increase
C	reducing the emf of the battery	☐	× Duh!
D	adding a resistor across the variable resistor	☐	✓ R of VR + extra resistor is less. Smaller proportion of voltage here.

(Total 1 mark)



Q10.

A student investigates how the potential difference V across the terminals of a cell varies with the current I in the cell.



Which graph correctly shows how V varies with I?

A ☐

B ☐

C ☐

D ☐

Knowledge.

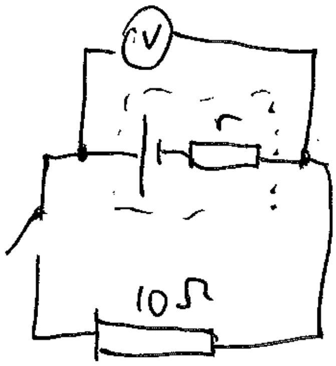
(Total 1 mark)

Q11.

A battery is connected to a 10 Ω resistor and a switch in series. A voltmeter is connected across the battery. When the switch is open (off) the voltmeter reads 1.45 V. When the switch is closed the reading is 1.26 V.

What is the internal resistance of the battery?

A	0.66 Ω	○
B	0.76 Ω	○
C	1.3 Ω	○
D	1.5 Ω	○



(Total 1 mark)

When open, voltmeter reads emf $= 1.45\,V$

When closed, voltmeter reads pd across resistor

$$I = \frac{V}{R} = \frac{1.26}{10} = 0.126\,A$$

$$\mathcal{E} = I(R + r)$$

$$1.45 = 0.126(10 + r)$$

Solve for r

Q12.

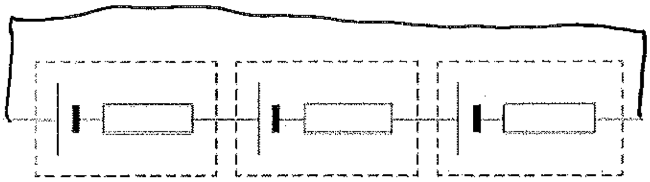
Three cells each have an emf ε = 1.5 V and an internal resistance r = 0.6 Ω.

Which combination of these cells will deliver a total emf of 1.5 V and a maximum current of 7.5 A?

In all cases, max current when shorted out as in A.

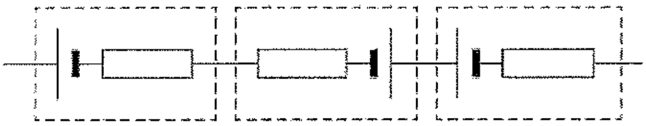
$I = \frac{\varepsilon}{r}$

A



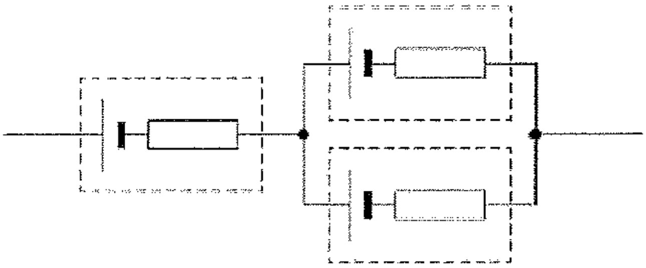
$\varepsilon = 4.5V$ ✗

B



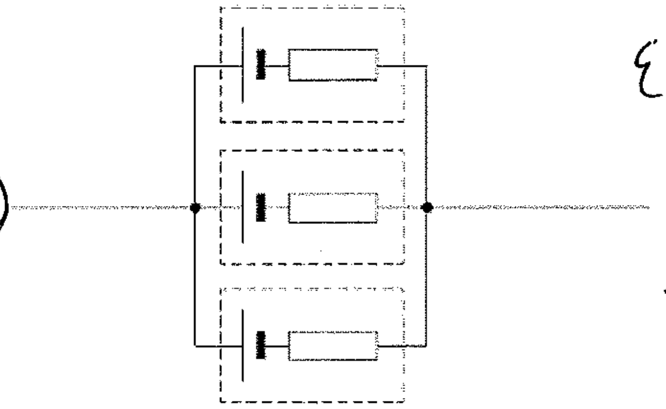
$\varepsilon = 1.5V$
$r = 1.8V$
$\therefore I \neq 7.5A$ ✗

C



$\varepsilon = 3V$ ✗

D



$\varepsilon = 1.5V$
$r = \frac{0.6}{3} = 0.2\Omega$
$I = \frac{1.5}{0.2} = 7.5A.$

A ☐

B ☐

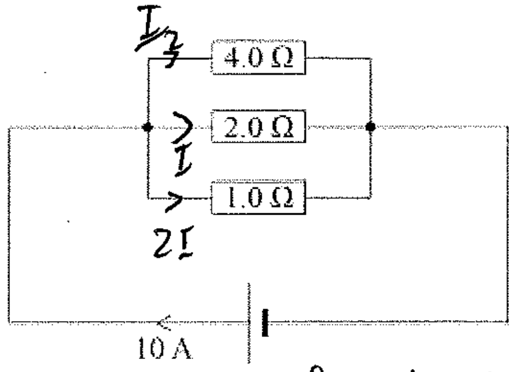
C ☐

D ☐

(Total 1 mark)

Q13.

The current in the cell is 10 A as shown.



V is constant, so $I \propto \frac{1}{R}$

What is the current in the 2.0 Ω resistor?

Several methods, here is a nice one

A 0.35 A

B 2.86 A

C 3.50 A

D 7.14 A

$$\frac{I}{2} + I + 2I = 10\text{ A}$$

$$3.5\,I = 10$$

$$I = \frac{20}{7}$$

(Total 1 mark)

Q14.

A battery of negligible internal resistance and an emf of 12 V is connected in series with a heating element. The heating element has a resistance of 6.5 Ω when in operation.

What is the energy transferred by the heating element when operating for 5 minutes?

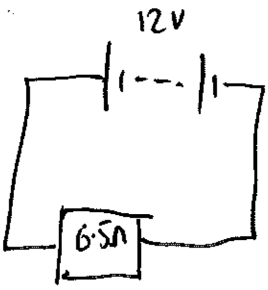
A 111 J

B 390 J

C 6650 J

D 23 400 J

(Total 1 mark)



$$\text{Power} = \frac{V^2}{R}$$

$$\text{Energy} = \text{power} \times \text{time}$$

$$= \frac{12^2}{6.5} \times 5 \times 60$$

Q15.

Which statement about superconductors is correct?

A	When a material becomes a superconductor, its resistivity is almost zero.	☐	x Exactly zero
B	The temperature at which a material becomes a superconductor is called the critical temperature.	☐	Knowledge.
C	When current passes through a superconductor the pd across it becomes a maximum.	☐	x $V = IR$ so zero V
D	Copper is a superconductor at room temperature.	☐	x Small but not zero R.

(Total 1 mark)

Q16.

A wire has a resistance R.

What is the resistance when both the length and radius of the wire are doubled?

A $\frac{R}{4}$ ☐

B $\frac{R}{2}$ ☐

C $2R$ ☐

D $4R$ ☐

$\rho = \frac{RA}{l}$

$\therefore R = \frac{\rho l}{A}$

$A = \pi r^2$

Double radius → 4x area

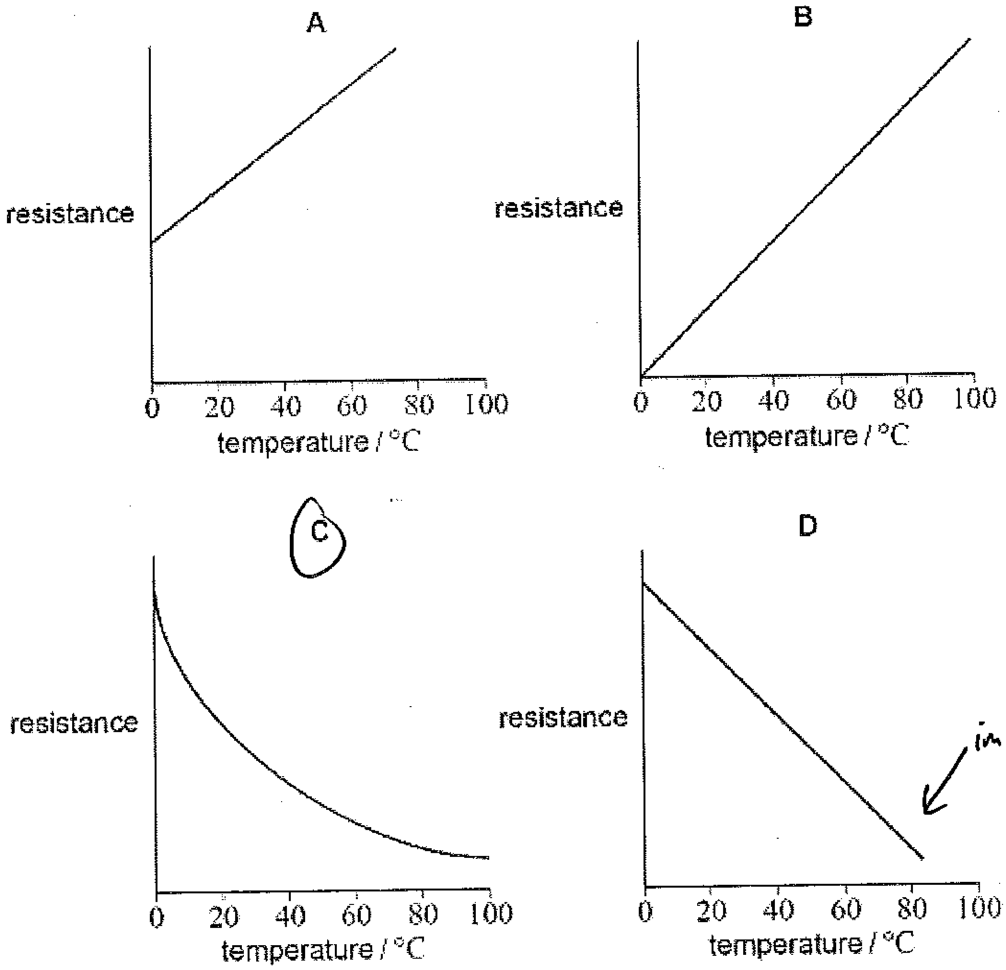
$\therefore R \propto \frac{l}{r^2}$ ← 2x, ← 4x

(Total 1 mark)

normal type.

Q17.

Which graph shows the variation of the resistance with temperature for an ntc thermistor?



implying $R = 0$ at ~90°C

A ☐

B ☐

C ☐

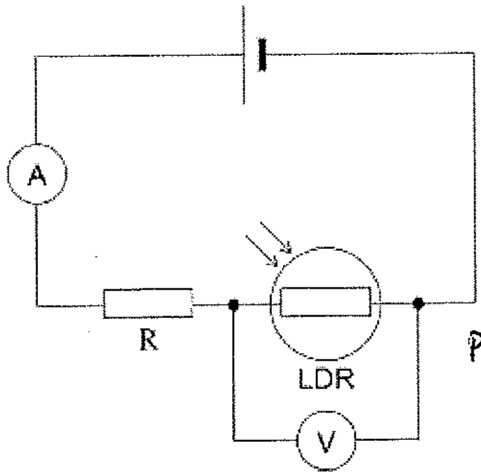
D ☐

Knowledg

(Total 1 mark)

Q18.

The figure shows a light dependent resistor (LDR) and fixed resistor R connected in series across a cell. The internal resistance of the cell is negligible.



Light intensity ↑ ⇒ R ↓ (knowledge)

Total resistance ↓ so current ↑

PD across resistor increases because $V = IR$

So PD across LDR must decrease.

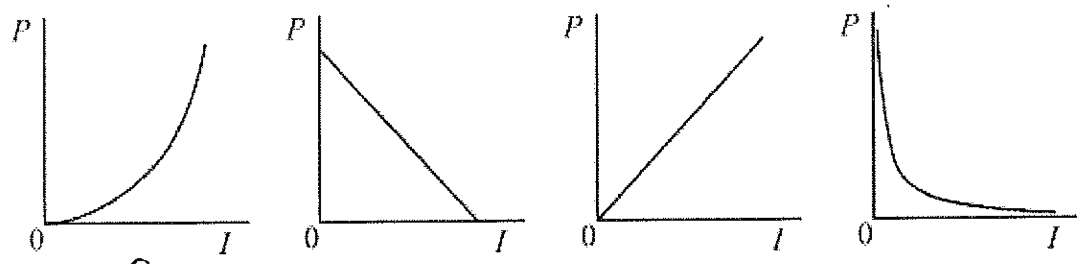
Which row shows how the readings on the ammeter and the voltmeter change when the light intensity incident on the LDR is increased?

	Ammeter reading	Voltmeter reading	
A	decreases	increases	○
B	decreases	decreases	○
C	increases	increases	○
D	increases	decreases	○

(Total 1 mark)

Q19.

Which graph shows how power dissipated P varies with current I in a component that obeys Ohm's law?



A B C D

A ☐

B ☐

C ☐

D ☐

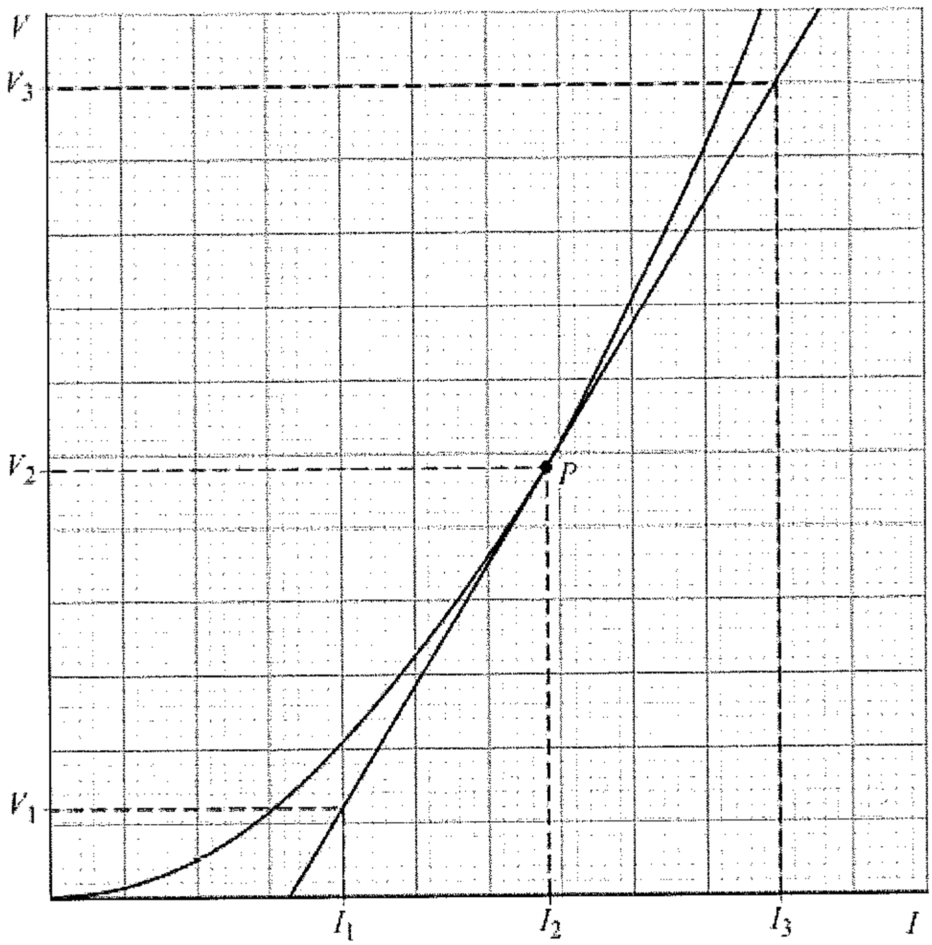
$P = I^2 R$

(Total 1 mark)

Q20.

The graph shows how the potential difference V across an electrical component varies with current I in the component.

A tangent has been drawn on the curve at point P for a current of I_2.



What is the resistance of the electrical component when the current in the component is I_2?

A $\dfrac{V_3 - V_1}{2I_3}$

B $\dfrac{V_3 - V_1}{I_3 - I_1}$

C $\dfrac{V_2}{I_2}$ By definition

D $\dfrac{2V_3}{I_2 - I_1}$

(Careful: resistance is only the gradient if $V \propto I$)

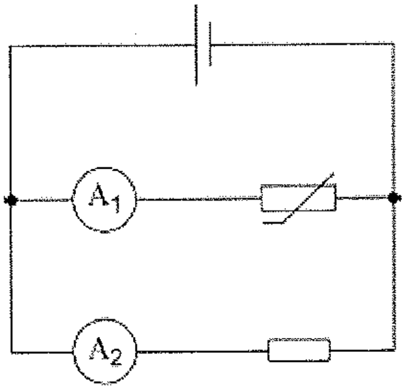
(Total 1 mark)

Q21.

(assume ntc)

A circuit consists of a cell, a thermistor, a fixed resistor and two ammeters.

Temp ↓ R ↑ (knowledge)



The cell has a constant electromotive force and negligible internal resistance. Readings from the two ammeters are taken.

Which row describes what happens to the current in each ammeter when the temperature of the thermistor decreases?

	Current in ammeter A_1	Current in ammeter A_2	
A	Decreases	Unchanged	○
B	Decreases	Increases	○
C	Increases	Decreases	○
D	Increases	Unchanged	○

(Total 1 mark)

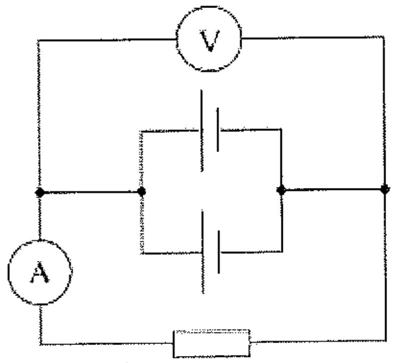
Parallel, so voltage is same across each branch.

In A_1, total resistance of branch ↑ so current ↓

In A_2, total resistance of branch unchanged, so current unchanged.

Q22.

A circuit consists of two identical cells, a resistor, an ammeter and a voltmeter. The cells each have an emf of 3.0 V and the resistor has a resistance of 12 Ω
The cells have negligible internal resistance.



Combined emf of cells = 3.0 V

$I = \frac{V}{R} = \frac{3}{12}$

Which row shows the readings on the voltmeter and ammeter?

	Voltage / V	Current / A	
A	3.0	0.25	⬭
B	3.0	0.50	⬭
C	6.0	0.25	⬭
D	6.0	0.50	⬭

(Total 1 mark)

Q23.

Which is equivalent to the ohm?

A J C^{-2} s^{-1} ⬭

B J C^{-2} s ⬭

C J s ⬭

D J s^{-1} ⬭

$R = \frac{V}{I}$

$V = \frac{\text{Energy}}{\text{charge}}$

$I = \frac{\text{Charge}}{\text{Time}}$

$\therefore R = \frac{E/Q}{Q/t} = \frac{Et}{Q^2}$

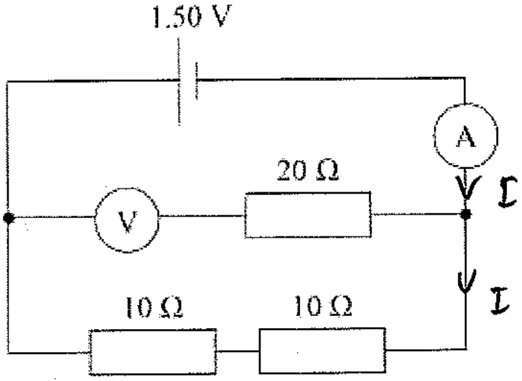
(Total 1 mark)

$\therefore$ Units : $\frac{J \times s}{C^2}$

Q24.

The circuit shows a cell with negligible internal resistance connected in a circuit with three resistors, an ammeter and a voltmeter.

(Stupid question - you would never connect a voltmeter like this)



Which row shows the readings on the ammeter and voltmeter?

	Current / A	Voltage / V	
A	0.075	0.75	○
B	0.075	1.50	○
C	0.150	0.75	○
D	0.150	1.50	○

(Total 1 mark)

Ideal voltmeter has infinite resistance.

So no current flows in top branch

$$I = \frac{V}{R} = \frac{1.5}{(10+10)} = 0.075\,A$$

As no current flows in top branch, pd across 20Ω resistor = 0

∴ Entire voltage drop must be across voltmeter = 1.5 V

Mark schemes

Q1.

(a) A combination of resistors in series connected across a voltage source (to produce a required pd) ✓

Reference to splitting (not dividing) pd

1

(b) When R increases, pd across R increases ✓

Pd across R + pd across T = supply pd ✓

So pd across T / voltmeter reading decreases ✓

Alternative:

Use of $V = \dfrac{R_1 \times V_{tot}}{R_1 + R_2}$ ✓

V_{tot} and R_2 remain constant ✓

So V increases when R_1 increases ✓

3

(c) At higher temp, resistance of T is lower ✓

1

So circuit resistance is lower, so current / ammeter reading increases ✓

1

(d) Resistance of T = 2500 Ω

Current through T = V / R = 3 / 2500 = 1.2 × 10^{-3} A ✓

(Allow alternative using $V_1/R_1 = V_2/R_2$)

pd across R = 12 − 3 = 9 V

The first mark is working out the current

1

Resistance of R = V / I = 9 / 1.2 × 10^{-3} = 7500 Ω✓

The second mark is for the final answer

1

(e) Connect the alarm across R instead of across T ✓

allow: use a thermistor with a ptc instead of ntc.

1

[9]

Q2.

(a) correct general shape ✓

accurate plotting to within $\frac{1}{2}$ square ✓ 2

(b) 12 (V) ✓, 30 (W) ✓ 2

(c) $R = \left(\frac{6}{1.9}\right) = 3.2\ (\Omega)$ ✓ 1

(d) Resistance increases ✓

Temperature increases ✓

More collisions / interaction of electrons with lattice ions ✓

Condone 'atoms', 'molecule'.

*Do **not** allow electron−electron collisions.* 3

(e) Can attain neither maximum nor minimum voltage ✓

Explanation of either maximum OR minimum ✓ 2

[10]

Q3.

(a) *(use of $R = \rho l/A$)*

$A = 9.7 \times 10^{-8} \times 0.50/0.070$ ✓ 1

$A = 6.929 \times 10^{-7}$ (m^2) ✓ 1

diameter = $\sqrt{(6.929 \times 10^{-7} \times 4/\pi)} = 9.4 \times 10^{-4}$ (m) ✓

CE for third mark if incorrect area 1

(b) $R = 1.5/0.66 = 2.3(\Omega)$ (2.27) ✓ 1

(c) *(use of $V = IR$)*

$I = 1.5/(22 + 1.2) = 0.065$✓(A) (0.0647) ✓ 1

(d) current in $R_1 = 0.66 - 0.0647 = 0.595$ (A) ✓

CE from 4.2/4.3 1

resistance of R_1 and probe = $1.5/0.595 = 2.52\ (\Omega)$ ✓

alternative method: $1/2.3 = 1/23.2 + 1/(R_{probe} + 2.4)$ ✓ 1

resistance of probe = $2.52 - 2.4 = 0.12\ (\Omega)$ ✓

correct rearrangement ✓

range 0.1 – 0.15 ✓

accept 1 sig. fig. for final answer

1

(e) cross-sectional area must decrease OR R α 1/A

indicated by downward arrow or negative sign which can be seen on answer line

1

area decreases by 1.6% hence diameter must decrease by 0.8% ✓

accept 1%

1

(f) ANY TWO FROM

correct reference to lost volts OR terminal pd OR reduced current ✓
reference to resistors not changing OR resistors constant ratio ✓
reference to voltmeter having high/infinite resistance (so not affecting circuit) ✓
reference to pd between AB being (very) small (due to closeness of resistance ratios in each arm) ✓
voltmeter (may not be) sensitive enough ✓

1
1

[12]

Q4.

(a) An increase in current / voltage leads to an increase in temperature (more heat generated) ✓

Ignore 'of particles' in first mark

Do not condone 'particles' in second mark

This causes an increase in the movement of the lattice/ions/atoms ✓

And therefore an increase in the rate of collisions with electrons ✓

Allow more frequent collisions

So the resistance increases as shown by V / I changing/V not proportional to I (on the graph) ✓

Allow correct reference to gradient of I / V curve unless the answer suggests that this is the resistance or inverse of resistance.

Max 4

(b) 14.3 (Ω)

Allow range 14 to 15

but calculated answer must lie between 14 and 15

1

(c) Determination of pd across either filament or resistor from graph ✓

Pd across resistor can be calculated from resistance value in (b)

Eg V = 0.18 × 14.3 = 2.6

Determination of pd across the other component, and values added ✓

Use of V = IR to give 3.4 (V)

Allow ecf if either value is wrong allow 2 max

Or

Clear attempt to determine total resistance and multiply by 0.18 ✓

Condone small rounding error

(Resistance of lamp at 0.18A = 4.4 Ω)

Total resistance = 18.7 Ω ecf from 2,2 ✓

3.4 V (ecf from 2.2) ✓

Allow for small rounding errors (eg allow range 3.3 to 3.5)

3

(d) Determination of current through either filament or resistor from graph ✓

Allow calculation of resistor current using 4/(answer to 2.2)

Determination of current through the other component, and values added✓

(Current through resistor = 0.28 A

Current through filament = 0.36 A)

R = V/I = 4/ (0.28 + 0.36) = 6.25 (Ω)

If either value wrong allow 2 max

Condone small rounding errors.

Or

Calculation of filament resistance or statement of resistor resistance ✓

Resistance of filament = 11.1 (Ω)

Calculation of other resistance and use of parallel formula (allow ecf from part b) ✓

Either resistance gets the first mark

6.2 -6.3 (Ω) ✓

3

(e) Calculation of area, ignoring power of ten errors.

$A = 8.0 \times 10^{-10}$ m^2

Correct resistivity 3.1×10^{-8} ✓

Allow ecf for A (for example use of d for r gives 3.2×10^{-11} for A and 1.2×10^{-7} for answer)

Ω m ✓

Some working must be shown for award of unit mark.

3

[14]

Q5.

(a) resistance of lamp B and D = $3.5^2/4.1 = 3.0$ (2.98)(Ω) ✓
resistance of lamp A and C = $6.0^2/6.0 = 6.0$ (Ω) ✓
pd across lamp B and lamp D = 3/9 × 9.0 = 3.0 (V) OR pd across lamp A and C = 6.0 (V) ✓
hence A and C normal brightness ✓

Can justify in terms of current i.e. current needed by A and C is 1 A provided resistance values calculated
Must have some correct working for conclusion mark

1
1
1
1

(b) the pd across new lamp = 0 / E does not light ✓
no current in E ✓
other lamps are not affected ✓
because the current in the lamps/pd across lamps does not change ✓

2nd and 3rd marks conditional on 1st mark

1
1
1
(MAX 3)

(c) in first circuit current in battery = 9.0/4.5 = 2.0 A ✓
in second circuit current in battery = 9.0/7 = 1.2857 A ✓
hence current in battery decreases ✓

Allow ecf from (a)
Original current = 2A can come from (a) and score here
If say circuit resistance increases so current decreases and no other marks awarded score 1 mark

1
1
1

[10]

Q6.

B

[1]

Q7.

A

[1]

Q8.

C

[1]

Q9.

D

[1]

Q10.
A

[1]

Q11.
D

[1]

Q12.
D

[1]

Q13.
B

[1]

Q14.
C

[1]

Q15.
B

[1]

Q16.
B

[1]

Q17.
C

[1]

Q18.
D

[1]

Q19.
A

[1]

Q20.

C [1]

Q21.
A [1]

Q22.
A [1]

Q23.
B [1]

Q24.
B [1]

Q3.

Experience from past physics exams at this level indicates that students are better at answering quantitative questions involving electric circuits and this is supported by evidence from this question where the calculations were frequently done well. Part (a) required students to calculate the diameter of the wire and a high proportion of students were able to do this successfully. Full marks were obtained by over 70% of students. There was more variation in parts (b), (c) and (d). While the majority of students were able to calculate the resistance of the circuit, analysing the parallel arrangement was more discriminating. In particular, calculating the resistance of the probe proved challenging. A common mistake was the assumption that the current divided equally in the two branches and therefore the current in the probe was the same as that calculated for R3. Many students found (e) difficult and tried to determine the percentage change in diameter using extended calculations which frequently led to arithmetic errors. The first mark was for recognition that the diameter must decreases and any indication of this such as a downward arrow or negative sign was accepted. The marks obtained for part (f) were disappointing in spite of the mark scheme being expanded to accept a greater range of answers. Very few students picked up that the question referred to the voltmeter reading rather than the pd between A and B. The first marking point was for explaining the effect the internal resistance would have on the circuit by for example reducing the current or terminal pd. The second mark was for a sensible suggestion explaining why the voltmeter reading did not change such as realizing that the closeness of the resistance ratios would make the pd being measured very small. Having the bridge circuit slightly off balance did mean that a comment on the high resistance of the voltmeter was relevant and some did identify this point.

Q4.

This question gave students the opportunity to demonstrate their skills reading graphs, as well as their knowledge and understanding of electricity.

(a) Several misconceptions were clear in some of the answers to this question. Many students misinterpreted the graph as a V-I graph and, of the rest, many suggested that gradient is equal to 1/R: teachers are encouraged to emphasise that the value of V and I at the point (or 1/gradient of the line from the point to the origin) gives the resistance of the filament. Other problems were related to lack of detail or ambiguous terminology. Many students lost a mark for being unclear about 'which particle moves more', and the requirement for an increase in the *rate* of collisions (rather than just the collisions) also proved to be a hurdle to many. Many answers were seen that suggested students applied little more knowledge or understanding than that required at GCSE level.

(b) This straightforward calculation was correctly performed by the large majority of students, suggesting that many who misinterpreted the axes in 02.1, were still able to use them correctly in this question.

(c) There were several different routes students could take to obtain the correct answer here, and all of them were given full credit. With many students not obtaining all three marks in what is a relatively straightforward calculation, it is suggested that teachers encourage students to sketch a small circuit diagram where one isn't provided if it assists them in answering questions. The most straightforward, and rarely seen, method was to simply read the value of the pds for both components at 0.18 A, and add them together. Many students embarked on complex analyses that almost inevitably led to errors and marks being lost.

(d) Many students have greater difficulties with parallel than series circuits and, again, the sketch of a simple circuit diagram would probably have assisted them here. The significant difference in performance between this and the previous question was seen in the award of 1 or zero marks: many more students were unable to make enough of an attempt to gain any credit. This was often due to an assumption that the 0.18 A current was still applicable here, with students then performing a simple V/I calculation for the wrong answer. Other common errors included difficulties adding resistances in parallel, a problem that would not have existed had these students realised that the total current could be obtained from the graph, and the resistance calculated from V/I.

(e) It was pleasing to note that this multi-step calculation was completed successfully by a large proportion of the students and that the correct unit was well known. Those who had difficulty tended to make power of ten errors or mistakenly use diameter for radius in the calculation of area, either of which still allowed for an 'error carried forward'. It should be emphasised that a correct unit on its own was not credited, and that some working, and an answer, had to be seen.

Q5.

This question required students to analyse a parallel circuit and predict the effect of changes in the circuit.

(a) As is often the case, students struggled to analyse this parallel circuit correctly. The commonest successful approach was to work out the resistance values for the lamps and then use these values to determine the potential difference across each lamp. A minority of students, having found the resistance values of the lamps, calculated the current in each branch and then compared this with the current required for normal operation. Only about a third of students were able to adopt either of these two approaches.

(b) Only a minority of students appreciated that the potential difference across lamp E would be zero and so there would be no current in the lamp. This meant that there were a considerable number of flawed arguments which assumed there was a current in E. Over 10% of students made no attempt at this question; in addition, 78.9% scored zero.

(c) The overall performance in this part of the question was also disappointing. The most accessible mark was the calculation of the initial current in the battery – which some students had already done in (a). Appreciating that lamp B failing resulted in a parallel and series circuit was not well understood and it was rare to see correct calculations of the new circuit resistance. A significant proportion of students did appreciate that the resistance had increased and this would reduce the current, but were unable to support this with correct calculations. A very high proportion of students (22.7%) failed to attempt this question.

Q6.

54% of students were able to perform this relatively straightforward calculation. Surprisingly D was the least popular distractor, suggesting students had more problems with correctly using seconds rather than minutes than dealing with the m in mA.

Q7.

With 55% of students giving the correct answer, this question proved to be reasonably accessible. This may be because the experiment is often carried out with a protective resistor in series with the diode. The most popular distractor, D, indicates some confusion between current and pd. A relatively high number of students opted for C, suggesting some difficulties working out whether the diode was reverse biased or not.

Q8.

Many students have difficulties with electricity questions. Using multiple choice questions such as this one may help deal with some misconceptions. The correct answer was given by 40% of students, but nearly 50% believed that adding a resistor in parallel would reduce the current (and hence the charge) through R, despite being told that the cell has negligible resistance. Presumably the students believed that the current through the cell does not change, and therefore the current is shared between the two resistors.

Q9.

This proved to be more demanding than expected, with more students choosing A than the correct answer (D). This was perhaps due to students realising that thermistors had something to do with temperature, without realising that the higher the temperature the lower the resistance. It may be that these students rejected the other answers without checking them as an understanding of resistors in series and parallel should have led to the correct answer.

Q10.

Students familiar with the characteristic for a fixed resistance were probably led to answer B without reading the question. This proved to be the most popular answer despite it being incorrect. Approximately 20% were sufficiently careful with their reading, or sufficiently familiar with the practical, to give the correct answer, A.

Q11.

This calculation was fairly demanding with only 27% of students giving the correct answer. In fact answers B, C and D proved to be almost equally popular, suggesting a fair amount of informed guessing was going on. It may have been made easier had a circuit diagram been provided. In the absence of one, students should be encouraged to draw their own in the spaces on the paper.

Q12.

Many students found this question a challenge with just over 50% selecting the correct answer. Students should be encouraged to check specification content and ensure they understand each statement. This type of calculation will be expected knowledge across the life of this specification.

Q13.

This proved one of the most accessible questions in section C, with nearly 80% of students selecting the correct answer. However, it was noted that the supporting working was not particularly convincing. Many students used the ratio of 4:2:1 for the current ratio rather than the ratio ¼: ½: 1. This error may have resulted in students obtaining the wrong answer if asked for the current in either the 4 Ω or 1 Ω resistor.

Q14.

This calculation was performed correctly by over 70% of students. The most frequently selected incorrect answer was distractor B. Students applied little physics here and simply found the product of 12, 6.5 and 5.

Q15.

Most students correctly identified B as the correct statement regarding superconductors. Distractor A proved a popular choice as many students are reluctant to recognise that superconductors have no resistance and prefer statements that suggest that superconductors have almost zero resistance.

Q16.

40% of students selected the correct answer. The most popular distractor was C; students had difficulty dealing with the fact that doubling the radius quadrupled the cross-sectional area. Where students had supporting working, with the resistivity formula, they had usually performed the calculation correctly.

Q17.

The low level of success here was surprising; less than 50% of students correctly identified the correct answer. In preparation for the exam, students would do well to be able to sketch all such graphs from memory, making any such graph instantly recognisable in questions like this.

Q18.

Over 10% of students did not select any answer. It is important that students develop exam technique to include a final page check to ensure all questions have been seen. Only 35% of students selected the correct answer; this demonstrates a lack of familiarity with the properties of LDRs and potential divider circuits.

Q19.

Students most frequently selected C as their answer. Unfortunately, students seemed unaware of the need for V to be a constant when inspecting $P = VI$ and assumed direct proportionality. As a result, only 28.8% gained this mark.

Q20.

Despite this idea being tested last year, students still seem to be unaware of how to determine resistance at a point on a curved V-I graph. The resistance is the ratio of the voltage and current at that point and not the gradient of the tangent to the curve. Distractor B was the most common answer selected by students; 32.1% of them gained the mark.

Q21.

Electricity remains a topic that students find challenging. Just under 20% of students selected the correct answer. The most commonly selected incorrect answer was distractor B. Students seemed unaware of the fact that the potential difference across the lower part of the circuit would be unaffected by an increase in the resistance of the thermistor.

Q22.

This question proved more accessible to higher performing students, with 34.5% selecting the correct answer. Those students who selected D (most common incorrect response) added the emfs of the cells despite the fact that the cells were connected in parallel. Students would do well to revisit rules for combining cells in series and identical cells in parallel.

Q23.

This question tested students' knowledge of formulae, units and their ability to rearrange. Over 30% were able to identify the correct answer. There were a number of pitfalls along the way and many students did not manage to deal with the s^{-1} in Cs^{-1} (the unit for the ampère); in this case they selected distractor A.

Q24.

This question proved a challenge (28.3% correct); the most common incorrect answer selected was distractor C. These students reasoned that the pd must be divided between the voltmeter and the 20 Ω resistor in a 1:1 ratio despite the voltmeter having an infinite resistance. Similarly, they were unaware that the total resistance in the circuit was 20 Ω rather than 10 Ω.