Mark schemes

Q1.

(a) Straight-line graph through the origin and passing through (0.5 A, 0.375 V) ✓

Line must:

- *be drawn with a ruler.*
- *be close to (0.5 A, 0.375). Do not allow vertical **and** horizontal inaccuracy.*
- *pass within their line's width of origin.*

1

(b) correct read-off of resistance for I = 1.9 A

OR

Use of $P = I^2R$ for their R

OR

Use of $V=IR$ **and** $P=VI$ for their R

OR

Use of $V=IR$ **and** $P=\frac{V^2}{R}$ for their R ✓

Allow R in range 3.5 to 3.7

(power =) 13(.0) (W) ✓

Accept answers in range 12.6 to 13.4

Allow 1 mark for 13.7(18) (W) or 14 (W) on answer line without supporting work.

2

(c) Use of $V_T = V_1 + V_2$

OR

Use of $V = IR$ for their V✓

(R =) 3.8 Ω ✓

(V =) 9 - 3.3 or (V=) 5.7 (V)

Alternative method:

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

OR

Use of $R_T = R_1 + R_2$ for their R_{lamp} **or** their R_T ✓

(R =) 3.8 Ω ✓

Expect to see $(R_{lamp}=)\ \frac{3.3}{1.5}$ *OR* (R_{lamp} =)2.2 (Ω)

And $(R_T=)\ \frac{9}{1.5}$ *OR* (R_T =)6 (Ω)

Alternative method:

Reads off R_{lamp} = 2.2 Ω

OR

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

OR

Use of $R_T = R_1 + R_2$ for their R_{lamp} **or** their R_T ✓

(R =) 3.8 Ω ✓

Allow R in range 2.1 to 2.2 Ω

Expect to see $R=\ \frac{9}{1.5}$ *OR R =6 (Ω)*

Range of R where read-off used for R_{lamp} is 3.8 to 3.9 Ω.

2

(d) **R**'s value must decrease ✓

- More current (in bulbs parallel section) ✓
- Idea this requires a lower resistance for **R** to maintain same pd across **R** (therefore same pd across bulbs). ✓

OR

- Total resistance (of **L1** & **L2)** is lower ✓
- Idea that the ratio of pd division For example:

V_R : V_L is same for **R** and **L1** & **L2** combination as for **R** and **L1**. ✓

Allow any value quoted for decrease.

Condone Max 2 for use of a calculation.

*Be wary of 'the resistance is decreasing', needs a definite statement that this relates to **R** to score **MP1**.*

3

[8]

Q2.

(a) Appropriate use of $V = IR$ ✓

e.g. for MP1:

- *determines total circuit resistance*
- *determines pd across thermistor*
- *use of* $= I(R_{XY} + R_{YZ})$ ✓

Condone POT error in MP1

Variable resistor resistance = 190 (Ω) ✓

Expect to see total circuit resistance of 542 (Ω)

Expect to see pd across resistor of 2.3 V.

Condone POT error in MP1

Calculator value: 191.67 Ω

2

(b) Evidence of 22 °C converted to K ✓

Determines R OR $\frac{3.2}{12}$ OR $\frac{3.2}{12\times10^{-3}}$ ✓

Allow ecf from MP1. Expect 295 K

Expect to see 267 Ω

Evidence of use of $\ln(\frac{R}{R_0})$ with their values ✓

Condone use of $R_0 = 190\ \Omega$ *in MP3*

B = 1110 ✓ K ✓

Accept 1100

Accept answers that round to 1110 or 1120

Allow ecf only from temperature conversion.

Do not accept k for K

5

(c) Current causes thermistor temperature to change ✓

Thermistor resistance decreases as temperature increases ✓

Allow a clear description of thermal runaway for both marks.

2

(d) Uses ammeter(s) (in series) to show current at X = current at Y = current at Z
OR
Uses voltmeter(s) to show that emf/terminal pd / 6.5 V = pd across XY + pd across YZ✓

Do not allow 'currents across'.

Do not accept 'battery pd' unless it is clearly being measured.

If points XYZ are not referred it must be clear where the meters are attached.

Links current readings to (conservation of) charge
AND
Links pd readings to (conservation of) energy✓

2

[11]

Q3.

(a) (±) 0.5(0) mm CAO ✓

1

(b) 6.72 mm ✓

tick in second box

1

(c) use of ratchet with valid justification

OR

use of thimble **and then** the ratchet with valid justification ✓

*allowable ideas should focus on the possible consequences of **not** using the ratchet:*

can cause the object being measured to be distorted / squeezed / crushed / subject to excessive force or WTTE;

can change the diameter / shape of the object;

*may lead to the reading shown being **smaller** than true value;*

damage might occur (to the mechanism);

the frame (of the micrometer) might become warped;

condone 'will over-tighten (micrometer)';

condone 'thimble used to close gap / clamp wire' then use ratchet to tighten or WTTE + justification

treat following as neutral:

'use the thimble then the ratchet to save time' / 'to get accurate reading'

'use ratchet to make sure wire is secure'

*'using thimble (or **not** using ratchet) might change the reading' / 'affect results' / 'might cause a zero error' / 'cause a reading below zero' / 'could lead to systematic error'*

1

(d) use of $I = \frac{(0.)931}{1.2}$

OR

$R = \frac{(0.)397}{\text{their } I}$ $_1$✓

for $_1$✓ allow I > 2 sf rounding to 0.78 (A)

OR

$\frac{(0.)397}{(0.)776}$ OR $\frac{(0.)397}{(0.)78}$ *in working*

OR

$R = \frac{(0.)397 \times 1.2}{(0.)931}$ *with any subject*

OR

use of a valid potential divider approach eg

$\frac{1.2}{1.2+R} = \frac{0.931}{0.397+0.931}$

R = 0.51 (Ω) $_2$✓

for $_2$✓ condone 0.512 OR 0.5117 (Ω)

2

(e) continuous ruled best-fit line drawn $_1$✓

*for $_1$✓ line **must not** pass above centre of 2nd point AND below centre of 4th point;*

reject hairy, thick or dashed lines

if withholding mark examiner must add comment to clip

gradient evaluated from ΔR divided by ΔL;

with correct $\Delta R \geq 0.2$ (Ω) OR correct $\Delta L \geq 150$ (mm) $_2$✓

$_2$✓ is for the process

if using points these must lie on their line;

do not penalise for AE / POT in result;

expect gradient about 1.66 (Ω m^{-1})

*withhold both marks for no line on **Figure 5***

2

(f) attempts to find ρX using $\frac{\pi d^2}{4} \times \frac{\Delta R}{\Delta L}$ $_1$✓

ρX in range below for their metal on the answer line $_2$✓

metal	resistivity / Ω m
copper	1.6 to 1.8 (× 10^{-8})
tungsten	5.4 to 5.9 (× 10^{-8})
alumel	3.3 to 3.8 (× 10^{-7})
nichrome	1.0 to 1.2 (× 10^{-6})

POT correct and unit = Ω m for their metal on the answer line $_3$✓

nichrome CAO $_4$✓

*for 1✓ expect use of their $\frac{\Delta R}{\Delta L}$ OR the closest value in **Table 1**;*

allow use of concordant $\frac{\Delta R}{\Delta L}$ and d values for the metal that is the valid choice for their $\frac{\Delta R}{\Delta L}$;

d must be correct for their $\frac{\Delta R}{\Delta L}$;

*if value not seen in working, judge d from their ρX; for no **part (e)** result condone the substitution of concordant R and L values for a point on **Figure 5** don't penalise for AE or POT*

for 2✓ ignore POT and use the most significant digits in their ρX to judge result, eg for alumel ρX = 0.351 scores 2✓3✗ because this is equivalent to 3.51×10^{-1}

allow >2 sf values that round to 2 sf in range

for 3✓ allow alternative valid answer eg (for nichrome) 1.1×10^{-3} Ω mm

*for 4✓ must be consistent with their **part (e)** $\frac{\Delta R}{\Delta L}$*

4

(g) the **error bars** for *L* / the horizontal error bars are the same length or WTTE 1✓

for 1✓ allow' they are 10 mm' / the width is same';

any quantitative detail eg limiting values / percentage uncertainty about the horizontal error bars is neutral

condone 'bars are same' / 'have same range' 'bars are constant' is neutral

quantitative comment about the **error bars** for *R* / the vertical error bars 2✓

for 2✓ expect (about) ± 0.02 / (height) 0.04 (Ω) AND fifth (about) ± 0.04 / (height) 0.08 (Ω);

allow suitable limiting values of the error bars eg (0.)329 - (0.)371 AND (0.)614 - (0.)692;

allow 'fifth is (about) twice the length of first'

detail in an annotated sketch can earn 1✓ and 2✓

'bars aligned with respective axes' / 'bars are equidistant above / below data point' are neutral

2

(h) idea that **any two** of maximum gradient, minimum gradient or mean gradient are determined using **lines** that pass through (all) the error bars $_1$✓

for $_1$✓ allow 'measure / find gradient' / 'gradient can be found';

insist on idea of a line but don't insist on 'draw / construct';

allow mean = 'best', maximum = 'steepest' etc, maximum OR minimum = 'worst';

'using the error bars' / 'draw line from top of first bar to bottom of last bar' etc are neutral

explains how to determine uncertainty in gradient $_2$✓

for $_2$✓ allow word equation or any of the following

$(m - m_2)$ OR $(m_1 - m)$ OR $\frac{(m_1 - m_2)}{2}$

where m = mean gradient

m_1 = maximum gradient, m_2 = minimum gradient

allow 'G' for gradient

allow 'best gradient - worst gradient' or vice versa etc

condone valid expressions for fractional uncertainty or for percentage uncertainty

2

[15]

Q4.

(a) Amount of **chemical energy** transferred / converted to **electrical energy** for 1 C of charge (through the battery).

OR

Work done in moving 1 C of charge **whole way** round circuit✓

Allow:

(The emf is) the terminal pd (of the battery) when there is no current in the battery.

1

(b) Use of $Q = It$

OR

Substitutes for I and t.

(Q =) 0.044 × 37 × 60 ***OR***

(Q =) 0.044 × 2220 ***OR***

(Q=) 97.68 (C)

Use of $Q = Ne$ ✓

(N=) $\frac{\text{their } Q}{1.6 \times 10{-}19}$ *or (N =) 6.25 x 10^{18} x their Q*

their Q must have supporting work which identifies it as Q

(N =) 6.1 × 10^{20} ✓

Accept answer correctly rounded to at least 2 sf.

Calculator display = 6.105 x 10^{20}

2

(c) Read off V = 3.4 V when I = 44 (mA) ✓

Accept any of the following pairs of values:

I (mA)	*V (V)*	*P (W)*
4 to 6	*2.8*	*0.011 to 0.017*
8 to 12	*2.9*	*0.023 to 0.035*
12 to 15	*3*	*0.036 to 0.045*
20	*3.1*	*0.062*
22 to 26	*3.2*	*0.070 to 0.083*
40 to 47	*3.4*	*0.136 to 0.160*
64 to 72	*3.6*	*0.23 to 0.26*
96 to 100	*3.8*	*0.36 to 0.38*

Use of $P = VI$ ✓

Substitutes a voltage between 2.8 V and 3.8 V and a corresponding current value from table. Expect to see a consistent power in range quoted for that voltage.

Condone POT error in sub for current and its subsequent power. In MP1 and MP2

***OR** Uses I = 0.044 (A) and 3 V < V < 4V and obtaining a consistent answer.*

(P =) 0.15 (W) ✓

Accept answer correctly rounded to at least 2 sf.

MP3 must be 0.15 (W) or 0.150 (W) or 0.1496 (W).

3

(d) **MP1✓**

Use of $V = IR$: (to find lost volts = Ir =) 0.044 × 1.5 OR 0.066 V

OR

$\left(\frac{\varepsilon}{I} =\right) \frac{12}{0.044}$ (To find total resistance = $\frac{3000}{11}$ or 272.7 (Ω))

MP2✓

(Total resistance - r = R =) $\frac{5967}{22}$ or **271.2 (Ω)**

OR

(Pd across R =) 271.2 × 0.044 or 11.9328 V or their R × 0.044

OR

(Total pd across LEDs =) 3 × 3.4 or 10.2 V **ECF**

OR

(Resistance of an LED =) $\frac{3.4}{0.044}$ or 77.3 (Ω) **ECF**

OR

(Resistance of an LED = $\frac{P}{I^2} =) \frac{0.15}{0.044^2}$ or 77.3 or 77.48 (Ω) **ECF**

MP3✓

(Total resistance of 3 LEDs =) 3 × 77.3 **or** 231.9 **or** 232.438 (Ω) **or** 3 x their resistance of one LED

OR

(Pd across **R** =) 12 - their total pd across LED - their lost volts or 1.734 (V)

OR

R = *R* - 3 × their resistance of one LED

OR

(*R* of **R** =) $\frac{\textit{their pd across unknown resistor}}{0{,}044}$ *or* $\frac{1{,}734}{0{,}044}$

MP4✓

(*R of* **R** =) 39(.4) (Ω) or 38.8 (Ω)

Alternative

MP1 *Use of ε = I(R + r) by substituting for ε, I and r (where R is external resistance)*

MP2

Rearrange ε = I(R + r) to find R = ***271.2 (Ω)***

Condone POT in any of the working for ***MP1****,* ***MP2*** *and* ***MP3****.*

Condone answers in range 38.5 Ω to 39.7 Ω

Treat use of their V from (c) as an ECF e.g.

An answer of 53 (Ω) gains ***4 marks*** *(uses V= 3.2 V)*

Other consistent uses of their V identifiable in (c) can achieve ***4 marks****.*

4

(e) **MP1**

lost volts = 3.5 × 1.5 or 5.25 V

OR

Current in LEDs = 8 mA (when V = 2.9 V)

Allow between 8 mA and 10 mA for this read-off.

OR

LEDs require 8.7 V to light✓

MP2

terminal pd = 6.75 V✓

MP3

LEDs won't light:

-because terminal pd is less than 8.7 V

-because pd across LED is less than 2.5 V, therefore, no current in LEDs

-because pd across **R** is zero as the resistance of LED is much greater the **R**, therefore, no current in LEDs

-Resistor **R** would require a pd of 0.315 V. Therefore, total pd required = 9.01 V is greater than terminal pd.

-their pd across each LED is below switch-on voltage (of 2.9 V)✓

***MP3** gives a valid reason why 6.75 V is insufficient.*
Needs to state LEDS won't light for to gain MP3.

3

[13]

Q5.

(a) (1 C of) the charge gains ε J on passing through cell

OR

energy transferred (by 1 C) in R_1 is V_1 (J)

OR

energy transferred (by 1 C) in R_2 is V_2 (J)

OR

energy transferred (by 1 C) in r is Ir (J) ✓

If no other mark awarded, allow one mark for definition of emf in terms of energy transfer.

accept: 'dissipated'

accept 'lost volts' for Ir but reject 'voltage across r'

accept 'work done' for 'energy transferred'

(for conservation of energy)

$\varepsilon = IR_1 + IR_2 + Ir$ ✓

Alternative for MP2

$\varepsilon = V_1 + V_2 + Ir$

provided that MP1 is awarded.

2

(b) Equates emf to Ir + 2.89 in some form ✓$_1$

If no other mark awarded, award one mark for use of emf value in MP2.

Allow in MP1 (their current/A) ×125Ω for 2.89 V

Calculates I from 2.89÷125 (=0.02312 A) ✓$_2$

Allow alternative routes for ✓$_1$ and ✓$_2$. E.g.

'Lost volts'= 0.11 V ✓$_1$

Applies potential-divider equation e.g.

0.11÷2.89 = r÷125 ✓$_2$

OR

3÷(125 + r) = 2.89÷125✓$_1$✓$_2$

Giving r = 4.76 (Ω) ✓$_3$

Must see at least 3 sf answer

Answer must round to 4.76(Ω)

3

(c) (Resistance splits 25 Ω and 104.8 Ω)

Applies potential divider formula eg $\frac{V}{3.00} = \frac{25}{129.8}$ ✓

V = 0.58 (V) ✓

Accept other routes for MP1 e.g.

using V = IR, with 25 Ω and their current, for example from

- *I = 0.023 A (from Q03.2)*
- $I = \frac{\text{emf}}{\text{total resistance}} = \frac{3}{125 + r}$
- $I = \frac{\text{terminal pd}}{125}$

OR

using $V = \frac{2.89}{5}$ *with an identification of 2.89 V as the terminal pd.*

If no other mark awarded, allow one mark for using 29.8 Ω instead of 129.8 Ω for total resistance giving 2.5(2) V.

2

(d) Any **four** from:

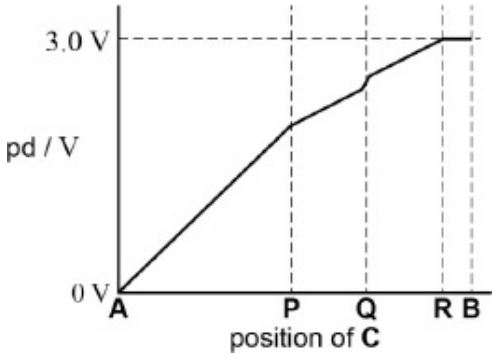
Straight line 0 V **A** to **P** 1✓

Less steep non-zero gradient from **P** to **Q** 2✓

Short steep increase at **Q** 3✓

Q to **R** about same non-zero gradient as **P** to **Q** 4✓

Horizontal line from **R** to **B** at 3.0 V 5✓



*For 3✓ allow range no greater than width of "**Q**" label on horizontal axis.*

*If graph sketched from 3 V (at **A**) to 0V (at **B**) award **max 2** (based on 2✓ and 4✓).*

If a single diagonal straight line from 0 V (at A) to B, award 1✓only.

*If a single diagonal straight line from 0 V (at A) to R and then horizontal to B, award only 1✓ **and** 5✓ if scored (**ie max 2**).*

Max 4

[11]

Q6.

(a) rate = 1.40 to 1.75 (V s^{-1}) $_1$✓

for $_1$✓ accept 2 sf 1.5, 1.6 and 1.7 (V s^{-1})

rate = 1.50 to 1.65 (V s^{-1}) $_2$✓

for $_2$✓ accept >3 sf rounding to value in range;
accept 2 sf 1.6;
expected answer is 1.57(2) (V s^{-1})

2

(b) maximum 1 mark per marking point (see $_1$✓ to $_4$✓ below)

reduces impact of statistical error (involved in reading and recording data manually) $_1$✓

data can be collected at a high(er) rate or wtte $_2$✓

idea that data (in digital form) may be easily processed $_3$✓

two (or more) sets of data (*I* and *V*) can be made simultaneously or wtte $_4$✓

treat suggestions that data logging improves 'precision' / 'resolution' / reduces 'uncertainty' / eliminates 'systematic' / 'parallax errors' / 'anomalous readings' as neutral

for > 2 ideas mark as a list

for $_1$✓ allow reducing 'human error' / 'random error' / 'improving accuracy' as same idea;
idea that random error / uncertainty can be eliminated is talk out;
condone 'no human error / reaction';

for $_2$✓ condone 'quickly' / 'works faster'
'collect data at a steady rate'/ 'saves time' / comments about 'reaction time' are neutral

for $_3$✓ eg can be transferred to / graphed with / analysed using a digital device or application eg computer / spreadsheet
allow 'can be processed automatically'

treat the following as neutral since they are not specifically applicable to this experiment:
can carry out experiment 'remotely' / 'in inaccessible or dangerous environments' / 'automatically' / 'without any human (being present)' or wtte;
can 'start / stop data collection at some suitable (future) time' / 'collect large amount of data' or wtte;
'a wide variety of sensors are available' / 'data logging is (increasingly) cheap'

Max 2

(c) identifies that **circuit 2** can produce the data because the pd can be varied between 0 V and 12 V 1✓

for 1✓ allow 'can achieve 12 V range' or wtte; reject 'can produce 0 V and 12 V'

identifies that **circuit 1** cannot produce (all of) the data shown on **Figure 2** 2✓

*for 2✓ allow '**circuit 1** is not suitable' / 'not **circuit 1**';*

award 1✗2✓ for 'neither can produce the data'

2

for **circuit 1** with **X** set to maximum resistance

calculates (minimum) *I*

OR

calculates (minimum) *V* 3✓

for 3✓ (at least one) result should be evaluated to min 2 sf but condone '≈ 0.7' if decimal intermediate result is ok;

do not accept rounding to 0.69;

allow use of 17.2 without justification;

minimum $I\left(=\frac{12}{17.2}\right)$ *= 0.70 A OR*

minimum $V\left(=12\times\frac{2.3}{17.2}\right)$ *= 1.6 V*

their minimum *I* or minimum *V* for **circuit 1** compared with value of first (or second) point in **Figure 2** 4✓

for 4✓ could say their minimum I > 0.36 / I for first data point < 0.7(0) / 0.70 > 0.36 etc

allow 'cannot produce I < 0.7(0) in Fig 2';

'cannot produce all the values' is not enough

2

(d) P = 6.82 in row 2 $_1$✓

I = 1.77 in row 4 $_2$✓

P = 17.0 in row 4 $_3$✓

	V / V	I / A	P / W
	3.30	1.07	3.53
$_1$✓	5.17	1.32	**6.82**
	7.69	1.59	12.2
$_2$✓$_3$✓	9.58	**1.77**	**17.0**
	11.47	1.94	22.3

for $_1$✓ CAO

for $_2$✓ allow 1.77 ± 0.01

for $_3$✓ ECF for their (incorrect) I × 9.58;

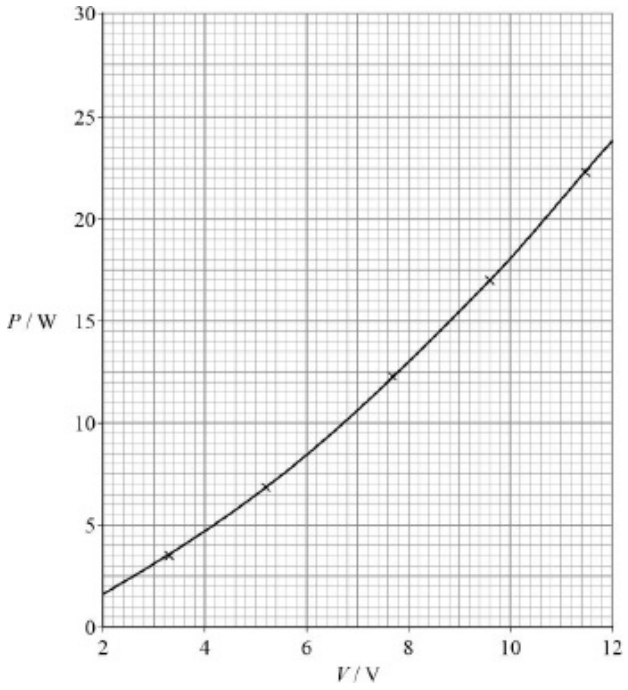
*deduct MAX 1 mark if any are **not** to 3 sf*

3

(e) vertical axis labelled P / W $_1$✓

suitable vertical scale for their data $_2$✓

5 points plotted AND smooth curve of increasing gradient $_3$✓



for $_1$✓allow P (W), P in W;

reject comma separator, eg P, W;

allow words, eg power for P / watt(s) for W

for $_2$✓expect 1 cm interval = 2 W OR 2 cm intervals = 5 W

vertical scale must

• be linear

• be marked in integer values

• be marked with a frequency of not less than 4 cm intervals

• cover the range of plotted points

assume P = 0 at unmarked origin

2

for $_3$✓check the plotting of any obviously suspect point;

*points must **not** be thick / faint / dots / blobs;*

line must

*• be a continuous **curve***

• be neither thick or faint

• (at least) extend from the first to the fifth point

• be a reasonable best-fit for their data; withhold mark if line deviates by ≥ 2 minor squares from examiner's best line (by eye)

if I / A is plotted award $_2$✓if the effective range of vertical scale is ≥ half height of grid

1

(f) evidence that P_r read-off to ± 1 minor grid square $_1$✓

for $_1$✓best-fit line must be extrapolated to V = 12 V (at the right-hand margin of the grid);

P_r correct to ± half a minor grid square;

expect P_r = 23.8 W for a curve but accept a read-off obtained from a straight best-fit line

reads off P_2 corresponding to 6 V;

evaluates $\frac{2 \times \text{their } P_2}{\text{their } P_r}$ × $_2$✓

$_2$✓is not contingent on $_1$✓

for $_2$✓expect P_2 = 8.5 W for a curve;

expected % in range 70% to 73%

*if no read-off evidence is seen on **Figure 3** check for the possibility that **Figure 1** was used to obtain P_r and P_2 eg by drawing a curve through points to intersect at V = 12 V, then*

using V (= 12) × I (= 1.98) P_r = 23.7

using V (= 6) × I (= 1.42) P_2= 8.5(2)

would lead to 72%

2

[16]

Q7.

(a) (pd across the variable resistor) = 11.25 (V) seen

For **Max 1**:

OR

Use of $V_0 = \frac{R_1}{R_1 + R_2} \times V_{in}$

Condone mix up of R_1 and R_2

OR

use of $V_1 : V_2 = R_1 : R_2$ or $\frac{V_1}{V_2} = \frac{R_1}{R_2}$

Condone V = 12 V and R = 25 Ω leading to an answer of 1.56 Ω or 1.6 Ω

OR

(I =) 0.45 A ✓

Condone V = 12 V and R = 25 Ω leading to I = 0.48 A and an answer of 1.56 Ω or 1.6 Ω

(R =) 1.7 (Ω) ✓ **c.a.o**

Accept a correctly rounded answer to 2 or more significant figure.

(Calculator displays 1.66666666)

2

(b) Clear read-off seen on graph of I = 1.7 A

Within $\frac{1}{2}$ square of accuracy (1.65 A to 1.75 A)

OR

use of $V = IR$ ✓

Accept $\frac{8}{1.65}$ = 4.8(4) or $\frac{8}{1.75}$ = 4.5(7) in use of $V = IR$

(condoning 'read-off' to within 1 square of accuracy)

Don't need to see read-off for use of $V = IR$

8 × 1.7 = 13.6 would be insufficient as use of and in this case MP1 can only be scored where read-off is seen.

(R =) 4.7 (Ω)

Allow answer in range 4.57 to 4.85

Do not accept 1 significant figure in answer

2

(c) As voltage increases the current increases / as the voltage increases more electrons move through the wire (per second) ✓

More collisions (per second) between the (conduction) electrons and the lattice ions / Vibration of the lattice ions increases ✓

Allow vibration of the ions in the filament / wire / metal increases

(Rate of) vibration of the lattice ions increases causing a greater number of collisions **per second** causing increased resistance ✓

Accept rate of collisions for number of collisions per second.

Talk out on MP3 where current decreases.

3

(d) use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ or $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

allow use of $\frac{1}{6} + \frac{1}{25}$ *seen without subject*

Alternative MP1:

(I_T = I_{lamp} + I_{XY} = 2.48 A) ***and*** *use of* $V = IR$

Accept a correctly rounded answer to 2 or more significant figure.

(R =) 4.8(4) (Ω)

(Calculator displays 4.838709677)

2

(e) use of $P = \frac{V^2}{R}$ by substitution of V = 12 V and $R = 4.8\ \Omega$

Ecf from part (d) for MP1 and MP2

MP1:

Condone use of R = 6 Ω or R = 25 Ω in this substitution for MP1 (where not ecf from part (d)

OR

Condone use of $P = IV$ or use of $P = I^2R$ by substitution of their (battery) I and ecf R from part (d). Must have clearly identified I in working in part (d) or by use of $I = \frac{12}{\text{ecf } R}$ *here*

(P =) 30 (W) ✓

Ecf answer must be $\frac{12^2}{R \text{ on answer line in part (d)}}$

(Calculator display for non-rounded answer 29.76)

Penalise answers with more than two digits that have been rounded to 1 significant figure.

2

(f) Wider range in Figure 4's circuit **and** lower efficiency in Figure 4's circuit

Details:

Voltage range is wider 0–12 V (in Figure 4's circuit) compared to 0.75 V – 12 V (in Figure 2's circuit) / can't get voltages between 0 and 0.75 V In Figure 2 / wider range when using **XY** as a potentiometer

OR

bulb won't light at lower voltages, so control is unaffected ✓

Condone referring to Figure 2 as Figure 3.

Allow 'can get zero volts in Figure 4'

At any particular voltage across lamp more power dissipated in circuit in Figure 4 / any voltage across the lamp there is always 12 V across the resistor in Figure 4's circuit which produces more heating (whereas only the remaining portion of 12 V is across the resistor in Figure 2's circuit) / for any current in the lamp there is always more current in Figure 4's circuit which produces more heating ✓

Current splits in Figure 4 is insufficient

3

[14]

Q8.

(a) 0.879 (m ✓)

1

(b) correctly determines R_4 **OR** divides their incorrect R_4 by their part **(a)** $_1$ ✓

Correct answer gives 0.15(1) ($\Omega\ m^{-1}$).

$_1$ ✓Correct R_4 = 0.13(3) Ω

*$_{12}$ ✓Allow a correction to m if their part **(a)** is in mm*

$_2$ ✓Condone 3 sf answer

2

(c) micrometer screw gauge

OR

digital (vernier) callipers $_1$✓

Treat references to zero error as neutral unless explicitly linked to reducing random error.

For $_1$ ✓allow 'micrometer' or 'screw gauge' or travelling microscope.

Reject '(vernier) callipers'.

repeat readings at different points (along the wire)

OR

repeat readings in different directions / orientations

OR

repeat readings AND reject / discard anomalies $_2$✓

Accept "readings" for "measurements".

Repeat "experiment" is insufficient.

calculate average / mean (from repeated readings) $_3$✓

for $_3$✓some mention of repeat (readings) owtte must be seen somewhere in body of answer

3

(d) use of $A = \frac{\pi d^2}{4}$ $_1$✓

ρ = their **(b)** × 1.1(3) × 10^{-7} (Ω m) $_2$ ✓

for $_1$✓ allow POT in d; either $A = \frac{\pi \times 0.38^2}{4}$ ***OR***

$A = \pi \times 0.19^2$ ***OR*** A *= 1.1(3) (×* 10^{-7}*) seen*

For $_2$ ✓ expected answer is 1.7 × 10^{-8} *(Ω m)*

If no other mark given, allow 1 mark for 6.8 × 10^{-8} *(Ω m)*

2

(e) decrease R_1 / 2.2 MΩ by a factor of 30

OR

increase R_2 / 3.9 kΩ by a factor of 30

OR

increase R_3 / 75 Ω by a factor of 30 ✓

unless quantitative change identified, must give new resistance, eg

(new) R_1 is 73 $k\Omega$

(new) R_2 is 120 $k\Omega$

(new) R_3 is 2.3 $k\Omega$

1

(f) 2.1 (mm) ✓

allow > 2 sf answer rounding to 2.1 (mm)

1

[10]

Q9.

(a) $R = \frac{V^2}{P} = \frac{6.2^2}{4.5} = 8.5(4)(\Omega)$ ✓

Condone use of W for P.

1

(b) Calculation of current in lamp (0.73 A)

OR

Calculation of current in 12 Ω resistor (0.52 A)

OR

Calculation of parallel pair resistance (5.0 Ω) ✓

*Allow ecf from **(a)***

Allow alternative methods

Calculation of total circuit current (1.2(4) A)

OR

Calculation of total circuit resistance (7.5 Ω)

OR

Expression of potential divider arrangement

$\frac{\varepsilon - 6.2}{r} = \frac{6.2}{\text{external } R}$ OR

$\frac{\varepsilon}{\text{total circuit restance}} = \frac{6.2}{\text{external R}}$

Give full credit to answers that use 9Ω :

Expected values for this method are

Lamp current = 0.69 A

Current in 12 Ω resistor = 0.52 A

Parallel pair resistance = 5.1(4) Ω

Total circuit resistance = 7.6(4) Ω

Total circuit current = 1.2(1) A

emf = 9.2(1) V

(emf = terminal pd + Ir = 6.2 + (1.24 × 2.5))

9.3(1) V ✓

3

(c) Evidence of calculation of A (= π (d / 2)^2 = 2.84 × 10^{-8}) ✓

Use of their A in the resistivity equation = RA/l ✓

To give 5.1 × 10^{-8} (Ω m) ✓

Allow POT errors in MP1 and MP2

Allow answers that round to 5.10 × 10^{-8} (Ω m)

3

(d) Resistance increases ✓

Reduces current through lamp

and lamp dimmer ✓

OR

Greater pd across plugs as potential divider

and lamp dimmer ✓

Do not condone explanations that confuse current and potential difference.

Do not condone "current across" or "pd through".

2

(e) (Resistance increases)

Reduces current in circuit / battery

OR

Increases (external) circuit resistance ✓

Reduces pd dropped across internal resistance of cell / increases terminal pd so lamp brighter ✓

Award MAX 1 for arguments dealing with initial dimming of bulb when wire attached.

Condone "pd across lamp and resistor / parallel section" for "terminal pd".

Condone "lost volts".

2

[11]