Mark schemes

1. (a) The amount of energy is transferred from **chemical energy** to **electrical energy** (for every coulomb of charge)✓

Alternative first mark:

*The work done in moving (1 coulomb of) charge **whole** way round circuit*

5.30 J of energy per coulomb of charge✓

2

(b) 5.30 – 1.05 = 4.25 (V) seen

or

4.25 V across 640 Ω resistor seen

or

use of $V = IR$✓

Allow use of $V = IR$ to find the current in the 320 Ω resistor. (I = 3.28 × 10^{-3} (A))

$(I = \frac{4.25}{640} =)$ 6.6(4) × 10^{-3} (A)

Where candidates assume voltmeter has resistance 320 Ω , their answer = 6.56 x 10^{-3} A. Do not credit this.

2

(c) Use of $V = IR$ seen (finds total resistance of circuit)
Or
Use of $V = IR$ for parallel section seen ✓

R_T = 798 (Ω) (expect to see 757 (7 mA) or 803 (6.6 mA) or 807 (6.56 mA)

Allow their R_T or their total resistance of the parallel section

Use of $R_T = R_1 + R_2$ **or** $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ seen (finds resistance of voltmeter)✓

(R =) 312.6 (Ω) or 313 (Ω) or 310 (Ω) seen ✓

$I = 3.28 \times 10^{-3}$ (A) (evidence for this may be seen in (b))

Alternatively:

Use of $V = IR$ seen (finds current in 320 Ω resistor)✓

Allow their I_T and their current in the 320 Ω resistor.

Use of $I_T = I_1 + I_2$ seen (finds current in voltmeter)✓

(R =) 312.6 (Ω) or 313 (Ω) or 310 (Ω) seen ✓

Answer is:

316 Ω where I = 6.6 mA

282 Ω where I = 7 mA

320 Ω where I = 6.56 mA

Must see working to support their answer.

No workings = zero marks.

3

(d) Use of $P = V^2 / R$ ✓

*Allow their V along with R from **part (c)***

Allow V = 5.3 with their R

Alternative 1st MP

*Use of $V = IR$ **and** $P = I^2R$ **or***

*$V = IR$ **and** $P = VI$ ✓*

(P =) 0.090 (W)✓

Answer = 0.094 (W) where R = 300 Ω

Condone 1 sf answer where R = 300 Ω is used.

2

(e) Current in circuit changes (as voltmeter position changes) / ratio of the voltage dropped across each resistor changes as voltmeter position changes. ✓

Because resistance in the circuit decrease / changes✓

Allow maximum of 1 mark for the reading will only be the emf if the voltmeter is across both resistors. ✓

2

[11]

2. B

1.7 A

[1]

3. (a) arrow between block and belt pointing upwards along the belt

1

(b) (F =) 19$g$sin23° to give 72.8 (N) ✓

Allow 2 sf answer.

1

(c) uses $F = \frac{\Delta(mv)}{\Delta t}$

*Allow for MP1 use of appropriate kinematic equation for a **AND** use of $F = ma$*

F = 12 (N) ✓

their (b) + 12 (N) ✓

Expect 82 or 85 (N)

3

(d) uses V and I to get total input power or energy ✓

P_{input} *of motor = 110 × 5.0 = 550 W*

$E_{input} = 550 \times \frac{8.0}{0.32} = 13\,750$ *J*

uses efficiency equation ✓

P_{useful} *to belt = 550 × 0.28 = 150 W*

E_{useful} *= 3850 J, from* $154 \times \frac{8.0}{0.32}$*, or 13 750 × 0.28*

determines power or energy to move one block ✓

P_{block} *= 22 or 23 W*

E_{block} *= 560 or 580 J*

divides (total) useful power or energy by individual power or energy to give answer of 6 blocks ✓

Allow ecf for MP4 only for their (c)

4

[9]

4. D

6 A

[1]

5. (a) R_{LDR} without light = 300 kΩ ✓

$I = \frac{V}{R} = \frac{5}{310 \times 10^3}$ = 16.1 × 10^{-6} A ✓

Allow ecf for their R

2

(b) V with without light = IR = 16.1 × 10^{-6} × 300 × 10^3 = 4.84 V✓

ecf from ***(a)***

Allow 92–100 kΩ

With light $V = \left(\frac{93}{93+10}\right)$ × 5.0 = 4.51 V ✓

Conclusion and calculate of change in voltage and comparison with 1.25 V✓

4.8 – 4.5 = 0.3 V so no.

Allow 1 sf (allow ecf)

3

[5]

6. A

$\frac{3R}{7}$

[1]

7. (a) reads off λ_p ${}_1$✓

for ${}_1$✓ *condone POT;*

expect λ_p *= 635 ± 2 (nm) /*

635 ± 0.02 × 10^{-9} */ 6.35 ± 0.02 × 10*$^{-7}$ *(m)*

allow evidence of working on ***Figure 1***

1

use of n × their λ_p = d sin θ ${}_2$✓

for ${}_2$✓ *accept subject* n *with no / incomplete substitution, eg*

$$N = \frac{\sin\theta}{n \times \lambda_p}$$

OR

subject d *and* *full* *substitution, eg*

$$d = \frac{5 \times \text{their } \lambda_p}{\sin 76.3} \; / \; 5.15 \times \text{their } \lambda_p$$ *5.15 × their* λ_p

OR

correct result d *= 3.27 (× 10*$^{-6}$ *(m));*

allow ECF in λ_p *including POT;*

allow recognisable d */ 2 sf intermediate result*

3

$$N = \left(= \frac{1}{d} = \frac{1}{3.27 \times 10^{-6}} \right) = 3.06 \times 10^5$$ ${}_3$✓

for ${}_3$✓ *accept ≥ 3 sf in range 3.05 to 3.07 × 10*^{5} *OR*

$$N = \frac{0.194}{\text{their } \lambda p}$$ *(allow ECF for* λ_p *out of range but*

not if due to POT)

1

(b) identifies an appropriate physical characteristic that makes the measurement of the (5th) maximum more difficult ✓

take 'it' to be the 5 th maximum / peak

(centre difficult to locate because)

(5th) 'maximum is wider' / 'peak less pronounced' / 'less defined' or wtte;

allow 'maximum more spread out' / 'less pronounced'

OR

maximum 'is fainter' / 'less bright' / 'intensity reduced';

reject 'not as clear'

OR

(cannot use edges to determine location of centre because)

'whole maximum (may be) not visible' / 'can't see edges'

OR

*(**L_R** produces a range of wavelengths so)*

4th and 5th / adjacent fringes may overlap

1

(c) extrapolation of linear region of the **L_R** characteristic $_1$✓

*for $_1$✓ reads off where a ruled extrapolation to the linear region of the **L_R** characteristic reaches the horizontal axis*

the line must be free from discontinuities; condone a ruled dashed line

condone tangent meeting curve at $I \geq 10$ mA

V_A for **L_R** in range 1.91 to 1.93 (V) $_2$✓

for $_2$✓ > 3 sf acceptable if rounding to 3 sf

2

(d) any fully correct calculation of the Planck constant $_1$✓

for $_1$✓ allow 2 sf

use of $c = 3(.00) \times 10^8$ AND $e = 1.6(0) \times 10^{-19}$

AND EITHER

V_A from (c) AND λ_p in range 620 to 650 nm / ECF their λ_p from (a)

OR

$V_A = 2.00$ AND λ_p in range 550 to 580 nm;

calculates mean of two valid calculations of the Planck constant;

result in range 6.10 to 6.50 × 10^{-34} (J s) $_2$✓

for $_2$✓ Planck constant result rounding to correct 3 sf

(check very carefully working leading to data booklet value 6.63 × 10^{-34})

1

(e) V_F corresponding to I_F = 21 mA read from **L_R** graph in **Figure 3**;

use of V_F = 2.01 (V) leading to R = 195 (Ω) earns both marks

calculates R from $\frac{6.1 - \text{their } V_F}{21(.0 \times 10^{-3})}$ ₁✓

*for ₁✓ accept evidence of working on **Figure 3** condone 2 sf eg V_F = 2.0 (V)*

allow POT error for I_F

1

R = 195 (Ω) from $\frac{6.10 - 2.01}{21(.0) \times 10^{-3}} = 195$ ₂✓ 195 ₂✓

for ₂✓ evidence to show use of V_F = 2.01 ± 0.01 (V) must be seen, ie allow

$\frac{6.10 - 2.00}{21(.0) \times 10^{-3}} = 195$ OR $\frac{6.10 - 2.02}{21(.0) \times 10^{-3}} = 194$

1

[10]

8. D

23.0 mA

[1]

9. C

13.5%

[1]

10. (a) Work done in moving 1 C of charge through the cell ✓
1.5 J of work is done in moving 1 C of charge through the cell ✓

OR

Amount of energy converted from other forms to electrical energy per 1 C of charge ✓

1.5 J of energy converted from other forms to electrical energy per unit charge (passing across the emf) ✓

OR

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

1.5 J of work is done in moving 1 C of charge the (whole way) round circuit ✓

2nd marking point obtains both marks

***Max 1 mark** available for the following:*

The emf is the terminal pd when there is no current in the cell (and this equals 1.5 V)

1.5 J of energy per 1 C of charge.

Allow a statement of Kirchhoff's 2 nd law for 1 mark. Where the law is in symbol form, the meaning of the symbols must be stated. Need a clear communication of internal and external resistances.

2

(b) P = VI

And

(P) = 0.465 (W) ✓

Seen to more than 2 sf with supporting equation with subject seen in working

1

(c) Use of appropriate power equation to determine wasted power
or
power dissipated in **R** = total power – their wasted power ✓

(P =) 0.40 W ✓

Alternative for 1 mark:

Use of $I = \frac{\varepsilon}{R+r}$

Or

pd across R = 1.5 – 0.65 x 0.31

or

pd across R = 1.2985 (V)

or

total resistance = 1.5/ 0.31

or

total resistance = 4.839 (Ω)

or R = 4.2 (Ω)

or $P = I^2$ *x their* R

or

$P = \frac{V^2}{R}$ *using their V and R* ✓

2

(d) Use of $E = P\,t$
or $E = VI\,t$
Or
$E = QV$ **and** $Q = It$ ✓

Allow use of the equation with their values.

An answer of 3.5 x 10^4 *is worth 1 mark*

(t =) 3.0(1) x 10^4 (s) ✓

2

(e) **MAX 3 from (1 to 4) or (5 to 8)**

It is suitable, because:

(1) Current required in lamp = 0.62 A or use of $I=\frac{P}{V}$ seen

(2) Resistance of lamp = 2.11 Ω or use of $R=\frac{V^2}{P}$ seen ✓

(3) current in each cell = 0.31 A ✓

(4) lost volts = 0.2 V
or
lost volts = 0.65 x 0.31 ✓

Check the diagram in part (e)

Must have the ***correct conclusion to award 4 marks.***

Conclusion: yes, terminal pd = **1.5 – 0.2** seen
or
terminal pd= 1.5 – 0.65 x 0.4 /1.3 ✓

OR

(5) total internal resistance = 0.325 Ω ✓
(6) total resistance in circuit = 2.44 Ω ✓
(7) Resistance of lamp = 2.11 Ω ✓
(8) pd splits in ratio of 0.325:2.11 ✓

Conclusion: yes, pd **across lamp is** $\frac{2.11 \times 1.5}{2.44}$ **(= 1.3 V) seen** ✓

Allow max 3 from a combination of two route [(2) and (7) worth total of 1 mark]

4

(e) (Cells must be added) in parallel ✓

Because:

more energy stored in the bank of cells / less power from each cell ✓

without increasing the voltage across the bulb (above 1.5 V)

or

without increasing the terminal pd (above 1.5V) ✓

Must link the cells being added in parallel to one or both reason to gain three marks.

Alternative:

- *In parallel*
- *Current shared by cells*
- *Takes longer to convert the energy stored in each cell.*

Alternative:

- *In parallel*
- *Less internal resistance*
- *Less power / energy wasted*

Cells in series statement means no marks can be obtained.

3

[14]

11. C

produce strong magnetic fields.

[1]

12. D

4.2 V 1.4 V

[1]

13. (a) to limit (maximum) current (when variable resistor is set to zero) ✓

Accept 'so cell is not short-circuited' for $_1$✓

to prevent overheating (of cell)
OR
to prevent damage to <u>cell</u>
OR
otherwise cell would discharge quickly ✓

'to avoid damaging components' is not enough for $_2$✓

2

(b) Line ruled through bottom of second error bar and top of ninth (3rd from right) error bar ✓

Ignore unit if given. Allow tolerance of 2 mm inside either error bar.

Determines their gradient, with $\Delta x \geq 0.2$ (A) ✓

(–)1.0 ± 0.1 (/ V A^{-1}) ✓

Expect to see 2 sf in any answer

3

(c) Attempt to calculate mean of their G_{min} and –1.3 ✓

Allow positive G values

1.1 (Ω) ✓

Ecf from (b). 1 mark max if r given as negative

2

(d) States that $\varepsilon = V + Ir$ **OR** calculates R = 0.39 (Ω) ✓

Allow ruled line drawn through (0.94, 0.37) and (0.70, 0.65) ✓

Use of $\varepsilon = V + Ir$ **OR** $\varepsilon = I(R + r)$ ✓

Adds their gradient to read off at I = 1.0 A ✓✓

OR

Use of y=mx+c with their gradient ✓

Intercept (c) determined ✓

1.4 (V) ✓

*Ecf from **(c)**. 3 sf max*

3

[10]

14. D

24 V

[1]

15. **B**

[1]

16. **C**

[1]

17. (a) Use of power equation

Or combination of power equation and $V = IR$

To get R = 96 (Ω). ✓

Must see some working

Do not allow reverse arguments

1

(b) Either calculation of current through one lamp

Condone use of any other method eg use of power = 4.5 W and power equation.

And multiply by 3

OR

calculate total resistance ✓ (and use $V = IR$)

To give 0.38 A. ✓ (at least 2sf)

Allow ecf for their R from (a) used or their I

Use of 100 Ω gives 0.36 A (0.4A)

2

(c) Evidence of equation to calculate area . ✓

2.8×10^{-8} m^2 ✓

Use of resistivity equation to get 49 Ω. ✓

Allow POT error in MP1

Evidence for MP2 may be in final answer

Accept 48 Ω

3

(d) Total resistance = 46 + 46 + 100/3 = 125 Ω. ✓

Allow ecf for incorrect resistance

Calculation of circuit current = 12/125 = 0.096 A. ✓

operating current of lamp (=1.5/12 = 0.13)/current for all 3 lamps to be fully on = 0.38 A. ✓

Yes demo works as lamps will be dimmer/ off (with constantan). ✓

If no other marks awarded, one mark each can be given for (max 2)

- *for resistance increases with length.*
- *Too much p.d. dropped across constantan*
- *Resistivity of constantan is greater than resistivity of copper*

For MP3 allow quoted comparison to previously calculated current in (b)

For MP4 allow ecf if answer is yes and is consistent with their calculation

4

(e) **Advantage**

Zero resistance/resistivity. ✓

Reduce heat/energy transfer / power loss in cables ✓

Difficulty

Difficult to maintain low temperature (over long distances) ✓

Must be kept at/below the critical temperature. ✓

Ignore references to critical field.

Allow very low resistance

Max 3

[13]

18. **B**

[1]

19. **B**

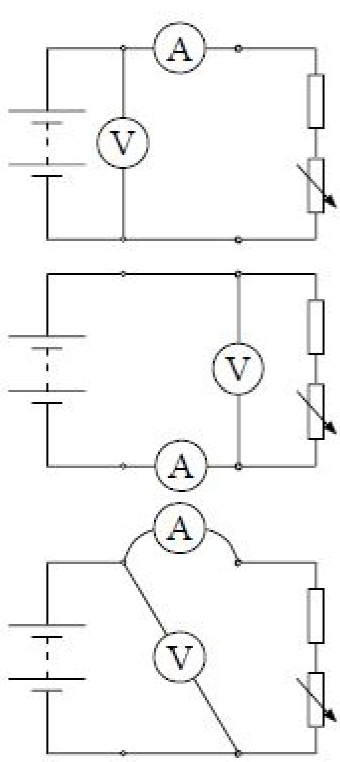
[1]

20. (a) valid continuous series circuit that includes ammeter, and one wire link (condone diagonal connections)

and

voltmeter between any two sockets that enable the terminal pd to be measured ✓

all of the following are acceptable:



links and connections

reject broken / dashed lines

tolerate diagrams with diagonal or non-straight connections between sockets if these will produce a valid circuit

don't insist on connection blobs

circuit must be continuous unless a switch is included: otherwise no gaps wider than the thickness of their links

inclusion of a switch is neutral but the length of the open switch must be ≥ length of the gap where the switch is connected: condone the whole gap between terminals vertically opposite the ammeter to be marked as an open switch

meters

correct ASE symbol for ammeter and correct ASE symbol for voltmeter are essential

one voltmeter and one ammeter only

meters must not be 'transparent'

positions of meters assume that the ammeter has negligible resistance and voltmeter has infinite resistance

1

(b) (with any switch closed) read ammeter and voltmeter

or

record / measure I and V;

adjust / vary / change resistance / (setting of) variable resistor / Q

and repeat (readings) 1✓

for 1✓ must produce a range of I, V values (>2 sets) and identify how this is achieved; it is not necessary to suggest range or number of sets

plot V (against) I 2✓

mark 2✓ independently of 1✓

2

ε = (vertical / y-axis) intercept 3✓

r = −gradient 4✓

2✓ 3✓ and 4✓ can be awarded for a suitable sketch graph

condone 'use the (variable) resistor to vary current and read I, V'

idea that R can be read from Q is neutral

for 2✓ (and further credit in 3✓ and 4✓) the ordinate and the abscissa must be identified;

allow 'plot V over I' or 'plot V/I'

allow 2✓ for reverse plot 'I (against) V'

then 4✓ for r = $r = \frac{-1}{\text{gradient}}$ and 3✓ intercept = $\frac{\varepsilon}{r}$

for 3✓ open circuit methods involving ε read directly using voltmeter are neutral

for 4✓ any subject but minus sign essential

2

variation

1✓ as above;

3✓ find R from V divided by I ; disconnect external circuit and measure ε directly;

4✓ plot $\frac{\varepsilon}{V}$ against $\frac{1}{R}$

2✓ gradient = r

(c) gradient calculation seen with Δn^{-1} divided by ΔI^{-1};

ε from 22 × gradient 1✓

for 1✓ do not penalise one read off error, (allow use of 0, 0) or for small steps

expect gradient ≈ 7.2(5) × 10^{-2} leading to ε = 1.594 (V)

do not allow reverse working based on answer to part (e)

1

ε minimum 3 sf; in range 1.58 to 1.61 (V) 2✓

2✓ is contingent on award of 1✓

1

(d) use of **Figure 3** to read off I^{-1} corresponding to $n^{-1} = 0.25$;

calculates I in range 0.23(2) to 0.24(4) (A) ✓

*do not insist on seeing evidence of working on **Figure 3***

expect $I^{-1} = 4.2 \pm 0.1$ (A^{-1}) leading to $I = 0.238$ (A)

(should expect 1 more sf than in 0.25 for 'show that' but condone 0.23 and 0.24 since result based on 2 sf data)

do not allow reverse working based on answer to (e)

1

(e) circuit resistance $R = 5.5$ (Ω) seen in (e) working 1✓

minimum 2sf V from their $I \times 5.5$

or

V from their ε − their $I \times r$ 2✓

for 1✓ allow $R = \frac{22}{4}$ or $\frac{11}{2}$; allow $R^{-1} = \frac{4}{22}$ etc

for 2✓ correct R only; expect $V = 1.3(1)$ V; use of $I = 0.25$ A gives $V = 1.38$ V

do not allow $V \geq$ their ε

r using lost volts divided by current; full substitution of their valid data

eg $r = \frac{1.58 - 1.31}{0.238}$ 3✓

or

r using formula for **Figure 3**; full substitution of their valid data

eg $r = \frac{\varepsilon}{I} - \frac{22}{4} = \frac{1.58}{0.238} - 5.5$ 3✓

or

r using either intercept on **Figure 3**; full substitution of their valid data

eg their vertical intercept ×−22 **or**

their horizontal intercept × ε 3✓

use of 'show that' or 2 sf data:

$r = \frac{\varepsilon - V}{I}$ *with* ε *= 1.6 V,* V *= 1.4 V and*

I *= 0.25 A gives r = 0.80 Ω*

$\frac{22}{n} = \frac{\varepsilon}{I} - r$ *with* ε *= 1.6 V,* I *= 0.25 A*

and n = 4 gives r = 0.90 Ω;

(can find r first, then V *using* $\varepsilon - Ir$*)*

a vertical intercept must be calculated; result is negative, eg vertical intercept = −0.053:

r = −1 × −0.053 × 22 = 1.17(Ω)

horizontal intercept = 0.73:

r = 1.6 × 0.73 = 1.18(Ω)

minimum 2 sf result in range 0.80 and 1.3(0) (Ω) 4✓

allow 4✓ only if there is clear evidence of a valid method leading to a result in range

4

(f) n = 2 **and** n = 3 1✓

n = 5 **or** n = 6 **or** n = 7 2✓

to improve distribution of points (along the line) or wtte 3✓

for 1✓ and 2✓ if suggesting more than three values for n accept only the last three

for 3✓ allow:

'spread out' / 'avoid concentrating' points'

where current / n is smaller' or wtte 'reduce distance between points (data)' / (add) detail

'most uniform distribution' / 'most equally spread out' / 'roughly evenly spaced'

reject:

'making points (data) 'equally' / 'evenly-spaced' / 'even spread' (without qualification)

'easier to plot / draw line' / 'line more accurate' / 'easier to see trend' are neutral

3

(h) both points move (by ≥ half a grid square) to the <u>right</u> 1✓

both points move (by ≥ half a grid square) causing the gradient of a straight line between them to be reduced 2✓

allow badly-marked points / use of arrows

*ignore any best-fit line added to **Figure 5***

for 1✓ rightwards motion of each point must be parallel to gridlines ± half small square

award of 2✓ mark is independent of 1✓ mark

for 2✓ the points do not need to move in the same direction

2

[17]

21. **D**

[1]

22. **A**

[1]

23. **C**

[1]

24. (a) Use of $P=VI$ or $P=I^2R$ or $P = \frac{V^2}{R}$ ✓

Use of $\Delta W=P\Delta t$ ✓

OR

Use of $\Delta Q=I\Delta t$ ✓

Use of $W=VQ$ ✓

2.1×10^5 (J) ✓

2 marks if time not converted to seconds (3600 J)

3

(b) Use of ρ = $\rho = \frac{RA}{L}$ ✓

0.91 (m) + appropriate conclusion ✓

Allow calculation of R, ρ or A assuming 0.85 m length, and conclusion for second mark:

R = 3.5 Ω

$A = 4.6 \times 10^{-6}$ m^2

$\rho = 2.1 \times 10^{-5}$ Ω m

2

(c) 350 (Ω) ✓

Full marks for correct answer

Max 3 from: ✓ ✓ ✓

15 (mA) read from graph

Allow 14.5 to 15.5

Conversion to A

pd across resistor = 7.4 – 2.2 = 5.2 V

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

Do not allow gradient calculation for R.

4

[9]

25. **A**

[1]

26. **C**

[1]

27. (a) Acceptable line ✓

Condone one failure from the following list

A. Line straight up to point 8 (expect ruled but condone freehand drawing)
B. Line shows balance of points on each side of drawn line
C. Line goes within region of data cross
D. Appropriate continuous transition between line and curve
E. Beyond point 12 shows either curve of decreasing gradient OR straight line through points 12 to 15
F. Thin line and non-variable thickness
G. Line of acceptable quality, eg not hairy or kinked

Please annotate on CMI+

The line must intersect with the cross of the data point.

However, condone point 14 or 15 being off line of best fit for a smooth curve.

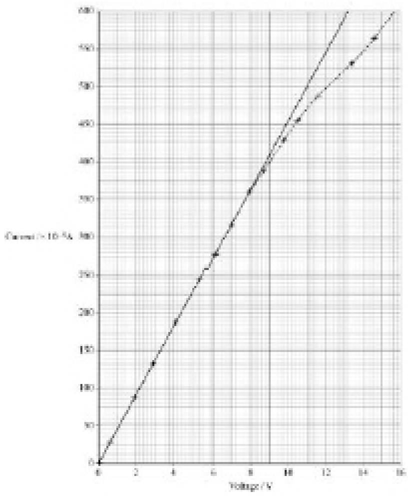
Condone partially erased and redrawn.

Do not allow double line under any circumstance.

Allow a curve with a slight inflection at point 14

(see example below)

Allow a split line where linear section has been extrapolated to the top of the grid e.g.



1

(b) Circle drawn around data point 9 (8, 360×10^{-3}) ✓

Condone circle drawn around

data point 10 (8.7, 390×10^{-3})

***provided that** linear section of line intersects with this cross.*

1

(c) Correct read off for voltage from candidate line $_1$✓

This voltage must be within one half-square of actual value.

Correct answer using $\left(\dfrac{\frac{their\ V}{0.55} - 22.2}{22.2}\right) \times 100$ $_2$✓

Penalise mid-calculation rounding.

Condone missing % sign;

2 or 3 significant figures for answer.

Penalise Physics Error of using gradient of tangent to determine the resistance.

2

(d) circuit **D** is correct $_1$✓

circuit **A** is incorrect because the ammeter is not measuring the current in **R**

OR
ammeter is not in series with R

OR
the ammeter is measuring the current in the power supply $_2$✓

circuit **B** is incorrect because the voltage range (shown in the data) cannot be produced

OR
cannot achieve voltage less than (about) 5 V $_3$✓

circuit **C** is incorrect because the voltmeter is not in parallel with **R**

OR
the voltmeter is not measuring the voltage across **R**

OR
the voltmeter reading equals emf minus voltage across **R** $_4$✓

Ignore unclear or incorrect explanation for MP1

$_2$✓ $_3$✓ and $_4$✓ are awarded for correct explanations not for a statement that a circuit is incorrect.

*for $_1$✓ accept implied answer that circuit **D** is correct if circuits **A**, **B** and **C** are all stated to be incorrect*

*for $_2$✓ any suggestion that in circuit **A** the voltmeter is in the wrong position forfeits the mark*

*Condone circuit **B** is incorrect "because the voltage cannot go down to zero" for $_3$✓.*

Or

*Condone circuit **B** is incorrect "there is less variation in voltage because the resistors are in series" $_3$✓.*

*for weak statements in MP2 and MP4 1 mark for 'circuit **A** is incorrect because ammeter is in wrong place' and 'circuit **C** is incorrect because voltmeter is in the wrong position'*

*If **A** / **B** / **C** is identified as correct then **MAX 2** for two statements that correctly explain why the others are unsuitable.*

*If no other marks awarded: **MAX 1** for "Circuit **B** is correct because the ammeter in series with resistor **R and** the voltmeter is in parallel with **R**".*

4

[8]

28. **B**

[1]

29. **A**

[1]

30. (a) 15(.0) (Ω) ✓

Only acceptable answer

Must be on answer line or clearly identified as (largest)R

by R = 15 (.0) (Ω) seen.

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

If not on the answer line, units must be stated.

1

(b) 1.4(1) (Ω) ✓✓

Only selects 2.2 Ω and 3.9 Ω in parallel ✓

Accept evidence from working or a clear labelled sketch of 2.2 Ω and 3.9 Ω in parallel

Possible allowed combinations include:

$$(\frac{1}{R} =)\frac{1}{2.2} + \frac{1}{3.9}$$

$$\text{Condone } R = \frac{1}{2.2} + \frac{1}{39}$$

$$(R =)\frac{1}{\frac{1}{2.2} + \frac{1}{3.9}}$$

$$(R =)(\frac{1}{2.2} + \frac{1}{3.9})^{-1}$$

$$(\frac{1}{R} =)\frac{5}{11} + \frac{10}{39}$$

$$(R =)\frac{2.2 \times 3.9}{2.2 + 3.9}$$

Accept 1.407 Ω but not >4 sf

Must be on answer line or clearly identified as (smallest)R

by R = 1.4 (1) (Ω) seen.

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

Common wrong answer = 0.71 (Ω) is worth one mark with correct supporting working

2

(c) Any of the following statements:

Power supply is on open circuit (so current is zero)

OR

Voltmeter has a (very) large resistance (so current is zero)

OR

No current (load) (so no lost volts)

OR

(Current is zero) so no lost volts

Accept 'negligible' current for zero current

Accept 'very large' resistance; don't penalise 'voltmeter has very large internal resistance'

Do not allow:

Resistance is zero

Only resistance is the internal resistance

No other component (this implies that the internal resistance is zero)

1

(d) (Current through power supply leads to)

lost volts (across the internal resistance)

OR

(Current through power supply leads to)

voltage drop across the <u>internal resistance</u>

OR

(Current through power supply leads to)

Some of the emf is used in the <u>internal resistance</u>

OR

Voltage is shared between the internal and external resistances

Allow correct 'energy transfer in the internal resistance' arguments

Must refer to a voltage across the internal resistance or r

except when the term "lost volts" is used.

Do not allow:

The current decreases

1

(e) $\varepsilon - V$ = (1.62 – 1.14 =) 0.48(0) (V)

<u>and</u>

$\frac{V}{R} = \left(\frac{1.14}{9.0} =\right) = 0.13(\text{V}\Omega^{-1})$ ✓

Both results required for ✓; accept 0.127 or 0.1267 for $\frac{V}{R}$

Do not allow answers expressed in terms of unknown variables

Answers must be on answer line or clearly identified as answer by using correct subject and equals sign

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

1

(f) Point correctly plotted to nearest 1 mm (half a grid square)

<u>and</u>

continuous ruled best fit line for the 5 (originally printed) points ✓

Withhold mark if point is hidden or if best fit line is of variable thickness or has discontinuities.

Data point should be marked with a cross. Both × and + marks are acceptable.

***Do not allow** points plotted as dots / dots in circles*

If point is wrongly calculated in Part 1.5 allow CE for an accurate plot of this but this should then be treated as anomalous when judging the best fit line.

The best fit line must intersect each of the 5 originally printed X symbols.

Allow no plot where ECF (even as algebraic equation) point won't fit on the grid <u>and</u> student has stated that it can't be plotted.

If no answer / no plottable answer in 1.5 but student chooses to plot a point then it must be the correct point only (0.13, 0.48)

1

(g) Gradient triangle for **Figure 3**; correct read-offs for points (± 1 mm) from triangle with the $\varepsilon - V$ step at least 0.5 V

Allow $\frac{y2 - y1}{x2 - x1}$ seen or gradient triangle drawn with $\frac{\Delta y}{\Delta x}$ seen, read-offs must be substituted into $\frac{y2 - y1}{x2 - x1}$ or $\frac{\Delta y}{\Delta x}$

Condone one read-off error in four read-offs for gradient method

(common error: candidates miss non-origin on ordinate axis)

(common error: makes a power of 10 error on abscissa)

r in range 3.49 to 3.95 (Ω)

Any correct method other than gradient method (no read-off errors here) allow 1 mark

i.e. allow 1 mark for the accurate use of 1 point from their line

r must be quoted to a minimum of 2 significant figures

***ecf** for r (their gradient from their best fit line)*

r must be supported by correct working

2

(h) The **Figure 1** method is better **because** more R values are available ✓

6 values of R (possible) for method (seen) in Fig 4 ✓

Do not allow:

The 2nd method has a wider range

The 2nd method has a larger maximum resistance

The 2nd method has a smaller minimum resistance

The 2nd method only goes up to 8.2 Ω

(resistances available in Fig 4: 2.0 Ω, 3.2 Ω, 4.3 Ω, 4.6 Ω, 5.0 Ω, 5.3 Ω)

2

[11]

31. **D**

[1]

32. (a) Mention of increase in lost volts/ pd across internal resistance (in cell)✓ (because)

current has increased

OR

internal resistance is a larger proportion of total resistance

OR

ratio of internal: external resistance is larger ✓

Accept reverse arguments

Do not accept terminal pd has decreased

Treat comments about resistance of lamp as neutral

2

(b) Lost volts reduced (current remains the same, V2 > V1)

OR

Effective internal resistance is a smaller proportion of total resistance / ratio of internal: external resistance is smaller ✓

(because)

two cells in parallel behave as a single cell (with the same emf) but with half the internal resistance / reduced internal resistance ✓

Alternative:

Current through each cell is less than cell on its own ✓

Decreased current through cell decreases lost volts / pd dropped across internal resistance ✓

2

[4]

33. **A**

[1]

34. (a) resistance of lamp B and D = $3.5^2/4.1 = 3.0\ (2.98)(\Omega)$ ✓
resistance of lamp A and C = $6.0^2/6.0 = 6.0\ (\Omega)$ ✓
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]

35. (a) Length of resistance wire = 50 × 2 × 3.14 × 4 × 10^{-3} = 1.26 m ✓

or 50 × 3.14 × 8 × 10^{-3}

1

Substitution of data in resistance formula

or $A = \rho L/R$ seen ✓

ecf for incorrect length from attempt at a calculation

1

Area of cross section = 2.1(1) × 10^{-9} (m^2) ✓

1

(b) Maximum possible pd across 0.25 kΩ is 9 V ✓

1

(Max power dissipated) = 9^2/250 = 0.32 W so resistor is suitable ✓

1

OR

When resistor dissipates maximum power

V^2 = 0.36 × 250 so max V = 9.5 V ✓

This is higher than the supply pd so this power dissipation so will not be reached ✓

OR

Power dissipated when output is 5 V = 4^2/250 = 0.064 W ✓

Which is below the max power dissipation of 0.36 W ✓

9^2/250 = 0.32 W with incorrect conclusion scores 1

Second mark implies the first

9^2/0.36 = 225 Ω alone is not a useful calculation in the context. Still need to explain the effect of using the 250 Ω

First mark is for a valid useful calculation

(c) Use of potential divider formula to determine resistance of parallel combination ✓

0.313 kΩ ✓

Use of equation for resistors in parallel ✓

540 Ω ✓

Alternative to find resistance of combination

Current in circuit at room temp = 4/250 = 16 mA ✓

Resistance of combination = 5/16mA = 313 Ω ✓

OR

$$\frac{V_{combination}}{V_{250}} = \frac{R_{combination}}{250}$$

$$\frac{5}{4} = \frac{R_{combination}}{250}$$

$R_{combination}$ *= 313 Ω*

OR

Current in circuit at room temp = 4/250 = 16 mA ✓

Current in thermistor = 5/750 = 6.7 mA ✓

Current in R = 9.3 mA ✓

R = 5/9.3 = 540 Ω ✓

2sf answer ✓

(only allowed with some relevant working leading to a resistor value)

Max 5

(d) Resistance of thermistor decreases ✓

Output pd decreases since

resistance of the parallel combination /circuit decreases

1

OR

lower proportion of pd across the parallel combination (or higher proportion across 250Ω)

OR

higher current so greater pd across the 0.25 k resistor ✓

Accept correct consequences for R increasing with temperature for 1 mark

1

[12]

36. **C**

[1]

37. **B**

[1]

38. **D**

[1]

39. (a) emf is the intercept on the pd / y axis ✓
gradient of the graph is –r / internal resistance is <u>minus</u> the gradient of the graph/modulus of gradient is r / absolute value of gradient is r / magnitude of gradient is r ✓

1
1

(b) figure 2 circuit supplies 50 mA ✓
figure 3 circuit has emf of 1.4 V ✓
and internal resistance of 12 Ω ✓
hence current of 78 mA which is >75 mA ✓

Can use different routes independently for fig 2 and fig 3

If candidates calculated current is not 50 mA or 75 mA allow CE for correct conclusion relating to 75 mA

Must explain which circuit <u>is</u> suitable. If their calculation shows neither circuit suitable must explain why <u>both</u> circuits not suitable

OR

calculate required pd is 0.45 V (0.075 × 6.0) ✓
show pd for cell in fig 2 is 0.1 V ✓
show pd across parallel cells in fig 3 is 0.4 V ✓
show total pd in fig 3 is 0.5 V which is greater than 0.45 V ✓

OR

calculate emf needed for 75 mA in fig 2 (1.05) ✓
calculate emf needed in fig 3 (1.35) ✓
comment on emf needed in fig 2 is larger than cell provides ✓
comment on emf in fig 3 being close to what is required ✓

from graph for current for current of 75 mA

from graph for current of ½ of 75 mA i.er. 37.5 mA

i.e. 0.1 V from single cell and 0.4 V from parallel cells

4

(c) useful power dissipated = $(75 \times 10^{-3})^2 \times 6$ ✓ (= 0.03375 (W))

Condone use of 78 mA gives answer of 285 W

If used resistance of 18 Ω then lose first mark but CE to give answer of 791 W

input power (at the cells) = 0.03375/.04 = (W) ✓

solar power = $0.8437 / (32 \times 10^{-4})$ = 260 (263.7 or 264) W m^{-2} ✓

CE from power calculation but not from % calculation

if incorrect % calculation at any stage only qualify for useful power mark

1
1
1

[9]

40. **B**

[1]