Electricity Answers

Current, Potential Difference, Resistor Networks, Resistance and Resistivity

1. Resistance calculations

Evidence of 20 Ω for one arm **(1)**

$\frac{1}{R} = \frac{1}{20} + \frac{1}{20}$ **(1)**

R = 10 Ω **(1)** 3

Comment

This combination used instead of a single 10 Ω resistor [or same value as before] **(1)**

because a smaller current flows through each resistor/reduce heating in any one resistor/average out errors in individual resistors **(1)** 2

[5]

2. Statement 1

Statement is false **(1)**

Wires in series have same current **(1)**

Use of $I = nAe\upsilon$ with n and e constant **(1)** 3

[The latter two marks are independent]

Statement 2

Statement is true **(1)**

Resistors in parallel have same p.d. **(1)**

Use of Power = V^2/R leading to $R\uparrow$, power $\downarrow$ **(1)** 3

OR as $R\uparrow$, $I\downarrow$ leading to a lower value of VI 3rd mark consequent on second

[6]

3. Charge calculation

$Q = 20\,000 \times 4.0 \times 10^{-4}$ s [substitution]
Q = 8.0 C/A s 2

Resistance calculation

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

$$= \frac{(1.7 \times 10^{-8}\,\Omega)(50\text{m})}{(1.0 \times 10^{-3}\,\text{m}^2)}$$

R = 8.5 × 10–4 Ω

Formula **(1)**

Correct substitution **(1)**
Answer **(1)** 3

Potential difference calculation
$V = IR$
= (20 000 A) × (85 × 10^{-5} Ω) [or their value] **(1)**
= 17 V [Allow full e.c.f] **(1)** 2

Explanation
For the tree: R or p is larger **(1)** 1

[8]

4. Diagram

Labelled wire and a supply **(1)**

Ammeter in series and voltmeter in parallel **(1)**

OR

Labelled wire with no supply **(1)**

Ohmmeter across wire **(1)** 2

Readings

Current and potential difference OR resistance (consistent with diagram) **(1)**

Length of wire **(1)**

Diameter of wire **(1)** 3

Use of readings

$R = V/I$ OR $\rho = RA/l$ **(1)**

Awareness that A is cross–sectional area (may be seen above and credited here) **(1)**

Repetition of calculation OR graphical method **(1)** 3

Precaution

Any two from:

- Readings of diameter at various places /different orientations
- Contact errors
- Zeroing instruments
- Wire straight when measuring length
- Wire not heating up / temperature kept constant **(1) (1)** 2

[10]

5. (a) Io and Jupiter: Time taken for electrons to reach Jupiter

$t = s/\upsilon = (4.2 \times 10^8 \text{ m})/(2.9 \times 10^7 \text{ m s}^{-1}) = 14.48 \text{ s}$

Correct substitution in $\upsilon = s/t$ (ignore powers of ten) **(1)**

Answer: 14.48 s, 14.5 s [no ue] **(1)** 2

(b) Estimate of number of electrons

$Q = ne = It$

$n = It/e$

$n = (3.0 \times 10^6 \text{ A})(1\text{s})/(1.6 \times 10^{-19} \text{ C})$

Use of $ne = It$ **(1)**

$(1.8 – 2.0) \times 10^{25}$ **(1)** 2

(c) Current direction

From Jupiter (to Io) / to Io / to the moon **(1)** 1

[5]

6. Charge

Charge is the current × time **(1)** 1

Potential difference

Work done per unit charge [flowing] **(1)** 1

Energy

9 V × 20 C **(1)**

= 180 J **(1)** 2

[4]

7. (a) p.d. across 4 Ω resistor

1.5 (A) × 4 (Ω)

= 6 V **(1)** 1

(b) Resistance R_2

Current through R_2 = 0.5 A **(1)**

$R_2 = \frac{6\,(V)}{0.5(A)}$

R_2 = 12 Ω **(1)** 2

[allow ecf their pd across 4 Ω]

(c) Resistance R_1

p.d. across R_1 = 12 − 6 − 4

= 2 V **(1)**

Current through R_1 = 2 A **(1)**

$R_1 = \frac{2(V)}{2(A)}$ = 1Ω **(1)**

[allow ecf of pd from (a) if less than 12 V]

Alternative method

Parallel combination = 3Ω **(1)**

Circuit resistance = 12(V)/2 (A) = 6Ω **(1)**

R_1 = 6 – (3 + 2) = 1 Ω **(1)** 3

[allow ecf of pd from (a) and R from (b)]

[6]

8. Definition of symbols:

n = number of electrons/carriers per unit volume (per m^3)
OR
electron (or carrier) density **(1)**

υ = average (OR drift) velocity (OR speed) **(1)** 2

Ratio	Value	Explanation
$\frac{n_y}{n_x}$	1	Same material **(1) (1)**
$\frac{l_y}{l_x}$	1	Connected in series/Kirchoff's 1st law/conservation of charge/current is the same **(1) (1)**
$\frac{v_y}{v_x}$	2	A is halved so v double [Accept qualitative, e.g. $A\downarrow$ so $v\uparrow$, or good analogy] **(1) (1)**

6

[Accept e.g. *ny* = *nx*.....]

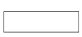
[No e.c.f]

[NB Mark value first, without looking at explanation. If value correct, mark explanation. If value wrong, don't mark explanation *except*: if υ_y/υ_x = ½ or 1:2, see if explanation is correct physics, and if so give **(1)**. No e.c.f.]

[8]

9. Metal wire:
straight line through origin

Semiconductor diode:
line along V axis for negative I
curve up in first quadrant 3

 in gap
p.d. across it (4.5 –1.9) V

$\therefore R_S = \frac{2.6\text{V}}{20\times10^{-3}\text{A}} = 130\Omega$ 3

[6]

10. <u>Resistance of strain gauge</u>

State $R = \frac{\rho l}{A}$ **(1)**
Use of formula **(1)**
x 6 **(1)**
R = 0.13 Ω [ecf their l] **(1)** 4

$$\left(\begin{array}{l} R = \frac{\rho l}{A} = \frac{9.9 \times 10^{-8}\,\Omega\text{m} \times 2.4 \times 10^{-2}\,\text{m} \times 6}{1.1 \times 10^{-7}\,\text{m}^2} \\ = 129.6 \times 10^{-3}\,\Omega \\ R = 0.13\,\Omega \end{array} \right)$$

<u>Change in resistance</u>

ΔR = 0.13 Ω × 0.001
$\Delta R = 1.3 \times 10^{-4}$ (Ω) [no e.c.f.]
OR
ΔR = 0.02 × 0.001
$\Delta R = 2.0 \times 10^{-5}$ Ω

0.1% → 0.001 **(1)**
Correct number for ΔR **(1)** 2

<u>Drift velocity</u>

Stretching causes *R* to increase **(1)**
Any two from:
• Current will decrease
• $I = nA\upsilon Q$
• Drift velocity υ decreases
• *nAe* constant **(1) (1)** 3

[9]

[For *R* decreasing, max 1:
Any one from:
• *I* will increase
• $I = nA\upsilon Q$
• υ will increase
• *nAe* constant]

11. <u>Definition of e.m.f. of a cell</u>

Work/energy (conversion) per unit charge 1

for the whole circuit / refer to <u>total</u> (energy) 1

OR

Work/energy per unit charge 1
converted from chemical to electrical (energy) 1

OR

$E = \dfrac{W}{Q}$ for whole circuit 1

All symbols defined 1

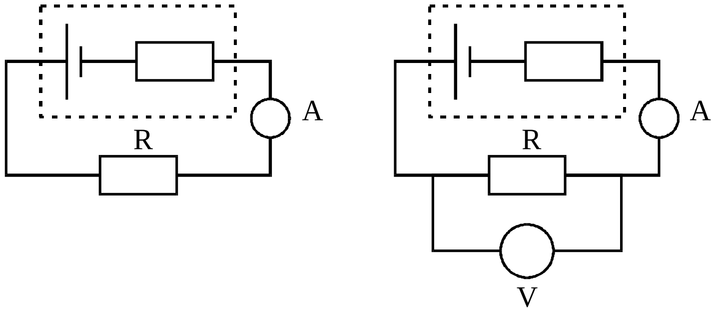
OR

$E = \dfrac{P}{I}$ for whole circuit 1

All symbols defined 1

[Terminal p.d. when no current drawn scores 1 mark only]

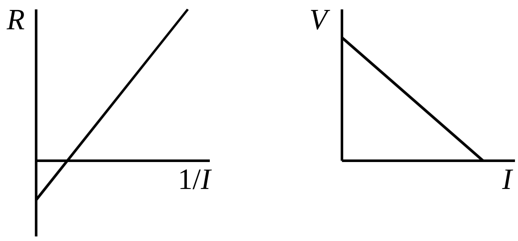
<u>Circuit diagram</u>



R	1	R (can be variable)	1	2
A in series	1	A and V correct	1	
		V as shown Or across R + A Or across battery		

[2nd mark is consequent on R(fixed, variable) or lamp]

<u>Sketch graph</u>



Graph correctly drawn with axes appropriately labelled and consistent with circuit drawn 1

Intercept on R axes $\equiv (-)r$ Gradient $\equiv (-)r$ [Gradient mark consequent on graph mark] 1

[Gradient may be indicated on graph]

[6]

12. (a) (i) Potential difference = work (done)/(unit) charge
OR Potential difference = Power/current **(1)** 1

(ii) J = kg m ^{2} s $^{-2}$ ***(1)***
C = A s or W = J s^1 **(1)**
V = kg m^2 A^{-1} s^{-3} **(1)** 3

(b) Converts 2 minutes to 120 seconds **(1)**

Multiplication of VIΔt or VΔQ **(1)**
Energy = 1440 J **(1)** 3

Example of answer:
Energy = 6.0 V × 2.0 A × 120 s
= 1440 J

[7]

13. <u>Current in heating element</u>

$p = VI$	$p = \frac{V^2}{R}$	1
$I = \frac{500\text{ W}}{230\text{ V}}$	$R = \frac{230^2}{500} / 105.8(\Omega)$	
$I = 2.2$ A	$I = 2.2$ A	1
		1

<u>Drift velocity</u>

Drift velocity greater in the thinner wire / toaster filament 1

<u>Explanation</u>

Quality of written communication 1

See $I = nAQ\upsilon$ 1

I is the same (at all points) 1

(probably) n (and Q) is the same in both wires 1

[8]

14. <u>Current:</u>
Conversion, i.e. 0.94×10^{-3} m s^{-1} **(1)**
Use of 1.6×10^{-19} C **(1)**
Answer 3.0 A
1.0×10^{29} m^{-3} × 0.20×10^{-6} m^2 × 1.6×10^{-19} C × 0.94×10^{-3} mm s^{-1} **(1)**
Current = 3.0 A [Accept 2.8 A if 0.9×10^{-3} used.] 3

<u>Resistance:</u>

Recall $R = \frac{\rho l}{A}$ **(1)**

<u>Substitution</u>:
$R = \frac{1.7 \times 10^{-8}\ \Omega\text{ m} \times 4.0\text{ m}}{0.20 \times 10^{-6}\text{ m}^2}$ **(1)**

Resistance = 0.34 Ω **(1)** 3

<u>Potential difference:</u>
Potential difference = 3.0 A × 0.34 Ω **(1)**
= 1.0 V (1.02 V)
[Mark for correct substitution of their values or for the answer of 1.0 V] 1

Explanation:
(Increasing resistivity) increases resistance **(1)**
Leads to a smaller current **(1)** 2

Comparison:
Drift velocity decreases (in second wire) **(1)** 1
[Allow $V_1/V_2 = I_1/I_2$]
[Allow e.c.f. answer consistent with their current answer]
[Resistivity up, current down
ρ up, I down / 2 (2nd mark)]

[10]

15. Calculation of voltages:

Any use of

Voltage	=	current x component resistance **(1)**
Ballast	=	150 V **(1)**
Filament	=	25 V **(1)** 3

Voltages on diagram:

3 voltages (150,25,25) marked on diagram near component; ignore units **(1)**
[Minimum 150 ÷(1 × 25)]
$V_{starter}$ = 30 V (marked on diagram) **(1)**

Fundamental change necessary:

(Free) charge carriers or free electrons, ionised, *particles* need to be charged **(1) (1)**

[NOT T ↑] 3

Calculation of power dissipated:

$V_{ballast}$	=	230V – 110 V **(1)**
I	=	120V/300 Ω
	=	0.40 A **(1)**
Power	=	230 V × 0.40 A [e.c.f for current]
	=	92 W **(1)** 3

Faulty component:

Starter is not breaking the circuit/starter still conducting **(1)** 1

[10]

16.

Word Equation	Quantity Defined	
Voltage ÷ Current	Resistance	**(1)**
Voltage × Current	Power	**(1)**
Charge ÷ Time	Current	**(1)**
Work done ÷ Charge	Voltage/p.d./e.m.f	**(1)**

[4]

17. Demonstration that resistance is 0.085 Ω:

$R = \rho l/A$ **(1)**

$= 1.7 \times 10^{-8}\ \Omega\text{m} \times 20\ \text{m} / (4.0 \times 10^{-6}\ \text{m}^2)$ **(1)** 2

Calculation of voltage drop:

V = 37 A × 0.085 Ω **(1)**

= 3.1 V × 2 = 6.3 V [Not if V_{shower} then found] **(1)** 2

[Only one conductor, leading to 3.1 V, gets 1st mark]
[Nothing if wires in parallel]

Explanation:

Lower resistance/R = 0.057 Ω/less voltage drop/new $V = \frac{2}{3}$ old V **(1)**

Power dissipated in cable/energy wasted/wire not so hot
OR more p.d/current/power to shower
OR system more efficient **(1)** 2

[6]

18. Proof:

$V = V_1 + V_2$	$V = V_1 + V_2$	**(1)**
$V = IR$ $\quad V_1 = IR_1 \quad V_2 = IR_2$	$\div I$	**(1)**
Substitute **and** cancel I	Sub using R =	**(1)**

3

Explanation of why it is a good approximation:

Resistance of connecting lead is (very) small **(1)**

So $I \times R_{(very)\ small}$ = (very) small p.d./e^{-1}s do little work so p.d. small/r small **(1)**

compared with rest of the circuit so p.d. small

2

Circumstances where approximation might break down:

If current is large **OR** resistance of rest of circuit is small **(1)**

[**Not** high voltage/long lead/thin lead/high resistivity lead/hot lead]

1

Calculation:

Use of $R = \dfrac{\rho l}{A}$ with A attempted × sectional area **(1)**

Correct use of 16 **(1)**

Use of $V = IR$ **(1)**

0.036 V **(1)**

4

[10]

19. Number of carriers or electrons per unit volume / per m^3 /carrier density/electron density **(1)**

[Not charge density / concentration]

Drift velocity OR drift speed OR average/mean/net/overall velocity **(1)** 2

[Not just velocity; not speed unless drift]

m^{-3} **(1)**

m^2 As m s^{-1} **(1)**

Multiply and reduce to A **(1)** 3

[Base units not needed]
[Mixed units and symbols could get the third mark]
[mA = m^{-1} loses 1 mark]

Metal:

M: *n* large so there is a current	n: *n* in metal <u>much</u> larger **(1)**
Insulator	
I: *n* zero (negligible)/very small so less current (or zero current)	Current in metal is larger **(1)**

2

[Ignore anything about *v*. Allow e.g. electron density for *n*]

[7]

20. <u>No</u>, because *V* is not proportional to *I* OR not straight line through origin / **(1)**
only conducts above 0.5 V / resistance changes 1

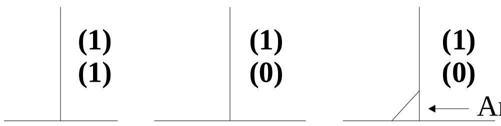
Use of *R* = 0.74 / current from graph **(1)**

= 9.25 Ω [9.0 – 9.5 Ω] [Minimum 2 significant figures] **(1)** 2

Calculation of p.d. across *R* [8.26]	Calculation of total resistance[109 – 115]	Ratio *R*: ratio *V*	*E* = Σ*IR* **(1)**
÷ *I*	– diode resistance [9]	Correct substitutions	Correct substitutions **(1)**
103 Ω [100 – 106] **(1)**			

3

[If not vertical line, 0/2]



Anything (gap, curve, below axis) **(1)(1)** 2

0.7 ≠ 0.7 0.7

[Otherwise **0 0**]

[8]

21. Use *R* = *ρl*/*A* OR correct rearrangement OR plot *R* → *l* gradient = *ρ* /*A* **(1)**
[Symbols or words]

With *A* = *tw* **(1)** 2

l = *RA*/*ρ* [Rearrangement mark symbols or numbers] **(1)**

Use of *A* = *tw* **(1)**

[Correct physical quantities substituted but ignoring unit errors, powers of 10]

= 110 m

[111 m] **(1)** 3

Reduce width/*w* of strip OR use thinner/*t* foil [Not reduce *A*; not increase *T*, *V*, *I*] **(1)**

Smaller *w*/*t*/*A* will be less accurate OR have larger error OR larger *R*
will be more accurate **(1)** 2

[Increase *w* or *t*, could give e.c.f. to increased accuracy]

[7]

22. $I^2 R / (\varepsilon I - I^2 r) / \dfrac{(\varepsilon - Ir)^2}{R}$ **(1)**

$I^2 r / (\varepsilon I - I^2 r)$ $\dfrac{(\varepsilon - Ir)^2}{R}$ **(1)**

εI *OR* $I^2 R + I^2 r / \varepsilon^2 / (\mathrm{R} + \mathrm{r})$ **(1)**

$\varepsilon I = I^2 R + I^2 r$ *OR* ($It = I^2 RT + I^2 rt$ / their (iii) = their (i) + their (ii) **(1)**

Cancel I (OR I and t) and arrange [only if energy equation is correct] **(1)** 5

Maximum current occurs when $R = 0$ **(1)**

$I_{\max} = \varepsilon/r$ **(1)** 2

OR larger r means smaller I **(1 mark)**

1 MΩ [Could be underlined OR circled] **(1)**

It gives the smallest current **(1)**

[If 100 kΩ this reason: 1 only] 2

[9]