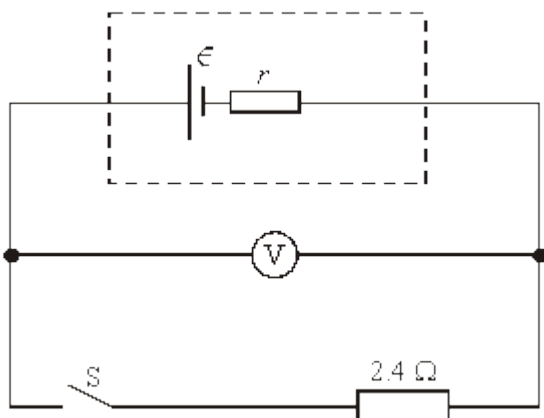


1

In the circuit shown the battery has emf ϵ and internal resistance r .



- (a) (i) State what is meant by the emf of a battery.

- (ii) When the switch S is open, the voltmeter, which has infinite resistance, reads 8.0 V . When the switch is closed, the voltmeter reads 6.0 V . Determine the current in the circuit when the switch is closed.

- (iii) Show that $r = 0.80\ \Omega$.

(4)

- (b) The switch S remains closed. Calculate

- (i) the power dissipated in the $2.4\ \Omega$ resistor,

- (ii) the total power dissipated in the circuit,

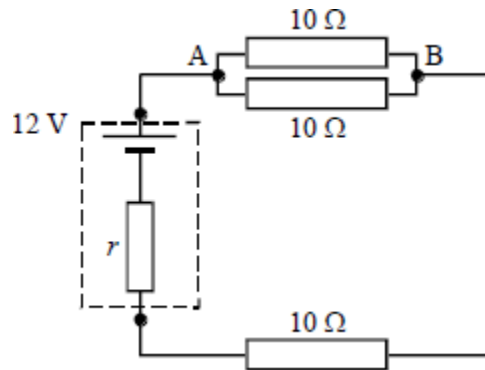
(iii) the energy wasted in the battery in 2 minutes.

(4)

(Total 8 marks)

2

A battery of e.m.f. 12 V and internal resistance r is connected in a circuit with three resistors each having a resistance of $10\ \Omega$ as shown. A current of 0.50 A flows through the battery.



Calculate

(a) the potential difference between the points A and B in the circuit,

(b) the internal resistance of the battery,

(c) the total energy supplied by the battery in 2.0 s,

(d) the fraction of the energy supplied by the battery that is dissipated within the battery.

(Total 7 marks)

3

The electrical energy for a small village of 155 houses is to be generated by a bank of solar cells. The average power used by each house, taken over a year, is 800 W.

The average power per square metre arriving at the surface of the Earth from the Sun is 650 W. The efficiency of the conversion of solar energy to electrical energy is 15%.

(a) (i) Calculate the average power the solar cells need to provide for the whole village.

(1)

(ii) Calculate the total area of solar cells needed to provide the power in (i).

(3)

(iii) Give **one** reason why, in practice, a greater area will need to be covered by solar cells.

(1)

(iv) Suggest **two** problems, other than the large area needed for solar cells, that occur using solar power alone to provide the supply to the village.

(2)

(b) The emf of the bank of solar cells is 230 V.

(i) Calculate the supply current when the village is using 75 kW, assuming the cells have no internal resistance.

(2)

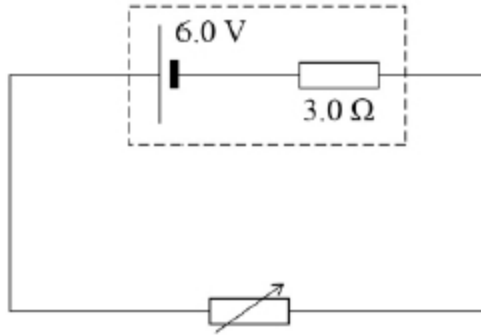
(ii) Calculate the potential difference delivered to the villagers' electrical equipment when the current calculated in (i) is produced in a bank of cells with an internal resistance of $0.050\ \Omega$.

(3)

(Total 12 marks)

4

The cell in the following circuit has an emf (electromotive force) of 6.0 V and an internal resistance of $3.0\ \Omega$. The resistance of the variable resistor is set to $12\ \Omega$.



How much electrical energy is converted into thermal energy **within the cell** in 1 minute?

A 0.48 J ☐

B 29 J ☐

C 45 J ☐

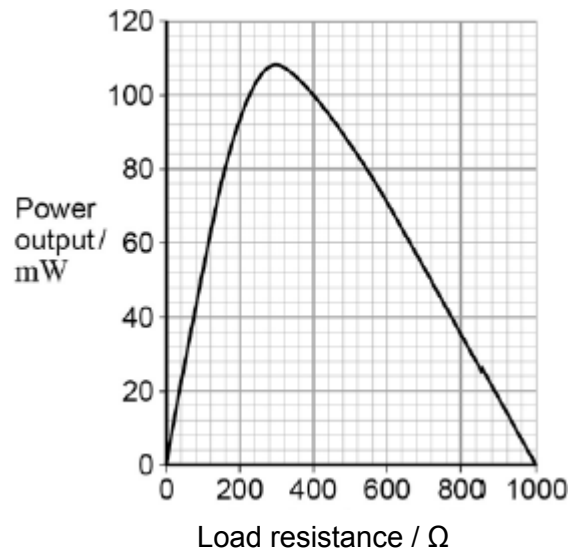
D 144 J ☐

(Total 1 mark)

5

Figure 1 shows data for the variation of the power output of a photovoltaic cell with load resistance. The data were obtained by placing the cell in sunlight. The intensity of the energy from the Sun incident on the surface of the cell was constant.

Figure 1



- (a) Use data from **Figure 1** to calculate the current in the load at the peak power.

- (b) The intensity of the Sun's radiation incident on the cell is 730 W m^{-2} . The active area of the cell has dimensions of $60 \text{ mm} \times 60 \text{ mm}$.

Calculate, at the peak power, the ratio $\frac{\text{electrical energy delivered by the cell}}{\text{energy arriving at the cell from the Sun}}$

(3)

- (c) The average wavelength of the light incident on the cell is 500 nm . Estimate the number of photons incident on the active area of the cell every second.

(2)

- (d) The measurements of the data in **Figure 1** were carried out when the rays from the sun were incident at 90° to the surface of the panel. A householder wants to generate electrical energy using a number of solar panels to produce a particular power output.

Identify **two** pieces of information scientists could provide to inform the production of a suitable system.

(2)

(Total 10 marks)

6

- (a) The power P dissipated in a resistor of resistance R is measured for a range of values of the potential difference V across it. The results are shown in the table below.

V / V	V^2 / V^2	P / W
1.00	1.0	0.21
1.71	2.9	0.58
2.25		1.01
2.67		1.43
3.00	9.0	1.80
3.27	10.7	2.18
3.50	12.3	2.43

(i) Complete the table above.

(1)

(ii) Complete the graph below by plotting the two remaining points and draw a best fit straight line.

(2)

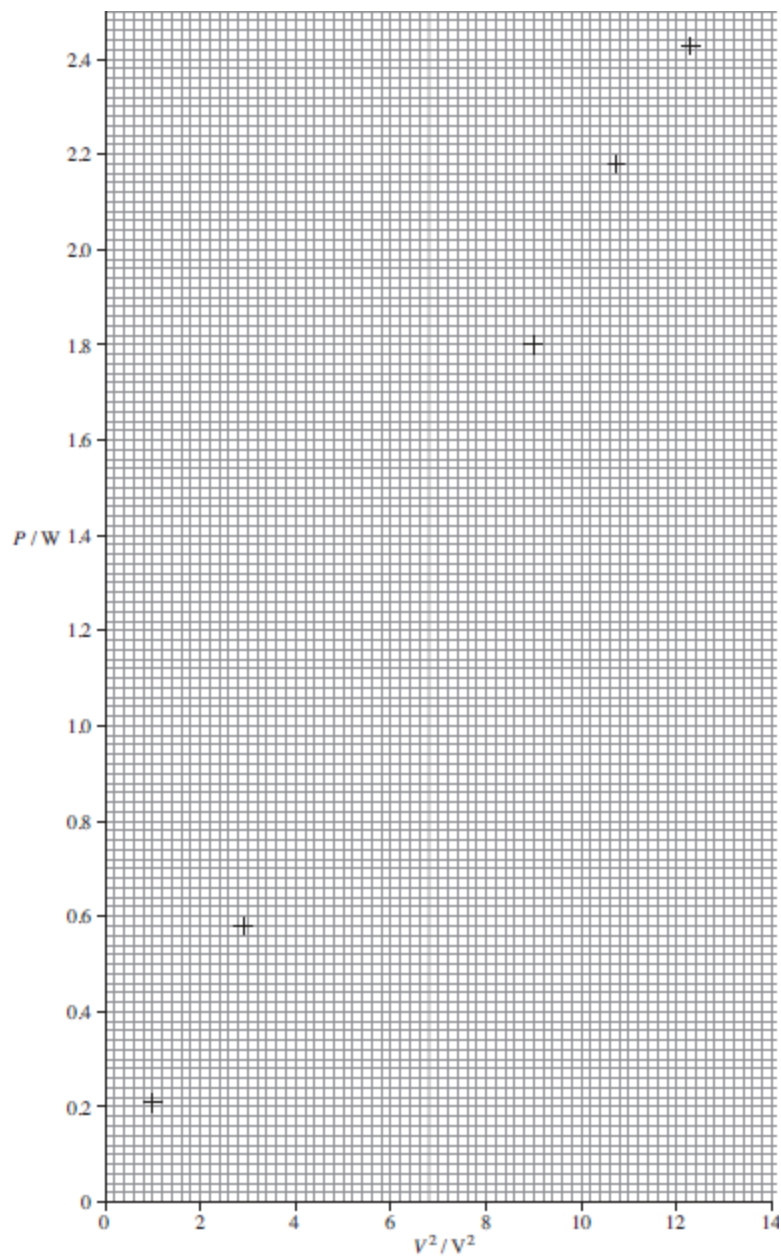
(iii) Determine the gradient of the graph.

gradient = _____

(3)

(iv) Use the gradient of the graph to obtain a value for R .

R = _____



(1)

(b) The following questions are based on the data in the table above.

(i) Determine the value of R when $V = 3.50$ V.

$R =$ _____ Ω

(1)

- (ii) The uncertainty in V is ± 0.01 V. The uncertainty in P is ± 0.05 W.

Calculate the percentage uncertainty in the value of R calculated in part (1).

percentage uncertainty = _____ %

(3)

- (iii) Hence calculate the uncertainty in the value of R .

uncertainty = _____

(1)

- (iv) State and explain whether the value of R you calculated in part (1) is consistent with the value of R you determined from the gradient in part (a)(iv).

(2)

(Total 14 marks)

7

A student investigates how the power dissipated in a variable resistor, Y , varies as the resistance is altered.

Figure 1 shows the circuit the student uses. Y is connected to a battery of emf $\mathcal{E}$ and internal resistance r .

Figure 1

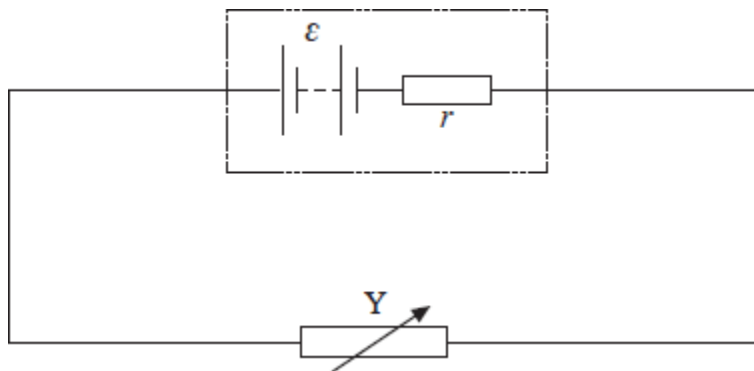
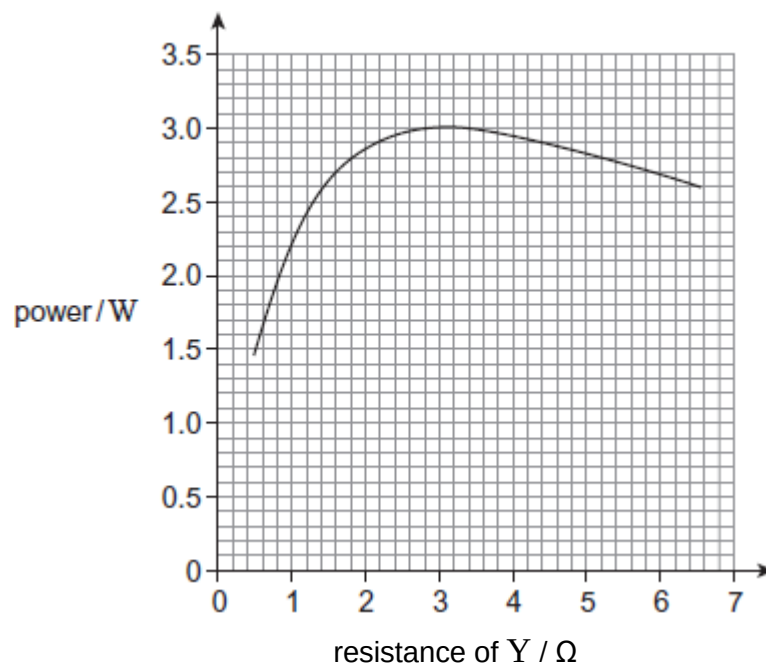


Figure 2 shows the results obtained by the student as the resistance of Y is varied from $0.5\ \Omega$ to $6.5\ \Omega$.

Figure 2



- (a) Describe how the power dissipated in Y varies as its resistance is increased from $0.5\ \Omega$ to $6.5\ \Omega$.

(2)

- (b) The emf of the battery is $6.0\ \text{V}$ and the resistance of Y is set at $0.80\ \Omega$.

- (i) Use data from **Figure 2** to calculate the current through the battery.

current _____ A

(3)

- (ii) Calculate the voltage across Y.

voltage _____ V

(2)

- (iii) Calculate the internal resistance of the battery.

internal resistance _____ Ω

(2)

- (c) The student repeats the experiment with a battery of the same emf but negligible internal resistance. State and explain how you would now expect the power dissipated in Y to vary as the resistance of Y is increased from $0.5\ \Omega$ to $6.5\ \Omega$.

(3)

(Total 12 marks)

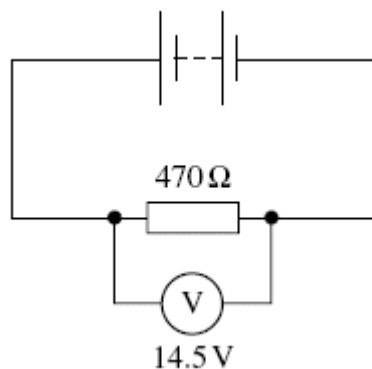
8

A very high resistance voltmeter reads 15.0 V when it is connected across the terminals of a power supply.

- (a) Explain why the reading on the voltmeter is equal to the emf of the power supply.

(3)

- (b) A resistor of value $470\ \Omega$ is connected across the terminals of the power supply in parallel with the voltmeter, as the figure below shows. The voltmeter reads 14.5 V .



- (i) Calculate the current in the $470\ \Omega$ resistor.

current _____ A

(2)

- (ii) Calculate the internal resistance of the power supply.

internal resistance _____ Ω

(3)

(Total 8 marks)

9

- (a) A steady current of 0.25 A passes through a torch bulb for 6 minutes. Calculate the charge which flows through the bulb in this time.

(2)

- (b) The torch bulb is now connected to a battery of negligible internal resistance. The battery supplies a steady current of 0.25 A for 20 hours. In this time the energy transferred in the bulb is 9.0×10^4 J. Calculate

- (i) the potential difference across the bulb,

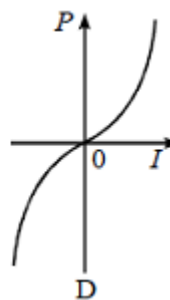
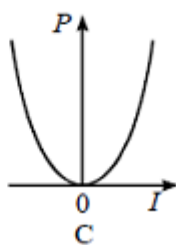
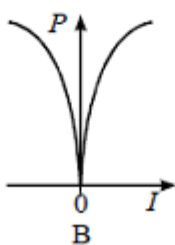
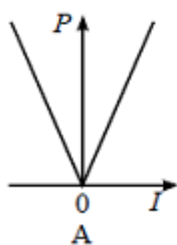
- (ii) the power of the bulb.

(3)

(Total 5 marks)

10

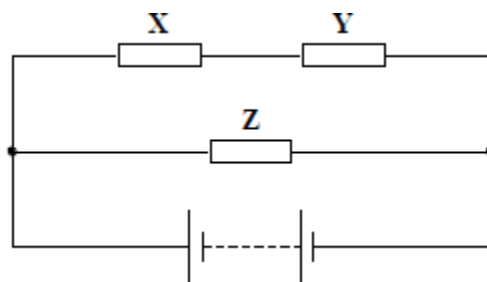
A metal wire is maintained at a constant temperature. Which one of the following graphs best represents the relationship between the dissipated power P and the current I in the wire?



(Total 1 mark)

11

Three identical resistors **X**, **Y** and **Z** are connected across a battery as shown.



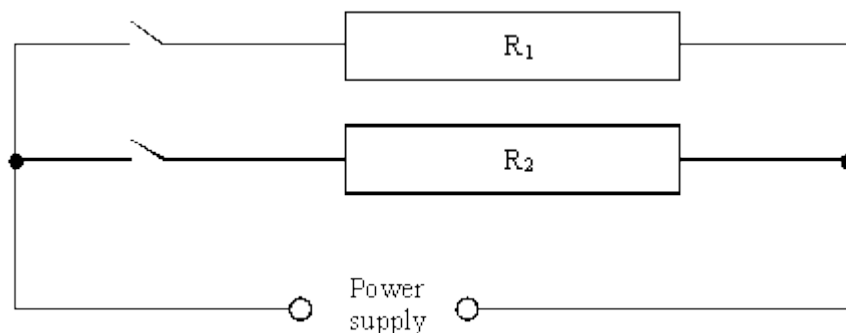
The ratio $\frac{\text{power developed in X}}{\text{power developed in Z}}$ is

- A $\frac{1}{4}$
- B $\frac{1}{2}$
- C 1
- D 2

(Total 1 mark)

12

The heating circuit of a hairdryer is shown in the diagram below. It consists of two heating elements, R_1 and R_2 , connected in parallel. Each element is controlled by its own switch.



The elements are made from the same resistance wire. This wire has a resistivity of $1.1 \times 10^{-6} \Omega \text{ m}$ at its working temperature. The cross-sectional area of the wire is $1.7 \times 10^{-8} \text{ m}^2$ and the length of the wire used to make R_1 is 3.0 m.

(a) Show that the resistance of R_1 is about 190 Ω .

(3)

- (b) Calculate the power output from the heating circuit with only R_1 switched on when it is connected to a 240 V supply.

Power output _____

(2)

- (c) With both elements switched on, the total power output is three times that of R_1 on its own.

- (i) Calculate the length of wire used to make the coil R_2 .

Length _____

(3)

- (ii) Calculate the total current with both elements switched on.

Total current _____

(2)

(Total 10 marks)

Mark schemes

1

- (a) (i) energy changed to electrical energy per unit charge/coulomb passing through
[or electrical energy produced per coulomb or unit charge]
[or pd when no current passes through/or open circuit] **(1)**

(ii) $I = \frac{6}{2.4} = 2.5 \text{ A}$ **(1)**

- (iii) (use of $\epsilon = I(R + r)$ gives) $\epsilon = V + Ir$ and $8 = 6 + Ir$ **(1)**

substitution gives $8 - 6 = 2.5r$ **(1)** (and $r = 0.8 \Omega$)

4

- (b) (i) (use of $P = I^2R$ gives) $P_R = 2.5^2 \times 2.4 = 15 \text{ W}$

[or $P = VI$ gives $P = 6 \times 2.5 = 15 \text{ W}$] **(1)**

(allow C.E. for value of I from (a))

(ii) $P_T = 15 + (2.5^2 \times 0.8)$ **(1)**

$= 20 \text{ (W)}$ **(1)**

(allow C.E. for values of P_R and I)

(iii) $E = 5 \times 2 \times 60 = 600 \text{ J}$ **(1)**

(allow C.E. for value of P from (i) and P_T from (ii))

4

[8]

2

(a) $R_{AB} = 5.0 \text{ (}\Omega\text{)}$ **(1)**

$V (= 5.0 \times 0.50) = 2.5 \text{ V}$ **(1)**

(b) $V_r = 12 - 2.5 + 5.0$ **(1)** $= 4.5 \text{ (V)}$ **(1)**

$r = \left(\frac{V_r}{I} = \frac{4.5}{0.5} \right) = 9.0 \Omega$ **(1)**

(c) $W (= EIt) = 12 \text{ J}$ **(1)**

(d) $W_r (= V_r It) = 4.5 \text{ (J)}$ **(1)**

$\frac{W_r}{W} \left(= \frac{4.5}{12} \right) = 0.375$ **(1)**

[Max 7]

3

(a) (i) 124 kW

B1

(1)

(ii) efficiency = useful power output/power input

C1

power needed = $(100 / 15) \times 124 = 827 \text{ kW}$

A1

area needed = 1270 m

(2)

B1

(3)

allow this mark only for 124 000 / 650 or (their power) / 650 (i.e. area for 100% efficient system)

B1

(1)

(iii) any good reason:

e.g. since the value is only an average so more needed sometimes

since little power is used at night more than the average is needed during the day

since some parts may be in shade (due to cloud)

since cloud may reduce intensity of radiation on the cells

since there will be less light in winter

(iv) there is no power at night

B1

the power fluctuates according to the weather conditions / cloud

B1

seasonal changes

B1

Max 2

(b) (i) power = VI or numerical substitution

C1

326A

A1

(2)

(ii) resistance = V/I in any form

or $V = E - Ir$

C1

p.d. across internal resistance = 16.3 V (e.c.f.)

or correct substitution in $V = E - Ir$

C1

p.d. at consumer 214 V (e.c.f. from (b)(i))

A1

(3)

[12]

4

B

[1]

5

(a) Peak power = 107 / 108 mW and load resistance = 290 / 310 Ω ✓

1

Use of power = I^2R with candidate values✓

1

$$0.0186 - 0.0193 \text{ A } \checkmark$$

1

(b) Area of cell = $36 \times 10^{-4} \text{ m}^2$ and solar power arriving = $730 \times (\text{an area}) \checkmark$

1

$$\frac{0.108}{2.62} \text{ seen } \checkmark$$

1

0.041 (correct answer only; lose if ratio given unit) $\checkmark$

1

(c) energy of one photon = $\frac{hc}{\lambda} = 4.0 \times 10^{-19} \text{ J } \checkmark$

1

$$\text{Number of photons} = \frac{730 \times 36 \times 10^{-4}}{4.0 \times 10^{-19}} = 6.6 \times 10^{18} \text{ s}^{-1} \checkmark$$

1

(d) **Two** from

Intensity of the sun at the Earth's surface

Average position of the sun

Efficiency of the panel

Power output of 1 panel

Weather conditions at the installation=

$\checkmark \checkmark$

Allow other valid physics answers=

2

[10]

6

- (a) (i) 5.1 and 7.1 ✓

Exact answers only

1

- (ii) Both plotted points to nearest mm ✓

Best line of fit to points ✓

The line should be a straight line with approximately an equal number of points on either side of the line

2

- (iii) Large triangle drawn at least 8 cm × 8 cm ✓

Correct values read from graph ✓

Gradient value in range 0.190 to 0.210 to 2 or 3 sf ✓

3

- (iv)
- $(R = \frac{1}{\text{gradient}}) = 5.0 \, \Omega$
- Must have unit ✓

*Allow ecf from gradient value***No sf penalty**

1

- (b) (i) 5.04 (
- Ω
-) or 5.0 (
- Ω
-) ✓

(Allow also 5.06 Ω or 5.1 Ω , obtained by intermediate rounding up of 3.50²)

$$\text{From } R = \frac{V^2}{P}$$

1

- (ii) (Uncertainty in
- $V = 0.29\%$
-)

Uncertainty in $V^2 = 0.57\%$, 0.58% or 0.6% ✓From uncertainty in $V = 0.01 / 3.50 \times 100\%$ Uncertainty in $P = 2.1\%$ ✓From uncertainty in $P = 0.05 / 2.43 \times 100\% = 2.1\%$ Uncertainty in $R = 2.6\%$, 2.7% or 3%

Answer to 1 or 2 sf only ✓

 $2.1\% + \text{uncertainty in } V^2 (0.6\%) = 2.7\%$ *Allow ecf from incorrect uncertainty for V^2 or P*

3

- (iii) (Absolute) uncertainty in
- R
- is (
- $\pm$
-) 0.14 or just 0.1
- Ω
- (using 2.6%)

(or 0.15 or 0.2 Ω using 3%) ✓*Must have unit (Ω)**Must be to 1 or 2 sf and must be consistent with sf used from (ii)**No penalty for omitting $\pm$ sign*

1

- (iv) Works out possible range of values of R based on uncertainty in (iii), e.g. R is in range 5.0 to 5.2 Ω using uncertainty of $\pm 0.1 \Omega$ ✓
No credit for statement to effect that the values are or are not consistent, without any reference to uncertainty
Allow ecf from (iii)

Value from (a)(iv) is within the calculated range (or not depending on figures, allowing ecf) ✓

Allow ecf from (a)(iv)

2

[14]

7

- (a) power increases to a maximum / (up) to 3.0 (2.8 -3.4) Ω / / (up)to 3.0 W ✓
 then decreases ✓

2

- (b) (i) (use of $P = I^2 R$)
 when $R = 0.8 \Omega$ power = 1.95 W ✓
 $1.9 = I^2 \times 0.8$ ✓
 $I = \sqrt{2.375} = 1.5(4) \text{ (A)}$ ✓
Range
1.9 - 2.0 W for power (first mark)
Current 1.5 – 1.6 A

3

- (ii) (use of $V = IR$)
 $V = 1.54 \times 0.8$ ✓
 $V = 1.2 \text{ V}$ ✓
CE from part (i)

2

- (iii) (use of $\varepsilon = V + Ir$)
 $6.0 = 1.2 + 1.54 \times r$ ✓
 $r = (6.0 - 1.2) / 1.54 = 3.1 \text{ (2.9 – 3.2)} (\Omega)$ ✓
 use of maximum power theorem (quoted) as alternative method can get both marks i.e. read peak maximum from graph
CE from part (ii)

2

- (c) power would decrease (as R increased) ✓
 pd / voltage across R is now constant / equal to emf ✓
 and so power proportional to $1 / R$ / inversely proportional to R OR
 can quote $P = V^2 / R$ but only if scored second mark ✓

3

[12]

8

(a) any **three** from

voltmeter resistance is high

B1

current in circuit is 0 or low

B1

no (low) energy lost in voltmeter

B1

no lost volts/volts lost overcoming internal resistance

B1

'load'/voltmeter resistance $\gg$ internal resistance

B1

voltage across voltmeter $\gg$ voltage across int. resistance

B1

3

(b) (i) current = $14.5/470$

C1

0.031 or 0.0309 (A) amps penalise 1 sf

A1

2

(ii) 'lost' pd in cell = 0.5 V

C1

internal resistance = $0.5 \times 470/14.5$ or $(0.5/0.031)$ etc)

C1

16 (Ω) (16.2) (16.7)

A1

or 13.9(14) using 0.031 A to calculate total circuit resistance

15.4(15) using 0.0309

A1

30 using 0.3

3

[8]

9

(a) $I = \frac{\Delta Q}{\Delta t} \left(\text{or } I = \frac{Q}{t} \right) \text{ (1)}$

$$\Delta Q = 0.25 \times 6 \times 60 = 90 \text{ C (1)}$$

2

(b) (i) $V = \frac{W}{Q} \text{ (1) [or } E = VIt]$

$$= \frac{9.0 \times 10^4}{0.25 \times 20 \times 60 \times 60} = 5.0 \text{ V (1)}$$

(ii) (use of $P = \frac{W}{t}$ gives) $P = \frac{9.0 \times 10^4}{20 \times 60 \times 60} = 1.2(5) \text{ W (1)}$

[or $P = IV$ gives $P = 0.25 \times 5 = 1.2(5) \text{ W}$]

(allow C.E. in alternative method for value of V from (i))

3

[5]

10

C

[1]

11

A

[1]

12

(a) $R = \rho l/A$ or $\rho = RA/l$

B1

$$R = 1.1 \times 10^{-6} \times 3.0 / (1.7 \times 10^{-8})$$

B1

$$= 194$$

at least 3sf

B1

3

(b) $P = V^2/R$ ($P = (240)^2/190$ or $(240)^2/194$)

OR use of $I = V/R$ and $P = I^2 R$

C1

$$= 300W \quad (303 \text{ or } 297 \text{ respectively})$$

A1

2

(c) (i) power output of $R_2 = 2 \times$ power output of R_1 (= 600 W)

B1

$$R_2 = 0.5 \times R_1$$

OR use of $R_2 = V^2/P_2$ and $I = RA/\rho$

C1

length in range 1.47..1.49 m **OR** = 1.5m
(900W gives length in range 0.97..0.99 m = 2 marks)

A1

3

(ii) Use of $I = P/V$ **OR** $I = V/R_1 + V/R_2$

C1

$$I \text{ in range } 3.7..3.8 \text{ A}$$

allow ecf from (b) or (c)(i)

(eg. I in range 4.9..5.1 A for 900 W)

A1

2

[10]