M1.(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 Ω 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 3.50^2)

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 × 100%
Uncertainty in P = 2.1% ✓
From uncertainty in P = 0.05 / 2.43 × 100% = 2.1%
Uncertainty in R =2.6%, 2.7% or 3%

Answer to 1 or 2 sf only ✓

2.1 % + uncty in V^2 (0.6%) = 2.7%
Allow ecf from incorrect uncertainty for V^2 or P

3

(iii) (Absolute) uncertainty in R is (±) 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 ± 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 ± 0.1 Ω ✓

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]

M2.(a) (i) Voltmeter across terminals with nothing else connected to battery / no additional load. ✓

1

(ii) This will give zero / virtually no current ✓

1

(b) (i) $\frac{VI}{\varepsilon I}$

Answer must clearly show power: εI and VI, with I cancelling out to give formula stated in the question ✓

1

(ii) Voltmeter connected across cell terminals ✓

Switch open, voltmeter records ε
Switch closed, voltmeter records V
Both statements required for mark ✓

Candidates who put the voltmeter in the wrong place can still achieve the second mark providing they give a detailed description which makes it clear that:

To measure emf, the voltmeter should be placed across the cell with the external resistor disconnected

And

To measure V, the voltmeter should be connected across the external resistor when a current is being supplied by the cell

2

(c) Vary external resistor and measure new value of *V*, for at least 7 different values of external resistor ✓

Precautions - switch off between readings / take repeat readings (to check that emf or internal resistance not changed significantly) ✓

2

(d) Efficiency increases as external resistance increases ✓

Explanation
Efficiency = Power in R / total power generated
$I^2R / I^2(R + r) = R / (R + r)$
So as *R* increases the ratio becomes larger or ratio of power in load to power in internal resistance increases ✓

Explanation in terms of V and ε is acceptable

2

[9]

M3.(a) (i) Use of *P* = *VI* with pair of valid coordinates from graph

C1

0.52 (W)

Allow 1sf if within 0.49 to 0.52

A1

2

(ii) Correct general shape

M1

Linear rise between 0.0 – 0.5 V and falls to zero at 0.71 V

A1

2

(iii) Use of *efficiency* = $\frac{\text{useful power out}}{\text{total power in}}$

C1

Use of $I = \frac{P}{A}$

C1

Their (i) / 67.5 (m^2) (7.7 × 10^{-3} if correct)

A1

3

(b) (i) 0.7 J of work done (by cell) per 1 C of charge (when moved round circuit)
OR
(Terminal) pd across (solar) cell with no load / current is 0.7 V
Not "per unit charge"

B1

1

(ii) 20 cells in series (to produce 14 V)

B1

Series arrangement has internal resistance of 15.6 Ω

B1

Cells in parallel (needed to reduce total internal resistance of array)

B1

80 cells / 4 parallel sets of 20 cells in series

B1

4

(c) The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.

Descriptor □ an answer will be expected to meet most of the criteria in the level descriptor.

Level 3 – good
-claims supported by an appropriate range of evidence;
-good use of information or ideas about physics, going beyond those given in the question;
-argument is well structured with minimal repetition or irrelevant points;

-accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling.

Level 2 – modest
-claims partly supported by evidence;
-good use of information or ideas about physics given in the question but limited beyond this;
-the argument shows some attempt at structure;
-the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling.

Level 1 – limited
-valid points but not clearly linked to an argument structure;
-limited use of information about physics;
-unstructured;
-errors in spelling, punctuation and grammar or lack of fluency.

Level 0
-incorrect, inappropriate or no response.

Some points:

Use on communication satellite:

Continuous supply of energy from Sun
No need for fuel (for power purposes)
Large area of solar cells not needed (but possible)
Low mass
Can be unfolded (after launch)
No environmental hazard
Reliable/no moving parts

Continuous operation:

Arrays need to track sun (to maximise absorption)
Shielding required as can be damaged by meteors or cosmic rays
Need storage system (rechargeable batteries / capacitors) for back up (if in shadow)
Limit use of energy-intensive operations

Use on space probe:

Light intensity / energy too low at large distance
Intensity falls as inverse-square
Area of array would be too large
Solar cells will have degenerated too much over this time

B6

6

[18]