1)

Question			Expected Answers	Marks	Additional Guidance
4	a		$\rho = RA/L$	B1	**Allow** Any subject for the equation
	b		$R = \frac{\rho \times 0.5}{0.5^2}$ resistance = 2ρ	C1 A1	**Allow** 2 marks for bald 2ρ or $\rho/0.5$
	c	i	$A = 1.6\times10^{-5} / 5.3\times10^{-2}$ A = 3.0(2) × 10^{-4} (m^2)	M1 A0	**Reject** Bald 3.02… × 10^{-4} – since it is a 'show' calculation
		ii	$\rho = \frac{7.8\times10^{-5}\times3.02\times10^{-4}}{5.3\times10^{-2}}$ resistivity = 4.4(4) × 10^{-7} (Ω m)	C1 A1	The first mark is for substitution into a correct equation – any subject **Allow** 2 marks for a bald 4.4 × 10^{-7}
	d		No change (to the value of resistivity) Resistivity depends (only) on the material / independent of A and L	M1 A1	
			Total	**8**	

2)

1 Planning (15 marks)

Defining the problem (3 marks)

P1 *A* is the independent variable or vary *A*. [1]

P2 *R* is the dependent variable or determine *R* for different *A*. [1]

P3 Keep the temperature (of glass) constant. Do not allow "controlled variable". [1]

Methods of data collection (5 marks)

M1 Basic circuit diagram. [1]
Ammeter and voltmeter with power supply, or
ohmmeter without power supply, or
bridge methods.

M2 Correct orientation of glass between electrodes – largest cross-sectional area. [1]

M3 A distance (thickness) measured using a micrometer/vernier scale/vernier callipers. [1]

M4 Method of determining area perpendicular to current flow. [1]
Distances measured and multiplied together.
This mark may only be scored if it is clear that the correct dimensions are being used.

M5 Method of determining resistance. [1]
Ohmmeter.
$R = V/I$ justified.
Description of balancing bridge with correct equation.

Method of analysis (2 marks)

A1	A2
R against $1/A$	ρ = gradient/l
R against l/A	ρ = gradient
$1/A$ against R or $1/R$ against A	ρ = 1/(gradient × l)
l/A against R or l/R against A	ρ = 1/gradient
lg R against lg A	$\rho = 10^{l \times \text{y-intercept}}$

[2]

Safety considerations (1 mark)

S1 Relevant safety precaution related to: [1]
EHT power supply (>100 V) – switch off before changing circuit/use of rubber gloves;
or handling glass – wear (thick) gloves.

Additional detail (4 marks)

D1/2/3/4 Relevant points might include [4]
Calculation of typical resistance of glass using value of resistivity given.
Range of ammeter or ohmmeter with reasoning.
Use of EHT or power supply >1000 V or microammeter/galvanometer.
Take many readings of thickness and average.
Good contact between circuit and glass e.g. metal plates, foil, conducting putty.
Metal plates/foil/conducting putty to cover all of the cross-sectional area in use.
Method of securing good contact between circuit and glass, e.g. g clamps, weights.
Clean/dry the glass.

[Total: 15]

3)

Means of measuring resistance or V and I **(1)**

Measure length of wire with metre rule **(1)**

Measure diameter **(1)**

Use of micrometer **(1)**

Calculate area (appropriate equation) **(1)**

Quote correct equation $\rho = \frac{RA}{l}$ **(1)**

Sensible precaution **(1)**

4 Planning (15 marks)

Defining the problem (3 marks)

P1 *A* is the independent variable or vary *A*. [1]

P2 *R* is the dependent variable or determine *R* for different *A*. [1]

P3 Keep the temperature (of glass) constant. Do not allow "controlled variable". [1]

Methods of data collection (5 marks)

M1 Basic circuit diagram. [1]
Ammeter and voltmeter with power supply, or
ohmmeter without power supply, or
bridge methods.

M2 Correct orientation of glass between electrodes – largest cross-sectional area. [1]

M3 A distance (thickness) measured using a micrometer/vernier scale/vernier callipers. [1]

M4 Method of determining area perpendicular to current flow. [1]
Distances measured and multiplied together.
This mark may only be scored if it is clear that the correct dimensions are being used.

M5 Method of determining resistance. [1]
Ohmmeter.
$R = V/I$ justified.
Description of balancing bridge with correct equation.

Method of analysis (2 marks)

A1	**A2**
R against 1/*A*	ρ = gradient/l
R against l/A	ρ = gradient
1/*A* against *R* or 1/*R* against *A*	ρ = 1/(gradient × l)
l/A against *R* or l/R against *A*	ρ = 1/gradient
lg *R* against lg *A*	$\rho = 10^{l \times \text{y-intercept}}$

[2]

Safety considerations (1 mark)

S1 Relevant safety precaution related to: [1]
EHT power supply (>100 V) – switch off before changing circuit/use of rubber gloves;
or handling glass – wear (thick) gloves.

Additional detail (4 marks)

D1/2/3/4 Relevant points might include [4]
Calculation of typical resistance of glass using value of resistivity given.
Range of ammeter or ohmmeter with reasoning.
Use of EHT or power supply >1000 V or microammeter/galvanometer.
Take many readings of thickness and average.
Good contact between circuit and glass e.g. metal plates, foil, conducting putty.
Metal plates/foil/conducting putty to cover all of the cross-sectional area in use.
Method of securing good contact between circuit and glass, e.g. g clamps, weights.
Clean/dry the glass.

[Total: 15]

5 Planning (15 marks)

Defining the problem (3 marks)

P1 *c*, *d* or *A* is the independent variable and *R* is the dependent variable or vary *c*, *d* or *A* and measure *R*. [1]

P2 If *c* varied then (*t* and) *d* or *A* kept constant, if *d* varied then (*t* and) *c* or *A* kept constant, if *A* varied then *c* or *d* kept constant. [1]

P3 Keep temperature constant. [1]

Methods of data collection (5 marks)

M1 Circuit diagram to measure resistance. [1]

M2 Use micrometer screw gauge to measure *d* or *t*. (Allow digital or vernier callipers) [1]

M3 Measure *c* with a ruler/metre rule. [1]

M4 Method of making contact with the strip e.g. use electrodes of at least same dimension as *c* or *d* or *t* or conducting paint methods. Do not allow crocodile clips, unless it is clear that the whole area of the end of the strip is covered. [1]

M5 Method to determine resistance. [1]

Method of analysis (2 marks)

A1 Plot a graph of *R* against *c*, 1/*d* or 1/*A* depending on orientation. Other alternatives possible, e.g. *R* against 1/*c* depending on orientation [1]

A2 Must be consistent with A1: $\rho = A \times$ gradient or $t \times$ gradient/*c* [1]
Other alternatives possible, e.g. $\rho = d \times$ gradient/*t*

Safety considerations (1 mark)

S1 Reference sharp edges or cutting metals, e.g. wear gloves. [1]

Additional detail (4 marks)

D1/2/3/4 Relevant points might include [4]

1. Insulate aluminium strip
2. Take many readings of *t* or *d* and average
3. Use a protective resistor/circuit designed to reduce current
4. Rearrange equation to determine graph using *c*, *d* and *t* or A
5. Determine typical resistance of aluminium strip
6. Likely meter range of ammeter/voltmeter/ohmmeter
7. Detail on cutting strip e.g. mark using set square

Do not allow vague computer methods.

[Total: 15]

6 **(a) (i)** Value of raw d in the range 0.15mm ≤ d ≤ 0.44mm. [1]

(b) (v) Value of l in range 0.1 m $< l <$ 1 m. Value of V in range 0.1 V ≤ V ≤ 2.0 V. [1]

(d) Six sets of readings of l and V scores 5 marks; five sets scores 4 marks etc. [5]
Major help from Supervisor –2 (setting up apparatus). Minor help from Supervisor –1.

Range of l : $\Delta l \geq 60$ cm. [1]

Column headings: [1]
Each column heading must contain a quantity and a unit.
The presentation of quantity and unit must conform to accepted scientific convention.
e.g. $1/l$ /m^{-1}, V/l / V m^{-1}.
Do not allow $1/l$ (m), V(V) / l (m).

Consistency: [1]
All values of raw l must be given to the nearest mm.

Significant figures: [1]
Significant figures for every row of values of $1/l$ same as or one greater than l as recorded in table.

Calculation: [1]
Values of V/l calculated correctly

(e) (i) Axes: [1]
Sensible scales must be used, no awkward scales (e.g. 3:10).
Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions
Scales must be labelled with the quantity that is being plotted.
Scale markings should be no more than three large squares apart.

Plotting of points: [1]
All observations in the table must be plotted.
Diameter of points must be ≤ half a small square (no "blobs").
Check that the points are plotted correctly.
Work to an accuracy of half a small square.

Quality: [1]
All points in the table must be plotted (at least 5) for this mark to be awarded. Scatter of points must be less than 0.1 m^{-1} from a straight line on the $1/l$ axis.

(ii) Line of best fit: [1]
Judge by balance of all points on the grid about the candidate's line (at least 5 points)
There must be an even distribution of points either side of the line along the full length.
Allow one anomalous point only if clearly indicated (i.e. circled or labelled) by the candidate. Line must not be kinked or thicker than half a small square.

(iii) Gradient: [1]
The hypotenuse of the triangle must be at least half the length of the drawn line.
Both read-offs must be accurate to half a small square in both the *x* and *y* directions.
The method of calculation must be correct.

y-intercept: [1]
Either:
Correct read-off from a point on the line and substituted into $y = mx + c$.
Read-off must be accurate to half a small square in both *x* and *y* directions.
Or:
Correct read-off of the intercept directly from the graph.

(f) (i) Value of *M* = candidate's gradient. Value of *N* = –(candidate's intercept). [1]

(ii) Answer in range ρ: $2.0 \leq \rho \leq 20.0 \times 10^{-7}\,\Omega\,\text{m}$. Consistent with units. [1]

[Total: 20]

7 (c) Six sets of readings of I and V scores 5 marks, five sets scores 4 marks, etc [5]
. Indicate the number of sets of readings.
Incorrect trend then –1 (wrong trend P increases, R^4 decreases).

Apparatus correctly set up without help from supervisor. [2]
Major help –2, minor help –1

Range of V: $V_{min} \leqslant 2$ V and $V_{max} \geqslant 10$ V. [1]

Column headings (V/V, I/A, P/W, R/Ω, R^4/Ω^4) [1]
Must have V and I columns.
Each column heading must contain a quantity and a unit where appropriate.
Ignore units in the body of the table.
There must be some distinguishing mark between the quantity and the unit
(solidus is expected but accept, for example, V(V)).

Consistency of presentation of raw readings. [1]
All raw values of V must be given to the same number of decimal places
and this must be 0.1 V.
All raw values of I must be given to the same number of decimal places

Significant figures. [1]
S.F. for P must be the same as, or one more than, the least number of S.F. used
in V or I. Check each row.

Values of R^4 correct. Underline and check the specified value of R^4. [1]
If incorrect, write in the correct value.

(d) (i) Graph
Axes: Sensible scales must be used, no awkward scales (e.g. 3:10). [1]
Scales must be chosen so that the plotted points must occupy at least half
the graph grid in both x and y directions. Indicate false origin with FO.
Scales must be labelled with the quantity which is being plotted. Ignore units.
Allow inverted axes but do not allow wrong graph.
Scale markings should be no more than three large squares apart.

Plots
All observations must be plotted.
Write a ringed total of plotted points. [1]
Do not accept blobs (points > 0.5 small square).
Ring and check a suspect plot. Tick if correct. Re-plot if incorrect.
Work to an accuracy of half a small square.

(ii) Line of best fit [1]
Judge by balance of at least 5 trend points about the candidate's line.
There must be an even distribution of points either side of the line along the whole length. Indicate best line if candidate's line is not the best line.
Lines must not be kinked.

Quality [1]
Judge by scatter of all points about a straight line.
All points in the table (minimum 5) must be within 50 mW of a straight line.
Do not award if wrong graph or wrong trend.

(iii) Gradient [1]
The hypotenuse of the triangle must be at least half the length of the drawn line.
Both read-offs must be accurate to half a small square.
If incorrect, write in correct value.
Check for $\Delta y / \Delta x$ (i.e. do not allow $\Delta x / \Delta y$).

y-intercept from graph or substitute correct read-offs into $y = mx + c$ [1]
Label FO.

(e) *a* = gradient value and *b* = *y*–intercept value. [1]
Units for *a* and *b* are correct (expect $W\Omega^{-4}$ for *a* and W for *b*). [1]
Range: $a = 3 \times 10^{-9} \pm 1 \times 10^{-9}$ or SV ± 33%

[Total: 20]