

9.3 Resistance, Ohm's law and I-V characteristics

Name: _____ Class: _____ Date: _____

Total: 25 marks

KEY WORDS resistance • Ohm's law • filament lamp
 • semiconductor diode • potential difference

Objective

Answer exam questions on **resistance** and **Ohm's law**: the definition of resistance, which components obey Ohm's law, and the I - V characteristics of a metal wire, a **filament lamp** and a **semiconductor diode**. Syllabus 9.3, learning outcomes 1 to 5.

You must be able to:

- define resistance and the ohm, and use $V = IR$
- state Ohm's law, and say why $R = V/I$ holds even when Ohm's law does not
- sketch and explain the I - V characteristics of a metallic conductor, a filament lamp and a diode
- explain why the resistance of a filament lamp rises as the current rises

1 Key knowledge and worked examples

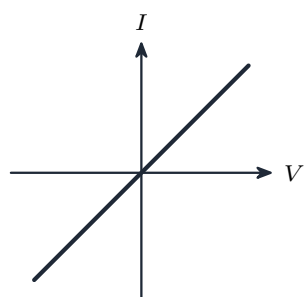
■ Key knowledge: resistance and Ohm's law

Term	Meaning
resistance	the potential difference across a component $\div$ the current in it, $R = \frac{V}{I}$
ohm	one volt per ampere: $1 \Omega = 1 \text{ V A}^{-1}$
Ohm's law (2 marks)	the current in a metallic conductor is proportional to the p.d. across it, provided its temperature (and other physical conditions) stays constant

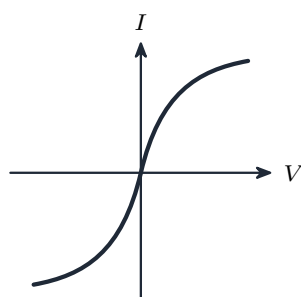
- $R = \frac{V}{I}$ is always true: it defines resistance; $I \propto V$ is true only for a straight I - V line through the origin (an **ohmic** component)

- use $R = \frac{V}{I}$ at the point, never the gradient of a curved I - V graph

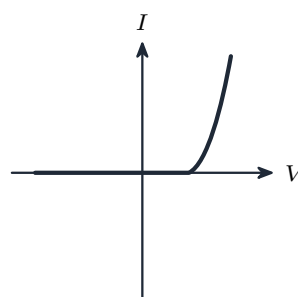
■ **Key knowledge: the three characteristics**



ohmic conductor



filament lamp



diode

Component	I - V graph	Resistance
metallic conductor at constant temperature	straight line through the origin, same in both directions	constant: it obeys Ohm's law
filament lamp	S-shaped curve through the origin, less steep as V rises	rises: a larger current heats the filament, and a hotter metal has a larger resistance
semiconductor diode	almost no current in reverse; in forward bias almost none until about 0.6 V, then a steep rise	very large in reverse, small once it conducts

■ **Worked example: is it ohmic?**

A component takes 0.40 A at 6.0 V and 0.25 A at 3.0 V.

1. **At 6.0 V** – V and I are known, and resistance is defined as $R = \frac{V}{I}$:

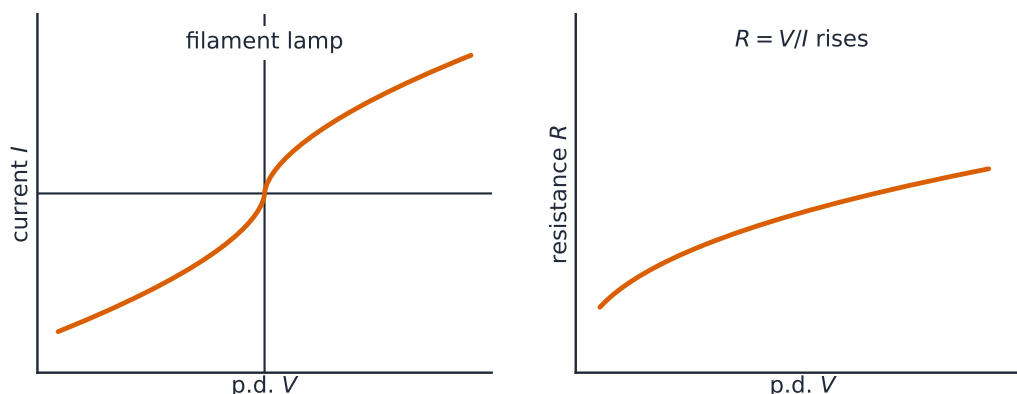
$$R = \frac{V}{I} = \frac{6.0 \text{ V}}{0.40 \text{ A}} = 15 \, \Omega$$

2. **At 3.0 V** – the same definition at the second point:

$$R = \frac{V}{I} = \frac{3.0 \text{ V}}{0.25 \text{ A}} = 12 \, \Omega$$

3. **Conclusion** – the resistance changes with the p.d., so the component does not obey Ohm's law.

■ Worked example: a filament lamp



A lamp takes 0.50 A at 6.0 V and 0.20 A at 1.0 V.

1. **At 6.0 V** – V and I are known, so use the definition $R = \frac{V}{I}$ at that point (never the gradient):

$$R = \frac{V}{I} = \frac{6.0 \text{ V}}{0.50 \text{ A}} = 12 \Omega$$

2. **At 1.0 V** – the same definition, at the lower p.d.:

$$R = \frac{V}{I} = \frac{1.0 \text{ V}}{0.20 \text{ A}} = 5.0 \Omega$$

3. **Why they differ** – at the lower p.d. the current is smaller, the filament is cooler, and its resistance is lower.

■ Worked example: a diode

A diode takes 20 mA at a forward p.d. of 0.70 V, and 1.0 μA at a reverse p.d. of 5.0 V.

1. **Forward** – V and I are known (20 mA = 0.020 A), so use $R = \frac{V}{I}$:

$$R = \frac{V}{I} = \frac{0.70 \text{ V}}{0.020 \text{ A}} = 35 \Omega$$

2. **Reverse** – the same definition, with 1.0 $\mu\text{A} = 1.0 \times 10^{-6} \text{ A}$:

$$R = \frac{V}{I} = \frac{5.0 \text{ V}}{1.0 \times 10^{-6} \text{ A}} = 5.0 \times 10^6 \Omega$$

3. **Conclusion** – small forward, enormous in reverse: the diode lets current through in one direction only.

2 Practice

Now use the methods above.

2.1 Define **resistance**.

[1]

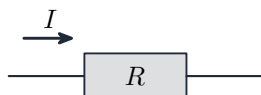
resistance

2.2 A component has a p.d. of 12 V across it and a current of 0.25 A in it. Calculate its resistance. [2]

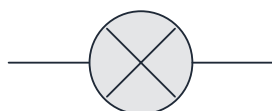


2.3 State **Ohm's law**.

[2]



2.4 State and explain what happens to the resistance of a filament lamp as the current in it increases. [2]



2.5 A diode takes a current of 15 mA at a forward p.d. of 0.72 V. Calculate its resistance. [2]



3 Exam-style questions

3.1 Which component has a resistance that stays constant as the p.d. across it changes?[1]

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A a filament lamp

B a semiconductor diode

C a metal wire at constant temperature

D a thermistor that warms up as the current rises

I-V characteristics

3.2 The p.d. across a filament lamp is doubled, and the current in it rises to 1.6 times its previous value. By what factor does the resistance of the lamp change? [1]

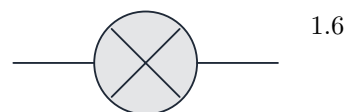
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A 0.80

B 1.25

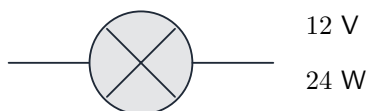
C 1.6

D 3.2



3.3 A filament lamp is marked "12 V, 24 W".

(a) Sketch the *I-V* characteristic of the lamp for positive and negative p.d. [2]



(b) At its normal operating p.d. of 12 V the current in the lamp is 2.0 A. Calculate the resistance of the lamp. [2]

(c) At a p.d. of 3.0 V the current in the same lamp is 0.80 A. Calculate the resistance and explain why it differs from your answer to (b). [3]

- (d) State whether the lamp obeys Ohm's law, and give a reason. [1]

3.4 A student measures the current in a semiconductor diode for p.d.s from -2.0 V to $+1.0\text{ V}$.

- (a) Sketch the I - V characteristic the student obtains. [3]



- (b) At $+0.80\text{ V}$ the current is 45 mA . Calculate the resistance of the diode at this p.d. [2]

- (c) State the resistance of the diode at -2.0 V , compared with your answer to (b). [1]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the p.d. across the component divided by the current in it

2.2

- $V = 12 \text{ V}$ and $I = 0.25 \text{ A}$ are known; resistance is defined as $R = \frac{V}{I}$

$$R = \frac{V}{I} = \frac{12 \text{ V}}{0.25 \text{ A}} = \mathbf{48 \text{ } \Omega}$$

2.3

- the current in a metallic conductor is proportional to the p.d. across it
- provided the temperature (and other physical conditions) stays constant

2.4

- the resistance **increases**
- a larger current heats the filament, and the resistance of the metal rises with temperature

2.5

- $V = 0.72 \text{ V}$ and $I = 15 \text{ mA} = 0.015 \text{ A}$; use $R = \frac{V}{I}$

$$R = \frac{V}{I} = \frac{0.72 \text{ V}}{0.015 \text{ A}} = \mathbf{48 \text{ } \Omega}$$

3.1 C

- a metal at constant temperature obeys Ohm's law, so its resistance is constant
- the lamp and the thermistor change temperature; the diode's resistance depends on the p.d.

3.2 B

- $R = \frac{V}{I}$, with V doubled and I multiplied by 1.6:

$$\frac{R_{\text{new}}}{R_{\text{old}}} = \frac{V_{\text{new}}/I_{\text{new}}}{V_{\text{old}}/I_{\text{old}}} = \frac{2}{1.6} = \mathbf{1.25}$$

- the resistance rises because the filament is hotter

3.3

(a) a curve through the origin that becomes less steep as the p.d. rises

- the same shape, inverted, for negative p.d.

(b) $V = 12 \text{ V}$ and $I = 2.0 \text{ A}$; use $R = \frac{V}{I}$

$$R = \frac{V}{I} = \frac{12 \text{ V}}{2.0 \text{ A}} = \mathbf{6.0 \Omega}$$

(c) $V = 3.0 \text{ V}$ and $I = 0.80 \text{ A}$; the same definition, $R = \frac{V}{I}$

$$R = \frac{V}{I} = \frac{3.0 \text{ V}}{0.80 \text{ A}} = \mathbf{3.8 \Omega}$$

- at the lower p.d. the current is smaller, so the filament is cooler and its resistance is lower

(d) no: its resistance changes as the p.d. changes (the I - V graph is not a straight line through the origin)

3.4

(a) almost zero current for all negative p.d.s

- almost zero current for small positive p.d.s, up to about 0.6 V
- then a steep rise in current

(b) $V = 0.80 \text{ V}$ and $I = 45 \text{ mA} = 0.045 \text{ A}$; use $R = \frac{V}{I}$

$$R = \frac{V}{I} = \frac{0.80 \text{ V}}{0.045 \text{ A}} = \mathbf{18 \Omega}$$

(c) very much larger (almost infinite): almost no current flows in reverse