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

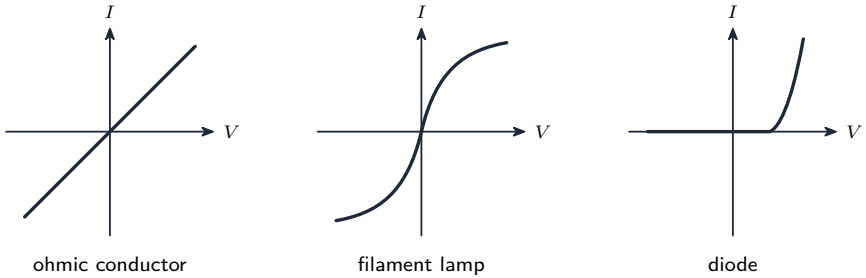
1 Key knowledge and worked examples

Key knowledge: resistance and Ohm's law

Term	Meaning
resistance	the potential difference across a component ÷ the current in it, $R = \dfrac{V}{I}$
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**

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

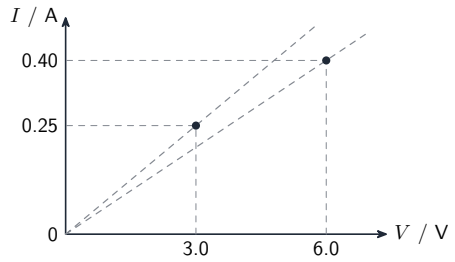
Key knowledge: the three characteristics



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 $R = \dfrac{V}{I}$:

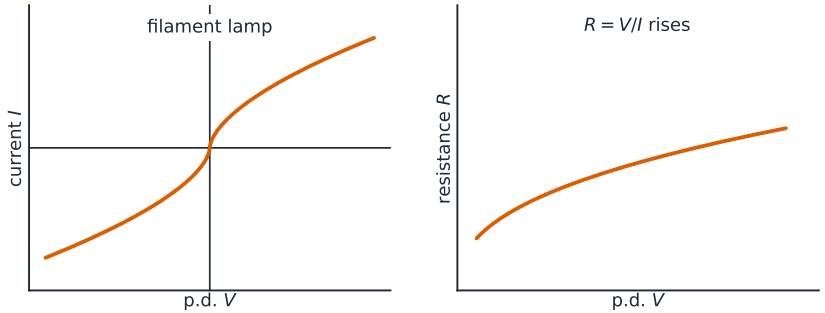
$$R = \frac{V}{I} = \frac{6.0\ \text{V}}{0.40\ \text{A}} = 15\ \Omega$$

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 $R = \dfrac{V}{I}$ at that point (never the gradient):

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

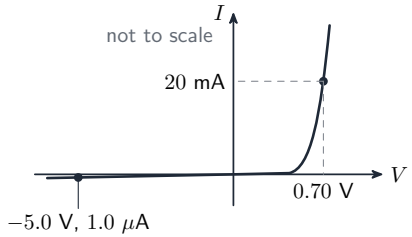
2. **At** 1.0 **V** – the same definition, at the lower p.d.:

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

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 $R = \dfrac{V}{I}$:

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

2. **Reverse** – the same definition, with 1.0 μA = 1.0×10^{-6} 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.

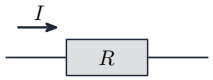
2 Practice

Now use the methods above.

2.1 Define **resistance**. [1]

resistance

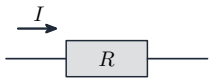
2.2 A component has a p.d. of 12 V across it and a current of 0.25 A in it. Calculate its resistance. [2]



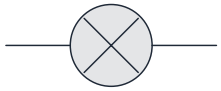
12 V

0.25 A

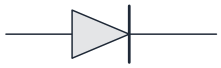
2.3 State **Ohm's law**. [2]



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]



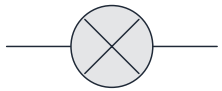
3 Exam-style questions

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

I–V characteristics

- **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

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]



- **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]

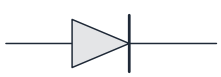
(b) At its normal operating p.d. of 12 V the current in the lamp is 2.0 A. Calculate the resistance of the lamp. [2]

(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 $+1.0$ V.

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



(b) At $+0.80$ 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]