

## 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

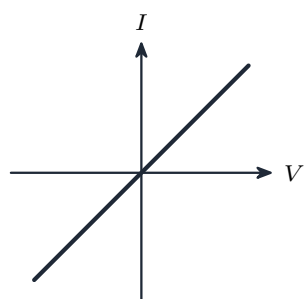
#### ■ Key knowledge: resistance and Ohm's law

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

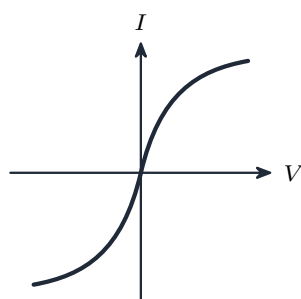
- $R = \frac{V}{I}$  is always true: it defines resistance;  $I \propto V$  is true only for a straight  $I$ - $V$  line through the origin (an **ohmic** component)

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

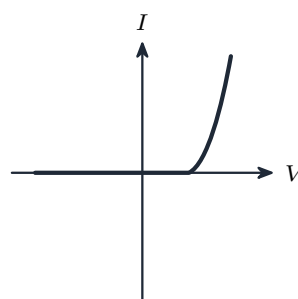
■ **Key knowledge: the three characteristics**



ohmic conductor



filament lamp

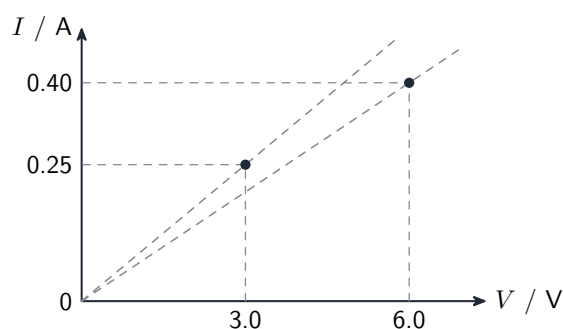


diode

| Component                                         | $I$ - $V$ graph                                                                                | Resistance                                                                             |
|---------------------------------------------------|------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| <b>metallic conductor</b> at constant temperature | straight line through the origin, same in both directions                                      | constant: it obeys Ohm's law                                                           |
| <b>filament lamp</b>                              | 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 |
| <b>semiconductor diode</b>                        | 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  $R = \frac{V}{I}$ :

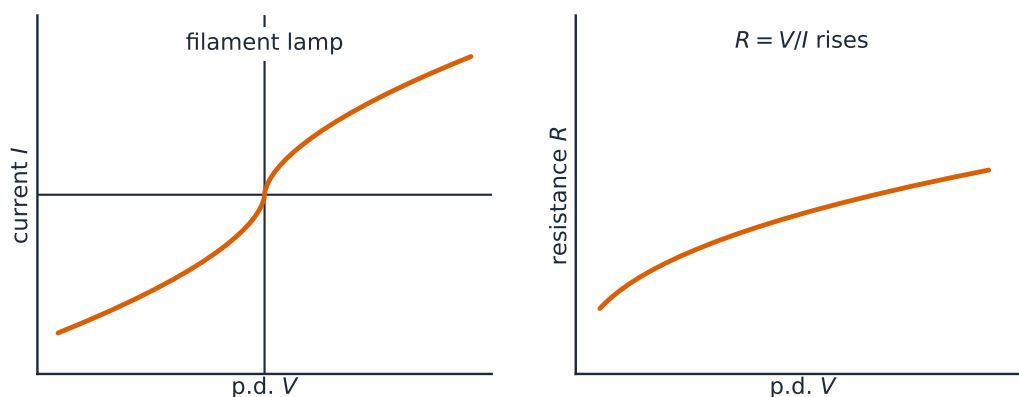
$$R = \frac{V}{I} = \frac{6.0 \text{ V}}{0.40 \text{ A}} = 15 \Omega$$

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):

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

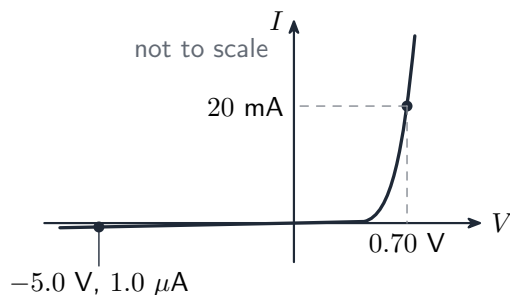
2. **At 1.0 V** – the same definition, at the lower p.d.:

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

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  $\mu\text{A}$  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

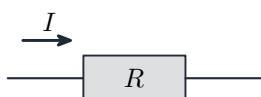
2.2 A component has a p.d. of 12 V across it and a current of 0.25 A in it. Calculate its resistance.

[2]



### 2.3 State Ohm's law.

[2]



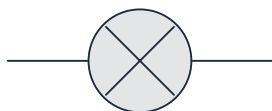
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### 2.4 State and explain what happens to the resistance of a filament lamp as the current in it increases.

[2]



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

[2]



15 mA

0.72 V

## 3 Exam-style questions

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

☐

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]

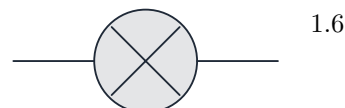
☐

A 0.80

B 1.25

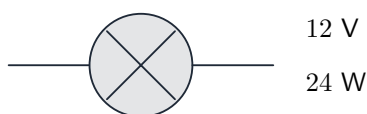
C 1.6

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  $-2.0\text{ V}$  to  $+1.0\text{ V}$ .

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



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

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