

Exercise walk-through

9.3

Resistance and resistivity

A-Level Physics

Sheet 9.3.1 – what you need to know

You must be able to:

- use $R = \frac{\rho L}{A}$, with the area from the diameter
- find the resistance of a stretched wire, and of a block between different faces
- find a resistivity from the gradient of a resistance–length graph
- state how an NTC **thermistor** and an **LDR** respond to heat and light

What the exam asks

“State and explain which resistor is made of wire with the larger cross-sectional area.” [2]

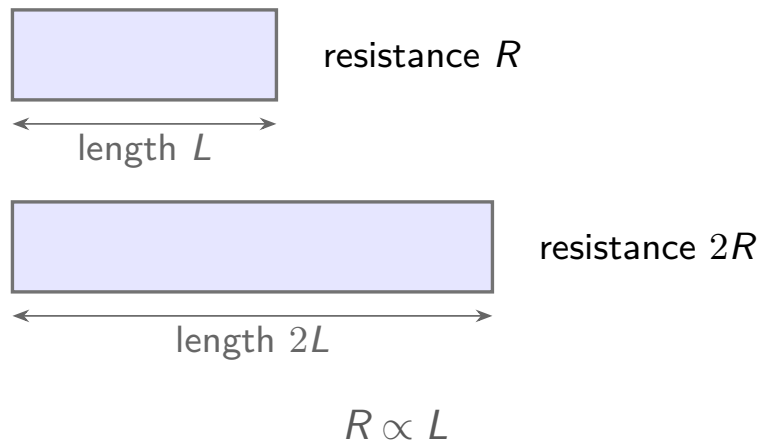
“State the effect of this change on the resistance of the lightning rod.” [1]

“State and explain how the resistance of wire Q compares with the resistance of wire P.” [4]

Practise on exercise sheet 9.3.1, then try the real exam questions on past-paper sheet 9.3.1.

Resistivity

same area A – twice the length gives twice R



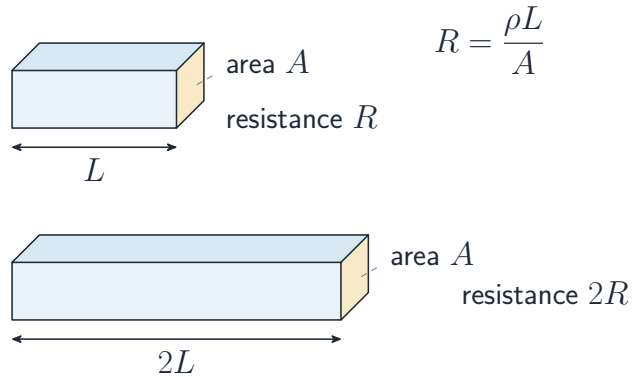
$$R = \frac{\rho L}{A}.$$

ρ is the **resistivity** (a material property, $\Omega \text{ m}$).

Copper: $L = 2.0 \text{ m}$, $A = 1.7 \times 10^{-7} \text{ m}^2$

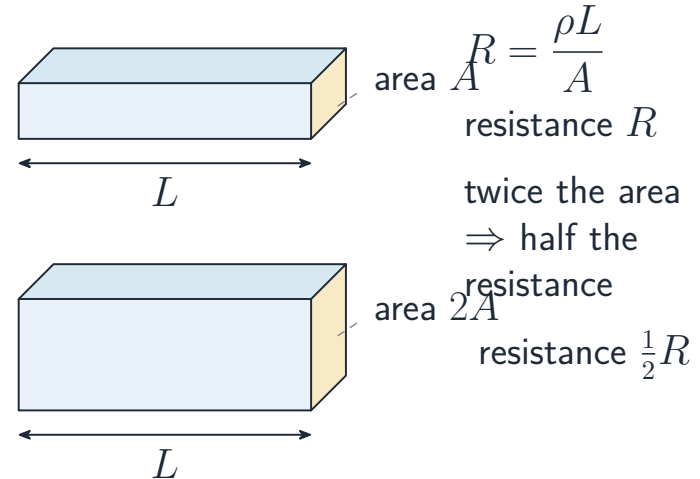
$$\begin{aligned} R &= \frac{\rho L}{A} = \frac{(1.7 \times 10^{-8} \Omega \text{ m})(2.0 \text{ m})}{1.7 \times 10^{-7} \text{ m}^2} \\ &= 0.20 \Omega \end{aligned}$$

What $R = \rho L/A$ is saying



twice the length $\Rightarrow$ twice the resistance

Twice the length, twice the resistance.



Twice the area, half the resistance.

ρ is the **resistivity**, a property of the **material** alone, in $\Omega \text{ m}$; R also depends on the shape.

A stretched wire

Stretching does not change the volume of metal, so AL stays the same: a longer wire is also **thinner**.

Double the length: half the area, so **four times** the resistance.

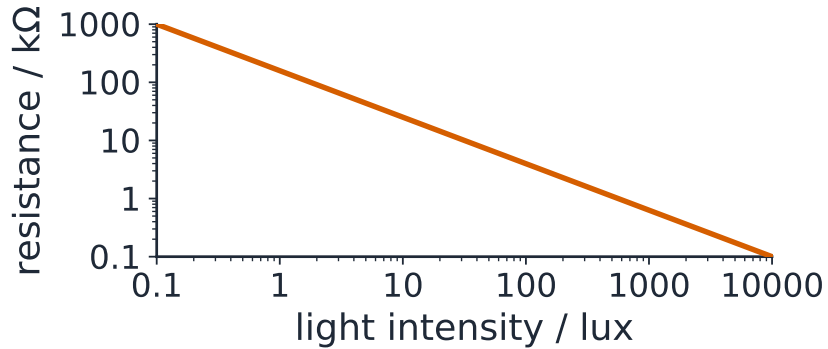
Stretched until its diameter is 90% of the old value

$$A \propto d^2: \quad \frac{A'}{A} = 0.90^2 = 0.81$$

$$AL \text{ constant: } \frac{L'}{L} = \frac{1}{0.81} = 1.23$$

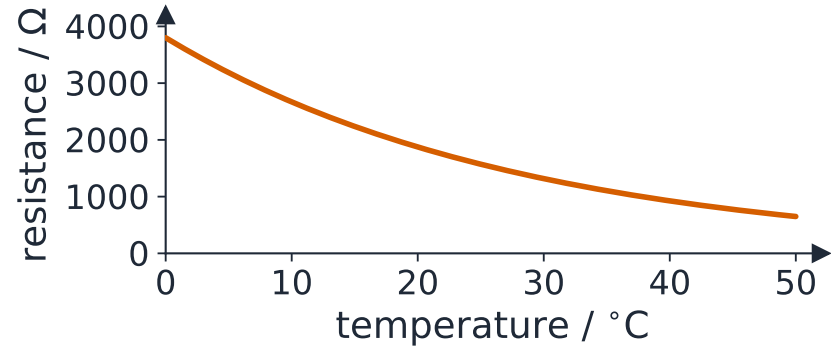
$$R' = \frac{\rho L'}{A'} = \frac{\rho(1.23L)}{0.81A} = 1.5 R$$

Light-dependent resistor and thermistor



LDR: more light $\Rightarrow$ lower R

LDR : R falls as light rises



NTC: R falls as T rises

thermistor : R falls as temp. rises

Both are semiconductors: light or heat **frees more carriers**, so R **falls** – the opposite of a metal.

Exercises 2.1·2.2

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]



Exercises 2.1·2.2

2.1 Define **resistance**.

[1]

resistance

2.1

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

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]



2.2

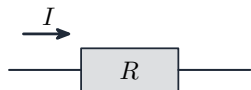
- $V = 12 \text{ V}$ and $I = 0.25 \text{ A}$ are known; resistance is defined as $R = \frac{V}{I}$

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

Exercises 2.3·2.4

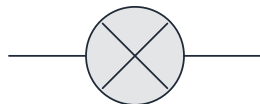
2.3 State Ohm's law.

[2]



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

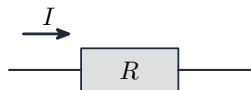
[2]



Exercises 2.3·2.4

2.3 State Ohm's law.

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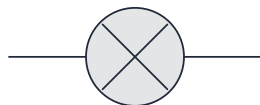


2.3

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

[2]



2.4

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

Exercise 2.5

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



2.5

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

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

Exercise 3.1

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

Exercise 3.1

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

3.1 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.

Exercise 3.2

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]

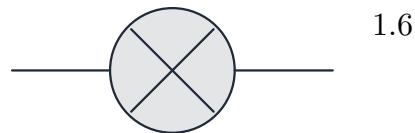
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A 0.80

B 1.25

C 1.6

D 3.2



Exercise 3.2

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]

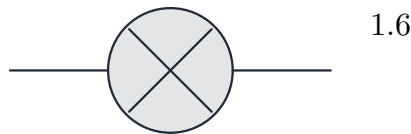
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A 0.80

B 1.25

C 1.6

D 3.2



3.2 B

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

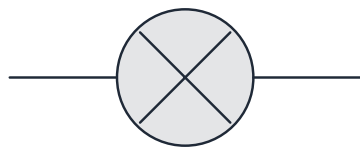
$$\frac{R_{\text{new}}}{R_{\text{old}}} = \frac{V_{\text{new}}/I_{\text{new}}}{V_{\text{old}}/I_{\text{old}}} = \frac{2}{1.6} = \mathbf{1.25}$$

- the resistance rises because the filament is hotter

Exercise 3.3 (a)

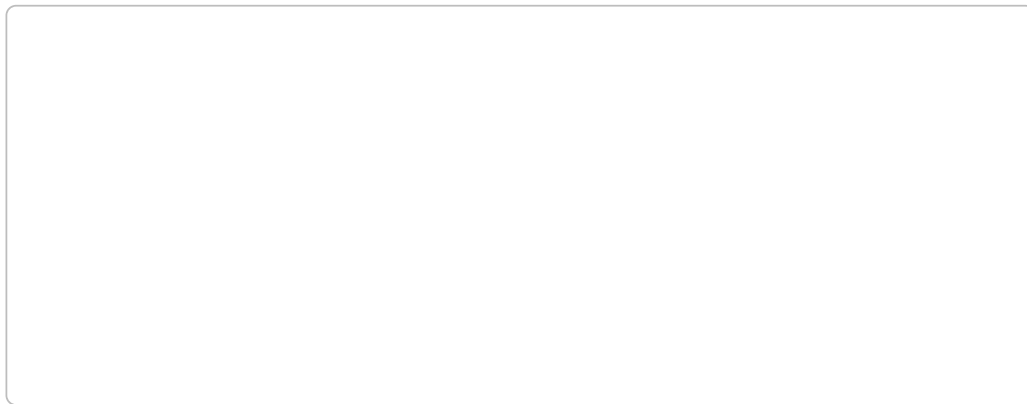
3.3 A filament lamp is marked "12 V, 24 W".

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



12 V

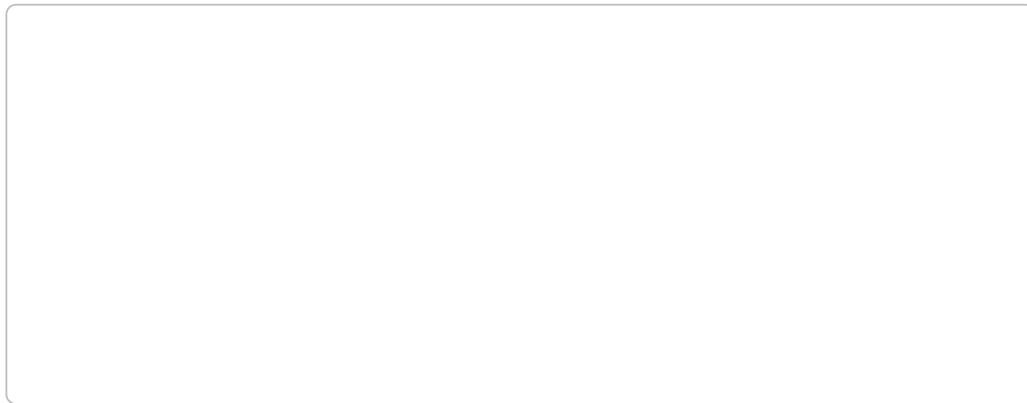
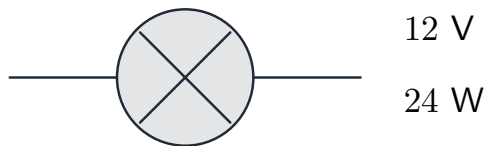
24 W



Exercise 3.3 (a)

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]



- (a) a curve through the origin that becomes less steep as the p.d. rises
- the same shape, inverted, for negative p.d.

Exercise 3.3 (b)

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

(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]

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

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

Exercise 3.3 (c)

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

(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]

Exercise 3.3 (c)

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

(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]

(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

Exercise 3.3 (d)

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

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

[1]

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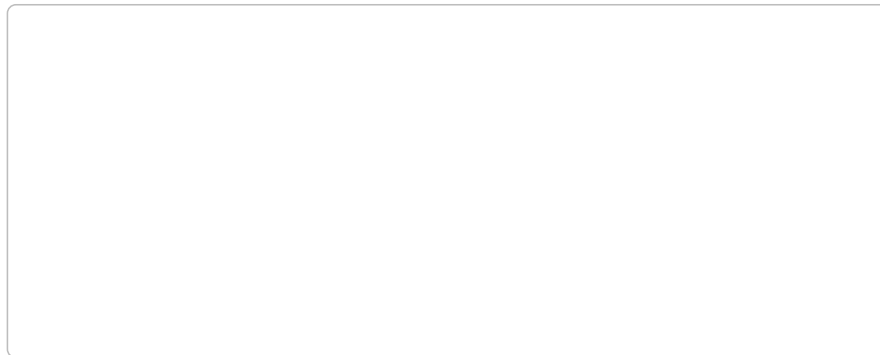
(d) no: its resistance changes as the p.d. changes (the I - V graph is not a straight line through the origin)

Exercise 3.4 (a)

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.

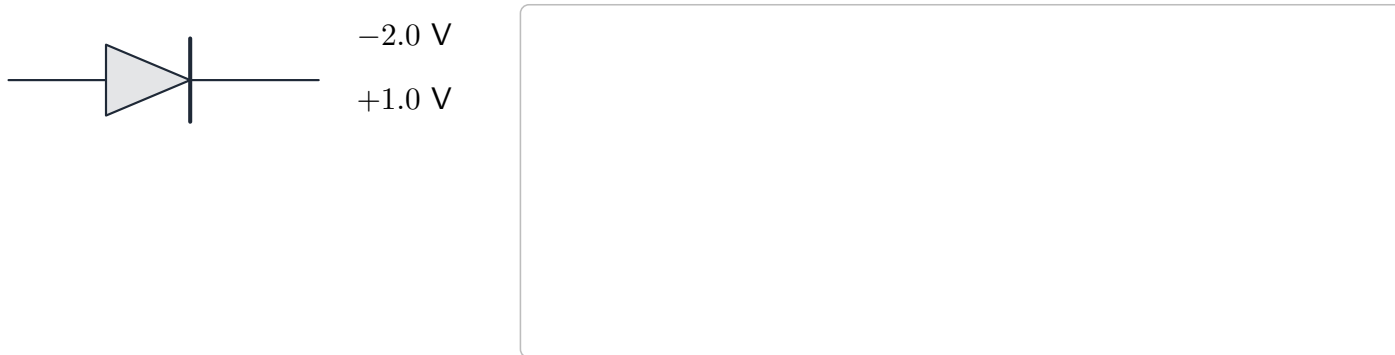
[3]



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



- (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

Exercise 3.4 (b)

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

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

Exercise 3.4 (b)

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

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

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

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

Exercise 3.4 (c)

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

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

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

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