Name	Date started	Target end date

GCE AS / A LEVEL — CONDUCTION OF ELECTRICITY QUESTION PACK

Legacy PH1 · New spec Unit 2 Topic 1 · AS unit, 20% of A-level

REVISE
.wales

PHYSICS — UNIT 2 · CONDUCTION OF ELECTRICITY

PH2.1 Conduction of electricity — current, drift velocity & nAve

Defining electric current, applying I = nAve to free-electron metals, and reasoning about current direction, charge carriers and continuity in series circuits.

NEW 2015 SPEC · UNIT 2 TOPIC 1

Estimated time for entire question pack: ~2 h 26 min

Derived from the legacy PH1 paper's pace of 80 marks in 1¼ hours.

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH1 papers (2008 modular spec) that maps onto new-spec Unit 2 Topic 1 (2.1).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

For Examiner's use only

Q	Source	Max	Mark
1	PH1 Jan 09 Q2	7	
2	PH1 Jan 12 Q5	9	
3	PH1 Jan 10 Q1	8	
4	PH1 Jun 09 Q5	9	
5	PH1 Jun 10 Q8	9	

Q	Source	Max	Mark
6	PH1 Jan 11 Q3	15	
7	PH1 Jan 13 Q6	10	
8	PH1 Jan 14 Q2	11	
9	PH1 Jun 15 Q3	15	
10	PH1 Jun 16 Q6	11	
	Total	104	

Conduction of Electricity — what the new spec asks

WJEC GCE AS / A Level Physics (from 2015) · Unit 2: Electricity & Light · Topic 2.1.

Electric current (A)

- Define electric current as rate of flow of charge: $I = \Delta Q / \Delta t$.
- Conventional current versus electron flow.
- Continuity of current at a junction (precursor to Kirchhoff I).

Charge carriers (A)

- Charge is quantised: $Q = ne$ with $e = 1.60 \times 10^{-19}$ C.
- Identify charge carriers in metals (electrons) and electrolytes (ions).

Drift velocity (B)

- Derive $I = nAve$ from a current-tube model.
- Use $I = nAve$ to find typical drift speeds in copper.
- Effect of changing A, n or material on v.

Conduction model (B)

- Describe random thermal motion superposed on a small drift.
- Compare drift speed to electron thermal speed.

Conduction of Electricity in one page

Quick-reference notes — revisit before each section.

Current basics

$I = \Delta Q/\Delta t$ (units A = C s^{-1}).

$Q = ne$ with $e = 1.60 \times 10^{-19}$ C.

Conventional current opposite to electron flow.

I = nAve

Microscopic current formula:

$I = nAve$ where n = carrier number density, A = area, v = drift speed.

Typical metal: $n \sim 10^{29}$ m^{-3}, $v \sim 10^{-4}$ m s^{-1}.

Conservation

Current is the same through every section of an unbranched series circuit.

At a junction: total in = total out.

Materials

Metals: free conduction electrons.

Electrolytes: positive and negative ions.

Semiconductors: electrons + holes.

Strategy

1. Read off I, A, n.
2. Solve $v = I/(nAe)$.
3. Compare with thermal speeds (~10^5 m s^{-1}) — very different.

Watch out for

n is per cubic metre, not per mole.

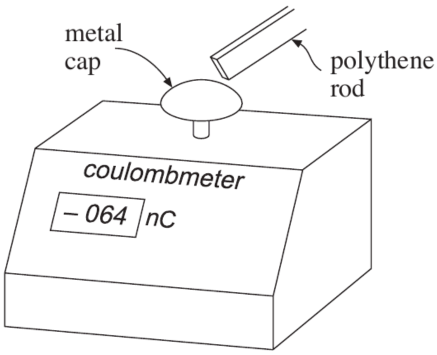
A in m^2 (convert from mm^2).

Electron drift is opposite to conventional current.

Section index

Use this index to jump straight to the section you need.

2. A polythene rod is rubbed with a duster. The rod is then scraped across the metal cap of a digital coulombmeter as shown in the diagram (a coulombmeter is a device for measuring electrical charge).



(a) (i) Explain why the reading on the coulombmeter is negative. [1]

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(ii) State the sign of the charge acquired by the duster. Explain your reasoning. [2]

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(b) The coulombmeter is now discharged by connecting a wire from the metal cap to the ground. The coulombmeter reading falls to zero.

(i) Calculate the number of charged particles that flow from the coulombmeter. [2]

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(ii) Calculate the time taken for this number of charged particles to flow past a point in the wire if the mean discharge current is 2 μA. [2]

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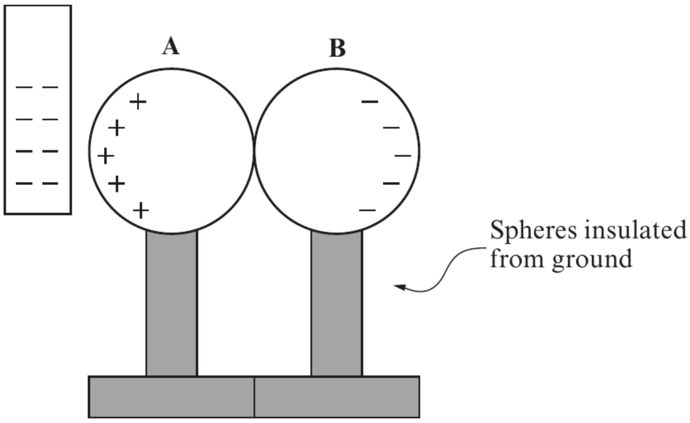
5. Two insulated metal spheres, **A** and **B** are placed in contact with each other. When a negatively charged rod is brought near, the charges become distributed on the metal spheres as shown.



(a) (i) State the particle which carries the negative charge. [1]

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(ii) Explain why the charges become distributed as shown. [3]

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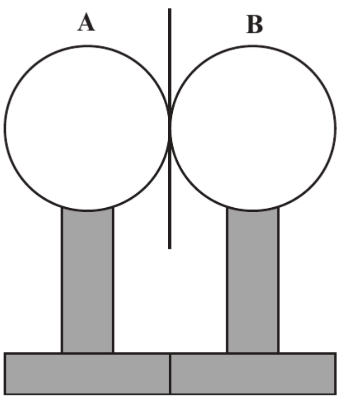
(iii) The following procedure is carried out:

- A thin insulating piece of cardboard is placed in between the spheres.
- The negatively charged rod is then removed.

Sketch the distribution of charges now on both spheres. [2]



(b) (i) In another process, a negatively charged rod is rubbed against one of the spheres and in doing so places approximately 300×10^9 free negative charges onto the sphere. Calculate the charge on the sphere. [1]

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(ii) The sphere is discharged in a time of 20 ps by connecting a wire from it to the ground. Calculate the mean current. [2]

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1. *(a)* Explain what is meant by an electric current. [1]

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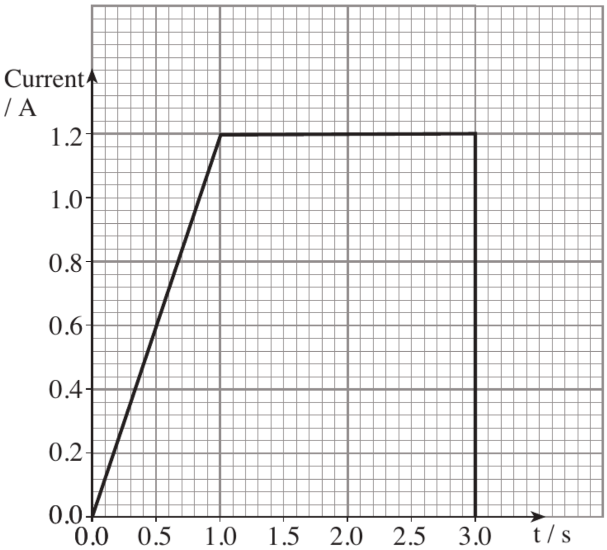
(b) The current through a conductor changes with time over a period of 3.0 s as shown.



(i) By considering the area under the graph calculate the total charge passing through the conductor in this time. [2]

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(ii) Calculate the total number of electrons flowing past a point in the conductor in this time. [2]

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(iii) Calculate the drift velocity of the electrons at t = 1.5 s. Take the cross-sectional area of the conductor to be $2.0 \times 10^{-6} m^2$ and the number of free electrons per m^3 to be $1.0 \times 10^{29} m^{-3}$. [3]

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5. (a) Explain what is meant by an electric current.

.... [1]

(b) The current, I, in a wire of cross-sectional area A is given by the formula.

$$I = nAve$$

(i) Derive the formula, giving a clearly labelled diagram.

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.... [4]

(ii) Calculate the mean drift velocity in a wire of cross-sectional area 2.0 mm^2 carrying a current of 3.0 A. The free electron density is $5.0 \times 10^{28}\, m^{-3}$

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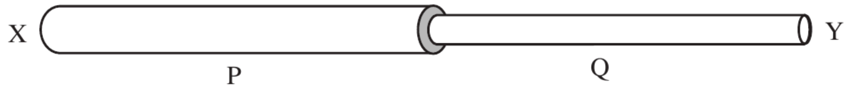
[2]

(iii)



Two copper wires, P and Q, are connected in series. P has 2 times the cross-sectional area of Q. A battery is connected between the ends, X and Y, of the combination. Complete the following sentences.

(I) The current in Q is .... the current in P. [1]

(II) The electron drift velocity in P is .... the electron drift velocity in Q. [1]

8. *(a)* *Copper is an electrical conductor*. Explain what this statement means. [1]

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(b) (i) The density of copper is 8920 kgm^{-3}. Calculate the mass of a copper wire that has a cross-sectional area of $2.0 \times 10^{-6}\,\text{m}^2$ and is 2.0 m long. [2]

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(ii) Determine the **total** number of free electrons in this wire given that an atom of copper has a mass of 1.05×10^{-25} kg and each atom contributes, on average, 1.5 electrons. [2]

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(iii) Calculate the mean drift velocity of the electrons in the wire when there is a current of 1.2 A. [4]

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Examiner only

3. *(a)* Derive, giving a labelled diagram, the relationship between the current I through a metal wire of cross sectional area A, the drift velocity, v, of the free electrons, each of charge e, and the number, n, of free electrons per unit volume of the metal. [4]
($I = nAve$).

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(b) Calculate the drift velocity of free electrons in a copper wire of cross sectional area $1.7 \times 10^{-6}\,m^2$ when a current of 2.0 A flows. [$n_{copper} = 1.0 \times 10^{29}\,m^{-3}$]. [2]

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(c) A potential difference is required across the copper wire in order for the current to flow. The size of the current depends on the wire's *resistance*. Explain in terms of free electrons, how this resistance arises. [2]

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(d) The copper wire in *(b)* is of length 2.5 m. When it carries a current of 2.0 A, it dissipates energy at the rate of 0.1 W. Calculate its resistivity. [4]

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(e) A second copper wire has the same volume as the wire in *(d)*, but is longer. Complete the table below indicating whether the quantity given is **bigger**, **smaller** or **the same** for this longer wire. [3]

Quantity	For the longer wire this quantity is ...
Cross-sectional Area	
n, number of free electrons/unit volume	
Resistivity	

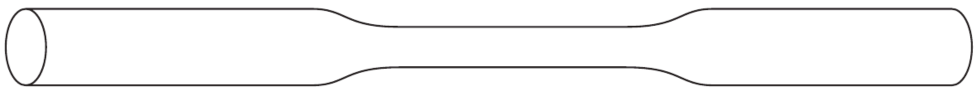
6. A power cable has a resistance of 11.2Ω and is made of an alloy of aluminium of resistivity $2.8 \times 10^{-8}\,\Omega\,m$. It is used to link a power station to a town 160 km away.

(a) (i) Show that the cross-sectional area of the cable is $4.0 \times 10^{-4}\,m^2$. [1]

(ii) Calculate the current in the cable given that the pd across it is 2.0 kV. [1]

(iii) Calculate the mean drift velocity of the free electrons in the cable given that there are 6.0×10^{28} atoms per m^3 of aluminium and each atom contributes 3 free electrons. [3]

(b) A small portion of the cable is damaged. As a result its cross-sectional area is less than that of the rest of the cable, as shown in the diagram.



(i) State how the current in the thinner portion compares with the current in the rest of the cable. [1]

(ii) State how the mean drift velocity of free electrons in the thinner portion compares with that in the rest of the cable. Justify your answer. [2]

(iii) Hence suggest, in terms of particles, why the damaged part of the cable will be prone to overheating. [2]

2. The current I in a metal conductor of cross-sectional area A is given by:

$$I = nAve$$

(a) State the meanings of n and v. [2]

n ....

v ....

(b) Show that the equation is correct in terms of units. [3]

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(c) (i) The current in a copper wire is 2.0 A. The wire has a cross-sectional area of 1.2 mm^2 and is 5.0 m long. Calculate the time it takes a free electron in the wire to travel from one end to the other. [Take $n_{copper} = 8 \times 10^{28}\ m^{-3}$.] [3]

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(ii) The **same current** (2.0 A) is now passed through a **thinner** wire of the **same length and material**. Use the above equation to explain the effect this change would have on the time for an electron to travel from one end to the other. [3]

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3. *(a)* (i) The current in a wire depends on its **resistance**. Explain, in terms of free electrons, how this resistance arises when a potential difference is applied across the wire. [2]

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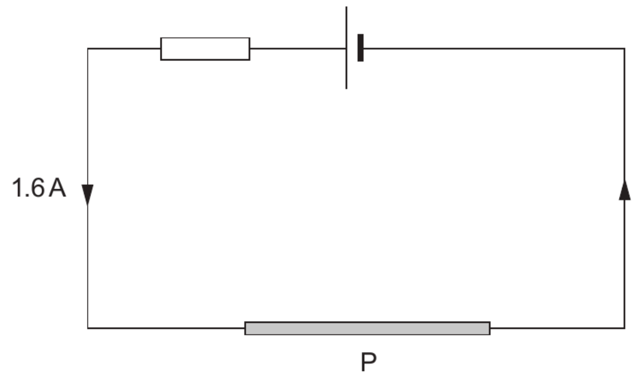
(ii) The wire (labelled P in the diagram) is connected to a fixed voltage source and a resistor to limit the current as shown. The wire is 0.4 m long and has a cross-sectional area of $2.0 \times 10^{-6}\,m^2$. When the current is 1.6 A it dissipates 1.8 J of energy in 1 minute. Calculate its resistivity. [4]



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Examiner only

(b) (i) The current, I, in a wire of cross-sectional area, A, is given by the formula:

$$I = nAve$$

Derive the formula. You may include a clearly labelled diagram. [4]

(ii) Calculate the drift velocity of the free electrons in the wire in *(a)*(ii) when the current through it is 1.6 A. [$n = 6.4 \times 10^{28}\,\text{m}^{-3}$] [2]

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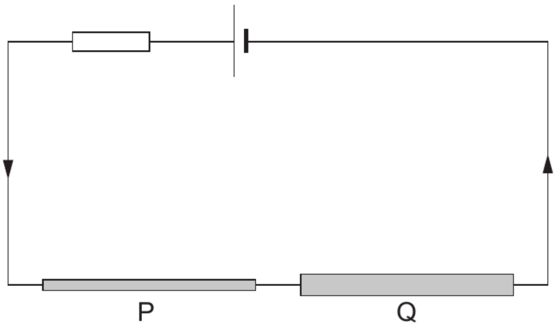
(iii) Wire P is now connected to another wire, Q, of the same material but with **twice** the cross-sectional area. The wires are connected to the same fixed voltage source and resistor.



Complete the following sentences by **circling the correct option** given in brackets.

(I) The current in the circuit containing both wires is **[less than 1.6 A] [equal to 1.6 A] [more than 1.6 A]**. [1]

(II) The current in P is **[less than] [the same as] [greater than]** the current in Q. [1]

(III) The electron drift velocity in Q is **[half] [the same as] [twice] [four times]** the electron drift velocity in P. [1]

Examiner only

6. *(a)* (i) Compare the movement of free electrons in a metal **before** and **after** a potential difference is applied to the metal. [4]

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(ii) Hence explain how resistance arises in a metal when a potential difference is applied to it. [1]

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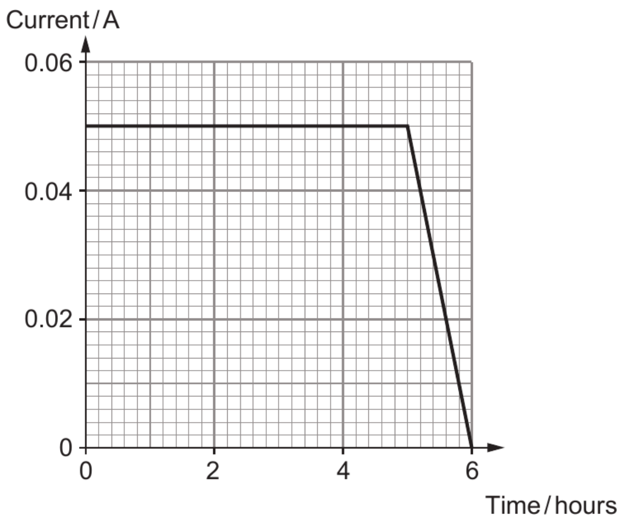
(b) A resistor is connected for many hours to a cell. The graph shows the variation of current, I, through the resistor with time, t.



(i) Calculate the charge which passes through the resistor:

I. during the first 5 hours; [2]

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Examiner only

II. in the last hour. [1]

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(ii) Calculate the energy dissipated by the resistor during the first 5 hours given that the cell has an emf of 3.2 V. [Assume internal resistance = 0 Ω.] [2]

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(iii) Calculate the rate at which the resistor dissipates energy during the first 5 hours. [1]

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END OF QUESTION PACK

10 questions · 104 marks · ~2 h 26 min

Source: WJEC PH1 (2008 modular spec)

Curated for WJEC Physics 2015 spec AS Unit 2 — Topic 1 (2.1)