Past-paper walk-through

Electric current ▪ 9.1

eXercise

Questions in this set

- 9702/11 N25 Q32 ▪ 1 mark
- 9702/14 N25 Q35 ▪ 1 mark
- 9702/12 J25 Q34 ▪ 1 mark
- 9702/13 J25 Q4 ▪ 1 mark
- 9702/13 J25 Q32 ▪ 1 mark
- 9702/14 J25 Q29 ▪ 1 mark
- 9702/12 M25 Q30 ▪ 1 mark
- 9702/22 M25 Q6 ▪ 13 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = “or words to that effect” – the wording need not match.

Question 32

9702/11 N25 ▪ Q32 ▪ 1 mark

What is a possible charge on a particle? **[1]**

A 6.40×10^{-20} C

B 4.00×10^{-19} C

C 1.12×10^{-18} C

D 9.11×10^{-18} C

Solution 32

A 6.40×10^{-20} C

B 4.00×10^{-19} C

C 1.12×10^{-18} C ✓

D 9.11×10^{-18} C

Why

- Charge is quantised: any charge must be a whole-number multiple of $e = 1.60 \times 10^{-19}$ C.
- Divide each option by e: A gives 0.4, B gives 2.5 and D gives 56.9.
- Only C gives a whole number, exactly 7.0.

Question 35

9702/14 N25 ▪ Q35 ▪ 1 mark

A wire carries a current of 5.6 A.

What is the number of conduction electrons that pass a point on the wire in a time of 20 s? **[1]**

A 1.8×10^{18}

B 2.2×10^{19}

C 3.5×10^{19}

D 7.0×10^{20}

Solution 35

A 1.8×10^{18}

B 2.2×10^{19}

C 3.5×10^{19}

D 7.0×10^{20} ✓

Why

- $Q = It = 5.6 \times 20 = 112$ C.
- $N = Q/e = 112/(1.60 \times 10^{-19})$.
- $= 7.0 \times 10^{20}$ electrons.

Question 34

9702/12 J25 ▪ Q34 ▪ 1 mark

A resistor of resistance $200\,\Omega$ is connected to a supply that has a p.d. of 4.00 V.

How many electrons enter the resistor in 4.00 s? **[1]**

A 3.13×10^{16}

B 1.25×10^{17}

C 5.00×10^{17}

D 1.25×10^{21}

Solution 34

- **A** 3.13×10^{16}
- **B** 1.25×10^{17}
- **C** 5.00×10^{17} ✓
- **D** 1.25×10^{21}

Why

- $I = V/R = 4.00/200 = 0.0200$ A.
- $Q = It = 0.0200 \times 4.00 = 0.0800$ C.
- $N = Q/e = 0.0800/(1.60 \times 10^{-19}) = 5.00 \times 10^{17}$.

Question 4

9702/13 J25 ▪ Q4 ▪ 1 mark

4 A sample of material has cross-sectional area A and length L. The temperatures at the two sides of the sample are T_1 and T_2. Thermal energy Q is transferred through the sample in time t.

These quantities are related by

$$\frac{Q}{t} = \frac{k \times A \times (T_1 - T_2)}{L}$$

where k is a constant.

What are the SI base units of k?

A $\mathrm{kg\,m\,s^{-3}\,°C^{-1}}$ **B** $\mathrm{kg\,m\,s^{-3}\,K^{-1}}$ **C** $\mathrm{kg\,m\,s^{-1}\,°C^{-1}}$ **D** $\mathrm{kg\,m\,s^{-1}\,K^{-1}}$

Solution 4

Answer: **B**

Why

- Rearranged, $k = (Q/t)L/(A\,\Delta T)$.
- Q/t is a power, kg m^2 s^{-3}; multiplying by m and dividing by m^2 leaves kg m s^{-3}.
- A temperature difference in SI *base* units is the kelvin, so k is kg m s^{-3} K^{-1} – the degree Celsius is not a base unit.

Question 32

9702/13 J25 ▪ Q32 ▪ 1 mark

32 The current I in a metallic conductor of cross-sectional area A is given by

$$I = Anve$$

where e is the elementary charge and v is the mean drift velocity of the conduction electrons.

What is represented by the letter n in the equation?

A density of conduction electrons

B number of conduction electrons per unit time

C number of conduction electrons per unit volume

D volume of conduction electrons

Solution 32

Answer: **C**

Why

- In $I = nAve$ the product Av is a volume swept out per second.
- Multiplying by n must give a number of electrons per second, so n counts electrons per unit volume.
- "Density" on its own would suggest mass per unit volume, a different quantity.

Question 29

9702/14 J25 ▪ Q29 ▪ 1 mark

29 The resistance of a lamp is 10 Ω and the potential difference across it is 6.0 V.

How many electrons pass through the lamp in a time of 24 hours?

A 5.2×10^{4} **B** 9.0×10^{19} **C** 5.4×10^{21} **D** 3.2×10^{23}

Solution 29

Answer: **D**

Why

- $I = V/R = 6.0/10 = 0.60$ A.
- $t = 24 \times 3600 = 86\,400$ s, so $Q = It = 51\,840$ C.
- $N = Q/e = 51\,840/(1.60 \times 10^{-19}) = 3.2 \times 10^{23}$.

Question 30

9702/12 M25 ▪ Q30 ▪ 1 mark

30 Two cylindrical conductors, X and Y, are made from the same material. The conductors have equal lengths, but Y has a smaller diameter than X.

X and Y are connected in series to a cell.

Which row compares the number of charge carriers per unit time passing through X and through Y and compares the average drift speed of the charge carriers in X and in Y?

	number of charge carriers per unit time	average drift speed of charge carriers
A	Y greater than X	Y greater than X
B	Y same as X	Y same as X
C	Y greater than X	Y same as X
D	Y same as X	Y greater than X

Question 30

Solution 30

Answer: **D**

Why

- They are in series, so the current is the same in both – the same number of carriers passes each second.
- $I = nAve$, and n is the same because the material is the same.
- Y has the smaller area, so its drift speed must be *higher* to carry that same current.

Question 6

9702/22 M25 ▪ Q6 ▪ 13 marks

6 A cylindrical copper wire P of length 0.24 m is shown in Fig. 6.1. 0.24 m 0.85 A Fig. 6.1 (not to scale)

The current in the wire is 0.85 A.

The resistance of the wire is 3.3 mΩ.

The total number of charge carriers N in the wire is 2.6 $\times$ 1022.

The resistivity of copper is 1.8 $\times$ 10–8 Ω m.

(a) Calculate the potential difference between the two ends of the wire.

potential difference = V [2]

(b) (i) Show that the cross-sectional area of the wire is 1.3 $\times$ 10–6 m2.

[2]

(ii) Show that the number density of charge carriers in the wire is 8.3 $\times$ 1028 m–3.

[1]

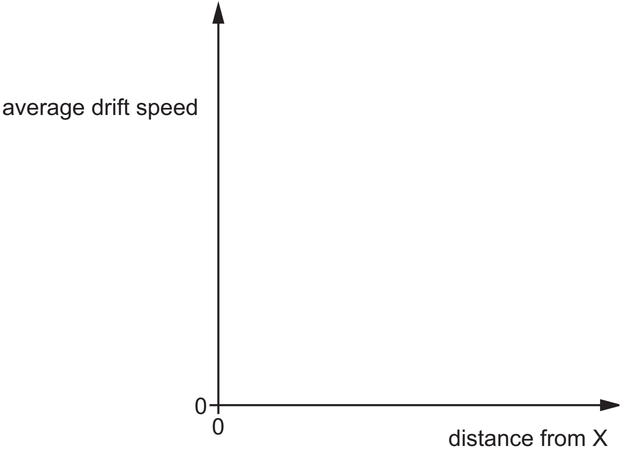
Question 6

(iii) Calculate the average drift speed of the charge carriers (electrons) in the wire.
average drift speed = m s–1 [2] , ,
(c) A different copper wire Q has the same volume as wire P, but non-uniform radius, as shown in Fig. 6.2. X r1 r2 Fig. 6.2 (not to scale)
The radius r1 at end X of wire Q is the same as the radius of wire P. Radius r2 is less than r1.
(i) State and explain how the resistance of wire Q compares with the resistance of wire P [4] , ,
(ii) On Fig. 6.3, sketch a graph of the variation of the average drift speed of the charge carriers with distance from end X of wire Q. 0 0 average drift speed distance from X Fig. 6.3
[2]
, ,

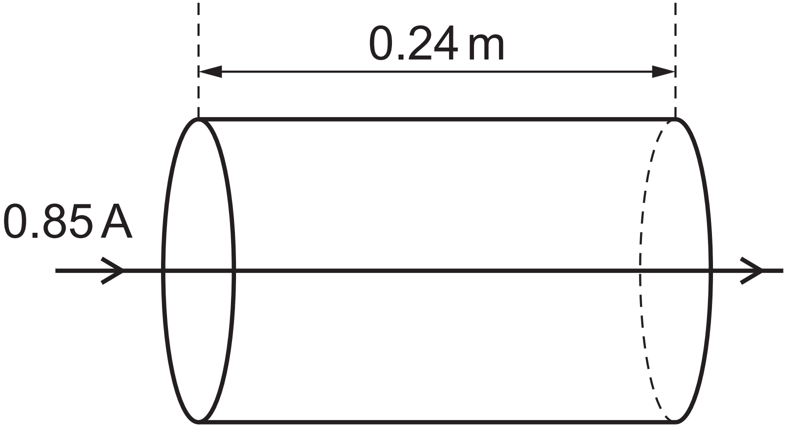
Question 6

(a) Calculate the potential difference between the two ends of the wire. **[2]**
(b)(i) Show that the cross-sectional area of the wire is 1.3×10^{-6} m^2. **[2]**
(b)(ii) Show that the number density of charge carriers in the wire is 8.3×10^{28} m^{-3}. **[1]**
(b)(iii) Calculate the average drift speed of the charge carriers (electrons) in the wire. **[2]**
(c)(i) Wire Q has the same volume as wire P but a non-uniform radius: the radius r_1 at end X equals the radius of wire P, and r_2 is less than r_1. State and explain how the resistance of wire Q compares with the resistance of wire P. **[4]**
(c)(ii) Sketch a graph of the variation of the average drift speed of the charge carriers with distance from end X of wire Q. **[2]**

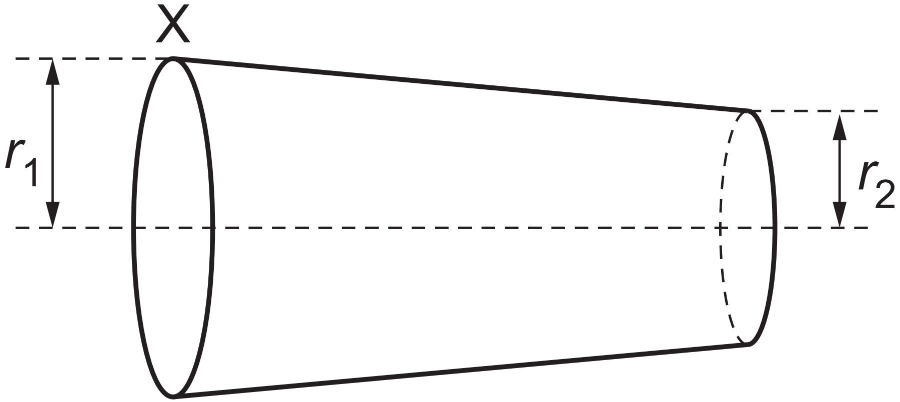
Question 6



Question 6



Question 6



Solution 6

(a)

Worked steps

- $V = IR = 0.85 \times 3.3 \times 10^{-3}$
- $V = 2.8 \times 10^{-3}$ V

Mark scheme

- V = IR
- = 0.85 × 3.3 × 10–3
- = 2.8× 10–3 V

Solution 6

(b)(i) Worked steps

- $R = \dfrac{\rho L}{A}$, so $A = \dfrac{\rho L}{R}$.
- $A = \dfrac{1.8 \times 10^{-8} \times 0.24}{3.3 \times 10^{-3}}$
- $A = 1.3 \times 10^{-6}$ m^2, as required.

Solution 6

Mark scheme

- $(A =)\ \rho L\ /\ R$
- $= 1.8 \times 10\text{–}8 \times 0.24\ /\ 3.3 \times 10\text{–}3 = 1.3 \times 10\text{–}6$ (m2)

Solution 6

(b)(ii) Worked steps

Number density is carriers **per unit volume**, so find the volume first.

- $V_{\text{wire}} = AL = 1.3 \times 10^{-6} \times 0.24 = 3.1 \times 10^{-7}\ \text{m}^3$
- $n = \dfrac{N}{V_{\text{wire}}} = \dfrac{2.6 \times 10^{22}}{3.1 \times 10^{-7}}$
- $n = 8.3 \times 10^{28}\ \text{m}^{-3}$, as required.

Solution 6

Mark scheme

- $(n =)\ 2.6 \times 1022$ / $(1.3 \times 10–6 \times 0.24) = 8.3 \times 1028$ (m–3)
- 9702/22
- February/March 2025

Solution 6

(b)(iii) Worked steps

- $I = nAvq$, so $v = \dfrac{I}{nAq}$.
- $v = \dfrac{0.85}{8.3 \times 10^{28} \times 1.3 \times 10^{-6} \times 1.6 \times 10^{-19}}$
- $v = 4.9 \times 10^{-5}$ m s^{-1}

About 0.05 mm per second — the drift is astonishingly slow, even though the lamp lights at once. **Mark scheme**

- v = I / nAq
- = 0.85 / (8.3 × 1028 × 1.3 × 10–6 × 1.6 × 10–19)

Solution 6

- $= 4.9 \times$ 10–5 m s–1
- OR
- v $=$ IL / Nq
- $= 0.85 \times 0.24$ / (2.6 $\times$ 1022 $\times$ 1.6 $\times$ 10–19)
- (C1)
- $= 4.9 \times$ 10–5 m s–1
- (A1)

Solution 6

(c)(i)

Mark scheme

- Length (of Q) is greater (than P)
- (Average cross-sectional) area (of Q) is less (than P)
- Resistance is proportional to length / (cross-sectional) area
- (so) the resistance (of Q) is greater (than P)

Solution 6

(c)(ii) Worked steps

Use $v = \dfrac{I}{nAq}$: the current is the same everywhere along the wire, and n and q are fixed, so $v \propto \dfrac{1}{A}$.

- At X the wire is at its widest, so the drift speed there is at its **lowest** — but not zero, so start the line above the origin.
- As the wire narrows, A falls and v rises.
- Because v goes as $1/A$, the rise gets steeper: draw a curve with an **increasing** positive gradient.

Solution 6

Mark scheme

- A line starting from a non-zero value of drift speed at distance $= 0$
- A line with an increasing positive gradient