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WORKSHEETS
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# OCR A AS Mean Drift Velocity worksheet

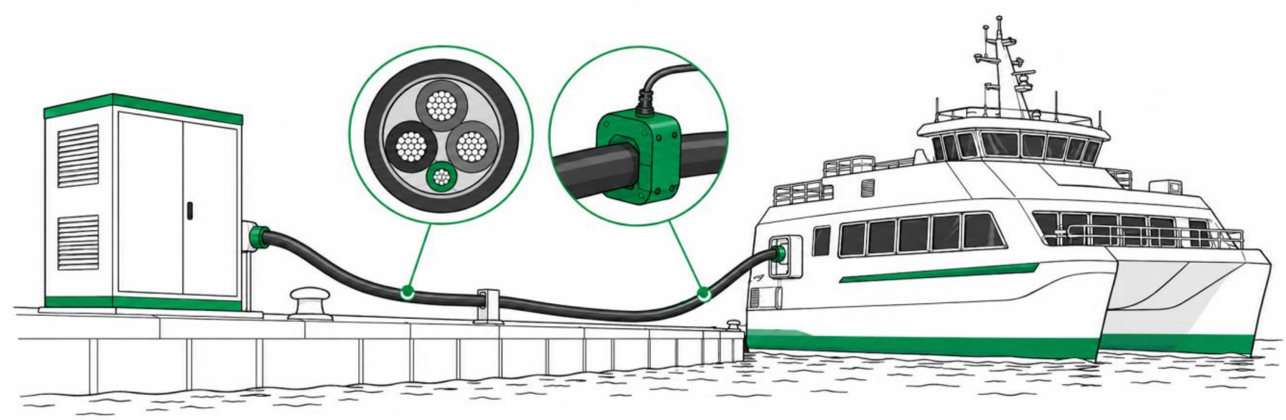
*35-40 minutes independent practice + 15-20 minutes review* | *44 marks*

## Specification points covered

- 4.1.2(a) Define and understand mean drift velocity of charge carriers.
- 4.1.2(b) Use and apply I = Anev, where n is the number density of charge carriers.
- 4.1.2(c) Distinguish conductors, semiconductors and insulators in terms of the number density of charge carriers.

**Aurora electric-ferry rapid-charging berth**

A shore cabinet charges an electric ferry through metal busbars, a four-core flexible cable and a semiconductor current sensor.
Use $e = 1.60 \times 10^{-19}$ C. Work in SI units and distinguish rapid random carrier motion from the much smaller mean drift velocity.



*Context diagram: the rapid-charging berth, four-core cable and current sensor.*

## 1. Meaning and model

**1. Define mean drift velocity of charge carriers. [1 mark]**

**2. Free electrons in a metal have rapid random motion even when there is no current. Explain how applying a potential difference produces a small mean drift velocity with a definite direction. [2 marks]**

## 2. Using I = Anev

**3. The equation I = Anev models current in a conductor. State what A and n represent and give the SI unit of each quantity. [2 marks]**

**4. The shore-side copper busbar carries 360 A. Its cross-sectional area is $4.8 \times 10^{-4}$ $m^2$ and its carrier number density is $8.5 \times 10^{28}$ $m^{-3}$. Calculate the mean drift velocity. Use $e = 1.60 \times 10^{-19}$ C. [2 marks]**

**5. Each circular copper core in the flexible charging cable has diameter 11.0 mm and carries 92 A. The carrier number density is $8.5 \times 10^{28}$ $m^{-3}$. Calculate the cross-sectional area of one core and its mean drift velocity. [3 marks]**

## 3. Geometry and shared current

**6. A replacement core is made from the same material and carries the same current, but its diameter is 8.0 mm rather than 11.0 mm. Determine the factor by which its mean drift velocity changes and calculate the new value using your answer to Question 5. [2 marks]**

**7. Four identical cores share a total current equally. One core is taken out of service while the total current is maintained. Determine the factor by which the mean drift velocity in each remaining core changes. Explain your reasoning. [2 marks]**

**8. Two sections of the charging link are in series and carry the same current. Section P has $A = 4.2 \times 10^{-4}$ m$^2$ and $n = 6.0 \times 10^{28}$ m$^{-3}$. Section Q has $A = 2.4 \times 10^{-4}$ m$^2$ and $n = 8.5 \times 10^{28}$ m$^{-3}$. Calculate $v_Q/v_P$ and state which section has the greater mean drift velocity. [2 marks]**

## 4. Comparing sections

**9. The table gives data for three parts of the charging system. Calculate the mean drift velocity in each section and rank the sections from smallest to largest mean drift velocity. [3 marks]**

| Section | Current I / A | Area A / $m^2$ | Number density n / $m^{-3}$ |
|---|---|---|---|
| P | 200 | $4.0 \times 10^{-4}$ | $8.5 \times 10^{28}$ |
| Q | 150 | $2.0 \times 10^{-4}$ | $8.5 \times 10^{28}$ |
| R | $5.0 \times 10^{-3}$ | $1.0 \times 10^{-6}$ | $2.0 \times 10^{22}$ |

**10. A copper link has cross-sectional area $6.0 \times 10^{-5}$ $m^2$, carrier number density $8.5 \times 10^{28}$ $m^{-3}$ and mean drift velocity $1.1 \times 10^{-4}$ m $s^{-1}$. Calculate the current in the link. [2 marks]**

**11. A semiconductor strip in the current sensor is 5.0 mm wide and 0.20 mm thick. It carries 12 mA and its charge carriers have mean drift velocity 0.035 m $s^{-1}$. Calculate the carrier number density and explain why the result is consistent with a semiconductor rather than a metal. [3 marks]**

## 5. Finding n from measurements

**12. A 1.20 m length of braided conductor has cross-sectional area $1.85 \times 10^{-4}$ m$^2$ and contains $1.88 \times 10^{25}$ free electrons. It carries 280 A. Determine its carrier number density and then calculate its mean drift velocity. [3 marks]**

**13. Use your mean drift velocity from Question 12 to calculate the time taken for an electron's net drift displacement to be 2.0 m. The ferry begins charging almost immediately after connection. Explain why these facts are consistent. [3 marks]**

## 6. Temperature, materials and graphs

**14. Heating the semiconductor current sensor increases its carrier number density by a factor of 6 while its current and dimensions remain constant. Determine the new mean drift velocity as a fraction of its original value. Evaluate the statement: 'the current stays constant because the charge carriers move faster'. [2 marks]**

**15. Three candidate materials have the carrier number densities shown. Match A, B and C to the metal busbar, semiconductor sensor and insulating cable sheath. Justify each match using number density. [3 marks]**

| Candidate | Carrier number density n / $m^{-3}$ |
|---|---|
| A | $8.5 \times 10^{28}$ |
| B | $2.0 \times 10^{22}$ |
| C | less than $1 \times 10^{8}$ |

**16. For one cable core, temperature, cross-sectional area and carrier number density are constant. State the shape of a graph of mean drift velocity v against current I, and write an expression for its gradient. [2 marks]**

## 7. Engineering limits

**17. A revised charger must supply 400 A through four identical copper cores. The maximum permitted mean drift velocity in a core is $8.0 \times 10^{-5}$ m $s^{-1}$ and n = $8.5 \times 10^{28}$ $m^{-3}$. Calculate the minimum cross-sectional area and minimum diameter of each core. Standard core diameters are 9.0 mm, 10.0 mm and 11.0 mm; select the smallest suitable size.** [4 marks]

**18. During one charging pulse, the mean drift velocity is $5.5 \times 10^{-5}$ m $s^{-1}$ for 180 s and then $2.75 \times 10^{-5}$ m $s^{-1}$ for 300 s, in the same direction. Calculate the net drift displacement of an electron. Explain why this displacement is not the distance travelled in its rapid random motion.** [3 marks]

**Review and improve**

- □ I distinguish mean drift velocity from rapid random carrier motion and signal propagation.
- □ I use area perpendicular to the drift and number density per cubic metre in I = Anev.
- □ I compare materials, cable geometries and current changes using proportional reasoning.