OCR A AS Charge and Current worksheet

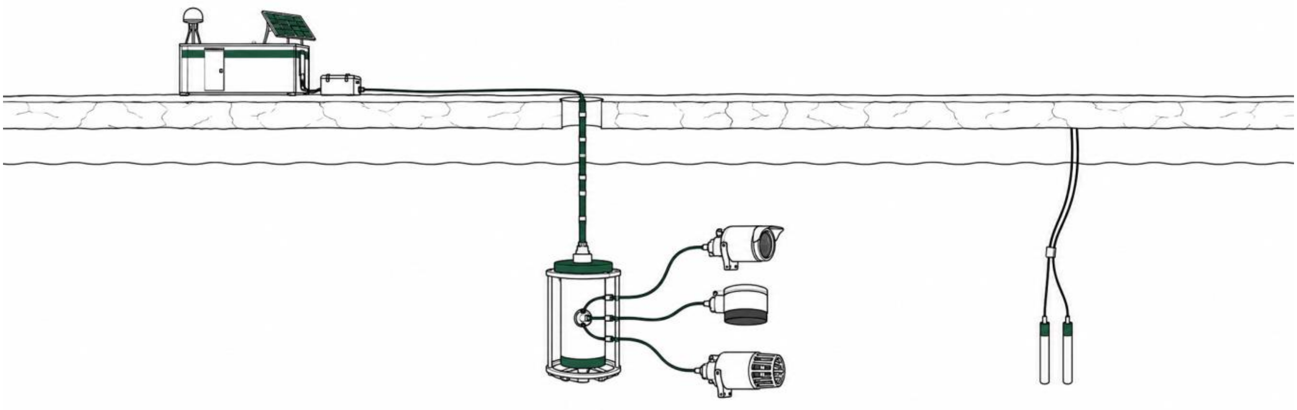
35-40 minutes independent practice + 15-20 minutes review | 44 marks

Specification points covered

- 4.1.1(a–d) Define current and the coulomb; use elementary charge and charge quantisation.
- 4.1.1(e–g) Identify charge carriers, compare conventional current with electron flow, and apply Kirchhoff's first law at a junction.
- 4.1.2(a–b) Understand mean drift velocity and use I = Anev.
- 4.1.2(c) Distinguish conductors, semiconductors and insulators using carrier number density.

Nereid under-ice ocean observatory

A surface station supplies an underwater pod through a metallic tether. The pod distributes current to a camera, sonar and pump, while a seawater probe conducts using ions.
Use $e = 1.6 \times 10^{-19}$ C. Show complete working, use SI units and describe current directions precisely.



Context diagram: the surface station, tether, instrument pod and seawater probe.

1. Charge foundations

1. Define electric current and define the coulomb. [2 marks]

2. A particle on the observatory has charge $+4.8 \times 10^{-18}$ C. Calculate the number of electrons transferred and state whether the particle gained or lost them. Use $e = 1.6 \times 10^{-19}$ C. [2 marks]

2. Charge in the tether

3. A sensor reports three possible net charges: $+3.2 \times 10^{-19}$ C, -4.8×10^{-19} C and $+7.0 \times 10^{-19}$ C. Identify which values are physically possible for an isolated object and explain your decision. **[2 marks]**

4. The observatory tether carries a steady current of 3.6 A for 150 s. Calculate (a) the charge transferred and (b) the number of electrons that pass a cross-section of the tether. **[3 marks]**

5. The metallic tether is connected to a direct-current supply. Compare the direction of conventional current with the direction of electron drift in the tether. **[2 marks]**

3. Current through the observatory

6. A camera switches on almost immediately after the surface supply is connected, even though the mean drift velocity of the electrons is small. Explain why these statements are consistent. [2 marks]

7. At a junction inside the underwater pod, 6.2 A enters. Currents of 1.8 A and 2.4 A leave through the camera and sonar branches. Calculate the current in the pump branch and explain the law used. [3 marks]

8. During a diagnostic cycle, the tether current has the values shown in the table. Calculate the total charge transferred during the 20 s cycle. [3 marks]

Time interval / s	Current / A
0 to 12	3.0
12 to 20	1.5

4. From moving carriers to current

9. A conductor has cross-sectional area A and carrier number density n. In time Δt, charge carriers with mean drift velocity v move a distance vΔt. Starting from the volume that passes a cross-section, derive I = Anev. [4 marks]

10. The copper tether has cross-sectional area 2.5×10^{-6} m^2 and carrier number density 8.5×10^{28} m^{-3}. Calculate the mean drift velocity when it carries a current of 7.0 A. [3 marks]

5. Changing a conductor

11. A short section of the same copper tether has half the cross-sectional area of the rest of the tether. The current is steady. State what happens to the mean drift velocity in the narrower section and explain why the current does not change at the boundary. [3 marks]

12. Heating a semiconductor sensor increases its carrier number density by a factor of 12. The current and cross-sectional area are kept constant. Determine the factor by which its mean drift velocity changes. [2 marks]

13. In the seawater probe, positive ions move towards the right-hand electrode and negative ions move towards the left-hand electrode. Explain how both movements can produce conventional current in the same direction. [3 marks]

6. Ionic and solid conductors

14. Use the carrier number densities in the table to identify material A, B and C as a conductor, semiconductor or insulator. Justify your choices using carrier number density. [3 marks]

Material	Carrier number density / m^{-3}
A	8.5×10^{28}
B	3.0×10^{20}
C	less than 1×10^{5}

15. Inside an ionic pump, 2.5×10^{15} singly positive ions move to the right each second while 1.0×10^{15} doubly negative ions move to the left each second. Calculate the magnitude and direction of the conventional current. [4 marks]

7. Engineering judgement

16. A proposed replacement tether has a carrier number density 100 times smaller than the present tether. Its cross-sectional area and mean drift velocity would initially be unchanged. Evaluate the claim that it will carry the same current, and state one change that could restore the original current. [3 marks]

Review and improve

- □ I can distinguish charge, current and the rate of flow of charge.
- □ I can track conventional current for electrons and for positive and negative ions.
- □ I can apply conservation of charge and I = Anev in unfamiliar situations.