

# ANSWERS

## CHAPTER E1

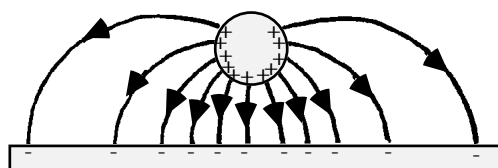
1.2 No. of excess electrons =  $\frac{-0.1 \times 10^{-6}\text{C}}{-1.6 \times 10^{-19}\text{C}} = 6.2 \times 10^{11}$

$6.2 \times 10^{11}$  electrons have been transferred from your hair to the comb.

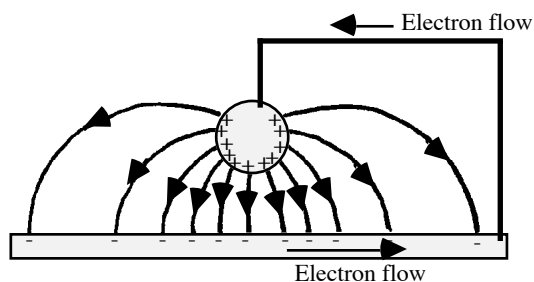
- 1.3 **Electrical:** 1, 2, 3, 4, 6, 8, 12, 13  
**Non-electrical:** 5, 11 (Gravity), 9 (Weak nuclear force).  
**Others:** 10 (A fictitious force)  
 7 (It is the strong nuclear force which holds a nucleus together. However the energy released in nuclear fission is derived from the electrostatic force which drives the fragments apart.)

- 1.4 When the dome is charged there is a charge equal in magnitude but opposite in sign on the earth. The process of earthing allows these charges to recombine.

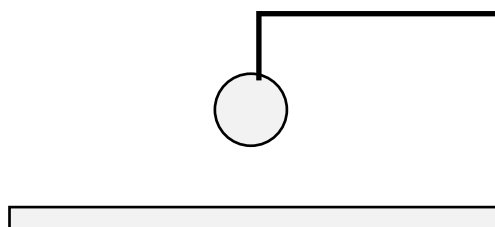
a)



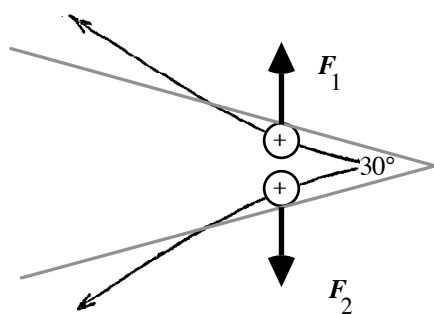
- b) The mobile charges (electrons) flow and recombine with the positive ions



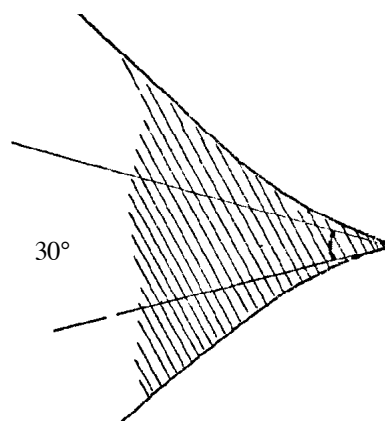
- (c) Finally, there is no separated charge and no field



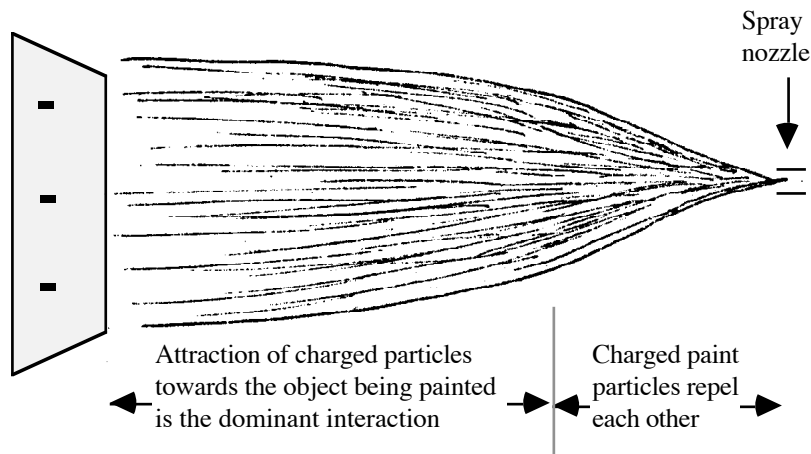
1.5



(a)



(b)



(c)

Charges repel and curve away from the 30° core (see figure a). As charges spread apart the force is reduced, and the curvature of the trajectory decreases. The pattern of spray from the nozzle is shown in figure b.

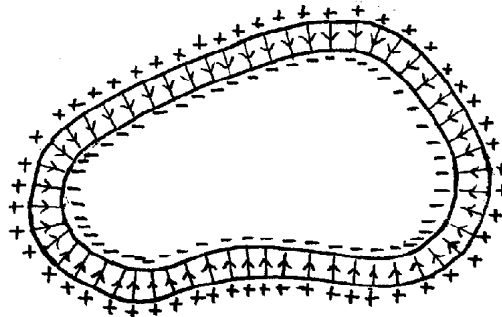
This analysis neglects other charges which may be present.

- (i) When the droplets are charged an equal negative charge will remain behind on the spray gun. We can assume that this is transferred from the spray head to earth through a conducting wire.
- (ii) The droplets are accelerated to the object to be coated by an electric field between the spray head and the object (i.e. the spray head is positively charged, the object negatively charged). The axial component of the velocity of the droplets in this field soon becomes greater than that due to their mutual repulsion, and the beam of droplets now curves towards the object, as shown in figure c.

**1.6** Static electric charge built up so that eventually a spark caused the petrol to ignite. A forensic scientist would attempt to reconstruct the circumstances which caused the accident. This procedure would include

- (a) looking for a mechanism for charge transfer (i.e. dissimilar materials rubbing),
- (b) looking for a mechanism (e.g. motion) which would separate this charge sufficiently to produce a spark,
- (c) searching for charge build-up under similar circumstances, using a field mill or similar device (i.e. measuring the electric field associated with charge build-up),
- (d) studying weather reports; electrostatic sparks are unlikely if surfaces are moist, or the relative humidity is greater than 50%.

**1.7** a)



Note: the thickness of the membrane is exaggerated.

- b) Assume that the field strength between the layers is given by the expression for the field between parallel plates.

$$i) \quad E = \frac{\sigma}{\epsilon_0}$$

ii) Zero.

$$= \frac{2.5 \times 10^{-6} \text{ C.m}^{-2}}{8.85 \times 10^{-12} \text{ C}^2.\text{N}^{-1}.\text{m}^{-2}}$$

$$= 2.8 \times 10^5 \text{ N.C}^{-1}.$$

**1.8** Magnitude of electrostatic force

$$\begin{aligned}
 F &= qE \\
 &= 1.6 \times 10^{-19} \text{ C} \times 2.8 \times 10^5 \text{ N.C}^{-1} \text{ (as the ion is singly ionised)} \\
 &= 4.4 \times 10^{-14} \text{ N.}
 \end{aligned}$$

Magnitude of gravitational force

$$\begin{aligned}
 &= mg \\
 &= 343 \times 1.67 \times 10^{-27} \text{ kg} \times 9.8 \text{ m.s}^{-2} \\
 &= 5.6 \times 10^{-24} \text{ N.}
 \end{aligned}$$

So the gravitational force is  $10^{10}$  times less than the electrostatic force.**1.9** a) See figure 1.7.

b) The magnitude of the field at the surface of the inner cylinder is given by

$$E(r_1) = \frac{\sigma}{\epsilon_0}, \text{ where } \sigma \text{ is the charge density on the cylinder.}$$

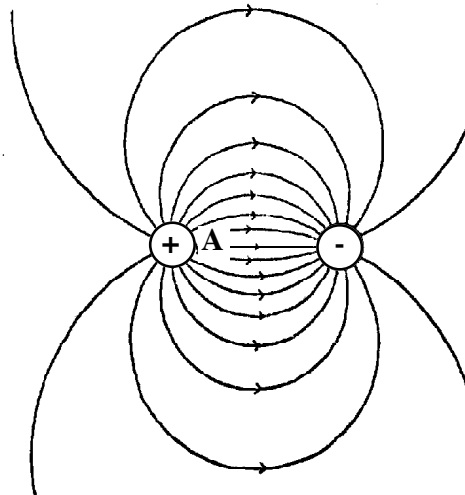
Imagine a concentric cylinder of radius  $r$  between  $r_1$  and  $r_2$  and length  $h$ . The number of field lines passing through the surface of the imaginary cylinder is equal to the number originating from the surface of the inner cylinder.

$$\begin{aligned}
 \frac{E(r)}{E(r_1)} &= \frac{\text{Area of cylinder radius } r_1}{\text{Area of cylinder radius } r} \\
 &= \frac{2\pi r_1 h}{2\pi r h} = \frac{r_1}{r}
 \end{aligned}$$

$$\text{i.e. } E(r) = E(r_1) = \frac{r_1}{r} \frac{\sigma}{\epsilon_0}.$$

**1.10** a)

$$\begin{aligned}
 \sigma &= \frac{q}{\text{Area}} \\
 &= \frac{q}{\pi d l} \\
 &= 6.4 \times 10^{-4} \text{ C.m}^{-2} \\
 E &= \frac{\sigma}{\epsilon_0} = 7.2 \times 10^7 \text{ N.C}^{-1}.
 \end{aligned}$$

b) See answer 1.9 (b)  $E(r) = \frac{r_1}{r} E(r_1) = 2.4 \times 10^7 \text{ N.C}^{-1}.$ **1.11** Fish tank, measuring apparatus, and leads from fish tank to measuring equipment must all be enclosed in a continuous metal shield.**1.12**

The magnitude of the electric field is maximum at point A in the diagram.

## CHAPTER E2

2.1 The field is non-uniform near the comb. The attractive force on the charge nearest the comb is greater than the repulsive force on the opposite charge, which is in the region of weaker electric field at a greater distance from the comb.

2.2  $E = 113 \text{ V.m}^{-1}$  directed vertically *down*. Potential = +339 V.

2.3

- |  |            |
|--|------------|
| 1) 1 mV  | 13) 1 V    |
| 2) 10 kV                                       | 14) 0.1 V  |
| 3) 1 V   | 15) 1 kV   |
| 4) 100 V (Less if skin resistance is very low) | 16) 100 V  |
| 5) 100 V (Less if skin resistance is very low) | 17) 10 V   |
| 6) 10 kV                                       | 18) 100 V  |
| 7) 10 kV                                       | 19) 100 V  |
| 8) 1 V   | 20) 1 V    |
| 9) 1 V   | 21) 1 V    |
| 10) 10 kV                                      | 22) 100 kV |
| 11) 10 $\mu\text{V}$                           | 23) 1 kV   |
| 12) 10 kV                                      | 24) 5 V    |

2.4 i) Energy =  $eV$

ii) Energy =  $1.6 \times 10^{-19} \text{ C} \times 2.5 \times 10^3 \text{ V} = 4.0 \times 10^{-16} \text{ J}$

2.5 As the cell is 90 mV *negative* with respect to extracellular fluid there will be a layer of *negative* charge at the inside surface of the cell membrane, and a corresponding layer of *positive* charge at the outside surface.

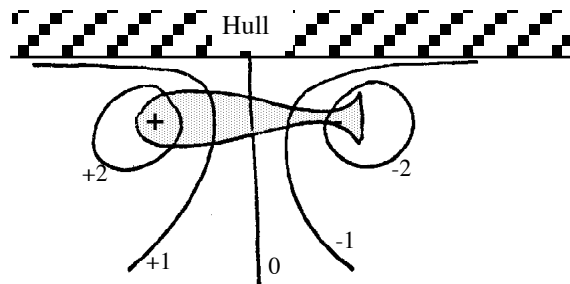
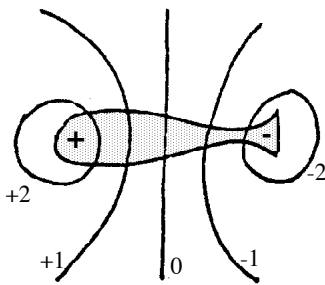
2.6 i)  $C = \frac{\epsilon A}{l}$  where  $\epsilon = k \epsilon_0 = 0.071 \text{ nF}$ .

ii)  $E = 90 \text{ kV.m}^{-1}$ .

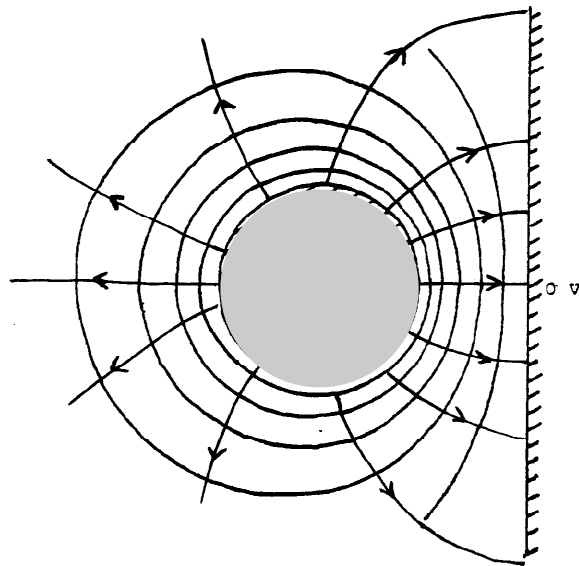
iii) Energy =  $\frac{1}{2} C V^2 = 0.29 \text{ pJ}$ .

iv)  $Q = CV = 4 \text{ pC}$ .

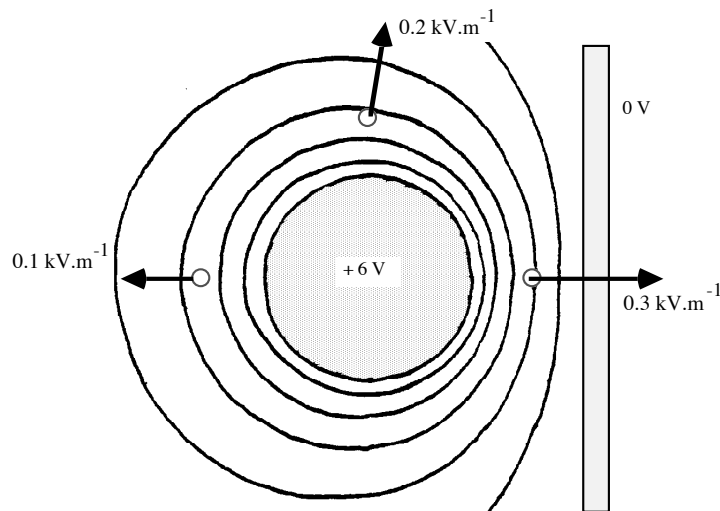
2.7



2.8 (i)



(ii)



10 mm to the right of the sphere 2 V and 3 V equipotentials are separated by 4 mm.

$$\therefore \text{Magnitude of electric field} = \frac{1 \text{ V}}{4 \times 10^{-3} \text{ m}} = 0.3 \text{ kV.m}^{-1}$$

Direction of electric field: *normal* to conducting plane, and directed *towards* the plane, see figure above, i.e. field is *normal* to the equipotentials

10 mm to left of sphere

$$\text{Magnitude of electric field} = 0.1 \text{ kV.m}^{-1}$$

Direction of electric field: *normal* to conducting plane, and directed *away* from the plane.

10 mm above sphere

$$\text{Magnitude of electric field} = 0.2 \text{ kV.m}^{-1}$$

Direction of electric field: *away* from conducting sphere, at an angle of  $\sim 80^\circ$  to a *normal* to the conducting plane (see figure), i.e. *normal* to the equipotentials.

## CHAPTER E3

**3.1** The flows of water and of electric charge are similar. However current carries *charge* and *mass*, while water flow carries only *mass*

- (a) Flow rate (the mass of fluid passing any point per time) is the hydrodynamic analogue of current.  
 (b) Pressure difference is the hydrodynamic analogue of potential difference.  
 (c) Hydrodynamic resistance (the ratio of pressure to mass flow rate) is the hydrodynamic analogue of resistance.

Water flow, like the flow of electric charge exhibits heating and mechanical effects. Unlike electric current, it does not exhibit magnetic or electrochemical effects, cause electrolysis or the emission of light, and its biological effects are different in nature from those of electricity.

**3.2** a) When you are interested in measuring the average value of  $I^2$  (i.e. the *heating* effect) of an alternating current.

b) To determine the average current over a long period of time, especially when a high precision is required.

**3.3** Increase in gravitational PE of house =  $mg\Delta h$

$$= 500 \times 10^3 \text{ kg} \times 9.8 \text{ m.s}^{-2} \times 1 \text{ m}$$

$$= 5 \text{ MJ.}$$

Electrical energy required =  $2 \times 5 \text{ MJ}$

$$= 10 \text{ MJ .}$$

1 kW.h =  $1 \times 10^3 \text{ J.s}^{-1} \times 3600 \text{ s}$

$$= 3.6 \text{ MJ .}$$

Hence energy required to lift house =  $\frac{10 \text{ MJ}}{3.6 \text{ MJ.(kW.h)}^{-1}}$

$$= 2.8 \text{ kW.h .}$$

Cost at 18 c / kW.h = 50 c .

**3.4** a) See figure 3.12.

b) 0.02 C. Number of electrons =  $1.3 \times 10^{17}$ .

c) Number of electrons transferred =  $1.3 \times 10^{17}$  (see answer b).

Mass of electron =  $9.1 \times 10^{-31} \text{ kg}$ .

Hence mass transferred =  $1.1 \times 10^{-13} \text{ kg}$ .

d) Power = 6.0 kW.

e)

$$\text{Energy} = \text{power} \times \text{time}$$

$$\text{Power} = 6.0 \text{ kW (See answer d)}$$

$$\text{Hence energy} = 0.60 \text{ kJ.}$$

f) Energy of one electron =  $\frac{\text{Total energy released}}{\text{No. of electrons which strike anode}}$

$$= \frac{0.60 \times 10^3 \text{ J}}{1.25 \times 10^{17}} \text{ (see answers b \& e)}$$

$$= 4.8 \times 10^{-15} \text{ J.}$$

$$\text{Kinetic energy} = \frac{1}{2} m v^2.$$

$$\text{Mass of electron} = 9.1 \times 10^{-31} \text{ kg ;}$$

$$\text{so } v = \left( \frac{2 \times 4.8 \times 10^{-15} \text{ J}}{9.1 \times 10^{-31} \text{ kg}} \right)^{1/2}$$

$$= 1.0 \times 10^8 \text{ m.s}^{-1}.$$

g) To prevent localized damage of the anode due to overheating. Heating will be minimized if the anode rotates through at least one turn during the exposure.

$$3.5 \quad j = \frac{1.5 \times 10^{-9} \text{ A}}{1.0 \times 10^{-6} \text{ m}^2} = 1.5 \times 10^{-3} \text{ A.m}^{-2}$$

$$\text{Mass flow rate } \mu = \frac{Im}{ze}$$

For the  $\text{Cl}^-$  ions, which carry *half* the current

$$\mu = \frac{1.5 \times 10^{-9} \text{ A} \times 5.9 \times 10^{-26} \text{ kg}}{2 \times 1.6 \times 10^{-19} \text{ C}} = 2.8 \times 10^{-16} \text{ kg.s}^{-1}$$

$$\text{Total mass of } \text{Cl}^- \text{ transferred} = 8.3 \times 10^{-15} \text{ kg}$$

For the  $\text{Na}^+$  ions, which carry the *other half* of the current

$$\mu = \frac{1.5 \times 10^{-9} \text{ A}}{2} \times \frac{3.8 \times 10^{-26} \text{ kg}}{1 \times 1.6 \times 10^{-19} \text{ C}}$$

$$\text{Total mass of } \text{Na}^+ \text{ transferred} = 5.3 \times 10^{-15} \text{ kg}$$

$$\text{Rate of flow of ions} = \frac{\text{Mass flow rate}}{\text{Mass of ion}} = \frac{Im}{ze} / m = \frac{I}{ze}$$

$$\text{Hence total no. of ions transferred in time } t = \frac{I}{ze} \times t = \frac{1.5 \times 10^{-9} \text{ A} \times 30 \text{ s}}{1 \times 1.6 \times 10^{-19} \text{ C}} = 2.8 \times 10^{11}.$$

$$3.6 \quad jA = q \times (\text{rate at which drops hit ground})$$

$$\text{Here } j = 1. \times 10^{-6} \text{ A.m}^{-2}; \quad A = 1.0 \text{ m}^2$$

and rate of drops hitting ground =  $100 \text{ s}^{-1}$

$$\text{so that } q = 1.0 \times 10^{-8} \text{ C.}$$

$$3.7 \quad \text{Mass flow rate } \mu = \frac{Im}{ze}$$

$$= \frac{10 \times 10^3 \text{ A} \times 1.1 \times 10^{-25} \text{ kg}}{2 \times 1.6 \times 10^{-19} \text{ C}}$$

$$\text{Total mass deposited} = \text{mass flow rate} \times \text{time} = 2.0 \text{ kg.}$$

$$3.8 \quad \text{Total energy consumed} = 100 \text{ kW} \times (4 \times 30 \text{ day} \times 0.5 + 8 \times 30 \text{ day} \times 0.1) \times 24 \text{ h.day}^{-1}$$

$$= 2 \times 10^5 \text{ kW.h.}$$

$$\text{Cost at } \$0.18 / \text{ kW.h} = \$4 \times 10^4.$$

3.9 a) The sample is *non-ohmic*; i.e. the voltage is *not* proportional to the current. There are insufficient measurements to determine the voltage-current characteristics of this material. In particular current at *zero volts* was not measured.

b) Static resistance:

$$R = \frac{V}{I} = a + bI$$

For  $I = 10 \text{ mA}$

$$R = 7.0 \text{ V.A}^{-1} + 2.0 \times 10^3 \text{ V.A}^{-2} \times 10^{-2} \text{ A}$$

$$= 90 \text{ V.A}^{-1}$$

$$= 90 \Omega$$

Dynamic resistance:

$$R_s = \frac{dV}{dI} = a + 2bI$$

For  $I = 10 \text{ mA}$

$$R_s = 110 \Omega$$

3.10

$$R = \frac{\rho l}{A}$$

$$\rho = \frac{RA}{l}$$

$$= \frac{2.15 \times 10^3 \Omega \times \left( \frac{5.0 \times 10^{-3} \text{ m}}{2} \right)^2 \times \pi}{0.64 \text{ m}} = 6.6 \times 10^{-2} \Omega.\text{m}$$

and  $\gamma = \frac{1}{\rho} = 15. \text{ S.m}^{-1}$ .

## CHAPTER E4

4.1 Molar mass of KCl =  $39.1 \text{ g.mol}^{-1} + 35.5 \text{ g.mol}^{-1} = 74.6 \text{ g.mol}^{-1}$

Hence mass of KCl required =  $5.00 \times 10^{-3} \text{ mol.L}^{-1} \times 74.6 \text{ g.mol}^{-1} \times 1.00 \text{ L} = 0.373 \text{ g}$ .

4.2 The amount of sugar in the solution will be  $\frac{2.0 \times 10^{-3} \text{ g}}{342 \text{ g.mol}^{-1}}$ .

The volume of solution will be  $V$  where

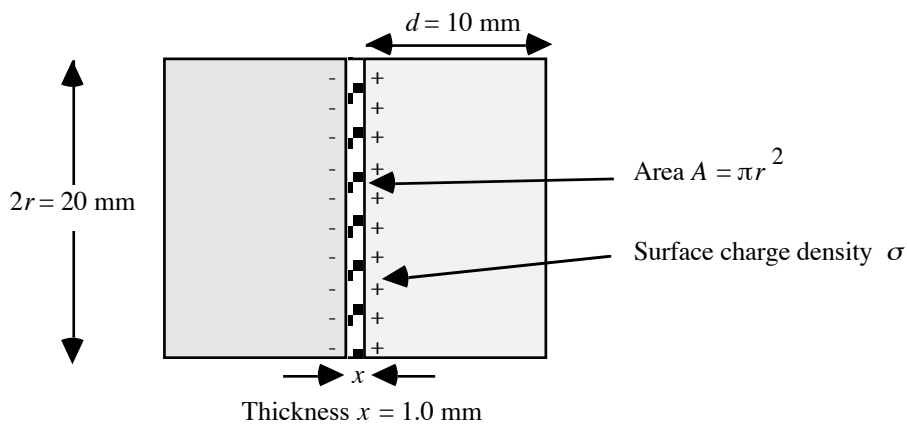
$$5 \times 10^{-3} \text{ mol.L}^{-1} = \frac{20 \times 10^{-3}}{342 \times V} \text{ mol.}$$

$$V = 11.7 \text{ mL}.$$

4.3 a) Mass of  $\text{Li}^+$  =  $7 \times 10^{-15} \text{ kg}$ .

b) No. of ions in cell =  $6 \times 10^{11}$ .

4.4



a)  $E = \frac{V}{x} = \frac{0.10 \text{ V}}{1.0 \text{ mm}} = 0.10 \text{ kV.m}^{-1}$

b)  $\sigma = k\epsilon_0 E$

$$\therefore q = k\epsilon_0 E \pi r^2 = 6 \times 10^{-13} \text{ C}$$

This is the magnitude of the charge on each of the surfaces.

c) No. of ions in one layer :

$$N_1 = \frac{\text{charge in one layer}}{\text{charge of one ion}} = \frac{k\epsilon_0 EA}{e}$$

No. of ions in cell of higher concentration:

$$N_2 = nv = N_0 Cv \quad [v = \text{volume of cell.}]$$

$$= N_0 CA d \quad [C = \text{concentration}]$$

$$N_0 = \text{Avogadro constant}$$

Hence fraction of ions which moved  $f = \frac{N_1}{N_2} = \frac{k\epsilon_0 EA}{eN_0 CA d} = \frac{k\epsilon_0 V}{xeN_0 Cd}$

Now  $\epsilon_0 = 9.0 \times 10^{-12} \text{ F.m}^{-1} = 9.0 \times 10^{-12} \text{ C.V}^{-1}.\text{m}^{-1}$ .

$$k = 2.0$$

$$V = 0.100 \text{ V}$$

$$x = 1.0 \times 10^{-3} \text{ m}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$N_0 = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$C = 0.010 \text{ mol.L}^{-1} = \frac{0.010 \text{ mol}}{10^{-3} \text{ m}^3} = 10 \text{ mol.m}^{-3}$$

$$d = 10 \times 10^{-3} \text{ m}$$

$$\therefore f = \frac{2.0 \times (9.0 \times 10^{-12} \text{ C} \cdot \text{V}^{-1} \cdot \text{m}^{-1}) \times (0.100 \text{ V})}{(1.0 \times 10^{-3} \text{ m}) \times (1.6 \times 10^{-19} \text{ C}) \times (6.02 \times 10^{23} \text{ mol}^{-1}) \times (10 \text{ mol} \cdot \text{m}^{-3}) \times (10 \times 10^{-3} \text{ m})}$$

$$\approx 2 \times 10^{-13}$$

This is the fraction of ions which have diffused through the membrane to form the charge double layer.

4.5 a)  $V = \frac{kT}{ze} \ln \left( \frac{C_1}{C_2} \right)$  with  $z = 1$ .

$$\frac{kT}{e} = \frac{1.38 \times 10^{-23} \text{ J} \cdot \text{K}^{-1} \times 293 \text{ K}}{1.60 \times 10^{-19} \text{ C}} = 0.0253 \text{ J} \cdot \text{C}^{-1}$$

$$= 25.3 \text{ mV}$$

So  $V = \frac{kT}{e} \ln \left( \frac{5.0}{1.0} \right) = 41 \text{ mV}$

b)  $V = \frac{kT}{e} \ln \left( \frac{5.0}{2.0} \right) = 23 \text{ mV}$ .

NOTE: The unit of concentration is not important here as we calculate the *ratio* of the concentrations.

4.6  $V = \frac{kT}{ze} \ln \left( \frac{C_1}{C_2} \right)$

$$\frac{C_1}{C_2} = e^{\frac{zeV}{kT}} \quad \text{with } z = 1$$

Recalling that  $\frac{kT}{e} = 25.3 \text{ mV}$  (see answer 4.5)

$$C_1 = C_2 e^{\frac{100 \text{ mV}}{25.3 \text{ mV}}} = 52.1 C_2$$

This equation tells us that  $C_1$  is greater than  $C_2$  but which of  $C_1$  and  $C_2$  is  $5.0 \text{ mmol} \cdot \text{L}^{-1}$  and which is unknown? The  $\text{Na}^+$  ions will have migrated from the stronger to the weaker solution and hence the weaker solution is positive with respect to the other. So  $C_2 = 5.0 \text{ mmol} \cdot \text{L}^{-1}$  and

$$C_1 = 52.1 \times (5.0 \text{ mmol} \cdot \text{L}^{-1}) = 0.26 \text{ mol} \cdot \text{L}^{-1}$$

4.7 See answer 4.6. This time we wish to find the concentration,  $C_2$ , of the weaker solution.

$$C_1 = C_2 e^{\frac{zeV}{kT}}$$

$$C_2 = C_1 e^{\frac{-zeV}{kT}}$$

Using  $z = 2$  and  $\frac{kT}{e} = 25.3 \text{ mV}$  we get

$$C_2 = (10.0 \text{ mmol} \cdot \text{L}^{-1}) e^{\frac{-2 \times 50 \text{ mV}}{25.3 \text{ mV}}}$$

$$= 0.19 \text{ mmol} \cdot \text{L}^{-1}$$

4.8 a) For Donnan equilibrium the concentration of permeant ions has adjusted so that they are in *Nernst equilibrium*

$$\text{i.e. } V = \frac{kT}{ze} \ln \left( \frac{C_1}{C_2} \right) \quad \dots (1)$$

where  $C_1$  and  $C_2$  are the concentrations of the permeant ions on opposite sides of the membrane.

The concentration of  $\text{K}^+$  ions on opposite sides of the membrane permits us to calculate the *Donnan potential*  $V$ .

$$V = \frac{1.38 \times 10^{-23} \text{ J} \cdot \text{K}^{-1} \times 293 \text{ K}}{1 \times 1.6 \times 10^{-19} \text{ C}} \ln \left( \frac{2.0}{0.1} \right) \quad \dots (2)$$

$$= 0.076 \text{ volt} = 76 \text{ mV} .$$

- b) We can use equation 1, knowing the Donnan potential and the concentration on one side of the membrane, to calculate the concentration of permeant ions on the other side of the membrane.

From equation 1

$$C_1 = C_2 e^{\frac{zeV}{kT}}$$

For  $\text{Na}^+$  ions, where  $z = 1$ ,  $V = 76 \text{ mV}$ ,  $C_2 = 1 \text{ mmol.L}^{-1}$

$$C_1 = 20 \text{ mmol.L}^{-1}.$$

For permeant *negative* ions in Nernst equilibrium the weaker solution will be negative.

So for  $\text{Cl}^-$  ions,  $z = 1$ ,  $V = 76 \text{ mV}$ ,  $C_1 = 2.00 \text{ mmol.L}^{-1}$ ,

$$C_2 = 0.10 \text{ mmol.L}^{-1}.$$

and for  $\text{Br}^-$  ions where  $z = 1$ ,  $V = 76 \text{ mV}$ ,  $C_1 = 0.0100 \text{ mmol.L}^{-1}$ ,

$$C_2 = 0.50 \mu\text{.mol.L}^{-1}.$$

## CHAPTER E5

- 5.1** A second electrode, inserted either into the specimen of interest or into a solution in electrical contact with the specimen, is required to complete a measuring circuit.

An electrode must be carefully selected so as not to interact with, or irritate, the specimen.

The electrode potential should not change appreciably when the current through the electrode changes either in magnitude or sense. This requires a *reversible electrode*, and possibly even a *salt bridge*, between the specimen and the wire to the measuring equipment.

**5.2**

$$\begin{aligned} V_{\text{cell}} &= V_{\text{Au}} - V_{\text{Cd}} \\ &= 80 \text{ mV} - (-43 \text{ mV}) \\ &= 123 \text{ mV}. \end{aligned}$$

**5.3**

$$\begin{aligned} V_{\text{cell}} &= V_{\text{Pd}} - V_{\text{Zn}} \\ 1.59 \text{ V} &= V_{\text{Pd}} - (-0.76 \text{ V}) \\ V_{\text{Pd}} &= 0.83 \text{ V} . \end{aligned}$$

- 5.4** Absolute values cannot be measured as any standard electrode used to complete the circuit will have its own (unknown) electrode potential.

- 5.5** The difference in the electrode potentials is due entirely to then different concentrations, so

$$V_2 - V_1 = \frac{kT}{2e} \ln \left( \frac{C_2}{C_1} \right)$$

where subscripts 1 and 2 refer to concentrations of  $0.10 \text{ mol.L}^{-1}$  and  $1.0 \text{ mol.L}^{-1}$  solutions respectively.

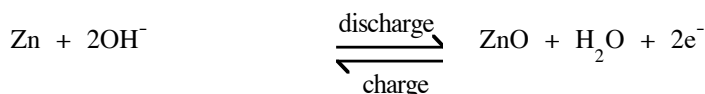
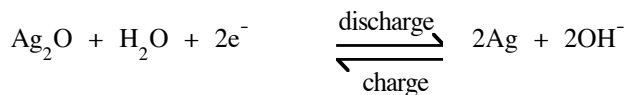
$$\begin{aligned} V_2 - V_1 &= \frac{1.38 \times 10^{-23} \text{ J.K.}^{-1} \times 297 \text{ K}}{2 \times 1.6 \times 10^{-19} \text{ C}} \ln \left( \frac{1.0 \text{ mol.L}^{-1}}{0.1 \text{ mol.L}^{-1}} \right) \\ &= 28 \text{ mV}. \end{aligned}$$

So  $V_2 = 0.31 \text{ V} + 28 \text{ mV} = 0.34 \text{ V}.$

Since  $V_2$  is the potential of copper in the standard concentration ( $1.0 \text{ mol.L}^{-1}$ ) of its own ion, measured against the standard hydrogen cell, the result should agree with the value in table 5.1.

- 5.6** Much corrosion is due to electrical currents of electrochemical origin. However chemical reactions, and the interchange of ions between a metal and an ionic solution (which causes changes in the structure of the metal) also causes corrosion.

5.7



$\text{Ag}_2\text{O}$  electrode is *positive*; Zn electrode is *negative*.

Strength of electrolyte does not change.

5.8 See chapter E5.

5.9 a) Increases.

$$\text{b) } 0.010 \text{ kg} \times 2 \times \frac{108 \text{ g.mol}^{-1}}{63.5 \text{ g.mol}^{-1}} = 0.034 \text{ kg.}$$

## CHAPTER E6

6.1 Similar to that for the magnetic field between two collinear bar magnets placed with unlike poles adjacent, as shown in figure 6.3(a).

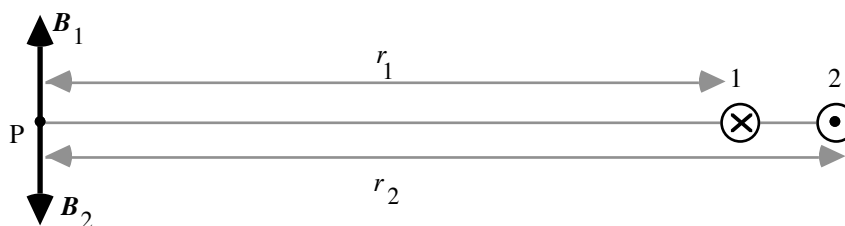
6.2 Similar to that for the magnetic field between two collinear bar magnets placed with like poles adjacent, as shown in figure 6.3(b).

6.3 Yes, if the field configuration is such that it always moves in the direction of the magnetic field - i.e. along a field line; or if there exists also a suitable electric field.

$$\begin{aligned} \text{6.4} \quad F &= IBl = IB.n 2\pi r \quad (n = \text{no. of loops}) \\ &= (0.30 \text{ A}) \times (0.05 \text{ T}) \times (200 \times 2\pi \times 0.020 \text{ m}) \\ &= 0.38 \text{ N.} \end{aligned}$$

$$\begin{aligned} \text{6.5} \quad B &= \frac{\mu_0 I}{2\pi r} \\ &= \frac{(4\pi \times 10^{-7} \text{ T.m.A}^{-1}) \times (10 \times 10^3 \text{ A})}{2\pi \times (10 \text{ m})} \\ &= 2 \times 10^{-4} \text{ T.} \end{aligned}$$

6.6



The magnetic fields of the individual wires at the specified point P are oppositely directed.

$$\begin{aligned} \text{Hence} \quad B &= \frac{\mu_0 I}{2\pi} \left( \frac{1}{r_1} - \frac{1}{r_2} \right) = \frac{\mu_0 I}{2\pi} \left( \frac{r_2 - r_1}{r_1 r_2} \right) \\ &\approx \frac{\mu_0 I (r_2 - r_1)}{2\pi r^2} \quad \text{where } r_2 \approx r_1 = 10 \text{ m} \end{aligned}$$

$$\text{So} \quad B = 2.0 \times 10^{-6} \text{ T.}$$

6.7 a) The wires are attracted towards each other. Force is perpendicular to the wire in each case.

b) 4 ×. (Both the field and the current with which it interacts are doubled.)

## CHAPTER E7

$$7.1 \quad \mathcal{E} = vBl$$

$$B = \frac{\mathcal{E}}{v l} = \frac{50 \times 10^{-6} \text{ V}}{10 \times 10^{-3} \text{ m} \cdot \text{s}^{-1} \times 40 \times 10^{-3} \text{ m}}$$

$$\therefore B = 0.12 \text{ T}$$

$$7.2 \quad \begin{aligned} \text{Speed of blood flow} &= v \\ \mathcal{E} &= vBl \\ \text{So } v &= \frac{\mathcal{E}}{Bl} \end{aligned}$$

Hence volume flow rate,

$$Q = v \times \text{cross-sectional area of artery}$$

$$= vA = v \cdot \frac{\pi l^2}{4}$$

$$\therefore Q = \frac{A}{Bl} = \frac{\pi l^2}{4Bl} = \frac{\pi l}{4B}$$

$$= \frac{\pi \times (2.5 \times 10^{-6}) \times (5.0 \times 10^{-3})}{4 \times (1.0 \times 10^{-3})} \text{ m}^3 \cdot \text{s}^{-1}$$

$$= 8.9 \times 10^{-6} \text{ m}^3 \cdot \text{s}^{-1} \text{ (8.9 mL} \cdot \text{s}^{-1}\text{)}.$$

$$7.3 \quad -40 \text{ mV}; 0 \text{ V}$$

$$\mathcal{E} = NA \frac{dB}{dt}$$

$$\therefore \frac{dB}{dt} = \frac{\mathcal{E}}{NA} = 200 \text{ T} \cdot \text{s}^{-1}$$

7.4 By measuring the voltage induced by the changing magnetic field.

$$B = B_0 \sin(\omega t)$$

$$\therefore \frac{dB}{dt} = \omega B_0 \cos(\omega t)$$

and  $\left(\frac{dB}{dt}\right)_{\text{max}} = \omega B_0$

$$\mathcal{E}_{\text{max}} = NA \left(\frac{dB}{dt}\right)_{\text{max}} = NA \omega B_0$$

$$\therefore B_0 = \frac{\mathcal{E}_{\text{max}}}{NA \omega}$$

So  $B_0 = \frac{4 \cdot \mathcal{E}_{\text{max}}}{N \pi d^2 \cdot 2 \pi f}$

$$= \frac{2 \cdot \mathcal{E}_{\text{max}}}{N \pi^2 d^2 f}$$

$$= \frac{2 \times (0.5 \text{ V})}{1000 \pi^2 \times (20 \times 10^{-3} \text{ m})^2 \times (50 \text{ Hz})}$$

$$= 5 \text{ mT}$$

$$7.5 \quad \begin{aligned} \mathcal{E} &= N \frac{d\Phi}{dt} \\ &= (500) \times (1.0 \text{ T} \cdot \text{m}^2 \cdot \text{s}^{-1}) \\ &= 500 \text{ V}. \end{aligned}$$

7.6 Silver. The detector will induce a larger eddy current in this material than in the others. This current gives a larger, more readily observed, magnetic field.

7.7 Moving the conducting sheet through the region of magnetic field produces induced EMFs and eddy currents in the sheet. The eddy currents in the conductor in turn experience a magnetic force which leads to a force on the conductor. The direction of the induced current density is such that it will produce effects opposing the change that set it up - hence the retarding force. The force can be reduced by pulling more slowly, since the induced EMF increases with the speed of the conductor. Clearly if you leave the plate alone, there will be no induced EMF, no current and no force.