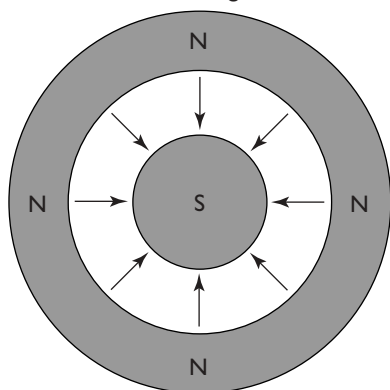


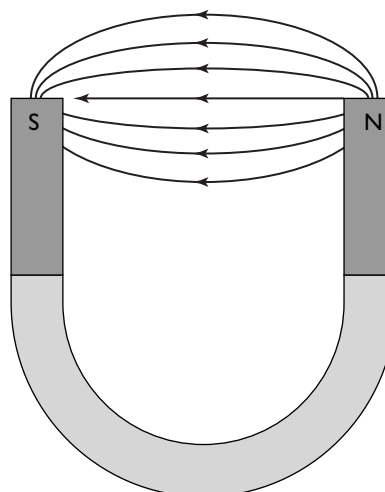
Magnetism – fields and forces

1. If the magnet attracts the piece of metal, the metal must be a magnetic material, which may or may not be a magnet. If the magnet repels the piece of metal from some angles, the metal must be a magnet with similar strength to the known magnet. Otherwise, if the piece of metal is a magnet, either much stronger or weaker than the known magnet, the two magnets will attract but the strength of attraction will depend on the part of the metal the pole of the magnet is touching.
2. *Declination*: this gives the direction of the horizontal component of the magnetic field, and so the direction of magnetic north.
3. As the material cools, the magnetic domains are aligned by the Earth's magnetic field.
4. There is a magnetic field at both ends which induces a field of the same orientation in the iron nail. Opposite poles attract and so the nail moves to the magnet.
5. The magnetic pole in the southern hemisphere is a north magnetic pole.
6. Each iron rod is magnetised in the same orientation. Adjacent north ends repel each other.

7. (a) circular magnet



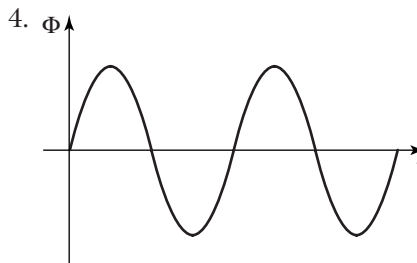
- (b)



8. Use the right-hand-grip rule.
 - (a) The direction of the magnetic field beneath the wire is north \Rightarrow No change.
 - (b) The direction of the magnetic field beneath the wire is south \Rightarrow Opposite direction.
9.
 - (a) Out of page
 - (b) Out of page
 - (c) Out of page
 - (d) Up the page
 - (e) To the right
10.
 - (a) Up the page
 - (b) to the left
 - (c) Down to the right
 - (d) Into the page
 - (e) Out of page
11.
 - (a) W: Out of page; X, Y, Z: Into the page
 - (b) W, X: To the right; Y, Z: To the left
12. Use the left-hand rule or the right-hand-slap rule.
 - (a) Into page
 - (b) Into page
 - (c) South
 - (d) Out of page
 - (e) North
 - (f) East
 - (g) South-east
 - (h) South
13. $F = nIlB$
 $= 1 \times 4.5 \times 0.05 \times 0.30$
 $= 0.07 \text{ N}$
14. $F = nIlB$
 $= 1 \times 2.4 \times 0.30 \times 0.25$
 $= 0.18 \text{ N}$
15. $F = nIlB$
 but $l = 2\pi r$
 $\Rightarrow F = 500 \times 15 \times 10^{-3} \times (2\pi \times 1.5 \times 10^{-2}) \times 2.0$
 $= 1.4 \text{ N}$

16. $F = nIB$
 $= 1 \times 1.8 \times 8.0 \times 10^{-2} \times 40 \times 10^{-3}$
 $= 5.8 \times 10^{-3} \text{ N}$
17. A DC current flows through a coil in a magnetic field. The field exerts forces of the same size, but of opposite direction on the opposite sides of the coil. These forces initially make the coil rotate, but the direction of the current needs to be reversed if the coil is to continue to rotate. This reversal is done by a commutator twice each cycle when the coil is at right angles to the field.
18. Use several coils of wire wrapped around a matchbox floating in a dish of water. Supply a DC current.
19. Fire an electron into a space. The direction it deflects can be used to determine the direction of the magnetic field, except where the electron is undeflected. The direction of the deflection is the direction of the force, the initial direction of the electron gives the opposite direction of the conventional current, and the hand rule (left-hand rule or right-hand-slap rule) gives the direction of the magnetic field. If the electron is undeflected, the magnetic field is either parallel or anti-parallel to the electron direction.
20. By travelling parallel or anti-parallel to the magnetic field.
21. An east-west power line would experience an up-down force because the current reverses direction at 50 Hz. For most lines, this would be too high a frequency to produce noticeable movement in the line. But there would be a particular length for which 50 Hz would be the resonant frequency.
22. No, not if the electron is at rest relative to the magnet.
23. (a) As the electrons approach the wire they experience a downwards magnetic field. They initially experience a force to the right.
 (b) The force on the electron is away from the wire.
24. (a) The electron experiences a force in a westerly direction and moves in a circle.
 (b) The electron moves in a circle and moves up, at the same time producing a spiral path.
25. (a) The commutator would counter the change in voltage and consistent movement would not be possible.
 (b) The motor would turn if it were turning at the same rate as the AC frequency and if the voltage changed direction when the coil was perpendicular to the field. This would be very unlikely.
26. (a) The two ways are series and parallel.
 (b) A series-wound motor produces a very large turning effect when it is started. This makes this sort of motor usual for trains and trams. Parallel-wound or shunt-wound motors maintain a steady speed with different loads and are used to drive such machines as lathes.

2. He used these to increase the amount of magnetic flux passing through the iron core.
3. (a) $\Phi = B_{\text{perpendicular}} \times A$
 $= 3.0 \text{ T} \times 0.050 \text{ m}^2$
 $= 0.15 \text{ Wb}$
 (b) $\Phi = 0.4 \text{ T} \times 4.5 \text{ cm}^2$
 $= 0.4 \text{ T} \times 4.5 \times 10^{-4} \text{ m}^2$
 $= 1.8 \times 10^{-4} \text{ Wb}$
 (c) $\Phi = 0.025 \text{ T} \times 12 \times 10^{-4} \text{ m}^2 \times 50$
 $= 1.5 \times 10^{-3} \text{ Wb}$



5. Clockwise current to produce a magnetic field into the page
6. (a) Anticlockwise current seen from above
 (b) No
 (c) Yes, clockwise current
7. (a) Anticlockwise current as seen from the left
 (b) Clockwise current produced
8. (a) Yes; as the coil starts to leave the magnetic field an anticlockwise current will be induced in order to produce a magnetic field out of the page.
 (b) Same as (a)
 (c) No, there is no change in flux.
 (d) Same as (c)
9. (a) $A = \pi r^2$
 $= \pi \times (5.0 \times 10^{-2})^2 \text{ m}^2$
 $= 7.895 \times 10^{-3} \text{ m}^2$
 $\Delta\Phi = \Phi_{\text{final}} - \Phi_{\text{initial}}$
 $= 0 - BA$
 $= 0 - 0.40 \times 7.85 \times 10^{-3}$
 $\epsilon = -N \frac{\Delta\Phi}{\Delta t}$
 $= \frac{-1 \times -0.40 \times 7.85 \times 10^{-3}}{0.2}$
 $= 0.016 \text{ V}$
 (b) $\Delta\Phi = 35 - 60$
 $= -25 \text{ Wb}$
 $\epsilon = -N \frac{\Delta\Phi}{\Delta t}$
 $= -1 \times \frac{-25}{1.5}$
 $= 17 \text{ V}$
 (c) $\Delta\Phi = -35 - 60$
 $= -95 \text{ Wb}$
 $e = -N \frac{\Delta\Phi}{\Delta t}$
 $= -1 \times \frac{-95}{2.5}$
 $= 38 \text{ V}$

Chapter 13

Generating electricity

1. Magnetic flux is the amount of magnetic field passing through an area.

10. (a) Circumference of loop = 10 cm

$$r = \frac{C}{2\pi} = 1.59 \text{ cm}$$

$$\Delta\Phi = -0.60 \text{ T} \times (\pi \times 0.0159^2) \text{ m}^2$$

$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$= -1 \times \frac{-0.60 \times \pi \times 0.0159^2}{0.3}$$

$$= 1.59 \times 10^{-3} \text{ V}$$

$$I = \frac{\varepsilon}{R}$$

$$= \frac{1.59 \times 10^{-3}}{0.4}$$

$$= 0.004 \text{ A}$$

- (b) $\Delta\Phi = -1.0 \text{ T} \times (0.26 \text{ m})^2$

$$= 0.0676 \text{ Wb}$$

$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$= -1 \times \frac{0.0676}{0.5}$$

$$= -0.1352$$

$$I = \frac{\varepsilon}{R}$$

$$= \frac{0.1352}{2.5}$$

$$= 0.054 \text{ A}$$

- (c) $\Delta A = \pi(0.04)^2 - \pi(0.08)^2$

$$= 1.51 \times 10^{-2} \text{ m}^2$$

$$\Delta\Phi = 2.0 \times 1.51 \times 10^{-2} \text{ Wb}$$

$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$= -1 \times \frac{2.0 \times 1.51 \times 10^{-2}}{0.8}$$

$$= -0.03775 \text{ V}$$

$$I = \frac{\varepsilon}{R}$$

$$= \frac{0.03775}{0.2}$$

$$= 0.19 \text{ A}$$

11. (a) $f = 50 \text{ Hz}$

$$T = 0.02 \text{ s}$$

Time for a quarter of a turn = 0.005

$$\Phi_{\text{initial}} = 0$$

$$\Phi_{\text{final}} = 2.5 \text{ T} \times 0.04^2$$

$$= 0.10 \text{ Wb}$$

$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$= -100 \times \frac{0.10}{0.005}$$

$$= 2000 \text{ V}$$

- (b) $\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$

$$\Phi_{\text{initial}} = 0$$

$$\Phi_{\text{final}} = 0$$

$$\Rightarrow \Delta\Phi = 0$$

$$\Rightarrow \varepsilon = 0$$

12. The rotating coil of the motor is in the magnetic field and so produces an induced EMF. If the motor is connected to a battery, this induced EMF will oppose the battery and is called a back EMF. If the motor is disconnected from the battery and forced to turn, an alternating EMF will be produced which will be rectified by the commutator.

13. (a) Simplify the induced EMF equation to:

$$\varepsilon = \frac{BA}{\Delta t}, \text{ rearranging } B = \frac{\varepsilon \Delta t}{A},$$

$$\text{so tesla} = \frac{\text{volt} \times \text{sec}}{\text{metre}^2}$$

- (b) Voltage = Current \times Resistance ($V = IR$), and

$$\text{Current} = \frac{\text{Charge}}{\text{Time}} \left(I = \frac{Q}{\Delta t} \right), \text{ so } \varepsilon = \frac{QR}{\Delta t}.$$

Substituting into the expression from

$$B = \frac{QR\Delta t}{\Delta t \times A} = \frac{QR}{A}, \text{ so tesla} = \frac{\text{coulomb} \times \text{ohm}}{\text{metre}^2}$$

- (c) Magnetic flux = Magnetic field \times Area ($\Phi = BA$)

$$\Phi = BA = \frac{QR}{A} \times A = QR, \text{ so weber} = \text{coulomb} \times \text{ohm}.$$

14. (a) $v = 6000 \text{ m s}^{-1}$ $t = 1.0 \text{ s}$

$$\text{distance} = vt$$

$$= 6000 \text{ m}$$

- (b) Area = $L \times W$
 $= 6000 \text{ m} \times 5000 \text{ m}$
 $= 3.0 \times 10^7 \text{ m}^2$

- (c) $\Delta\Phi = BA$
 $= 0.1 \times 10^{-3} \text{ T} \times 3.0 \times 10^7$
 $= 3000 \text{ Wb}$

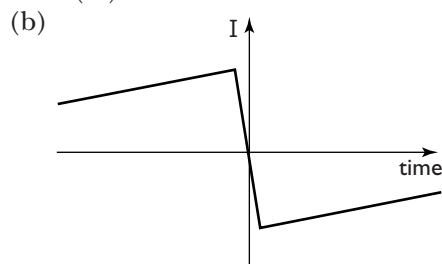
$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$= -1 \times \frac{3000}{1}$$

$$= -3000 \text{ V}$$

$$\varepsilon \text{ (magnitude)} = 3000 \text{ V}$$

15. (a) (i) Anticlockwise from above
 (ii) Zero current
 (iii) Clockwise current from above



- (c) The loss in gravitational potential energy as the magnet fell was not fully converted into kinetic energy — some went into electrical energy. The magnet fell slower than it would have without the coil.
- (d) The change in magnetic flux is zero, so the two areas under the graph cancel each other out.
- (e) If the magnet is accelerating, the current below the coil, where it is travelling faster, will produce a larger current, but for a shorter time.

$$16. \quad \varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$\Rightarrow IR = \frac{\Delta\Phi}{\Delta t} \text{ (magnitude only)}$$

$$\Rightarrow \frac{Q}{\Delta t} R = \frac{\Delta\Phi}{\Delta t} \text{ where } Q = \text{charge}$$

$$\Rightarrow Q = \frac{\Delta\Phi}{R}$$

$$= \frac{3.0 \text{ T} \times 1.6 \times 10^{-3} \text{ m}^2}{0.2 \Omega}$$

$$= 0.024 \text{ C}$$

17. The loss in gravitational potential energy as the metal rod fell was not fully converted into kinetic energy. Some of it was converted into electrical potential energy of the separated charges.

18. The falling magnet induces circular currents in the metal tube whose magnetic fields produce repulsion from below and attraction from above. This is an effective air resistance as the size of the induced currents depends on the speed of the falling magnet — a condition for terminal velocity.

19. (a) As the rod falls through the magnetic field, the falling electrons are pushed to the left end of the rod, making the right end positive. This establishes a difference in voltage between the ends. The rod will continue to fall, gaining speed. The electrons will have a greater vertical speed and will experience a greater sideways force. This will make the difference in voltage greater. As long as the rod accelerates, the voltage difference will increase.

(b) This process differs from the charging of a capacitor in that the force needed to separate the charges is from within the rod, rather than from an external battery, and the voltage difference will continue to increase as the rod speeds up until the rod reaches a terminal velocity. The rate at which the voltage increases will also depend on the acceleration and is likely to be constant. In a capacitor, the initial increase is rapid, followed by a levelling off.

20. In both cases, there is an induced EMF; however, plastic is an insulator, so the electrons are not free to move as in the case of a conductor. In the wire there is a current, but there is no current in the plastic.

21. If the approaching north end of the magnet to a coil produced a magnetic field with the south end towards the magnet, the magnet would be attracted and speed up, and so induce an even stronger field whose south end would make the magnet travel even faster. Thus, kinetic energy would be created from nothing.

22. (a) The faster the motor is turning, the quicker the coil is cutting the magnetic field in the motor, so the larger the back EMF.

(b) At slow speeds there is a small back EMF, so the current will be higher than when the motor is spinning faster.

(c) The low resistance of the coils will produce a very large current which will overheat the motor.

23. Distance covered by axle in one second

$$= vt$$

$$= 120 \text{ km h}^{-1} \times 1 \text{ s}$$

$$= \frac{120}{3.6}$$

$$= 33.33 \text{ m}$$

$$\text{Area covered} = L \times W$$

$$= 33.33 \times 1.5$$

$$= 50 \text{ m}^2$$

$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$$

$$= -1 \times \frac{40 \times 10^{-6} \text{ T} \times 50 \text{ m}^2}{1}$$

$$= 2.0 \times 10^{-3} \text{ V}$$

Chapter 14

Transmission of power

$$1. \quad \frac{V_{\text{sec}}}{V_{\text{prim}}} = \frac{N_{\text{sec}}}{N_{\text{prim}}}$$

$$\Rightarrow V_{\text{sec}} = \frac{2000}{100} \times 240$$

$$= 4800 \text{ V}$$

$$2. \text{ (a) } V_{\text{sec}} = \frac{N_{\text{sec}}}{N_{\text{prim}}} \times V_{\text{prim}}$$

$$= \frac{6}{300} \times 240$$

$$= 4.8 \text{ V}$$

$$\text{(b) } V_{\text{prim}} = \frac{N_{\text{prim}}}{N_{\text{sec}}} \times V_{\text{sec}}$$

$$= \frac{300}{6} \times 9$$

$$= 450 \text{ V}$$

$$3. \text{ (a) } N_{\text{prim}} = \frac{V_{\text{prim}}}{V_{\text{sec}}} \times N_{\text{sec}}$$

$$= \frac{240}{12} \times 50$$

$$= 1000 \text{ turns}$$

$$\text{(b) } I = \frac{P}{V}$$

$$= \frac{20 \times 5}{12}$$

$$= 8.3 \text{ A}$$

$$\text{(c) } P_{\text{prim}} = V_{\text{prim}} I_{\text{prim}} = 20 \times 5 \text{ W}$$

$$I_{\text{prim}} = \frac{20 \times 5}{240}$$

$$= 0.42 \text{ A}$$

$$4. \quad V_p = 240 \text{ V}_{\text{RMS}}$$

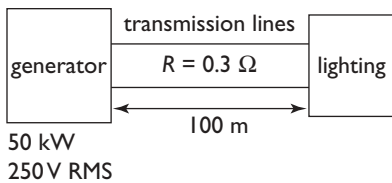
$$V_s = 6 \times 1.5 = 9 \text{ V}$$

$$\frac{N_p}{N_s} = \frac{240}{9}$$

$$= 27:1$$

5. A transformer does not work with constant DC voltage, such as that supplied by a battery or a regulated power supply, because there is no change in the magnetic flux.

6. To enable the direction of the magnetic field to change as quickly as the current changes direction.



7. (a) Voltage across generator = $250 V_{RMS}$

$$I = \frac{P}{V}$$

$$= \frac{50\,000}{250}$$

$$= 200 \text{ A}$$

(b) $P_{\text{loss}} = I^2 R$

$$= (200)^2 \times 0.3$$

$$= 12 \text{ kW}$$

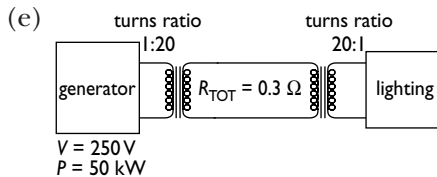
(c) $V = IR$

$$= 200 \times 0.3$$

$$= 60 \text{ V}$$

(d) $V = 250 - 60$

$$= 190 \text{ V}$$



(i) $I = \frac{P}{V}$

$$= \frac{50\,000}{250 \times 20}$$

$$= 10 \text{ A}$$

$$P_{\text{loss}} = I^2 R$$

$$= (10)^2 \times 0.3$$

$$= 30 \text{ W}$$

(ii) $V = IR$

$$= (10)^2 \times 0.3$$

$$= 3.0 \text{ V}$$

(iii) $V = 250 - 3$

$$= 247 \text{ V}$$

8. (a) $R = \frac{V}{I} + \frac{240}{40} = 6.0 \Omega$

(b) $R = 6.0 + 0.2 = 6.2 \Omega$

(c) $V = 6.2 \times 240 = 232 \text{ V}$

- (d) (i) Calculate resistance of workshop:

$$P = VI$$

$$= \frac{V^2}{R}$$

$$\Rightarrow R = \frac{V^2}{P}$$

$$= \frac{(240)^2}{20\,000}$$

$$= 2.88 \Omega$$

Effective resistance of workshop and house (in parallel):

$$\frac{1}{R_{\text{eff}}} = \frac{1}{2.88} + \frac{1}{6.0}$$

$$\Rightarrow R_{\text{eff}} = 1.95 \Omega$$

(ii) Total resistance = $1.95 + 0.20$
= 2.15Ω

$$V = \frac{1.95}{2.15} \times 240$$

$$= 218 \text{ V}$$

9. RCI devices offer greater protection than a circuit breaker or fuse because they switch off the current with a much smaller change in current. The current is switched off much more quickly than with a circuit breaker or fuse.