25 Magnetism and Electromagnetism

1. A magnetic substance is one which can be magnetised. One naturally occurring substance is magnetite, Fe_3O_4.

2. A magnetic pole is permanent while an induced magnetic pole is temporary.

3. Suspend both rods so they can move freely. Bring one end of a permanent magnet near one end of each rod. Next bring the other end of the magnet near the same end of each rod. The rod which is a magnet would be attracted to one end of the magnet and repelled from the other. The other rod would be attracted in both cases.

4. Different types of magnetic substances are affected differently by magnetic fields. Some, such as pure iron make induced (temporary) magnets while others such as steel make permanent magnets. Permanent magnets made from rare earth alloys retain their full magnetic strength almost indefinately while alloys such as alnico do not.

5. Research into magnetic alloys and supermagnets produces better, more efficient or smaller magnetic components in machines.

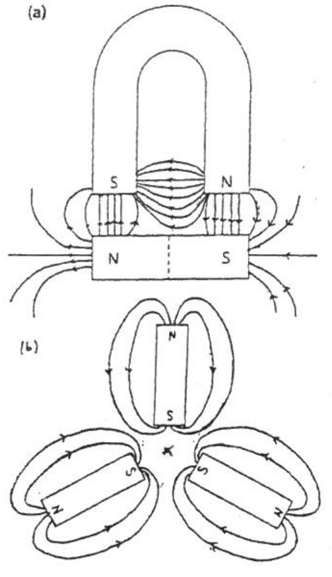
6. Materials such as iron and steel become magnetised by (i) domains which are favourably orientated with the external field enlarging (ii) domains rotating to become more favourably orientated. Note: the reorientation of the domains can be effected by changing the distribution of electrons so the spin of unpaired electrons is favourable to the outside field. NB: Whole particles can move if hot. Audio tapes however have particles of magnetic material embedded in a material which lets them change orientation. Particles of ferrochrome are relatively heavy and thus require a stronger magnetic field to orientate them.

7. The magnetic flux ϕ is the total number of magnetic field lines passing through a region. Magnetic flux is measured in weber, Wb. Magnetic flux density, B, is the magnetic flux per unit area. It is measured in tesla, T

8. $$B = \frac{\phi}{A} = \frac{2.5 \times 10^{-5}\ Wb}{0.15 \times 10^{-2} \times 7.5 \times 10^{-3}\ m^2}$$
$$= 2.2\,T$$

9.

(a)



X = the neutral point where there is no magnetic effect

Angle of INCLINATION: downward dip of compass needle

10. The angle of declination is the angular difference between the Earth's magnetic axis and its spinning geographical axis.

The Van Allen belts are part of Earth's magnetosphere. One belt is made up of captured protons while the other contains captured electrons. The particles come from the solar winds. In times of intense solar particle bombardment the protons and electrons spiral along the earth's magnetic field lines (in opposite directions). Close to the poles, the particles collide with air molecules in the upper atmosphere, causing aurorae.

11. (a) $$B = \frac{kI}{r} = \frac{2 \times 10^{-7} \times 5.5\ N\,m^2\,A}{0.15\ m\,A^2}$$
$$= 7.3 \times 10^{-6}\ T \quad \left(= \frac{N\,m}{A}\right)$$

Direction depends on position.

(b) $$B = \frac{2 \times 10^{-7} \times 25}{0.15} = 33 \times 10^{-6}\ T$$

12. $$B = \frac{2\pi k N I}{L} = \frac{2\pi \times 2 \times 10^{-7} \times 8000 \times 15}{0.2}$$
$$= 0.75\ T$$

13. $$I = \frac{Br}{k} = \frac{1.5 \times 10^{-3} \times 0.01\ \cancel{N\,m}\ A^2}{2 \times 10^{-7}\ \cancel{N\,m}\ A}$$
$$= 75\ A \text{ from A to B}$$

14. Effect of I_1 on P_1 and P_2:
$$B = \frac{kI}{r} = \frac{2 \times 10^{-7} \times 12}{0.04}$$
$$= \underline{0.6 \times 10^{-4}\ T \text{ Down}} \text{ on } P_1 \text{ and } P_2$$

Effect of I_2 on P_1 and P_2:
$$B = \frac{kI}{r} = \frac{2 \times 10^{-7} \times 15}{0.03} = \frac{1 \times 10^{-4}\ T}{\text{UP }(P_1)\quad \text{DOWN }(P_2)}$$

Total effect: $P_1 = (0.6\downarrow + 1.0\uparrow) \times 10^{-4} = \underline{0.4 \times 10^{-4}\ T \uparrow}$

$P_2 = (0.6\downarrow + 1.0\downarrow) \times 10^{-4} = 1.6 \times 10^{-4}\ T \downarrow$

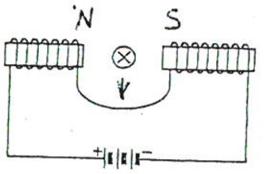
15. $I = 8A$
$B = 1.5 \times 10^{-3}$ T
$L = 1.2 \times 10^{-2}$ m

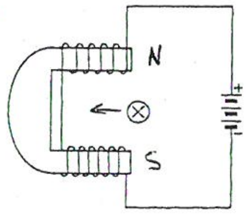
$F = BIL = 1.5 \times 10^{-3} \times 8 \times 1.2 \times 10^{-2}$
$= 1.4 \times 10^{-4}$ N to the right

16. $L = 0.085$ m
$I = 25$ A
$B = 0.025$ T
$F = BIL = 2.5 \times 10^{-2} \times 25 \times 0.10$
$= 5 \times 10^{-2}$ N up the page

17. (a) Right hand grip rule tells us that to the left of the wire is N and to the right is S. Magnetic field therefore travels from L to R and current is flowing into the page. The RH motor rule tells us that the wire will move DOWNWARDS

(b) The RH grip rule tells us that above the wire is a North pole while below it is a South pole. The RH motor rule predicts movement of the wire to the left.

(a)


(b)


18. (a) The RH motor rule predicts that the wire BA will move down and CD will move up.

(b) The commutator ensures that electric current in the coil reverses twice each revolution. This makes sure the coil keeps spinning in the same direction.

(c) $F = BIL = 0.35 \times 10.5 \times 0.05$
$= 0.18375$ N ≈ 0.18 N

(length of wire is 0.07 but field is 0.05 m wide)

19. (a) $F = Bqv$
$= 0.35 \times 3.0 \times 10^{-19} \times 0.001 \times 3 \times 10^{8}$
$\approx 3.2 \times 10^{-14}$ N

NB $c = 3 \times 10^{8}$ m/s

(b) $F = ma \quad \therefore \quad a = \frac{F}{m}$
$a = \frac{3.2 \times 10^{-14}}{5.65 \times 10^{-27}} = 5.6 \times 10^{12}$ ms^{-2}

20 (a) The RH motor rule predicts that
X is +ve
Y is +ve
Z is -ve

(b) $r = \frac{mv}{qB}$

Since we are told that q, v and B are the same for each particle then $r \propto m$. That is, the larger the value of m, the larger the radius of curvature:
$\therefore$ Y is the heaviest
X is the lightest.

21 Darwin is closest to the equator and has the smallest value of B and smallest angle of dip. I have assumed a linear relationship between value of magnetic field strength and latitude.

This seems a fair assumption. On my globe the difference in latitude between Perth and Darwin is twice that of Perth to Hobart. The change in magnetic field strength between Perth and Darwin is also roughly twice that of the change from Perth to Hobart.

Using this relationship I have estimated Brisbane (above Perth) to be 5.5×10^{-6} T and Melbourne (below Perth the same amount as Brisbane is above) to be 6.3×10^{-6} T.

Differences in the structure and density of underlying rocks and differences in height above sea level would affect these estimates.

The magma does not have an even pattern. Some parts of earth have little or no field, or even a reversal of field eg Rio de Janero

22. Constantly rummageing around for videos/audio cassettes bumps them. This hitting can re-align the domains and affect tape quality. Arrange them so you can easily see the one you want. A steel box would protect them from Earth's field.

23. $B = \frac{\phi}{A} \qquad \phi = B \times A$
$= 5.0 \times 10^{-4} \times .15 \times .125$
$= 9.4 \times 10^{-6}$ wb

24. Using the RH grip rule:
(a) A North B South
(b) A North B South
(c) A and B are not magnetised. The wire carrying I in is close to the one taking I out.

25. $F = \frac{K I_1 I_2 L}{d} = \frac{2 \times 10^{-7} \times 2.5 \times 3.5 \times 1m}{0.015}$ (1 m gives F for each metre)
$= 1.2 \times 10^{-4}$ N per m attraction

33 (a) Use the Right Hand Motor Rule. Remember that CONVENTIONAL current is opposite in direction to electron flow.
Answer: magnetic field is into the page

(b) $E_K = qV$ ← charge on 1 electron

$= 1.6 \times 10^{-19}\ C \times 200\ JC^{-1}$

$= \underline{3.2 \times 10^{-17}\ J}$

(c) Force on a charged particle in a magnetic field:

$F = Bqv$

Centripetal force:

$F_c = \frac{mv^2}{r}$

$F = F_c$

$\therefore Bqv = \frac{mv^2}{r}$

$\therefore r = \frac{mv^2}{Bqv} = \frac{mv}{Bq}$

$r = \frac{mv}{qB}$

(d) $\therefore m = \frac{rqB}{v}$ ——————— (i)

From above:

$Bqv = \frac{mv^2}{r}$ ——————— (ii)

From (b):

$E_K = qV = \frac{1}{2}mv^2$

$\therefore mv^2 = 2qV$ ——————— (iii)

substitute $2qV$ for mv^2 in (ii)

$\therefore Bqv = \frac{2qV}{r}$

$\therefore v = \frac{2qV}{r} \times \frac{1}{Bq}$

$\therefore v = \frac{2V}{Br}$

Substitute $\frac{2V}{Br}$ for v in (i):

$\therefore m = \frac{rqB}{1} \times \frac{Br}{2V}$

$\therefore m = \frac{qB^2r^2}{2V}$

If $B = 0.02\ T$ and $r = 2.5 \times 10^{-3}\ m$

$m = \frac{1.6 \times 10^{-19} \times (0.02)^2 \times (2.5 \times 10^{-3})^2}{2 \times 200}$

$= \underline{1.0 \times 10^{-30}\ kg}$

34 $F = BIL$ $F = 1 \times 10^{-3} \times 9.8\ N$

$\therefore I = \frac{F}{BL}$ $B = 0.2\ T$

$L = 5 \times 10^{-2}\ m$

$= \frac{1.0 \times 10^{-3} \times 9.8\ N}{0.2 \times 5 \times 10^{-2}\ Tm}$

$= \underline{0.98\ A}$ from Y to X

36 (a) The particles bent most will be those with the greatest charge. For particles with the same charge, the lighter particles will bend more.

Arranging the ions from the lighter, more charged particles to the heavier, least charged particles will give the spectrum shown. That is:

	a	b	c	d
Mass no. → / Atomic no. →	${}^{3}_{2}He^{+2}$	${}^{4}_{2}He^{+2}$	${}^{3}_{2}He^{+1}$	${}^{4}_{2}He^{+1}$
$\frac{m}{e}$ ratio	$\frac{3}{2}$	$\frac{4}{2}$	$\frac{3}{1}$	$\frac{4}{1}$

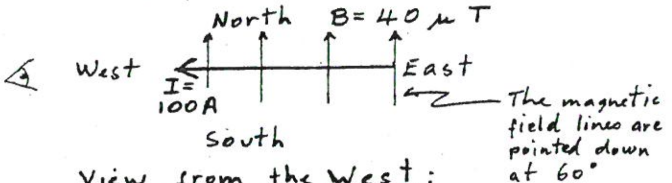
(b) The ions arranged as above from lighter, more charged to heavier, less charged:

${}^{200}_{80}Hg^{+2}$ ${}^{204}_{80}Hg^{+2}$ ${}^{200}_{80}Hg^{+}$ ${}^{204}_{80}Hg^{+}$ Hg_2^{+} Hg_2^{+} Hg_2^{+}

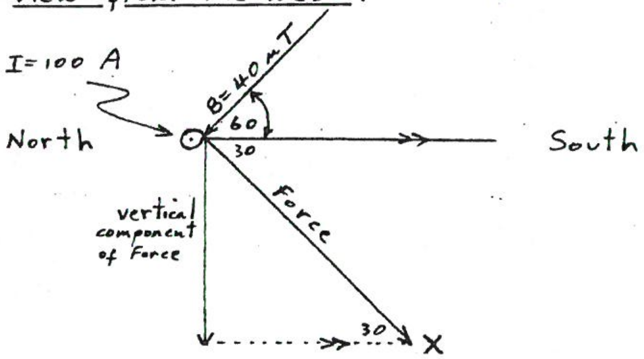
Possible make up of Hg_2^{+}:
- ${}^{200}_{80}Hg$ with ${}^{200}_{80}Hg$
- ${}^{200}_{80}Hg$ with ${}^{204}_{80}Hg$
- ${}^{204}_{80}Hg$ with ${}^{204}_{80}Hg$

26.

View from above:



View from the West:



Force on 10 m of power line (This force is in direction X) = $BIL \sin\theta$

Earth's field is 60° to horizontal but 90° power line

$= 40\mu T \times 100\,A \times 10\,m \sin 90°$

$= 4 \times 10^{-2}$ N

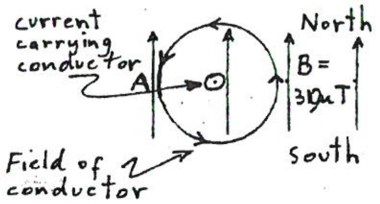
Vertical component of Force [NOT ASKED FOR IN QUESTION] $= 4 \times 10^{-2} \sin 30$

$= 2 \times 10^{-2}$ N downwards

27.

At point "A":

Earth's field = – Field around wire



$\therefore 30\mu T = \frac{KI}{r}$

$\therefore I = \frac{30 \times 10^{-6} T \times r}{K} = \frac{30 \times 10^{-6} \times 0.050}{2 \times 10^{-7}}$

$= 7.5$ A

Direction:

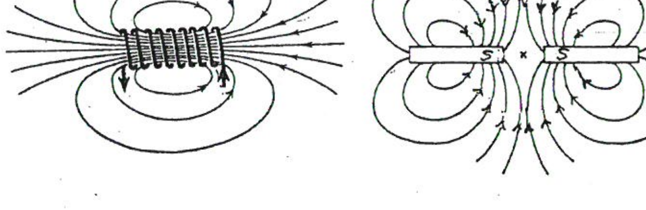
A current from East to West and from West to East will give a net field strength of zero 5.2 cm from the wire.

28

$B = \frac{\pi K I}{r} \times 10$ (no. of turns) $= \frac{\pi \times 2 \times 10^{-7} \times 10}{0.05}$

$\approx 1.3 \times 10^{-4}$ T into page

29.



For horseshoe magnet: see p 522

30. A moving coil loudspeaker uses a movable coil attatched to a paper cone. The coil is placed in the magnetic field of a permanent magnet. The amplifyer supplies current to the coil. The current varies according to the sound fed into the microphone. This current produces movement in the coil which, in turn vibrates the paper cone, producing sound.

This loudspeaker can be used in reverse as a moving coil microphone.

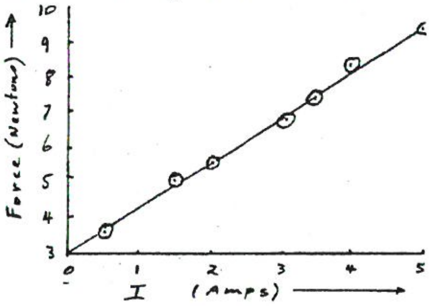
31. Assume overhead wires are 4 m above you

$\therefore B = \frac{KI}{r} = \frac{2 \times 10^{-7} \times 500}{4}$

$= 2.5 \times 10^{-5}$ T

This is too small to interfere with the watch

32.



(a) From the graph: When $I = 0$, the force down on the spring balance is due to the weight. Theirfore wt. of coil = 3.0 N

(b) Magnetic field strength can be calculated two ways. Try both:

(i) From the formula

$F = BIL$

(5.6, 2.0) Substitute 3rd data pt:

$F = 2.6$ N (5.6 – 3)

$I = 2.0$ A

$L = 100 \times 0.1$

(10 cm is in the field. There are 100 turns)

$\therefore B = \frac{F}{IL}$

$= \frac{2.6 N}{2.0 A \times 100 \times .1m}$

$= 0.13$ T

Note: To get a good answer by this method you have to select a "good" data point, by luck (or insight) for example substitute the 1st data point (3.5, 0.5).

(ii) From the graph

$y = mx + c$

$F = B \times L \times I$

$\therefore m = B \times L = B \times 10m$

$(L = 100 \times 0.1 m)$

$\therefore \frac{\Delta y}{\Delta x} = \frac{9.5 - 3.5}{5.0 - 0.5}$

$\therefore \frac{6N}{4.5A} = B \times 10m$

$\therefore B = \frac{6}{4.5} \times \frac{1}{10} \frac{N}{Am}$

$= 0.13$ T

(c) The magnetic field moves from L → R, Force is downwards. Therefore current must be anticlockwise if you are looking from S

(d) For the balance to read zero, force must be upwards. Current must be clockwise

$\therefore F = $ weight of coil $= 3\,N = BIL$

$\therefore I = \frac{3N}{B \times L} = \frac{3N}{0.13 T \times 10m}$ $\left(= \frac{N\,Am}{N\,m}\right)$

$= 2.3$ A

PTO.