Magnetism and Matter

1a) The three independent quantities used to specify earth's magnetic field are :-

i) magnetic declination ii) angle of dip
iii) horizontal components of earth's magnetic field.

b) Britain is closer to magnetic north pole. So, the angle of dip is greater in Britain in India. It is about 70° in Britain

c) Magnetic lines of force of earth's magnetism will seem to come out the ground at melbourne. in Australia because this region lies in southern hemisphere of earth's magnetic north pole

d) Earths magnetic field is exactly vertical at the poles ~~at~~ and so horizontal components of earth's field is zero which makes the compass needles point in any direction at the geomagnetic north / south pole

e) Magnetic field $\vec{B}$ at an equatorial point of earth's magnetic dipole is given by $B = \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3}$

Now $m = 8 \times 10^{22}\ JT^{-1}$. $R = 6.4 \times 10^6 m$

$$B = \frac{10^{-7} \times 8 \times 10^{22}}{(6.4 \times 10^6)^3} = 0.3 \times 10^{-4} T = 0.3G$$

f) The earths field is only approximately a dipole field. N-S poles may arise due to the different deposits of magnetised minerals

2a) Yes It does change with time. Time scale appreciable change is roughly a few hundred years. But even on much smaller scale of a few years. its variation are not completely negligible

b) The temperature of earth's core is very high. So Iron exist as molten state being at a temp. higher than curie point is not ferromagnetic

c) Radioactivity may be one of possible sources for charged current in the outer conducting regions of the earth's core. which are thought to be responsible for earths magnetism

d) Earth's magnetic field get recorded weakly in certain rocks during them solidification

e) At large distences the field gets modified due to field of Ions in motion The field of these ions in turn is sensitive to extraterestial disturbance such as solar winds

f) when a charged particle moves in a magnetic field it get deflected along a circular path of radius.

$$R = \frac{mv}{eB} \quad \left[\because evB = \frac{mv^2}{R} \right]$$

3) Here $\theta = 30^\circ$, $B = 0.25T$, $\tau = 4.5 \times 10^{-2} J$ $m = ?$

$\tau = mB\sin\theta$

$$m = \frac{\tau}{B\sin\theta} = \frac{4.5 \times 10^{-2}}{0.25 \times \sin 30^\circ} = 0.36 J T^{-1}$$

4) Here $m = 0.32 J T^{-1}$, $B = 0.15 T$

i) The bar will be in a stable equilibrium when its magnetic moment $\vec{m}$ is parallel to $\vec{B}$ $(\theta = 0^\circ)$. Its potential is minimum is given by $U_{min} = -mB\cos 0^\circ = -0.32 \times 0.15 \times 1$

$$= -4.8 \times 10^{-2} J$$

The bar will be in unstable equilibrium when its magnetic moment $\vec{m}$ is antiparallel to $\vec{B}$ ($\theta = 180^\circ$) its potential energy is maximum and is given by

$U_{max} = -mB\cos 180^\circ = -0.32 \times 0.15 \times (-1)$

$= + 4.8 \times 10^{-2}$ J

5) Here N = 800, $A = 2.5 \times 10^{-4}$ m², I = 3.0 A

$m = NIA = 800 \times 3 \times 2.5 \times 10^{-4} = 0.60$ J T^{-1}

6) Here, $m = 0.60$ J T^{-1}, $B = 0.25$ T, $\theta = 30^\circ$

$\tau = mB\sin\theta = 0.60 \times 0.25 \times \sin 30 = 7.5 \times 10^{-2}$ J T^{-1}

7) $m = 1.5$ J T^{-1}, $B = 0.22$ T

i) Given $\theta_1 = 0^\circ$, $\theta = 90^\circ$

$\therefore W = -mB(\cos\theta_2 - \cos\theta_1)$

$= -1.5 \times 0.22(\cos 90^\circ - \cos 0^\circ)$

$= 0.33 \times (0-1) = + 0.33$ J

Torque ~~R~~ $\tau = mB\sin 90^\circ = 1.5 \times 0.22 \times 1 = 0.33$ N m

(ii) Given $\theta_1 = 0^\circ$, $\theta_2 = 180^\circ$

$W = -1.5 \times 0.22 \times \cos(180^\circ - \cos 0^\circ)$

$= -0.33 \times (-1-1) = 0.66$ J

Torque = $\tau = mB\sin 180^\circ = 1.5 \times 0.22 \times 0 = 0$

8) Here N = 200, $A = 1.6 \times 10^{-4}$ m², I = 4.0 A

a) Magnetic moment of solenoid of turns N area of cross section and carrying current I is

$m = NIA = 2000 \times 4.0 \times 1.6 \times 10^{-4}$ Am²

$= 1.28$ Am²

This magnetic moment acts along the axis of the solenoid in a direction related to sense of current via the right hand screw rule

b) Net force experienced by the magnetic dipole in uniform magnetic field = 0

The magnitude of torque τ exerted by the magnetic field $\vec{B}$ on the solenoid. is given by

$$\tau = mB\sin\theta = 1.28 \times 7.5 \times 10^{-2} \times \sin 30^\circ = 0.048\,Nm$$

This torque align the axis of solenoid along the field $\vec{B}$

9) Here $N = 16$, $r = 10\,cm$, $0.10\,m$, $I = 0.75\,A$.

$B = 5.0 \times 10^{-2}\,T$, $\nu = 2.0\,s^{-1}$

Magnetic moment of coil is $m = NIA = NI\,\pi r^2$

Frequency of oscillation $\nu = \frac{1}{2\pi}\sqrt{\frac{mB}{I}}$

$\therefore$ Moment of inertia

$$I = \frac{mB}{4\pi^2\nu^2} = \frac{NI\pi r^2 \cdot B}{4\pi^2\nu^2} = \frac{16 \times 0.75 \times (0.1)^2 \times 5 \times 10^{-2}}{4 \times 3.14 \times 4}$$

$$= 1.2 \times 10^{-4}\,kgm^2$$

10) Here $\delta = 22^\circ$, $B_H = 0.35\,G$, $B = ?$

$$B = \frac{B_H}{\cos\delta} = \frac{0.35\,G}{\cos 22^\circ} = \frac{0.35\,G}{7.272} = 0.38\,G$$

11) $B_H = 0.16\,G$ $\quad \delta = 60^\circ$

$$B = \frac{B_H}{\cos\delta} = \frac{0.16}{\cos 60^\circ} = \frac{0.16}{1/2} = 0.32\,G.$$

Thus earths magnetic field has a magnitude of $0.32\,G$ and lies in a vertical plan 12° west of the geographic meridian making an angle 60° (upwards)

13) As the null points lie on the x-axis of magnet, therefore

$B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{3m}{r^3} = B_H$

Magnetic field of the magnet on its normal bisector at the same distance will be

$B_{equa} = \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3} = \frac{B_H}{2} = \frac{0.36}{2} = 0.18G.$

∴ Total magnetic field at the required point on normal bisector is $B_{equa} + B_H = 0.18 + 0.36 = 0.54G.$

18) Suppose the neutral point lies at a distance r from the cable. Then at the neutral point

$\frac{\mu_0 I}{2\pi r} = B_H$ $\quad r = \frac{\mu_0 I}{2\pi B_H} = \frac{4\pi \times 10^{-7} \times 2.5}{2\pi \times 0.33 \times 10^{-4}} = 1.5 \times 10^{-2} m = 1.5cm$

As the direction of the magnetic field of the cable is opposite to that of $\vec{B_H}$ at points above the cable.
So the line of neutral points lies parallel to and above the cable at distance of 1.5cm from it