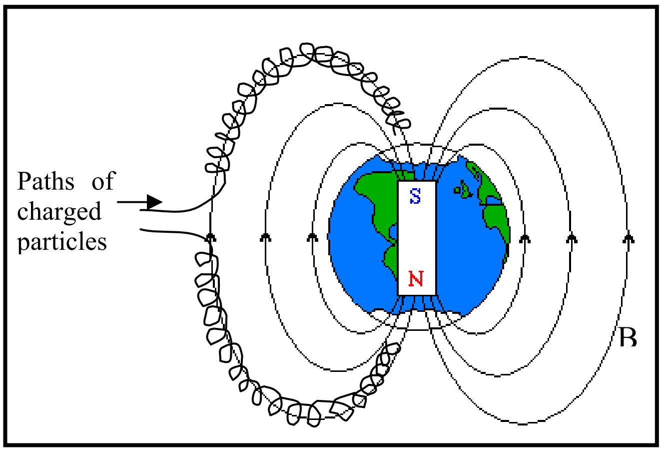
Workshop Tutorials for Biological and Environmental Physics

Solutions to ER7B: **Magnetic Fields**

A. Qualitative Questions:

1. The Earth's magnetic field.

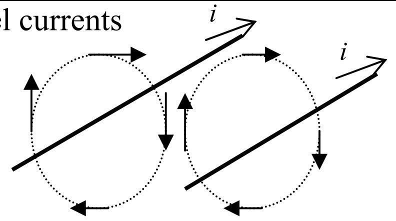
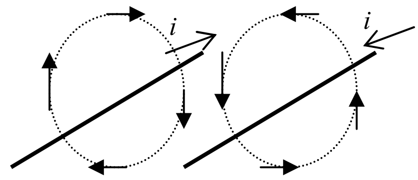
a. and **b** See diagram.



c. The auroras are caused by charged particles entering the Earth's magnetic field where they follow helical paths along the field lines either north or south. The light observed as auroras is due to ionization of atoms in the atmosphere when they collide with high speed charged particles. The free electrons resulting from the collisions recombine with ionised atoms, losing energy in the process which is emitted as light of the auroras.

d. Near the poles the field lines are denser, hence the field is stronger. Charged particles tend to become trapped in these regions, hence they are more likely to interact with air here and produce the auroras. *See anything strange about this picture?* The Earth's North Pole, at the top, is actually the south pole of Earth's magnetic dipole! The north pole of a compass needle is attracted to the geographical North Pole.

2. Magnetic fields from electric blankets.

a. parallel currents	opposite currents.
	
Fields reinforce each other above and below the blanket, and cancel between the wires.	Fields tend to cancel each other above and below the blanket, and reinforce between the wires.

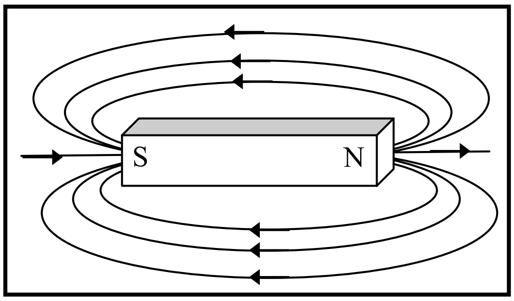
b. The wiring on the right gives a lower magnetic field above (and below) the blanket.

B. Activity Questions:

1. Magnets and magnetic fields

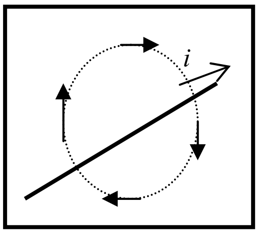
Magnetic field lines start at north poles and end at south poles.

The Earth's magnetic field is like that of a bar magnet, but the Earth's North Pole is in fact a magnetic *south* pole.



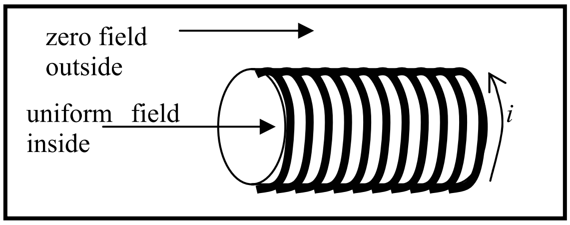
2. Magnetic field around a current carrying wire

The magnetic field lines are circles around the wire. If you point your right thumb in the direction of the current your fingers will curl in the direction of the magnetic field. When the direction of the current is reversed the direction of the magnetic field is also reversed.



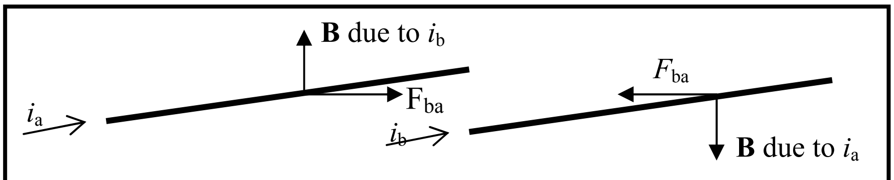
3. Solenoid

The field inside the solenoid is approximately uniform, while that outside the solenoid is approximately zero. If the solenoid was infinitely long the field outside would be exactly zero.



4. The magnetic force - pinch effect

When the currents are in the same direction the wires attract each other. The wires can be made to repel by reversing the direction of the current in one wire.



D. Quantitative Question:

1. Acceleration of ions in the blood due to the heart's magnetic field.

a. The maximum possible acceleration will occur when the ion is moving at right angles to the magnetic field as this is when the maximum force occurs.

The acceleration $a = F/m = qvB\sin\theta/m = \dfrac{1.6\times10^{-19}\text{C}\times0.52\text{m.s}^{-1}\times5.5\text{T}\times\sin90^{\circ}}{61\times1.67\times10^{-27}\text{kg}} = 0.045\times10^{-3}\ \text{m.s}^{-2}$.

This is 0.045 mm.s^{-2}, which is small, but enough to accelerate the ions from one side of a blood vessel to the other in a short time.

b. The minimum acceleration will be zero which occurs when the ion moves parallel to the magnetic field. From part **a**, $a = qvB\sin 0^{\circ}/m = 0$.

2. The magnitude of the magnetic field, B, inside a solenoid is given by $B = \mu_0 ni$, where n is the number of turns (N) divided by the length (a) of the solenoid ($n = N/a$). The length (L) of wire needed is the number of turns (N) multiplied by the circumference of one turn: πd where d is the diameter of the solenoid. Putting these together we find that N drops out and we get:

$$L = \frac{\pi d.Ba}{\mu_0 I} = \frac{\pi\times0.51\ \text{m}\times0.015\ \text{T}\times0.23\ \text{m}}{4\pi\times10^{-7}\text{T.m.A}^{-1}\times1.5\ \text{A}} = 3\ \text{km}$$