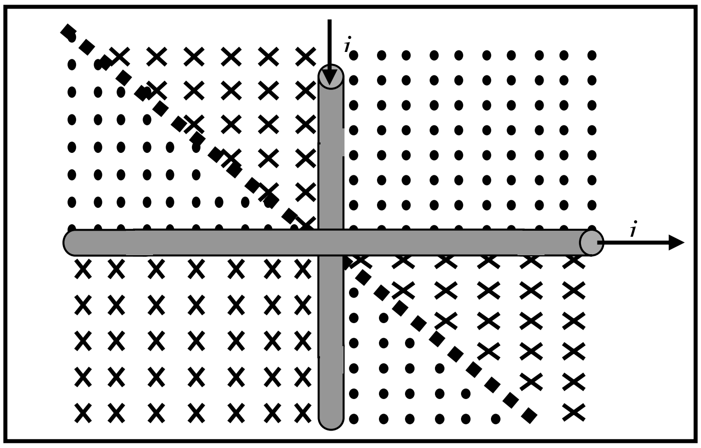
Workshop Tutorials for Technological and Applied Physics

# Solutions to ER7T: **Magnetic Fields**

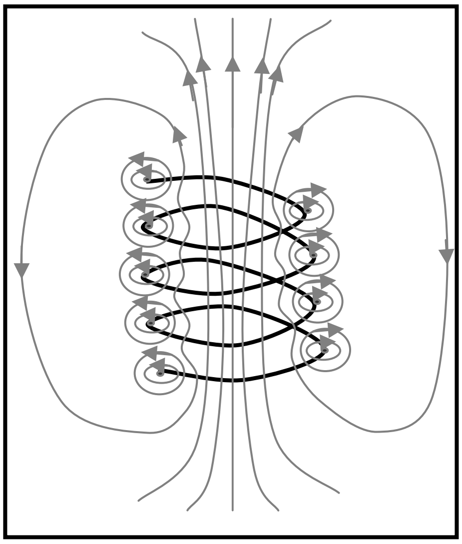
## A. Qualitative Questions:




**1.** Current carrying wires and magnetic fields.

**a.** See diagram opposite. Dots show field out of the page, × is field into the page. Along the thick dotted line the fields will cancel and there will be no net field.

**b.** If the wires were free to move they would both rotate and settle along the diagonal with parallel currents. Any small movement which moves the wires away from being completely perpendicular will result in the wires being either attracted to each other or repelled.



**2.** Oscillator circuits often made using capacitors and inductors

**a.** The energy is stored in the capacitor by virtue of the electric field between the plates which arises from the separated charges stored on them. The energy can be thought of as being stored in the electric field.

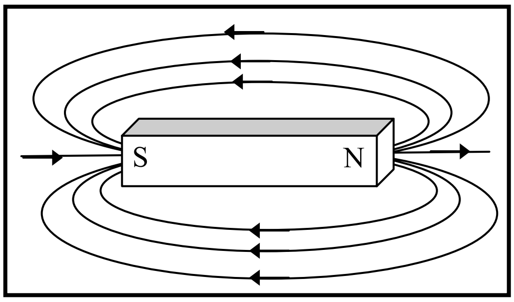
**b.** The energy is stored in the inductor by virtue of the magnetic field caused by the current flowing through the inductor. The energy can be thought of as being stored in the magnetic field.

**c.** See diagram opposite.

**d.** Consider a simple ideal circuit containing a capacitor and an inductor, a switch and no resistance. Assume that initially the capacitor is charged and the switch is open. When the switch is closed, current is set up in the inductor as the capacitor discharges. This current produces a magnetic field in and around the inductor.

Since the current is changing the magnetic flux is changing in the inductor and an *emf* which opposes the change is produced. This back *emf* causes a current in the opposite direction, recharging the capacitor. The process then repeats itself, giving an oscillating current. A capacitor and inductor, together with an energy source such as a battery can be connected to drive a small speaker to give a sound at a particular frequency. The frequency will depend on the values of capacitance and inductance in the circuit.

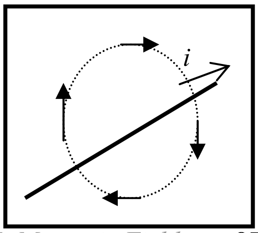
## B. Activity Questions:




### 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.

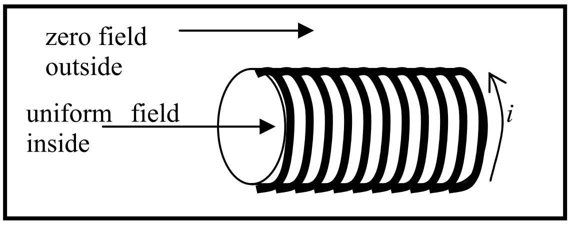



### 2. Magnetic field around a current carrying wire

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.

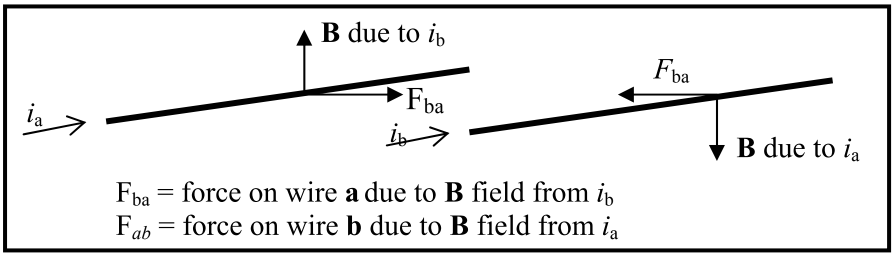
**3. Solenoid**

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.

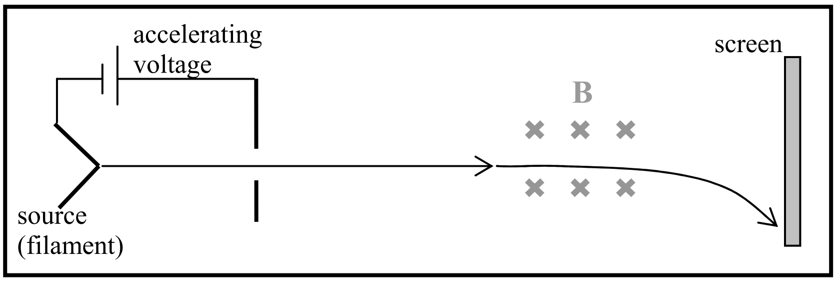



**D. Quantitative Question:**

**1.** An electron in a television set.

**a.** See diagram opposite.

Note that the magnetic field is produced by coils (not shown). The deflection in one direction and sometimes both may be achieved with an electric field rather than a magnetic field.




**b.** The electron gains 1 eV for each volt that it is accelerated through, hence it gains 20 keV as it passes through the accelerating voltage, which is $20\times10^3$ eV $\times 1.6\times10^{-19}$ J.eV$^{-1}$ = $3.2\times10^{-15}$ J

**c.** $KE = \frac{1}{2}mv^2$. Rearrange to get $v = \sqrt{2(\text{K.E}/m)} = \sqrt{2(3.2\times10^{-15}\text{ J} / 9.1\times10^{-31}\text{ kg})} = 8.4\times10^7$ m.s$^{-1}$.

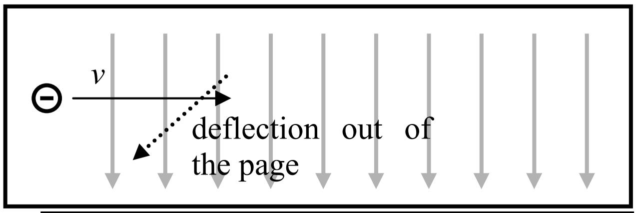
Note that at this speed, $\sim0.3\times c$, relativistic effects should be allowed for. Hence this is an over estimate of the electron's speed.

**d.** The radius of curvature of the path is

$r = mv/qB = 9.1\times10^{-31}$ kg $\times 8.4\times10^7$ m.s$^{-1}$/$1.6\times10^{-19}$C $\times$ 100 mT

$= 4.8\times10^{-3}$ m = 4.8 mm

**e.** See diagram opposite. Note that because the electron is negatively charged the deflection is the opposite way to a positive (conventional) current.




**2.**

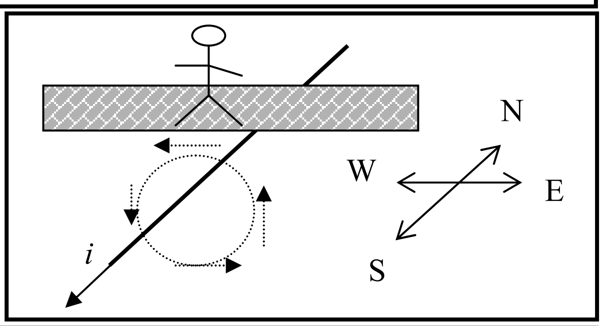
**a.** The direction of the magnetic field is to the west.

It has a magnitude of

$B = \mu_o i/2\pi r$

$= 4\pi\times10^{-7}$ T.m.A$^{-1}$ $\times$ 100A / $2\pi \times 2.0$ m

$= 1.0\times10^{-5}$ T = 10 $\mu$T.




**b.** See diagram opposite. Using vector addition the field at the point where the man is standing is 22 $\mu$T, pointed 63$^o$ west of north. Hence the needle is pointing 27$^o$ away from (magnetic) north, and the platform entrance is likely to be built at an odd angle.