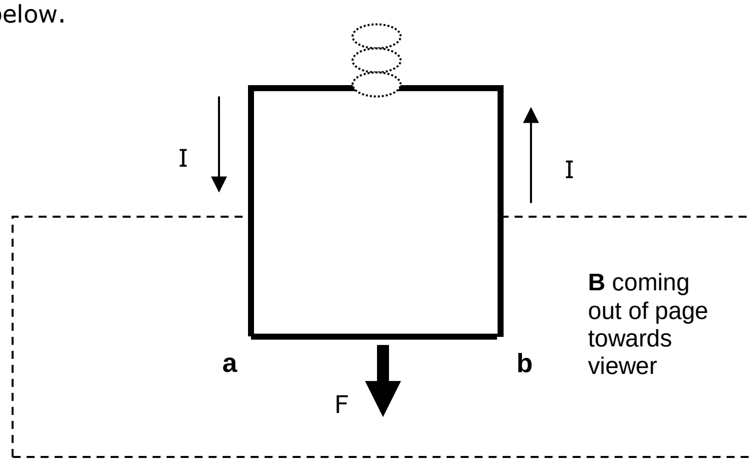
UNL2206, Nature's Threads: Tutorial 5

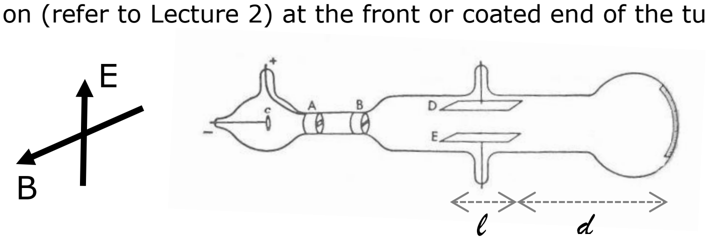
1) **'Weighing' a magnetic field** – a rectangular loop of wire hangs vertically as illustrated below.



A magnetic field **B** is directed horizontally, perpendicular to the wire and points out of the page. The magnetic field **B** is very nearly uniform along the horizontal portion of wire ab (of length 10.0cm) which is near the centre of a large magnet producing the field. The top portion of the wire loop is free of the field. The loop hangs from a balance which measures a downward force (in addition to the gravitational force) of F = 3.48×10^{-2} N when the wire carries a current of I = 0.245 A. What is the magnitude of the magnetic field B at the centre of the magnet?

2) How could you tell whether moving electrons in a certain region of space are being deflected by an electric field or by a magnetic field (or by both)?

3) J.J. Thomson's discovery of the electron in 1897 utilised a 'cathode-ray' tube (as illustrated below) in which an *electric field* was applied between the plates D & E. This resulted in a deflection (refer to Lecture 2) at the front or coated end of the tube given by:



Electric deflection = $e E \ell d / m v^2$

where e was the charge of a 'cathode-ray' particle (*i.e.* an electron), m it's mass & v it's horizontal velocity. However, a measurement of only an electric deflection is clearly not sufficient to determine the intrinsic properties (charge & mass, or more precisely the ratio e/m) of the electron unless one also knows the value of the electron's velocity. To circumvent this, Thomson also applied a uniform magnetic field within the deflection region, but at right-angles to the direction of the electric field, resulting in a magnetic deflection of the 'cathode-rays' at the front end of the tube. Obtain a formula for this magnetic deflection of an electron. traveling at a velocity v.

Given that, for electric and magnetic fields of 1.5×10^4 Newtons/Coulomb & 5.5×10^{-4} Newtons/Amp-metres respectively, the electric & magnetic deflections were each measured to be 0.08 metres, obtain the electron's velocity.

Finally, determine Thomson's value for the ratio e/m, given that in his experiment, the length of the deflection region (ℓ) was fixed at 0.05 metres, while the length of the drift region (d) was 1.1 metres.

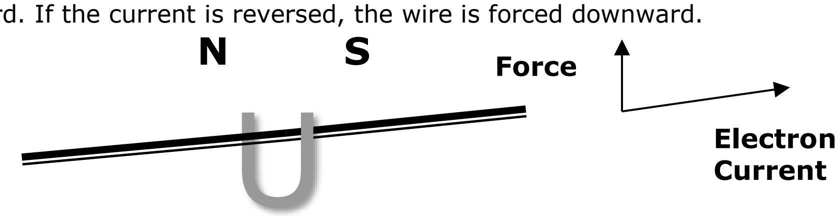
4) **Electron's path in a magnetic field** – an electron travels at 2.0 x 10^7 m/s in a plane perpendicular to a 0.010 T uniform magnetic field. Describe its path.

5) **Electron speeds in a conducting wire** – a copper wire, 3.2 mm in diameter, carries a 5.0A current. Determine the drift speed of the free electrons. *Hint: assume that one electron per copper atom is free to move about (the others remain bound to the atom).*

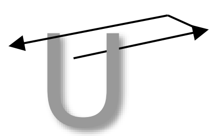
6) **The Hall Effect** – When a current carrying conductor (assumed to be of a rectangular shape) is firmly held in place in a magnetic field, the field exerts a sideways force on the charges moving in the conductor. Therefore the free or conduction electrons in it will move closer to one side of the conductor than the other and hence there will be a potential difference, known as the Hall emf, between the two faces of the conductor.

A long copper strip 1.8 cm wide and 1.0 mm thick is placed in a 1.2 T magnetic field. When a steady current of 15 A passes through it, the Hall emf is measured to be 1.02 μV. Determine a) the drift velocity of the electrons and b) the density ie the number per unit volume of free (conducting) electrons in the copper.

7) When electrons in a wire flow through a magnetic field in the direction shown, the wire is forced upward. If the current is reversed, the wire is forced downward.



If a loop of wire is instead placed in the magnetic field and the electrons flow in the direction shown below, the loop will tend to

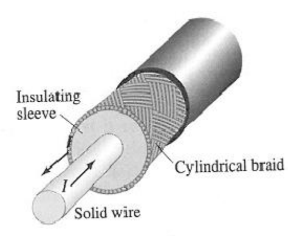


a) rotate clockwise b) rotate anti-clockwise c) do nothing

8) Using Ampère's Law, obtain that the magnetic field a perpendicular distance r from a long wire carrying an electrical current I has a magnitude $B = \mu_0 I/2\pi r$.

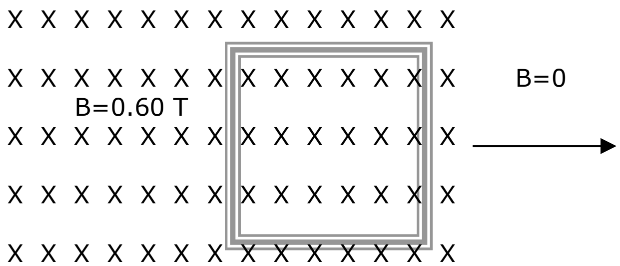
9) Show that the magnetic field within a long solenoid of n turns per unit length carrying a current I is along its axis and has a magnitude $B = \mu_0 nI$.

10) In situations where a small signal must travel over a distance, a "shielded cable" is used in which the signal wire is surrounded by an insulator and then enclosed by a cylindrical conductor. Why is a "shield" necessary?



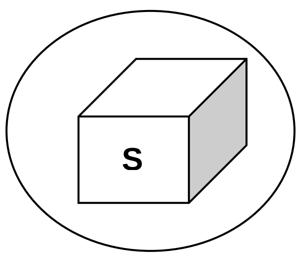
11) **Faraday's paradox** - Consider a cylindrical coil of wire wrapped around a piece of iron. If a current is made to flow in the wire, the iron becomes a magnet. By symmetry, one might have expected that if the iron were a magnet, a current would then flow in the wire. Why do you think this cannot be true?

12) A square coil of side 5.0 cm contains 100 loops and is positioned perpendicular to a uniform 0.60 T magnetic field, as shown in the figure below. It is quickly and uniformly pulled from the field(moving perpendicular to **B**) to a region where B drops abruptly to zero. It takes 0.10 s for the whole coil to reach the field–free region. Find (a) the change in flux through the coil, (b) the emf and current induced if the coil's resistance is 100 Ω, and (c) how much energy is dissipated in the coil. (d) What was the average force required?



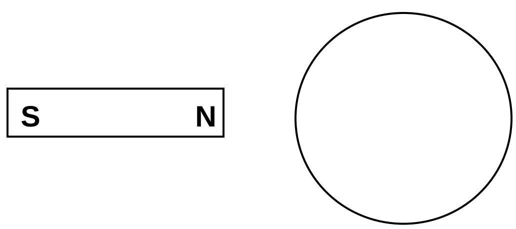
13) In which direction is the current induced in the coil for each situation illustrated below?

a)



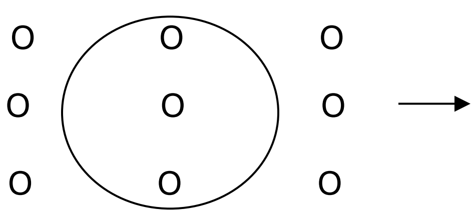
N magnetic pole moving toward the coil from above the Page

b)



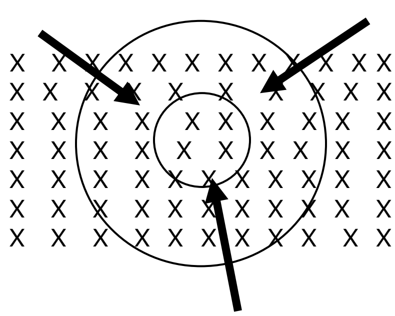
North magnetic pole moving toward the coil in the plane of the page

c)



Pulling the coil to the right out of a magnetic field that points out of the page

d)



Shrinking a coil in a magnetic field pointing into the page

14) A light bulb is connected by a thick wire to an ac source. Part of the wire is in the shape of a coil. After a piece of iron is shoved into the coil, the light

a) brightens
b) dims
c) is not affected

What about if the light bulb were to be connected to a dc source (eg a battery) instead and again part of the wire, in the shape of a coil, has shoved into it a piece of iron?

15) **Does a moving airplane develop a dangerous emf?** - An airplane travels 1000 km/h in a region where the Earth's magnetic field is 5.0×10^{-5} T and is nearly vertical. What is the potential difference induced between the wing tips that are 70 m apart?

16) The armature of a 60 Hz ac generator rotates in a 0.15 T magnetic field. If the area of the coil is 2.0×10^{-2} m^2, how many loops must the coil contain if the peak output is to be $\mathcal{E}_0$ = 170 V?

17) Both an electric motor and a generator consist of coils of wire on a rotor that can spin in a magnetic field. The basic difference between the two is whether electric energy is the input and mechanical energy the output (a motor), or mechanical energy is the input and electric energy the output (a generator). Now, current is generated when the rotor is made to spin either by mechanical or electrical energy – it needn't "care" what makes it spin. So is a motor also a generator when it is running?

a) Yes, it will send an electric energy output through the input lines and back to the source.
b) It would if it weren't designed with an internal bypass circuit to prevent this problem
c) No, the device is either a motor or a generator – to be both at the same time would violate energy conservation

18) **Transmission lines** – An average of 120kW of electric power is sent to a small town from a power plant 10 km away. The transmission lines have a total resistance of 0.40 Ω. Calculate the power loss if the power is transmitted at (a) 240 V and (b) 24,000 V.

Compare the total resistance of the power lines above with the resistance of a 100 W light bulb, operating at 240 V.