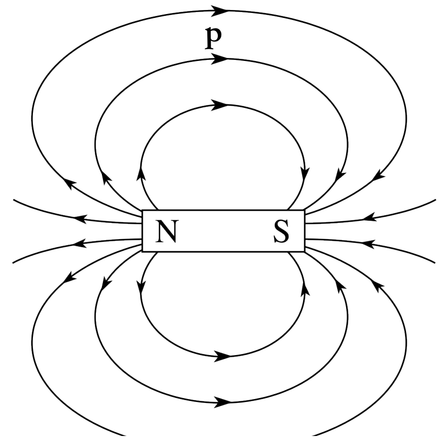
Part 3: The B-Field, the B-Force, and the B-Flux

1. We know that, at the most basic level, an electric field is created by charged particles. But what creates a magnetic field, at the most basic level? (Do not write “a magnet.” That is not the answer.)

2. The diagram to the right shows the B-field around a bar magnet. Assume that the magnet is surrounded by vacuum and that there are no other significant fields in this region.

   Imagine that an electron is placed at point ***p***. Assume that initially the electron is at rest relative to the magnet. What will happen to the electron over time? In what direction will it be pulled? How will it move? What if, instead of an electron, it were a proton or a neutron? Would this change anything? How? Explain.

   The electron will stay right where it is, at point ***p***. It will experience no force, because magnetic fields only exert forces on ***moving*** charges.

3. Imagine that a proton is moving past point ***p***. Does it experience a force? Why? Explain.

   Yes, the proton will experience a force, because it is moving relative to the magnet. According to Lorentz’s Law ($\vec{F}_B = q\vec{v} \times \vec{B}$), a moving charge experiences a magnetic force.

4. Does the direction the proton is moving affect the ***direction*** of the force it experiences? Does the direction the proton is moving affect the ***magnitude*** of the force it experiences? Is there a direction it could be moving at that particular point (***p***) that would cause it to experience no force at all? Are there directions that would maximize the force it experiences? If so, which ones?

   Direction of motion of the charge affects both direction & magnitude of the force. Because F is the cross product of $q\vec{v}$ and $\vec{B}$, the magnitude is a function of the sine of theta, and so the force will be greatest if the proton is moving perpendicular to the field line—i.e. up, down, into the paper, or out of the paper. If the proton moves parallel to the field line (left or right) then it will experience no force at point p (since sin0 = sin(π) = 0).

5. Assume that the proton is moving ***down*** at a velocity of 8 m/s as it passes point ***p***. Assume further that the strength of the B-field at point ***p*** is 3 T. Find the magnitude and the direction of the ***force*** on the proton. Find the magnitude and direction of the ***acceleration*** of the proton.

   $\vec{F}_B = q\vec{v} \times \vec{B} = qvB \sin 90 = (1.6\times10^{-19})(8)(3) = 3.84\times10^{-18}\ newtons$

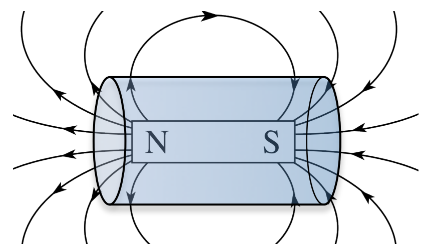
   By the right hand rule, this force will point out of the page. For acceleration:

$$\sum \vec{F} = m\vec{a}$$

$$3.84\times10^{-18} = m_{proton}\vec{a} = (1.67\times10^{-27})\vec{a}$$

$$\vec{a} = 2.30\times10^{9}\ m/s^2$$

6. Now imagine a cylinder surrounding the same bar magnet shown above. At a point directly in the center either end of the cylinder, the strength of the B-field is 6 T. Find the net magnetic flux through the cylinder.



   Net flux = 0. By Gauss's Law for magnetic flux, net magnetic flux through a closed surface is always 0.

7. A current is running through a long, straight wire. Draw the magnetic field lines in the vicinity of the wire. Your diagram should include:
   A. a head-on view, as though the current were coming out of the paper towards you;
   B. a (slightly angled) side-view, showing the current running left-to-right across the page.

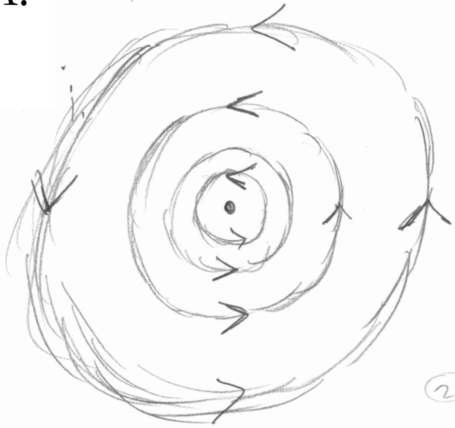
   See next page for solutions.

8. Two wires are placed side-by-side in parallel. A current runs through each wire.
   A. The currents run in the same direction. What will happen to the wires?
   They are attracted by magnetic forces.

   B. The currents run in opposite directions. What will happen to the wires?
   They are repelled by magnetic forces.

Answers to problem 7.

A. A MAGNETIC FIELD!

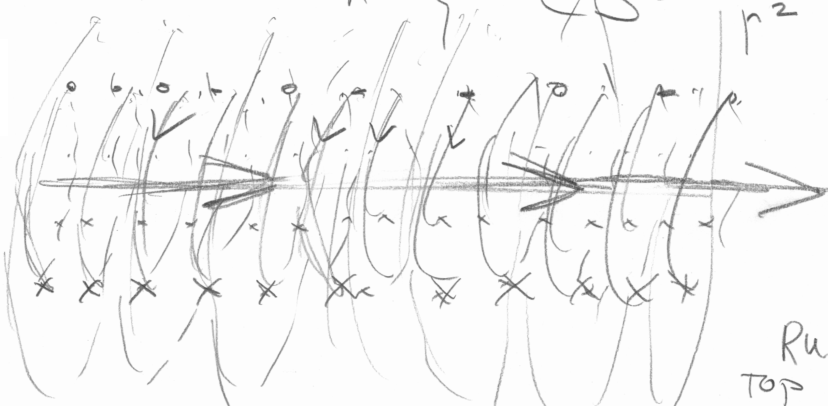


① CONCENTRIC (CLOSED) CIRCLES ENCLOSING THE STRAIGHT CURRENT,

② RUNNING COUNTER-CLOCKWISE (right-hand rule)

③ getting LESS AND LESS DENSE AS THEY get FARTHER AND FARTHER AWAY ($B \propto \frac{1}{r^2}$)

B.



CONCENTRIC CIRCLES RUNNING FROM TOP out of page to BOTTOM in page

Part 4: Maxwell's Equations

Answers to the questions in this section will be revealed in Tuesday's lecture!!!!!!