Phys 112 2019

Lecture 15

Thurs: Physics Seminar

Fri: HW by 5pm

Supp Ex: 54, 55, 57, 58, 59, 60

Ch 24 Q 8, 10

Fields produced by currents

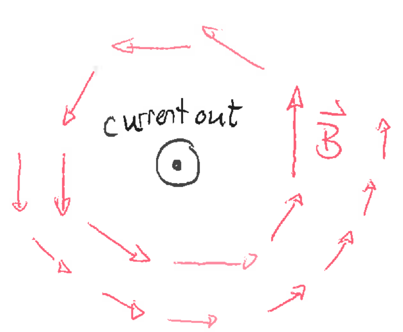
A general observation is:

$\boxed{\text{Any current produces a magnetic field}}$

A magnetic field consists of a vector at each location and in order to completely describe this, we need:

1) magnitude
2) direction

The basic rule for direction comes from a section of straight current. In this case the magnetic field vectors lie in planes perpendicular to the current and circle the current in the sense given by the r.h. rule



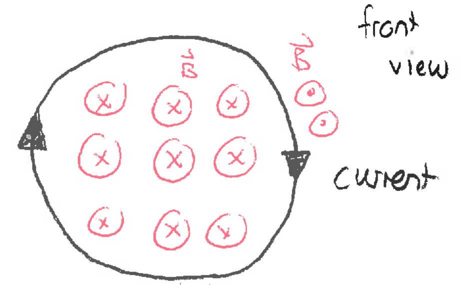
Before presenting the rules for the magnitude of the field we consider other current configurations

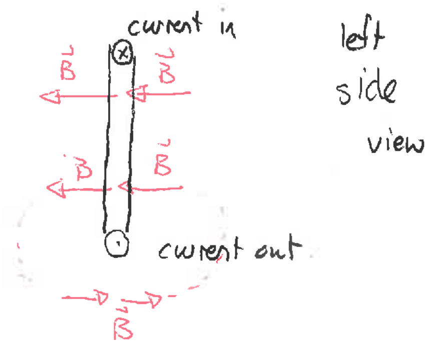
1) Loop of current

Current can be made to circle around a loop and this will produce a magnetic field.

We can assess the direction by adding contributions from various small segments of the loop. We see that they all add in the interior of the loop. An alternative r.h. rule is

Orient r.h. so fingers circle in direction of current. Thumb points in direction of field

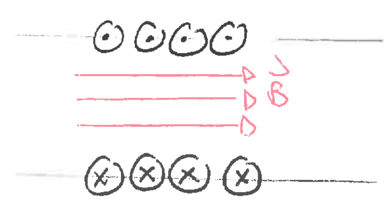




Demo: Current board - show loop field

2 Solenoid

A solenoid is a stack of closely spaced loops. The rule for determining the direction is the same as for a single loop



cross section side view

Demo: Show tube

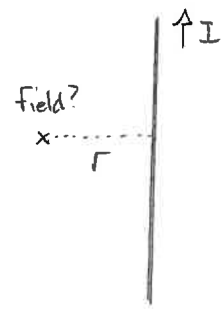
Demo ~~Fee~~ PhET Faraday's electromagnetic lab

— note like magnetic field of bar magnet.

Magnitude of a magnetic field produced by a straight current.

For an infinitely long straight current, a more sophisticated calculus-based treatment of magnetic fields gives an exact rule for the strength of the field.

> The magnitude of a magnetic field produced by an infinitely long straight current is
>
> $$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$
>
> where r is the distance from the current to the field point.



Here

$$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{Tm/A} = 1.26 \times 10^{-6}\ \mathrm{Tm/A}$$

is a universal constant called the permeability of free space. Then the units of magnetic field are Tesla (T).

Quiz!

Magnitude of fields produced by circular currents.

It is possible to determine the exact magnetic field for a collection of loops of current. Thus:

> The magnetic field at the center of N loops with radius R is
>
> $$B = \frac{\mu_0 N I}{2R}$$

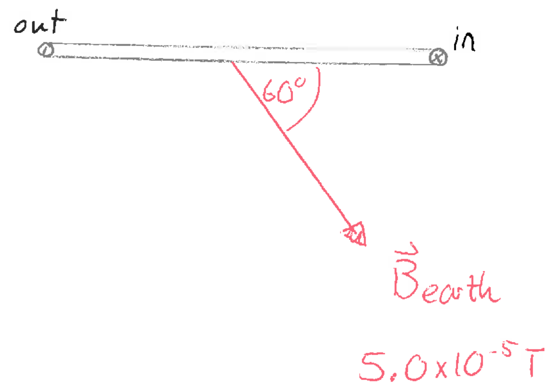
Finally the field inside an <u>infinitely long solenoid</u> is:

$$B = \frac{\mu_0 N I}{L}$$

where N is the total number of coils and L is the length of the solenoid.

Quiz 2

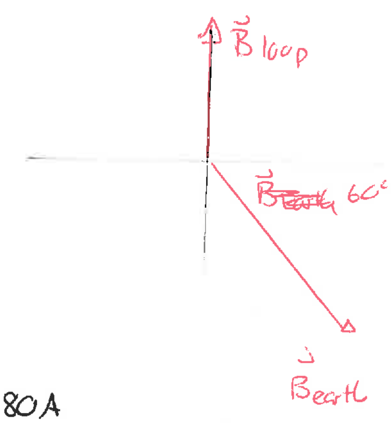
Example: A loop is placed in Earth's magnetic field as illustrated. The loop has ten turns, each with radius 0.090m and carrying current 0.80A Determine the net magnetic field produced by the loop and Earth.



Answer: The field is

$$\vec{B} = \vec{B}_{Earth} + \vec{B}_{loop}$$

and the two vectors are illustrated



Then we need magnitude:

$$B_{loop} = \frac{\mu_0 N I}{2R} = \frac{4\pi\times10^{-7}\,Tm/A \; 10 \times 0.80A}{2\times 0.090m}$$

$$= 5.6\times10^{-5}\,T.$$

Now we need components

$B_{earth\,x} = + B_{earth}\cos 60^\circ$

$= 5.0\times10^{-5}\,T \cos 60^\circ$

$= 2.5\times10^{-5}\,T$

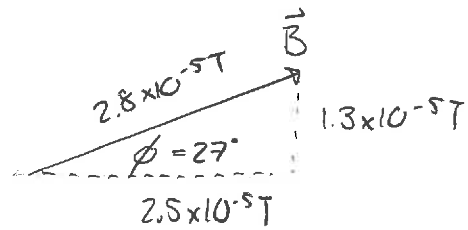
	x	y
$\vec{B}_{earth}$	2.5×10^{-5} T	-4.3×10^{-5} T
$\vec{B}_{loop}$	0	5.6×10^{-5} T

$$B_{earth\ y} = -B_{earth} \sin 60^\circ$$

$$= -5.0\times10^{-5}\,T \sin 60^\circ = -4.3\times10^{-5}\,T$$

So $B_x = 2.5\times10^{-5}\,T$

$B_y = 1.3\times10^{-5}\,T$



Then $B = \sqrt{B_x^2 + B_y^2} = 2.8\times10^{-5}\,T$

$\phi = \arctan\left(\frac{1.3}{2.5}\right) \Rightarrow \phi = 27^\circ$ $\boxed{E}$