Phys 132 2022

Lecture 20

Mon: HW by 5pm

Ex 110, 116, 118, 119, 120, 121, 122, 124

Tues: Warm Up 8

Weds: Review II

Thurs: Exam II Covers capacitors, circuits L12 → 19

Ch 26.5, 26.6

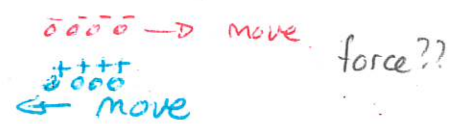
Ch 27, 28

2017 Ex II Q1→4

2018 Ex II Q1→9.

Magnetic Fields

We will now begin to explore interactions between moving charged particles. The rules of electrostatics do not predict correctly in these situations. The rules that do predict correctly involve magnetism and magnetic fields.



Although we will develop precise rules involving currents it will first be useful to illustrate some ideas using bar magnets, since these will describe the operation of compass needles.

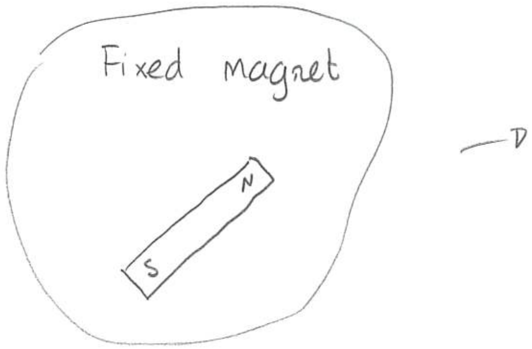
Bar magnets have two poles: North (N) and South (S). We can readily observe:

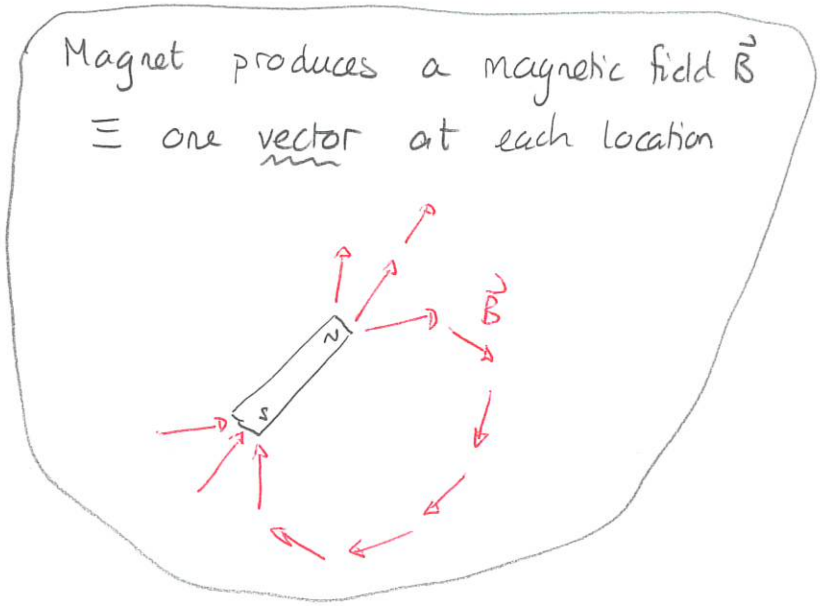
like poles repel   opposite poles attract.

The strategy for describing how magnets

- interact with other magnets
- interact with moving charges

involves the concept of a magnetic field. This is a collection of vectors, one at each location, denoted $\vec{B}$. Schematically





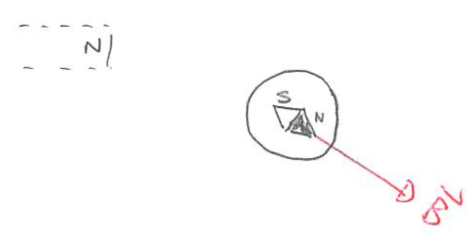
Demo: PhET Magnet + Compass (no field)

As with any vector, a magnetic field vector will have

- a magnitude (in Teslas (T)) to be quantified when we introduce magnetic forces
- a direction that is described in terms of the action on an ordinary compass needle.

The direction of a magnetic field is the same as the direction in which a compass needle (with friction/damping) will eventually point.

Demo: Compass near bar magnet



Demo: Compass and needle board

Demo: PhET Magnet + Compass with field

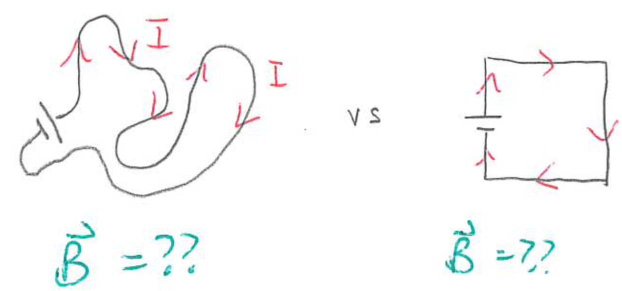
Electric currents and magnetism

The detailed description of magnetism begins with an accidental discovery by Oersted (19th century) that electric currents can exert forces on magnets. The general rule is:

> Any electric current produces a magnetic field.

Demo: Current board + magnets.

Then the task is to determine the magnetic field produced by a current. This will depend on:



1) the current strength
2) the geometric configuration of the current
3) the location at which the field is to be determined

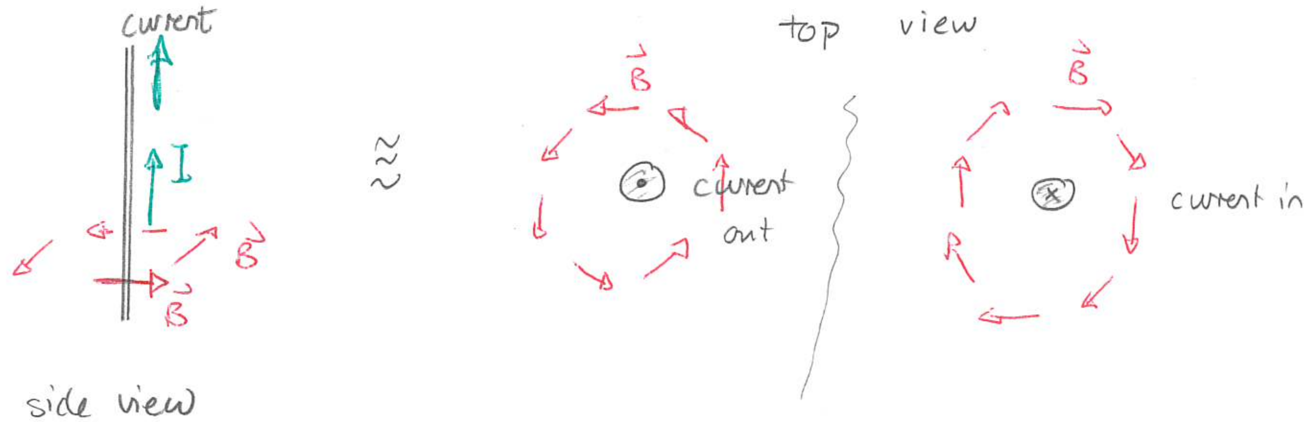
Straight sections of current

The easiest situation to analyze is that where the current flows in a straight line – for example, along a straight wire. So we consider:

1) a current flowing in a straight line
2) a current which is uniform along the wire and does not vary with time.

We find that

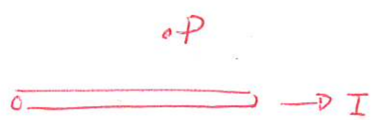
> the magnetic field produced by a straight section of current circles the current



The sense in which the field circles is obtained via a right-hand rule

> 1) Hold current/wire with r.h. so that thumb points along current
> 2) Fingers indicate sense in which current circles.

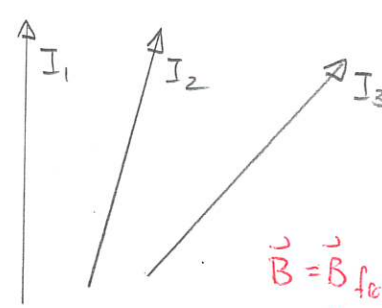
Warm Up 1



Warm Up 2

In general there may be multiple sources of magnetic fields. Then:

> The magnetic field produced by multiple current sources is the vector sum of the magnetic fields produced by each source.



$\vec{B} = \vec{B}_{from 1} + \vec{B}_{from 2} + \vec{B}_{from 3}$

Quiz 1 90%

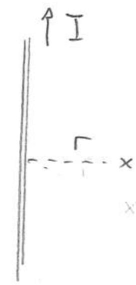
We now need a rule for the field produced by any straight section of current, or in fact for any current.

There is a general rule that allows one to determine the field produced by any straight section of uniform current. This is called the Biot-Savart law and will be covered later. A mathematically simpler version, called Ampère's law allows calculation in very symmetrical situations. This can be applied to an infinitely long current.

Consider the magnetic field produced by an infinitely long uniform, straight, constant current. The magnitude of the field is

$$B = \frac{\mu_0}{2\pi} \frac{I}{r}$$

where r is the distance from the wire to the field point.



Here

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

(Teslas)

is a constant called the permeability of free space.

Quiz 2 80%