PH202-1G
Spring 2014

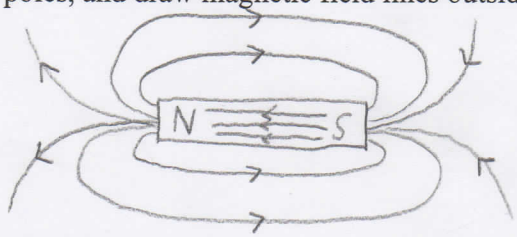
Worksheet February 10

Magnetic field

How are magnetic field lines oriented with respect to north and south magnetic poles?

Magnetic field lines are oriented from the north pole to the south pole.

Draw a bar magnet, label the poles, and draw magnetic field lines outside of and within the bar magnet.



Magnetic force

Under what condition will a charged particle experience a magnetic force from a magnetic field?

The charged particle must be moving in a direction that is not parallel to the field.

Give a mathematical expression for the magnetic force on a charge particle and the units for magnetic field in terms of other units you have studied.

$F_B = q v B \sin\theta$ $\qquad$ $1\ \text{tesla (T)} = 1\ \frac{N}{A \cdot m} = 1\ \frac{N \cdot s}{C \cdot m}$

Under what condition is the magnetic force at a maximum?

The magnetic force is at a maximum when the particle's velocity is perpendicular to the magnetic field ($\sin 90° = 1$)

How do you determine the direction of the magnetic force on a charged particle?

Right hand rule - thumb of right hand in direction of velocity, fingers in direction of field. Magnetic force is in direction of palm for a positive charge.

What kind of motion does a magnetic force cause? Give a mathematical expression for the force that causes this kind of motion.

$F_c = m\frac{v^2}{r}$

Magnetic forces cause uniform circular motion, so speed does not change.

Mass spectrometer

Explain qualitatively how a mass spectrometer works. What happens to the sample being analyzed? What properties does the mass spectrometer actually measure?

The sample is ionized and then accelerated by a potential difference. The moving ions are subjected to a magnetic field. The field strength is adjusted until the ions strike a detector at a fixed distance.

Give a mathematical expression for the mass of a sample ion.

$$m = \underbrace{\frac{er^2}{2V}}_{\text{Fixed}} \underbrace{B^2}_{\text{magnetic field is the quantity measured}}$$

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1. Three particles are moving within a magnetic field. The first particle has a charge of 70 μC and is moving at an angle of 15° with respect to the magnetic field with speed 20 m/s. The second particle has a charge of 60 μC and is moving at an angle of 30° with respect to the magnetic field with speed 15 m/s. If the first particle experiences a magnetic force of magnitude 0.0020 N, what is the magnitude of the force on the second particle?

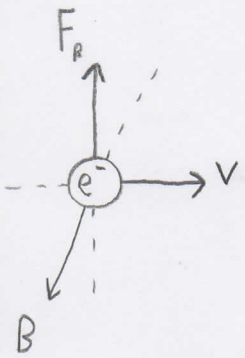
We need to find the magnetic field from the information about the first particle.

$$B = \frac{F_{B-1}}{q v \sin\theta} = \frac{0.0020\ N}{70\ \mu C \cdot 20\ m\cdot s^{-1} \sin 15^\circ} = 5.520\ \frac{N}{A\cdot m} = 5.520\ T$$

$$F_{B-2} = q v \sin\theta B = 60\ \mu C \cdot 15\ m\cdot s^{-1} \sin 30^\circ (5.520\ T) = 0.0025\ N$$

2. An electron (mass $9.109\cdot10^{-31}$ kg) moves to the right with a speed of $3.0\cdot10^{5}$ m/s. If you want the electron to move in a circle around a point 450 nm above its current position, in what direction should you apply a magnetic field and what should be its magnitude?

Direction should be out of page (opposite of right hand rule because charge is negative).



$$F_B = F_C$$

$$qvB = m\frac{v^2}{r}$$

$$B = \frac{mv}{qr}$$

$$B = \frac{9.109\cdot10^{-31}\ kg \cdot 3.0\cdot10^{5}\ m\cdot s^{-1}}{1.602\cdot10^{-19}\ C \cdot 450\cdot10^{-9}\ m} = 3.8\ T$$

θ is 90° and $\sin 90^\circ = 1$

3. A newly discovered protein is analyzed using a mass spectrometer which uses lasers to fragment the protein into ions with charge $+e$. These ions are accelerated through a potential difference of 20 V and then subjected to a perpendicular magnetic field. A detector located 13 cm away from the cathode records a signal when the strength of the magnetic field is 35 mT and 38 mT. What are the masses of the two protein fragments that cause these signals?

$$m_1 = \frac{e r^2 B^2}{2V} = \frac{1.602\cdot10^{-19}\ C\ (0.13\ m)^2 (35\cdot10^{-3}\ T)^2}{2\cdot20\ V} = 8.3\cdot10^{-26}\ kg$$

$$m_2 = \frac{1.602\cdot10^{-19}\ C\ (0.13\ m)^2 (38\cdot10^{-3}\ T)^2}{2\cdot20\ V} = 9.8\cdot10^{-26}\ kg$$