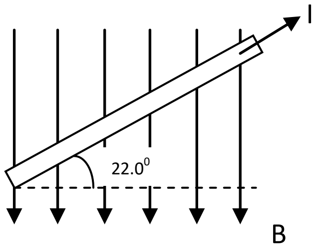
Magnetic Force on Moving Charges

Problems Worksheet

1. Calculate the magnitude of the force applied to a 22.0 cm straight wire carrying 4.00 A perpendicular to a 80.0 mT magnetic field.

2. The 56.0 cm wire below carries a 650 mA current. A 560 μT magnetic field is applied in the direction indicated in the diagram.



   a. What is the magnitude of the force acting on the wire?

   b. What direction is the force applied?

   c. What is the minimum flux density capable of producing this force on the wire? Describe how this could be achieved.

3. In Perth, the Earth's magnetic flux density is 55.0 μT and inclined at 30^0. An overhead power line, carrying 800 A which flows from east to west, has a mass of 1.20 kgm^{-1}.

   a. Calculate the magnitude of the force per metre acting on the power line.

b. Find the ratio of the magnetic force to gravitational force acting on the power line.

c. Is the magnetic force acting on the power line an important factor for engineers to consider in the design stage? Justify your response.

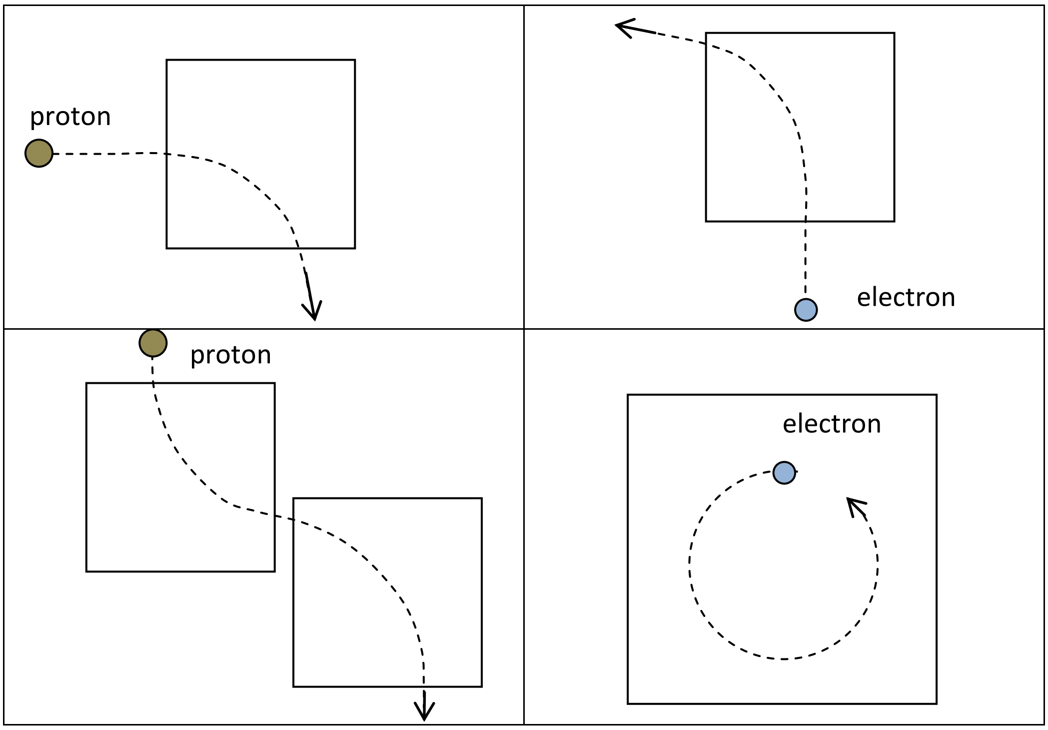
4. Two 3.00 m long parallel wires are separated by 25.0 cm. Each has a 5.00 A current flowing and the currents flow in the same direction.
   a. Will the wires experience attraction or repulsion while the currents flow?

   b. What is the magnetic flux density produced at wire 2 because of the current flowing through wire 1?

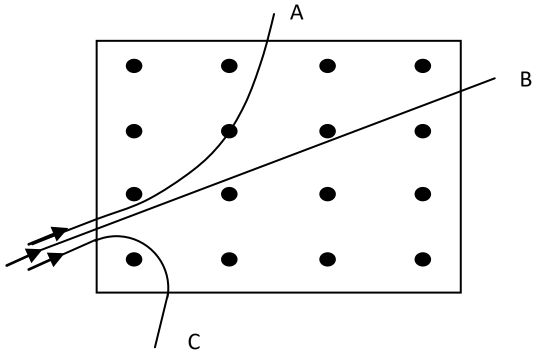
   c. Calculate the force applied to wire 2.

d. Consider a parallel pair of long wires separated by a distance d. The current in one wire is I_1 and the current in the other wire is I_2. Show that the force per unit length felt by each wire is $\frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$.

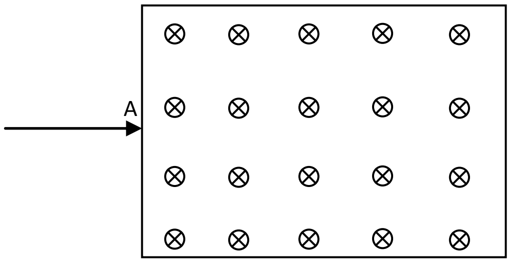
5. Draw in the magnetic field inside each box that would be capable of deflecting the particle along the path shown in each diagram.



6. Three particles all pass through a uniform magnetic field. The path each particle took through the field is shown below. Compare the charges of particle A B and C if all particles had the same mass and the same initial velocity.



7. An electron is moving through a magnetic field with a density of 0.855 T at a speed of 4.65×10^4 ms^{-1}.



a. What is the magnitude of the force acting on the electron while it is in the field?

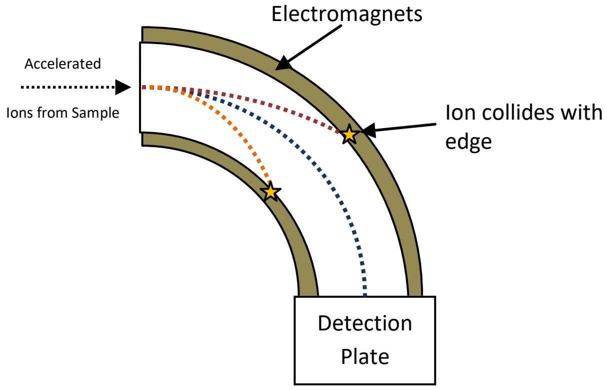
b. What direction is the force acting on the electron at position A, just as the electron enters the field.

c. Briefly describe how the force acting on the electron at position A would be affected by changing the following properties of the electron or the field it is passing through:

Change to electron or the field	**Change to force**
Electron is positively charged	
Electron travels twice as fast	
Electron has twice the mass	
Magnetic flux density is halved	
Magnetic flux is redirected to point from left to right	
Magnetic flux is redirected to point up the page	

d. What radius of curvature would the electron follow while in this field?

8. A mass spectrometer is a device that is used to help determine the atomic composition of unknown samples by detecting the mass of atoms that make up the sample. The sample is ionised and the ions are accelerated up to the same speed. The ions are directed into a curved vacuum tube. The ions follow the curved path because of the presence of a variable magnetic field. A detection plate is used to record the quantity of ions that successfully navigate the curved path.



   a. What is the purpose of the electromagnets in a mass spectrometer?

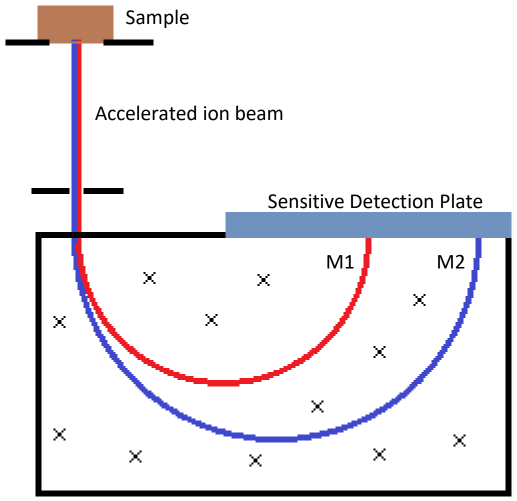
   b. The middle dashed line represents an ion from the sample which reaches the detection plate. Assuming all ions had a single positive charge, explain why not all ions successfully reach the detection plate.

   c. What changes need to be made to the mass spectrometer to detect other types of single positive ions produced from the sample?

d. What changes need to be made to the mass spectrometer to detect any negative ions that were released from the sample?

e. A lithium ion (+1 charge) has a mass of 1.15×10^{-26} kg and after being released from the sample is accelerated up to 8.56×10^{4} ms^{-1}. If the mass spectrometer curved path has a radius of 1.20 m, what is the required magnetic flux density needed to detect these ions?

9. Another design of mass spectrometer does not use a variable magnetic field. Ions are shot into the field at a specific velocity but the detector is widened and is sensitive enough to pick up the exact location where the ions impact the detector.



a. Are the ions released by the sample positive or negative?

b. Which ion (M1 or M2) would have the greater mass? Justify your answer with relevant formula.

c. Two ions of equal charge are detected on the detection plate. Ion M1 was detected 46.0 cm away from where the beam entered the field while ion M2 was detected 58.0 cm from the beam's entry point. How heavy is the heavier ion compared to the lighter ion?

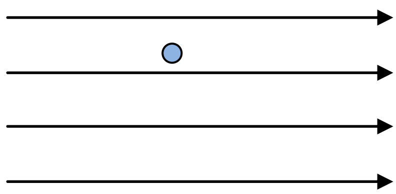
d. Which of the following statements is **false**. Justify your response.
   i. The kinetic energy of the ion is constant within the magnetic field
   ii. The work done by the magnetic field on the ion increases with ion mass
   iii. The acceleration of the ion is not constant within the magnetic field

The following questions assume knowledge of electric fields.

10. A proton, moving at 3.00×10^3 ms^{-1}, moves into a 425 NC^{-1} electric field.
    a. Calculate the magnitude of the force applied to the proton due to the electric field.

b. Calculate the density of the magnetic field that could be used to stop the acceleration of the proton due to the electric field.

c. The diagram below shows the proton within the electric field. The proton is currently moving down the page. Indicate on the diagram which direction the magnetic field should be applied to stop the acceleration of the proton. Clearly label the magnetic field.

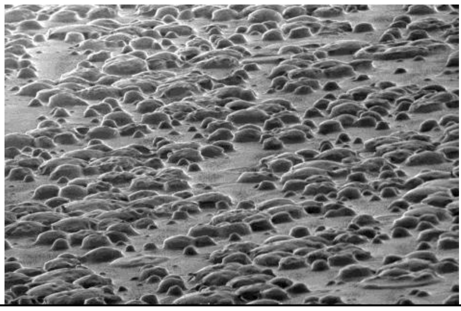


d. With both the magnetic and electric field turned on, use a single line with an arrow to show the path the proton would follow if it was moving at half of its originally stated velocity. Clearly label this line as the proton's path.

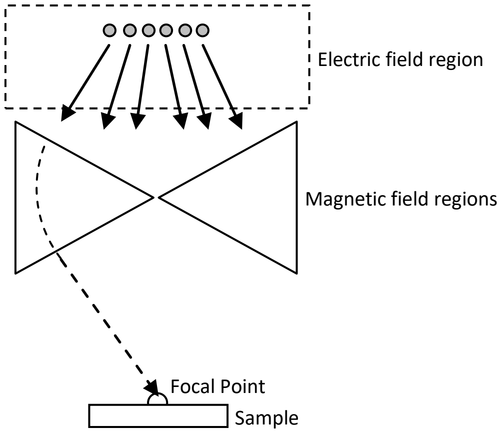
11. A doubly charged ion is accelerated by a potential difference of 2.30×10^4 V and then enters a magnetic field with a density of 0.800 T. If the ion follows a path of curvature of 5.00 cm, determine the mass of the ion.

12. A scanning electron microscope (SEM) fires a relatively slow electron beam at a sample which is used to take an image of the surface of the sample. The electron beam of a SEM used to photograph the back of a Post-it note (below-left) was accelerated using a 68.0 NC^{-1} uniform electric field.

A magnetic field is then used to focus the beam, much like a glass lens can be used to focus light. The electric field region, the magnetic field region and the path of one of the electrons is shown below-right.



Post-it note sticky label viewed using SEM



a. Draw the magnetic field inside the triangular regions that could cause the required deflection for all electrons to hit the focal point.

b. Why is the magnetic field region triangular shaped?

c. Which direction is the electric field applied within the electric field region to accelerate the electrons down the page towards the sample?

d. Calculate the force applied by the electric field on the electrons.

e. How long would the electric field need to be to ensure the electrons reached a speed of 8.80 x 10^5 ms^{-1} if starting from rest?

