ICLICKER QUESTION

What is the magnetic force on the curved portion of the wire? (The magnetic field is uniform).

\[ d\vec{F} = I\, d\vec{l} \times \vec{B} \]

a) \( 2IRB\hat{k} \)

b) \( -2IRB\hat{k} \)

c) \( \pi IRB\hat{k} \)

d) \( -\pi IRB\hat{k} \)

e) 0
An electron beam is directed out of the screen. If bar magnet’s north end approaches the beam in a direction parallel to it

a) The beam will be deflected up.
b) The beam will be deflected down.
c) The beam will be deflected to the right.
d) The beam will be deflected to the left.
e) The beam will not be deflected at all.
An electron beam is directed out of the screen. If bar magnet’s south end approaches the beam, from above, in a direction perpendicular to it

a) The beam will be deflected up.
b) The beam will be deflected down.
c) The beam will be deflected to the right.
d) The beam will be deflected to the left.
e) The beam will not be deflected at all.
Current Loop on a Magnetic Field

\[ \vec{F}_B = 0 \]

\[ \Sigma \vec{F} = 0 \]

\[ \Sigma \vec{\tau} \neq 0 \]

\[ \vec{\tau} = \hat{\mu} \times \vec{B} \quad \text{Torque on a current carrying loop} \]

\[ U = -\hat{\mu} \cdot \vec{B} \quad \text{Potential Energy} \]

\[ \hat{\mu} = I \hat{A} \quad \text{Magnetic dipole moment.} \]
A particle of charge q travels horizontally with velocity \( \vec{v}_0 \). At time \( t_1 \) it enters a uniform magnetic field magnitude B and directed downwards. Then, at time \( t_2 \), the magnetic field is turned off and the velocity of the particle is \( \vec{v}_2 \). Which statement is TRUE.

- a) \( \vec{v}_0 = \vec{v}_2 \) and \( |\vec{v}_0| = |\vec{v}_2| \)
- b) \( \vec{v}_0 < \vec{v}_2 \) and \( |\vec{v}_0| < |\vec{v}_2| \)
- c) \( \vec{v}_0 > \vec{v}_2 \) and \( |\vec{v}_0| > |\vec{v}_2| \)
- d) \( \vec{v}_0 \neq \vec{v}_2 \) and \( |\vec{v}_0| = |\vec{v}_2| \)
- e) \( \vec{v}_0 \neq \vec{v}_2 \) and \( |\vec{v}_0| \neq |\vec{v}_2| \)
Charged Particle Moving Perpendicularly Through a Uniform Magnetic Field

- If a charged particle is moving at a constant speed, perpendicularly to a uniform magnetic field, its path will be circular (i.e. is in uniform circular motion).

![Diagram of a charged particle moving through a magnetic field](image)
ICLICKER QUESTION

Two particles of the same mass enter a magnetic field with the same speed and follow the paths shown. Which particle has the bigger charge?

a) Path a)

**b) Path b)**

c) Both charges are equal

d) Impossible to tell from the picture
Mass Spectrometer

A mass spectrometer can be used to measure the masses of atoms.
Velocity Selector

The first component of a mass spectrometer selects particles coming with a specific speed (i.e. a velocity selector).

When the particle enters the selector with speed $\nu$ the forces acting on it are ($\vec{F}_g \ll \vec{F}_B$ and $\vec{F}_E$):

$$\Sigma \vec{F} = q\vec{v} \times \vec{B} - q\vec{E} = m\vec{a}$$
Velocity Selector

Observations:

• If $\nu$ is too large, then $F_B$ will dominate resulting in an upwards acceleration (w.r.t. drawing in previous slide).

• If $\nu$ is too small, then $F_E$ will dominate resulting in a downwards acceleration.

• There must be some $\nu$ such that the forces are balanced: 
  
  $$q\nu B - qE = 0$$

  $$\nu = \frac{E}{B}$$
Mass Spectrometer

Observation: The ions reaching the second magnetic field will have the same speed \((E/B)\)

- Then their radius of curvature are directly proportional to their mass and inversely proportional to their charge:

\[
m_1 = R_1 \frac{qBB'}{E} \quad m_2 = R_2 \frac{qBB'}{E}
\]
Biot-Savart Law

• The vector $d\mathbf{B}$ is perpendicular to both $d\mathbf{\ell}$ and to the unit vector $\hat{r}$.
• $d\mathbf{B}$ is proportional to $\sin\theta$, where $\theta$ is the angle between $d\mathbf{\ell}$ and $\hat{r}$ and to the magnitude of the length element $d\mathbf{\ell}$.
• $d\mathbf{B}$ is proportional to the current.
• The magnitude of $d\mathbf{B}$ is inversely proportional to $r^2$.

\[ d\mathbf{B} = \frac{\mu_0 I d\mathbf{\ell} \times \hat{r}}{4\pi r^2} \quad [\text{Biot – Savart Law}] \]

\[ \mu_0 = 4\pi \times 10^7 \text{ N/A}^2 \quad [\text{Permeability of free space}] \]
Calculate the magnetic field at point O for the current-carrying wire segment shown. The wire consists of two straight portions and a circular arc of radius R, which subtends an angle $\theta$. The arrowheads on the wire indicate the direction of the current.

$$dB = \frac{\mu_0}{4\pi} \frac{Id\ell \times \hat{r}}{r^2}$$
Consider a thin, straight wire carrying a constant current I and placed along the x axis. Determine the magnitude and direction of the magnetic field at point P due to this current.

\[ \vec{B}(0,a) = \int_{-\infty}^{\infty} \frac{\mu_0 I d\ell \times \hat{\mathbf{r}}}{4\pi r^2} \]

For an infinitly long wire:

\[ B = \frac{\mu_0 I}{2\pi a} \]
**Force between Two Parallel Wires**

The magnitude of the magnetic field produced at the position of wire 2 due to the current in wire 1 is:

\[ B_1 = \frac{\mu_0 I_1}{2\pi d} \]

The magnitude of the force this field exerts on a length \( \ell_2 \) of wire 2 is:

\[ F_2 = I_2 \ell_2 B_1 \]

\[ F_2 = I_2 \ell_2 \left( \frac{\mu_0 I_1}{2\pi d} \right) = \frac{\mu_0 I_1 I_2}{2\pi d} \ell_2 \]