Consider the passage of a horizontal electron beam through a velocity selector, where the electric field $\vec{E}$ points downward and the magnetic field $\vec{B}$ points into the paper.

Based on the Lorentz force law, what is the critical speed $v_c$ (the speed at which the horizontal electron beam is not deflected)?

1. $v_c = \frac{B^2}{E}$
2. $v_c = \frac{B}{E}$
3. $v_c = \frac{E^2}{B}$
4. $v_c = B\frac{E}{E}$
5. $v_c = \frac{E}{B^2}$
6. $v_c = \frac{1}{B E}$
7. $v_c = \frac{B}{E^2}$
8. $v_c = B^2 E$
9. $v_c = B\frac{E^2}{B}$
10. $v_c = \frac{E}{B}$ correct

Explanation:
Consider the net effect of the electric force and the magnetic force which oppose each other. At the critical speed, the magnetic force is exactly canceled by the electric force, i.e., the Lorentz force

$$\vec{F}_L = q\vec{v} \times \vec{B} = 0$$

so the critical speed is $v_c = \frac{E}{B}$.

If the speed of the electrons is greater than the critical speed, the trajectory of the electron beam will be:

1. undeflected.
2. deflected upward and into the paper.
3. deflected upward.
4. deflected out of the paper.
5. deflected into the paper.
6. deflected upward and out of the paper.
7. deflected downward and out of the paper.
8. deflected downward. correct
9. deflected downward and into the paper.

Explanation:
The magnetic force points downward. If $v > v_c$, the magnetic force will be stronger, so the electron beam will be deflected downward.

Consider the setup of a velocity selector for the case where the electric field $\vec{E}$ is pointing downward along $y$ axis.
Choose the direction of the magnetic field $\vec{B}$ such that a negatively charged particle, moving at an appropriate speed in the positive $x$-direction ($\hat{i}$), passes through the $\vec{E}$ and $\vec{B}$ region undeflected.

1. $\vec{B} = \frac{1}{\sqrt{2}}(\hat{j} - \hat{k})$
2. $\vec{B} = \frac{1}{\sqrt{2}}(-\hat{j} + \hat{k})$
3. $\vec{B} = -\hat{i}$
4. $\vec{B} = +\hat{k}$
5. $\vec{B} = -\hat{j}$
6. $\vec{B} = +\hat{i}$
7. $\vec{B} = -\hat{k}$ correct
8. $\vec{B} = \frac{1}{\sqrt{2}}(\hat{j} + \hat{k})$
9. $\vec{B} = +\hat{j}$
10. $\vec{B} = \frac{1}{\sqrt{2}}(-\hat{j} - \hat{k})$

Explanation:
The negatively charged particle passes through the selector undeflected when the electric force is equal and opposite to the magnetic force. Since the electric field is pointing in the negative $y$ direction, and the particle’s charge is negative, the particle feels an electric force in the positive $y$ direction.

$$\vec{F}_E = |q| E \hat{j}$$

where $E$ is the magnitude of the electric field. We must choose the magnetic field such that the magnetic force is in the negative $y$ direction. The general equation for the magnetic force is given by

$$\vec{F}_B = q(\vec{v} \times \vec{B})$$

We want $\vec{F}_B$ to point opposite to $\vec{F}_E$, i.e., in the $(-\hat{j})$ direction to have a chance of cancelling the net force. Considering only the unit vectors along which the above vectors point, we must satisfy

$$-\hat{j} = -(\hat{i} \times \hat{r}) \quad (1)$$

where $\hat{r}$ denotes the unknown direction in which $\vec{B}$ must point. Since

$$\hat{i} \times (-\hat{k}) = \hat{j}$$

we see that equation (1) for $\hat{r}$ is satisfied by

$$\hat{r} = -\hat{k}$$

so the magnetic field must point into the page. This can be verified by using the right hand rule.

Drummond HW2 03
004 10.0 points

A vertical electric wire in the wall of a building carries a DC current of 20 A upward.

What is the magnitude of the magnet field at a point 0.1 m due north of this wire?

Your answer must be within $\pm 1.0\%$

Correct answer: 40 $\mu$T.

Explanation:

Let : $I = 20$ A.
The magnetic field due to a current carrying wire at a distance \( r \) is

\[
B = \frac{\mu_0 I}{2 \pi r} = \frac{(4 \pi \times 10^{-7} \text{ T m}) (20 \text{ A})}{2 \pi (0.1 \text{ m})} = 40 \mu \text{T}.
\]

**Drummond HW2 01**

**005 10.0 points**

A wire carrying a current 20 A has a length 0.1 m between the pole faces of a magnet at an angle 60° (see the figure). The magnetic field is approximately uniform at 0.5 T. We ignore the field beyond the pole pieces.

What is the force on the wire?

Your answer must be within ± 1.0%

Correct answer: 0.866025 N.

**Explanation:**

Let: \( I = 20 \text{ A} \),
\( \ell = 0.1 \text{ m} \),
\( \theta = 60° \), and
\( B = 0.5 \text{ T} \).

\[
F = I \ell B \sin \theta,\quad \text{so}
\]

\[
F = (20 \text{ A})(0.1 \text{ m})(0.5 \text{ T}) \sin 60° = 0.866025 \text{ N}.
\]

**Circular Motion of a Particle**

**006 (part 1 of 3) 10.0 points**

Consider the circular motion of a positively charged particle in the plane of this paper, due to a constant magnetic field \( \vec{B} \) which points out of the paper. Neglect the effect due to gravity.

What is the direction of the orbital motion of the particle?

1. clockwise **correct**
2. Insufficient information
3. counterclockwise

**Explanation:**

To maintain a circular orbit, the magnetic force on the particle must be directed toward the center of the circle. From the right hand rule we see that orbit must be in the clockwise direction for the force to point radially inwards.

**007 (part 2 of 3) 10.0 points**

What is the radius of the orbit?

1. \( r = \frac{m v^2}{qB} \)
2. \( r = \frac{q v^2}{m B} \)
3. \( r = \frac{v B}{q m} \)
4. \( r = \frac{m B}{q v} \)
5. \( r = \frac{q B}{mv^2} \)
6. \( r = \frac{m v}{q B} \) **correct**
7. \( r = \frac{q m}{v B} \)
8. \( r = \frac{q v}{m B} \)
9. \( r = \frac{v^2 B}{q m} \)
10. $r = \frac{q B}{m v}$

**Explanation:**
From Newton’s second law

\[ F = q v B = m \frac{v^2}{r} \]

\[ r = \frac{m v}{q B}. \]

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**008 (part 3 of 3) 0.0 points**
WITHDRAWN

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**Magnetic Field in a Cyclotron**

**009 (part 1 of 2) 10.0 points**

A proton in a cyclotron is moving with a speed of $4.24 \times 10^7$ m/s in a circle of radius 0.564 m. 1.67 $\times$ 10$^{-27}$ kg is the mass of the proton, and 1.60218 $\times$ 10$^{-19}$ C is its fundamental charge.

What is the magnitude of the force exerted on the proton by the magnetic field of the cyclotron?

Your answer must be within ± 1.0%

Correct answer: $5.32315 \times 10^{-12}$ N.

**Explanation:**

Let:  
$v = 4.24 \times 10^7$ m/s,  
$m_p = 1.67 \times 10^{-27}$ kg,  
r = 0.564 m, and  
$q_e = 1.60218 \times 10^{-19}$ C.

The magnetic force is the centripetal force which keeps the proton in circular motion. From the centripetal force equation, we have

\[ F = \frac{m_p v^2}{r} \]

\[ = \frac{(1.67 \times 10^{-27} \text{ kg})(4.24 \times 10^7 \text{ m/s})^2}{0.564 \text{ m}} \]

\[ = 5.32315 \times 10^{-12} \text{ N}. \]

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**010 (part 2 of 2) 10.0 points**

What is the magnitude of the magnetic field required to keep it moving in this circle?

Your answer must be within ± 1.0%

Correct answer: 0.783597 T.