Your Comments

I can use the right hand rule and figure out the answers.. but I still don't understand this whole "magnetic field" idea.

Yay for right hand rules! Except I keep messing them up but I don't know why.

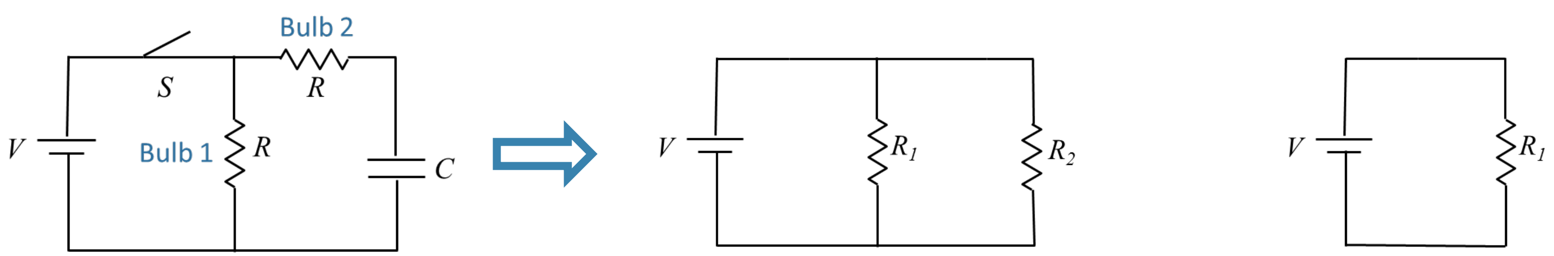
Which hand do we use for the right hand rule? I'm ambidextrous does that matter?

It's one thing to see these ideas on paper, but could you please give us a real idea of what the magnetic field actually is? Like in quantum or more advanced physics, all these crazy things can be explained and understood conceptually, such as E=mc^2. What really is magnetic field other than "that thing that moves stuff because of current"?

I always thought they just lied and said that the south pole was the north pole in compasses so that they wouldn't have to explain it. Apparently that was the wrong assumption.

The velocity selector takes time to comprehend. Please go over this again in class.

In the great words of Jesse Pinkman from Breaking Bad..."YEAH! MAGNETS!"



Short time: $I_{tot} = 2V/R$, $I_1 = I_{tot}/2 = V/R$

Long time: $I_1 = V/R$

Physics 212
Lecture 12

Today's Concept:

Magnetic Force on Moving Charges

Key Concepts:

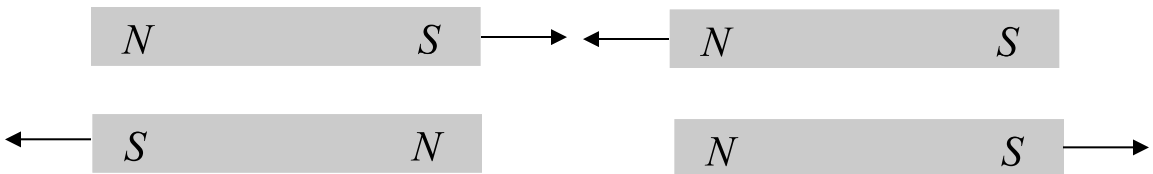
1) The force on moving charges due to a magnetic field.
2) The cross product.

Today's Plan:

1) Review of magnetism
2) Review of cross product
3) Example problem

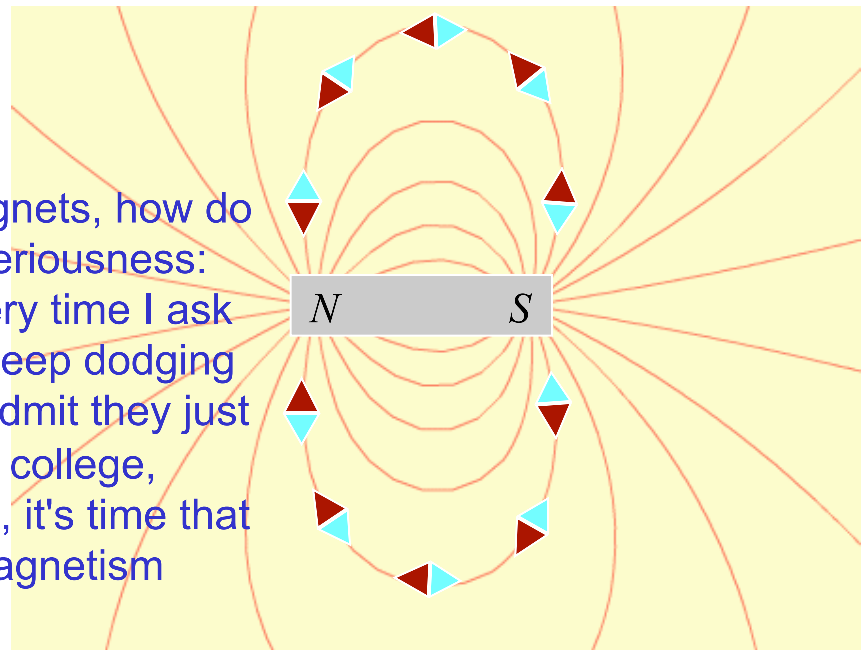
Magnetic Observations

Bar Magnets

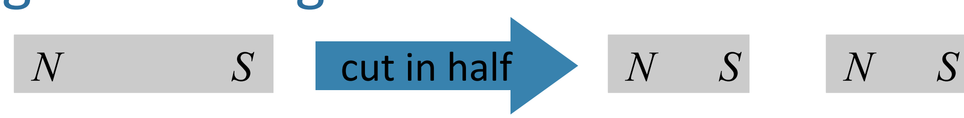


Compass Needles

I'm sure you're getting a lot of "Magnets, how do they work?" comments, but in all seriousness: can you explain this? I feel like every time I ask someone who ought to know, the keep dodging the question until they eventually admit they just can't explain it. I'm a sophomore in college, taking electricity and MAGNETISM, it's time that I be brought up to speed on this magnetism thing. Thank you.

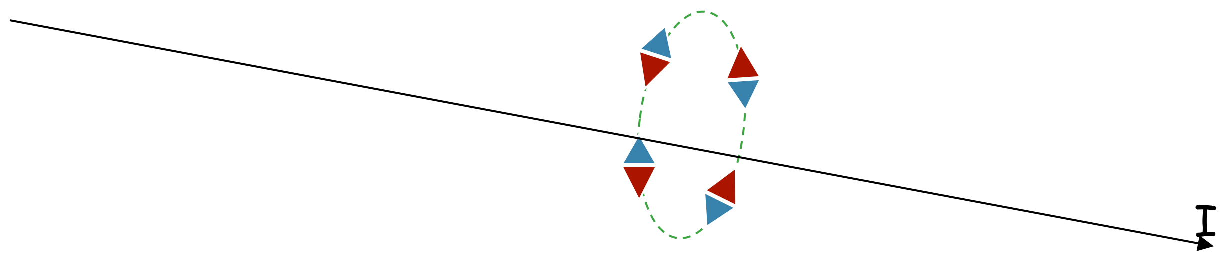


Magnetic Charge?



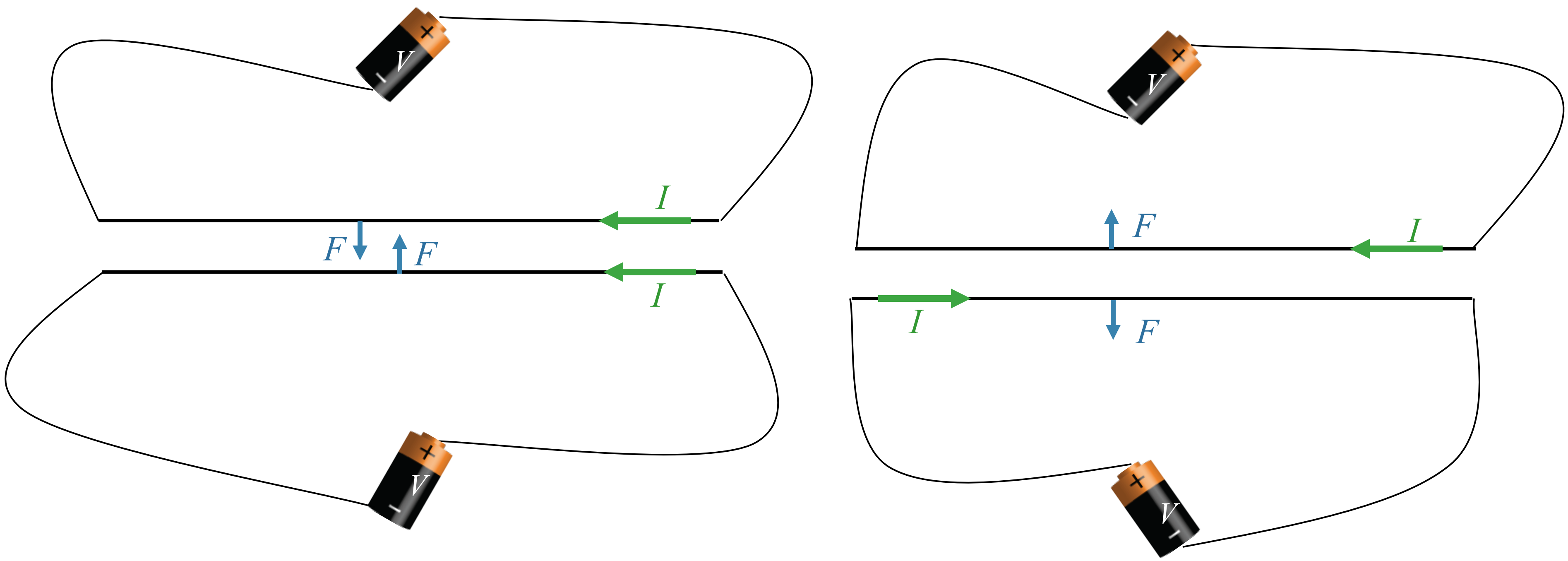
Magnetic Observations

Compass needle deflected by electric current

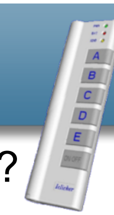


Magnetic fields created by electric currents

Magnetic fields exert forces on electric currents (charges in motion)



Magnetic Observations



really confusing on how to figure out the force direction and what do the "Xs" really mean??

I (out of the screen) *I* (into of the screen)

Case I **Case II**

The magnetic field at *P* points

A. $\boxed{\text{Case I: left, Case II: right}}$

B. Case I: left, Case II: left

C. Case I: right, Case II: left

D. Case I: right, Case II: right

WHY? Direction of $\vec{B}$: right thumb in direction of $\vec{I}$, fingers curl in the direction of $\vec{B}$

Magnetism & Moving Charges

All observations are explained by two equations:

$$\boxed{\vec{F} = q\vec{v} \times \vec{B}}$$

Today

$$\boxed{d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2}}$$

Next Week

Cross Product Review

Cross Product different from Dot Product

$A \bullet B$ is a scalar; $A \times B$ is a vector

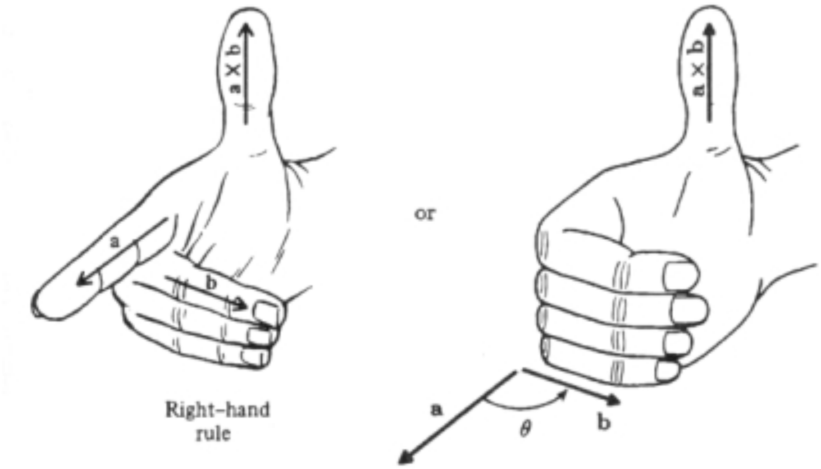
$A \bullet B$ proportional to the component of B parallel to A

$A \times B$ proportional to the component of B perpendicular to A

Definition of $A \times B$

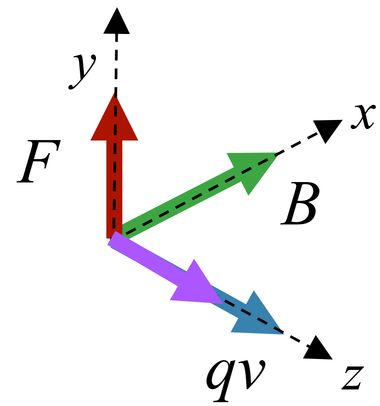
Magnitude: $AB\sin\theta$

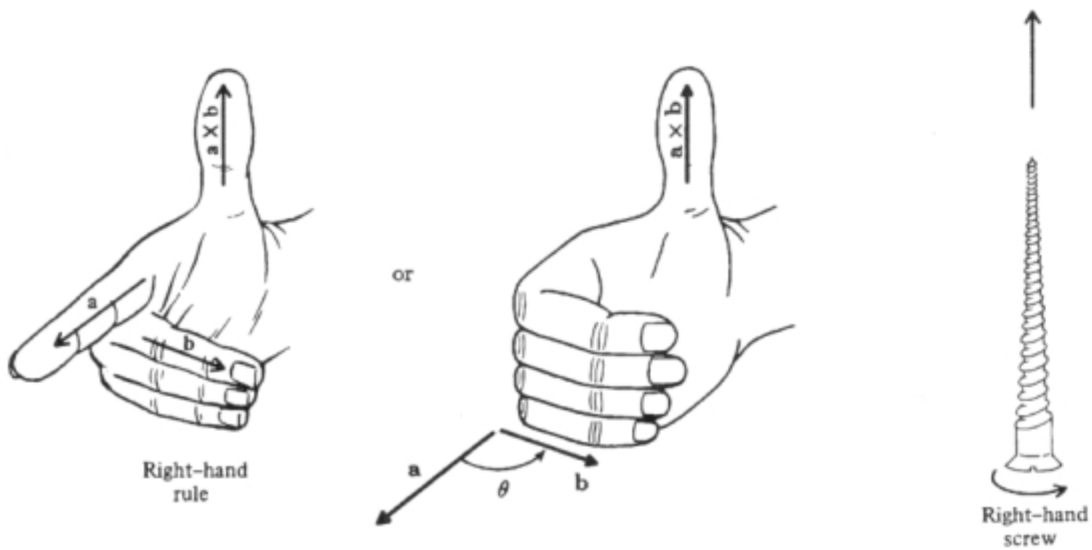
Direction: perpendicular to plane defined by A and B with sense given by right-hand-rule



Remembering Directions: The Right Hand Rule

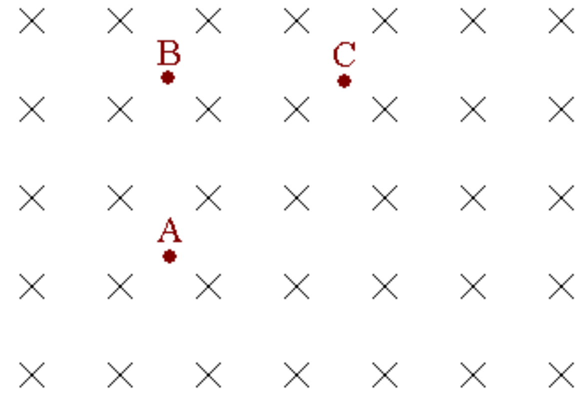
$$\vec{F} = q\vec{v} \times \vec{B}$$





CheckPoint 1a

Three points are arranged in a uniform magnetic field. The B field points into the screen.



A positively charged particle is located at point A and is stationary. The direction of the magnetic force on the particle is

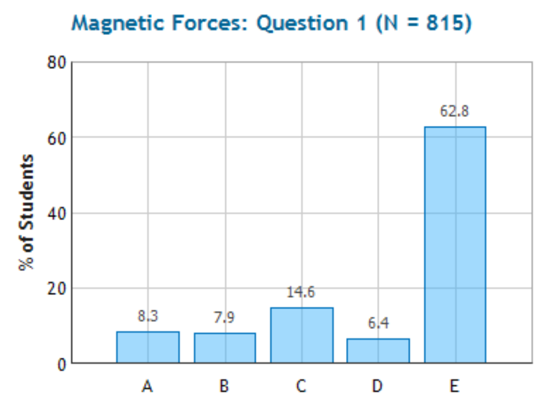
A. right ***B.*** left ***C.*** into the screen ***D.*** out of the screen

$\boxed{\textit{\textbf{E.}}\ \text{zero}}$

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

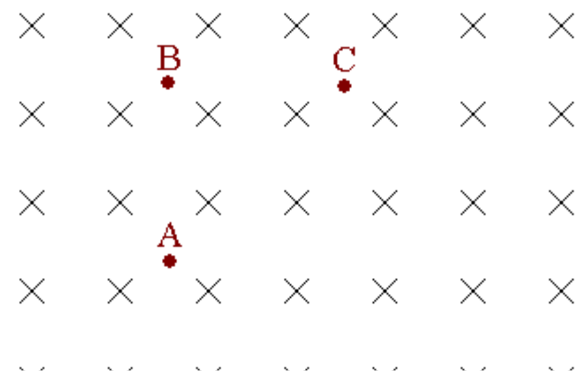
The particle's velocity is zero.

There can be no magnetic force.



CheckPoint 1b

Three points are arranged in a uniform magnetic field. The B field points into the screen.



The positive charge moves from A toward B. The direction of the magnetic force on the particle is

A. right

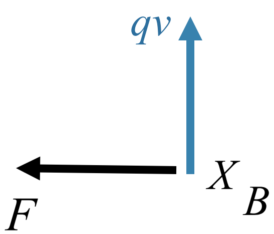
B. left

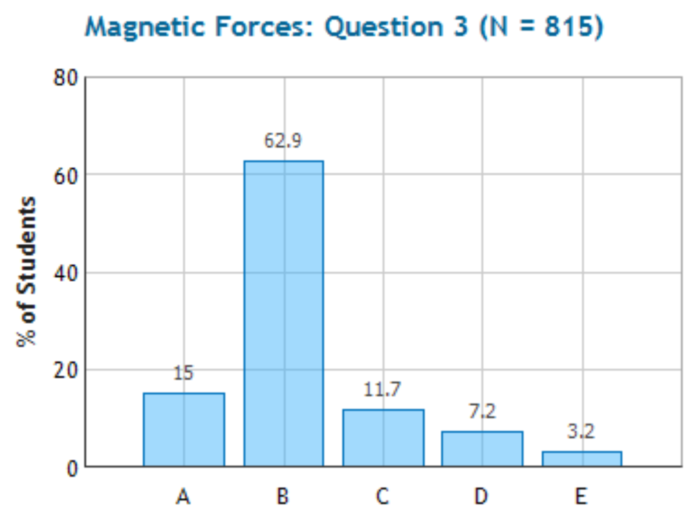
C. into the screen

D. out of the screen

E. zero

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





Cross Product Practice

Protons (positive charge) coming out of screen

Magnetic field pointing down

What is direction of force on POSITIVE charge?

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

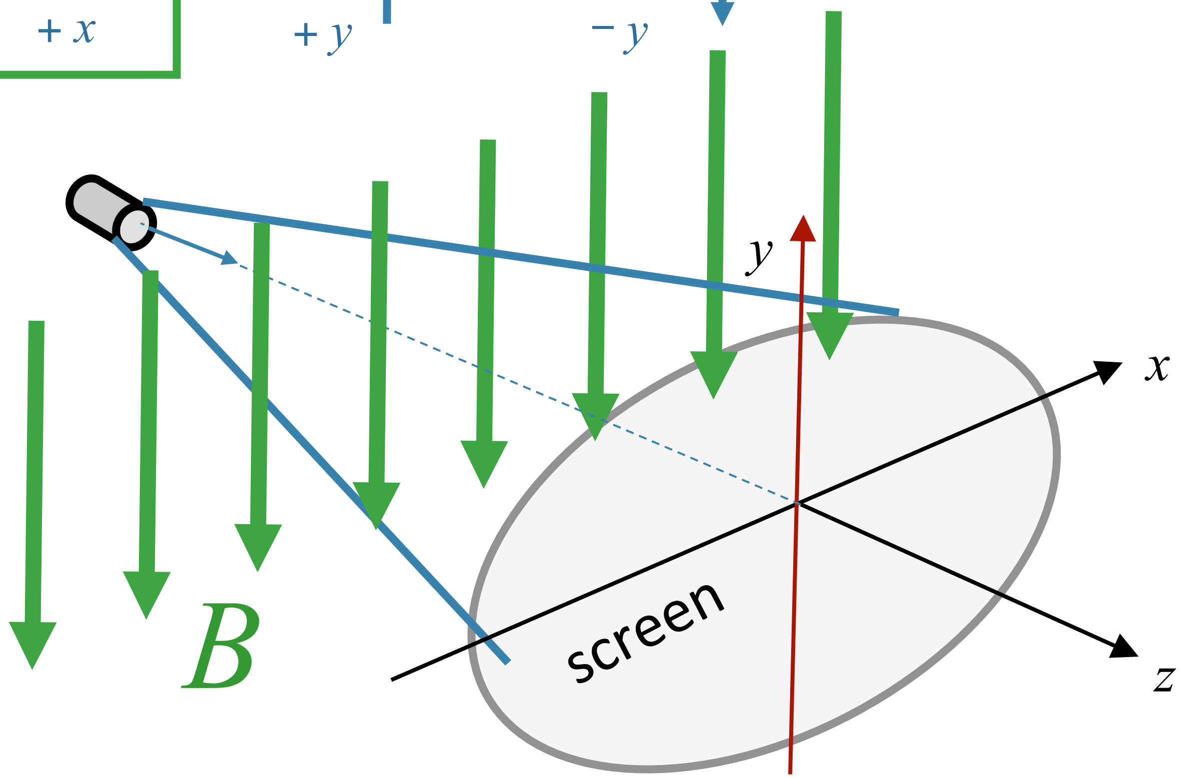
A) Left $-x$

B) Right $+x$

C) UP $+y$

D) Down $-y$

E) Zero



Motion of Charge q in Uniform B Field

Force is perpendicular to v

Speed does not change

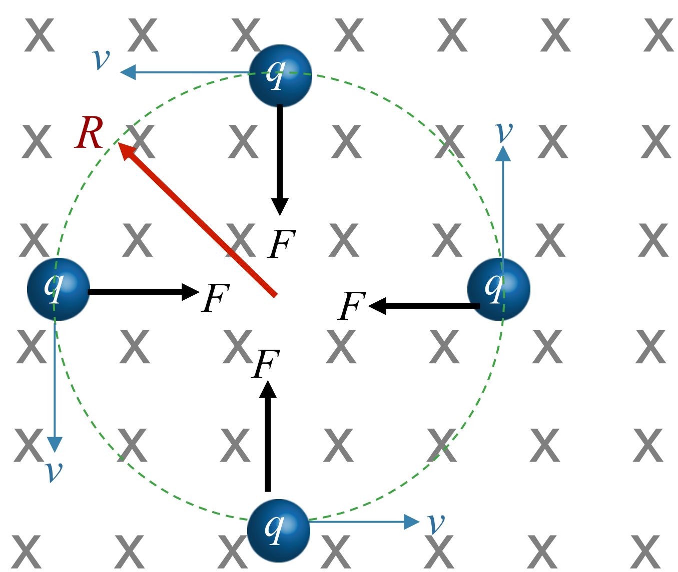
Uniform Circular Motion

Solve for R:

$$\vec{F} = q\vec{v} \times \vec{B} \Rightarrow F = qvB$$

$$a = \frac{v^2}{R}$$

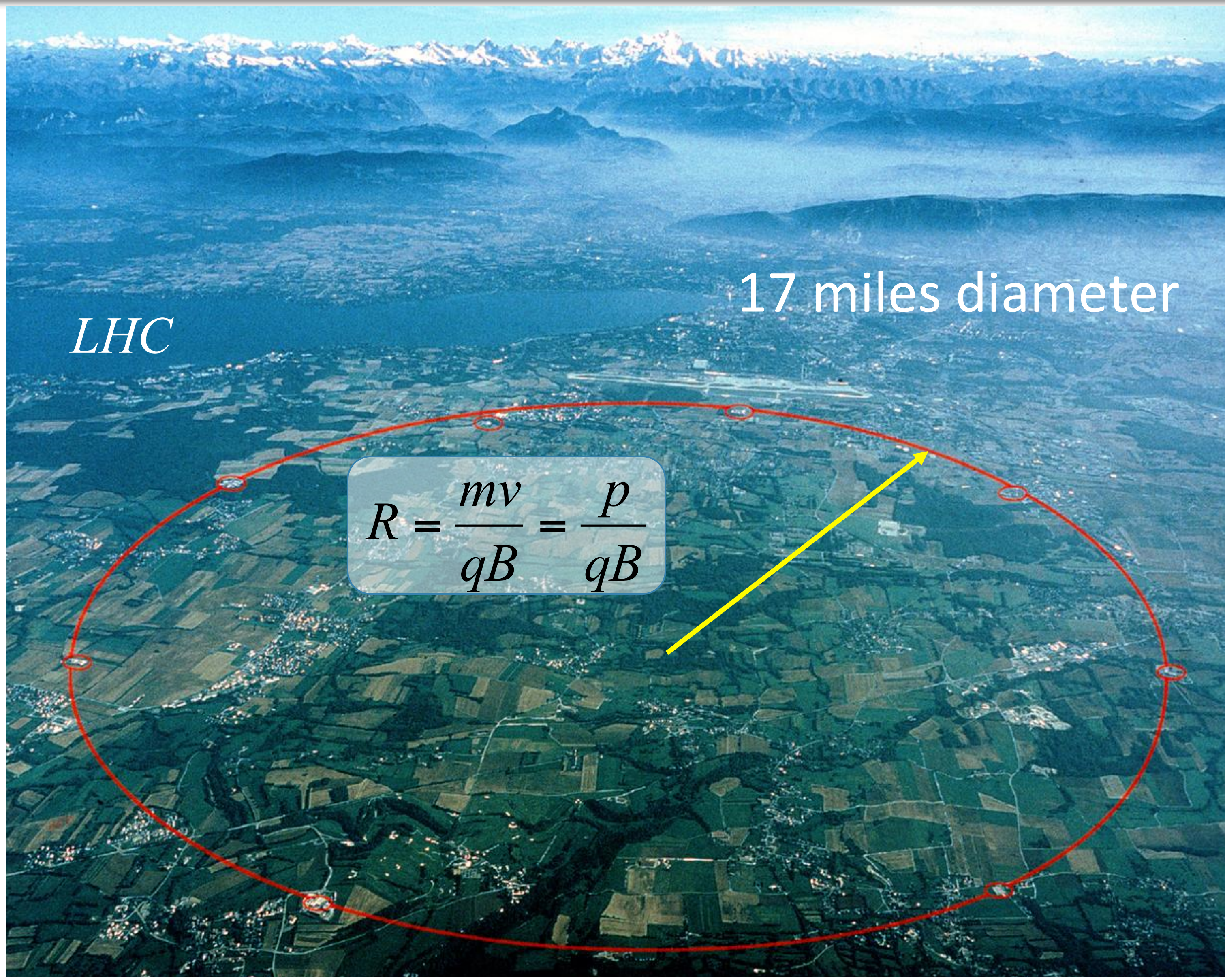
$$qvB = m\frac{v^2}{R} \quad \longrightarrow \quad R = \frac{mv}{qB}$$



Uniform B into page

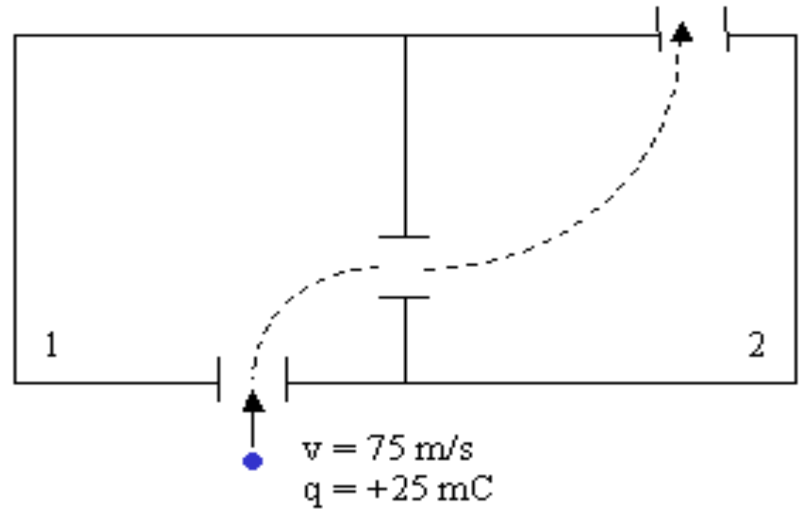
Demo

Can you take us to the LHC to see some of the big magnets in the ring and the detectors there?



CheckPoint 2

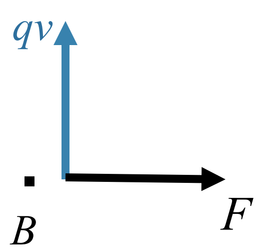
The drawing below shows the top view of two interconnected chambers. Each chamber has a unique magnetic field. A positively charged particle is fired into chamber 1, and observed to follow the dashed path shown in the figure.

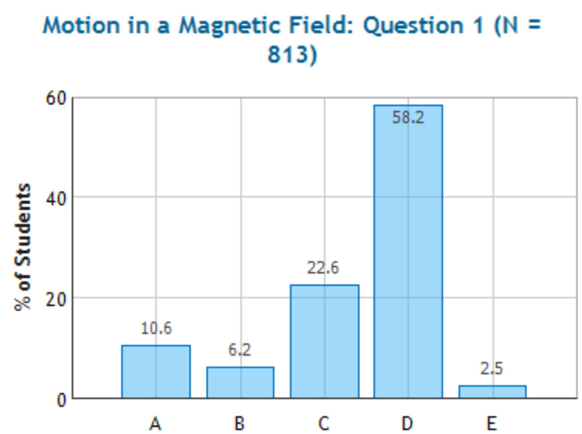


What is the direction of the magnetic field in chamber 1?

A. up ***B.*** down ***C.*** into the page ***D.*** $\boxed{\text{out of the page}}$

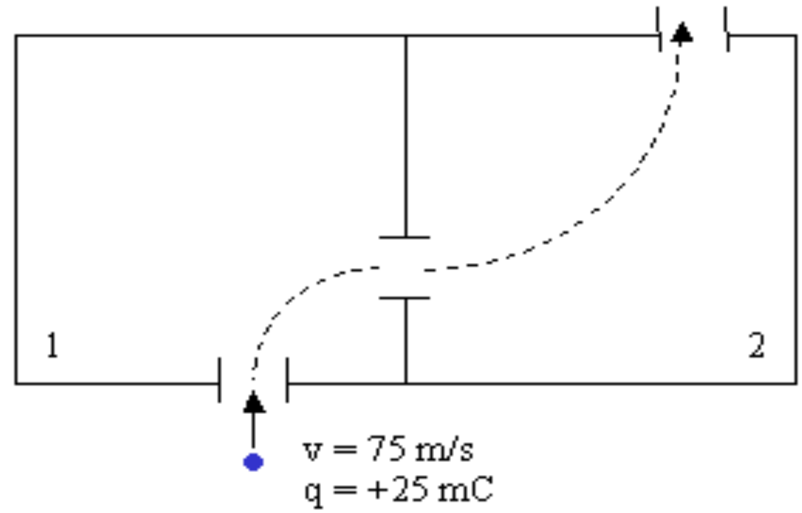
$$\vec{F} = q\vec{v} \times \vec{B}$$





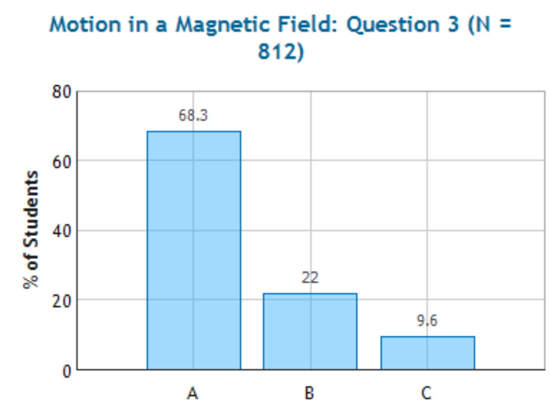
CheckPoint 8

The drawing below shows the top view of two interconnected chambers. Each chamber has a unique magnetic field. A positively charged particle is fired into chamber 1, and observed to follow the dashed path shown in the figure.



Compare the magnitude of the magnetic field in chamber 1 to the magnitude of the magnetic field in chamber 2

A. $|B_1| > |B_2|$ ***B.*** $|B_1| = |B_2|$ ***C.*** $|B_1| < |B_2|$



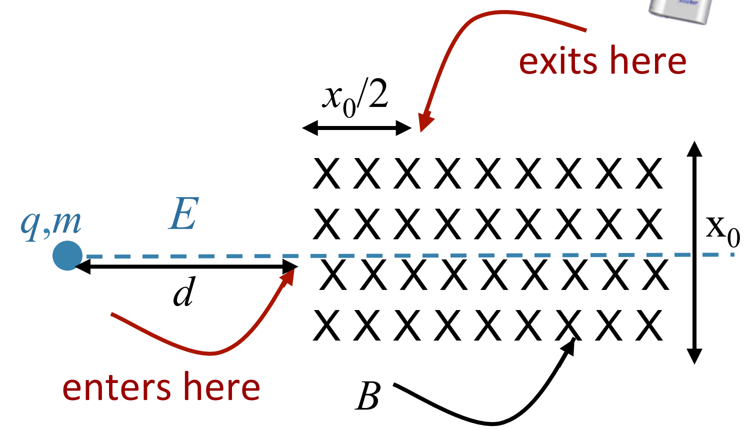
Observation: $R_2 > R_1$

$$R = \frac{mv}{qB} \longrightarrow |B_1| > |B_2|$$

Calculation

A particle of charge q and mass m is accelerated from rest by an electric field E through a distance d and enters and exits a region containing a constant magnetic field B at the points shown. Assume q,m,E,d, and x_0 are known.

What is B?



Conceptual Analysis

What do we need to know to solve this problem?

A) Lorentz Force Law $(\vec{F} = q\vec{v}\times\vec{B} + q\vec{E})$

B) E field definition

C) V definition

D) Conservation of Energy/Newton's Laws

E) All of the above

Absolutely ! We need to use the definitions of V and E and either conservation of energy or Newton's Laws to understand the motion of the particle before it enters the B field.

We need to use the Lorentz Force Law (and Newton's Laws) to determine what happens in the magnetic field.

Calculation

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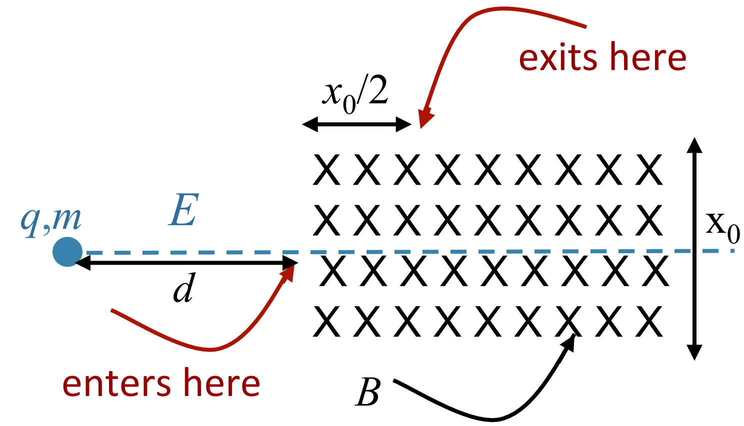
What is B?



Strategic Analysis

Calculate v, the velocity of the particle as it enters the magnetic field

Use Lorentz Force equation to determine the path in the field as a function of B

Apply the entrance-exit information to determine B

Let's Do It !

Calculation

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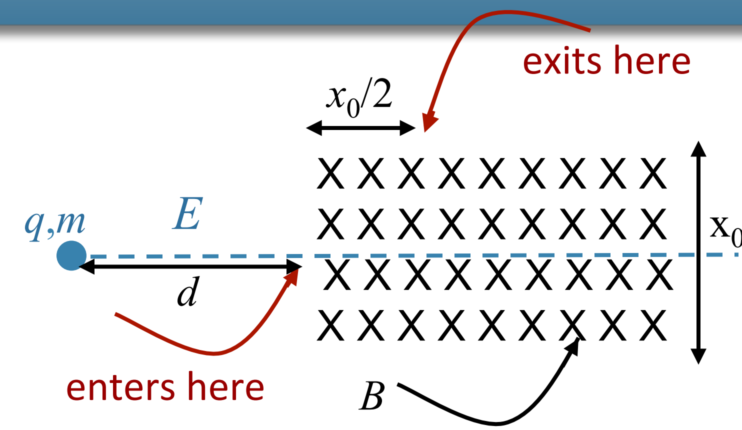

What is B?

- What is the change in the particle's potential energy after travelling distance d?

$\boxed{\Delta U = -qEd}$ (A)

$\Delta U = -Ed$ (B)

$\Delta U = 0$ (C)

- Why??
  – How do you calculate change in the electric potential given an electric field? → $\Delta V = -\int \vec{E} \cdot d\vec{\ell} = -Ed$
  – What is the relation between the electric potential amd the potential energy? → $\Delta U = q\Delta V$

Calculation

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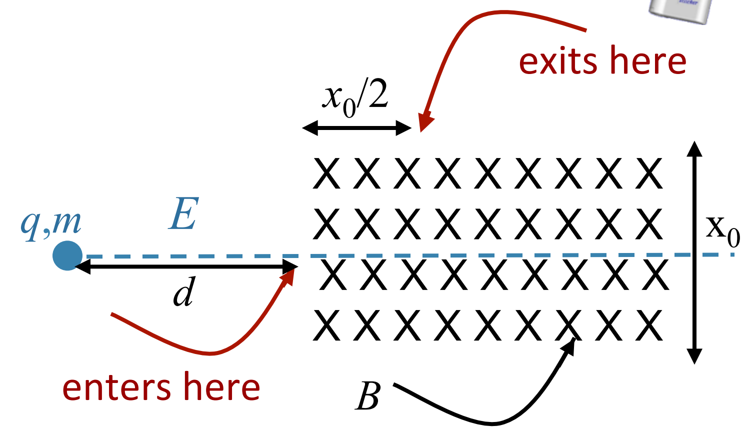
What is B?



What is v_0, the speed of the particle as it enters the magnetic field ?

$$v_o = \sqrt{\frac{2E}{m}}$$
A

$$\boxed{v_o = \sqrt{\frac{2qEd}{m}}}$$
B

$$v_o = \sqrt{2ad}$$
C

$$v_o = \sqrt{\frac{2qE}{md}}$$
D

$$v_o = \sqrt{\frac{qEd}{m}}$$
E

Why?

Conservation of Energy

Initial: $Energy = U = qV = qEd$

Final: $Energy = KE = ½\, mv_0^2$

$$\rightarrow \tfrac{1}{2} m v_o^2 = qEd \rightarrow v_o = \sqrt{\frac{2qEd}{m}}$$

Newton's Laws

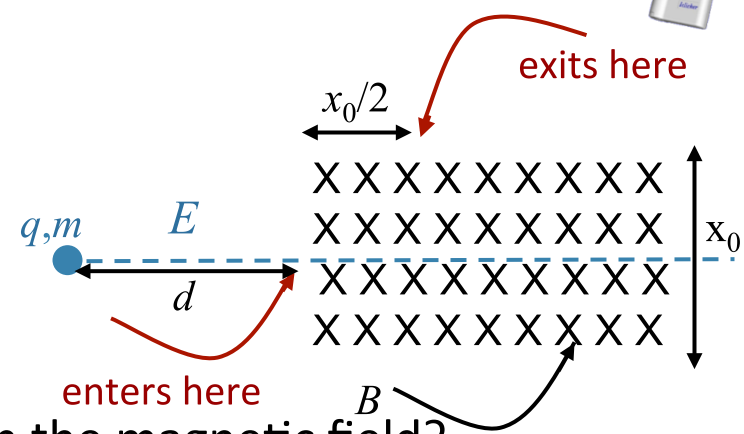
$a = F/m = qE/m$

$v_0^2 = 2ad$

$$\rightarrow v_o^2 = 2\frac{qE}{m}d \rightarrow v_o = \sqrt{\frac{2qEd}{m}}$$

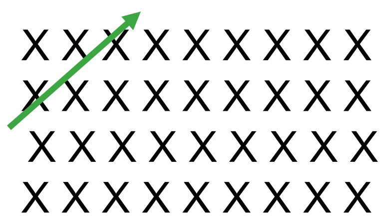
Calculation

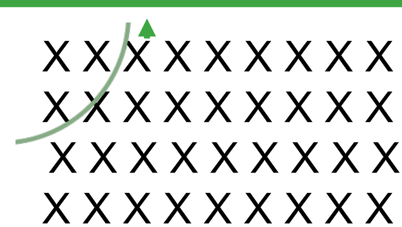
A particle of charge q and mass m is accelerated from rest by an electric field E through a distance d and enters and exits a region containing a constant magnetic field B at the points shown. Assume q,m,E,d, and x_0 are known.

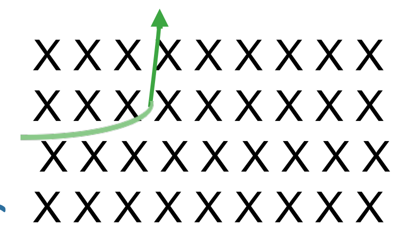


What is B? $v_o = \sqrt{\frac{2qEd}{m}}$

What is the path of the particle as it moves through the magnetic field?

A 

B 

C 

Why?

Path is circle!

Force is perpendicular to the velocity

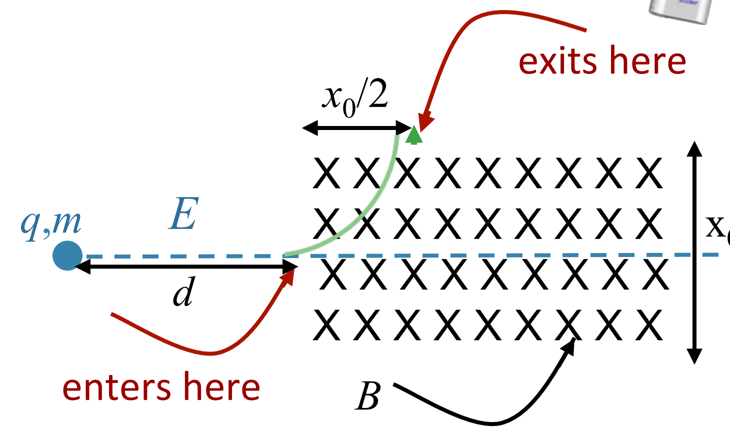
Force produces centripetal acceleration

Particle moves with uniform circular motion

Calculation

A particle of charge q and mass m is accelerated from rest by an electric field E through a distance d and enters and exits a region containing a constant magnetic field B at the points shown. Assume q,m,E,d, and x_0 are known.

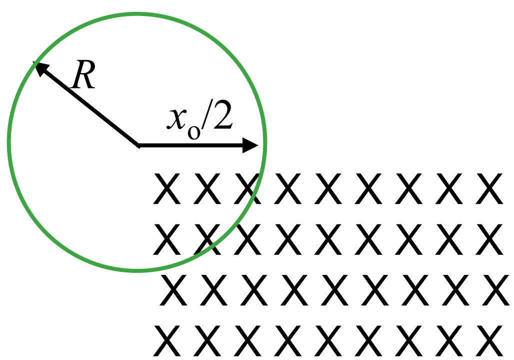
What is B? $v_o = \sqrt{\frac{2qEd}{m}}$



What can we use to calculate the radius of the path of the particle?

A	B	C	D	E
$R = x_o$	$R = 2x_o$	$\boxed{R = \frac{1}{2}x_o}$	$R = \frac{mv_o}{qB}$	$R = \frac{v_o^2}{a}$

Why?



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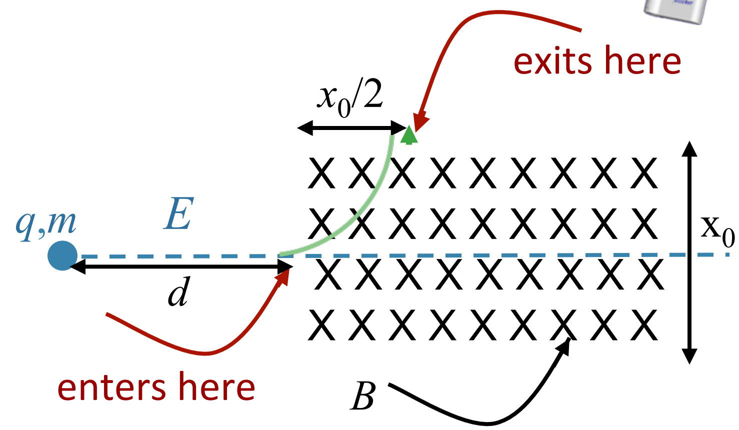

What is B?

$$v_o = \sqrt{\frac{2qEd}{m}} \qquad R = \tfrac{1}{2}x_0$$

A: $B = \dfrac{2}{x_o}\sqrt{\dfrac{2mEd}{q}}$

B: $B = \dfrac{E}{v}$

C: $B = E\sqrt{\dfrac{m}{2qEd}}$

D: $B = \dfrac{1}{x_o}\sqrt{\dfrac{2mEd}{q}}$

E: $B = \dfrac{mv_o}{qx_o}$

Why?

$$\vec{F} = m\vec{a} \rightarrow qv_oB = m\frac{v_o^2}{R} \rightarrow B = \frac{m}{q}\frac{v_o}{R} \rightarrow B = \frac{m}{q}\frac{2}{x_o}\sqrt{\frac{2qEd}{m}} \rightarrow B = \frac{2}{x_o}\sqrt{\frac{2mEd}{q}}$$