

Mar 20

Get clickers and whiteboards

Next week office hours canceled. Email me questions.

**Last midterm is April 1 (no fooling).
Practice exam is on website.**

Q20.3a

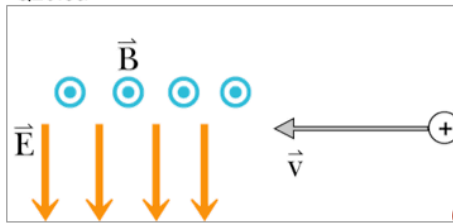


Diagram showing a positive charge moving to the left (indicated by $\vec{v}$) in a region with a uniform electric field $\vec{E}$ pointing down and a uniform magnetic field $\vec{B}$ pointing out of the page (indicated by blue circles with dots). Four points A, B, C, and D are marked along the path of the charge.

Forces on the moving POSITIVE charge:		
	$\mathbf{F}_{\text{elec}}$	$\mathbf{F}_{\text{mag}}$
A	UP	UP
B	DOWN	DOWN
C	UP	DOWN
D	DOWN	UP

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B} \leftarrow \text{Lorentz force}$$

Q20.3b

Diagram showing a negative charge moving to the left with velocity $\vec{v}$ in a region with a uniform electric field $\vec{E}$ pointing down and a uniform magnetic field $\vec{B}$ pointing out of the page (indicated by blue circles). The charge is represented by a circle with a minus sign. Four points (A, B, C, D) are marked along the path of the charge.

Forces on the moving NEGATIVE charge:

	$\mathbf{F}_{\text{elec}}$	$\mathbf{F}_{\text{mag}}$
A	UP	UP
B	DOWN	DOWN
C	UP	DOWN
D	DOWN	UP

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

Q20.3c

	Particle of charge $+q$ travels in a straight line at constant speed. Which is true? ☒ A. $qE = qvB$ ☐ B. $E = B$ ☐ C. $E = q / (vB)$ ☐ D. $qE = qB$
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$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

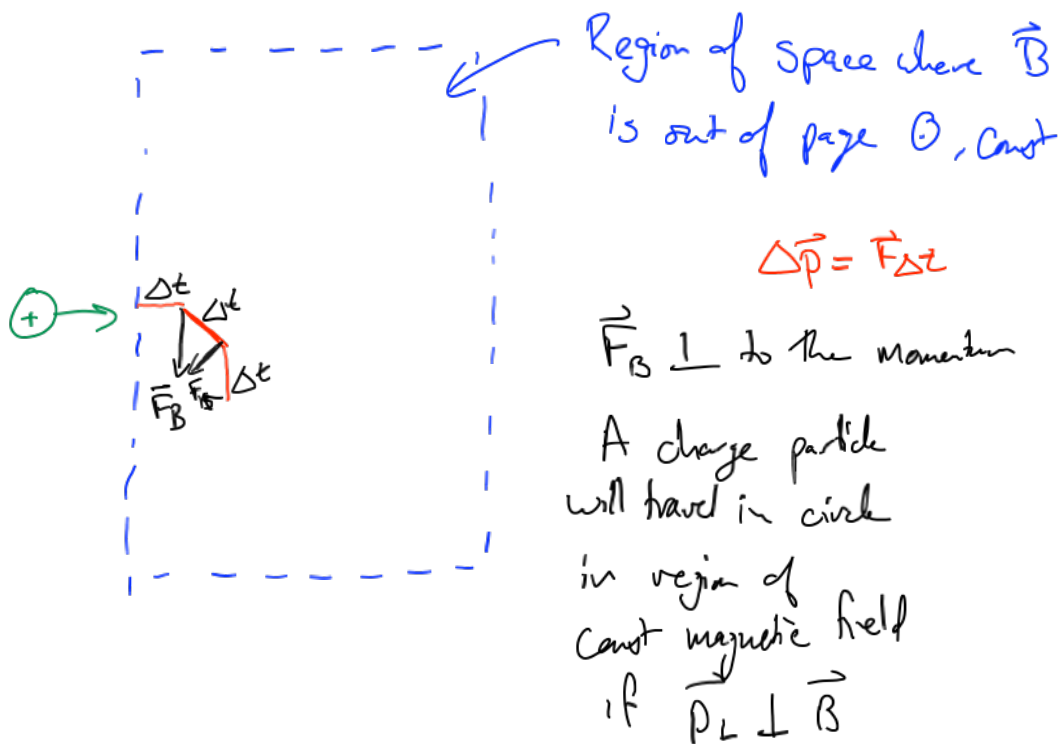
$$|q\vec{E}| = |q\vec{v} \times \vec{B}|$$

$$E = |\vec{v} \times \vec{B}|$$

$$\hookrightarrow vB = E$$

velocity selector

Ponderable: You spin me right round



5. After being in the magnetic field for a short time Δt , how has the magnitude of the proton's momentum changed?

- A. It has increased
- B. It has decreased
- C. It has not changed

Magnetic forces only change the direction of proton

Magnetic forces do no work KE, PE are unchanged

$$W = \int \vec{F} \cdot d\vec{r} = 0$$

What is radius of circle?

Hint: $\left| \frac{d\vec{p}}{dt} \right| = |\vec{p}|/R$

$$\frac{d\vec{p}}{dt} = \vec{F}_{\text{net}}$$

(in const $\vec{B}$)

$$\left| \frac{d\vec{p}}{dt} \right| = \frac{|\vec{p}|v}{R} = |q\vec{v} \times \vec{B}| = |q|vB \sin \theta \Rightarrow$$

← non rel. $p = mv$

$$\frac{|\vec{p}|}{R} = |q|B \sin \theta$$

$$mv = R|q|B$$

If $\vec{v} \perp \vec{B} \Rightarrow \sin \theta = \sin 90 = 1 \Rightarrow$

Demo: VPython Helix

Ponderable: Force on a current-carrying wire



+ charge carriers not moving $\Rightarrow$ no force

- charges feel force into page

total of $n A \Delta l$ charge carriers in wire (Area A , length Δl)

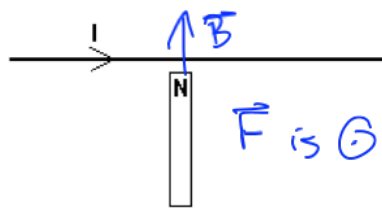
But $n A q v = I$

$$\begin{aligned}\vec{F}_{\text{mag}} &= n A \Delta l q \vec{v} \times \vec{B} \\ &= I \Delta \vec{l} \times \vec{B}\end{aligned}$$

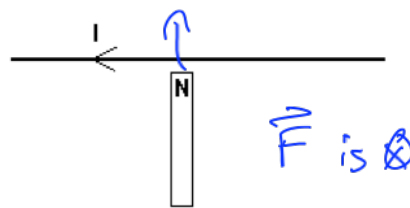
$\Delta \vec{l}$ is in direction
as $\vec{E}$ in wire, I

$$\vec{F} = I \Delta \vec{\ell} \times \vec{B}$$

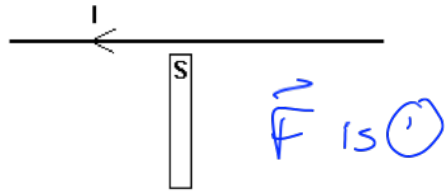
Tangible: Swing Low...



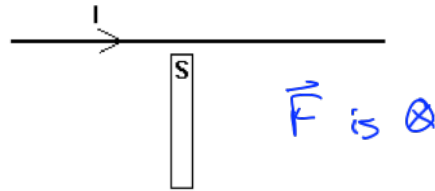
A.



B.



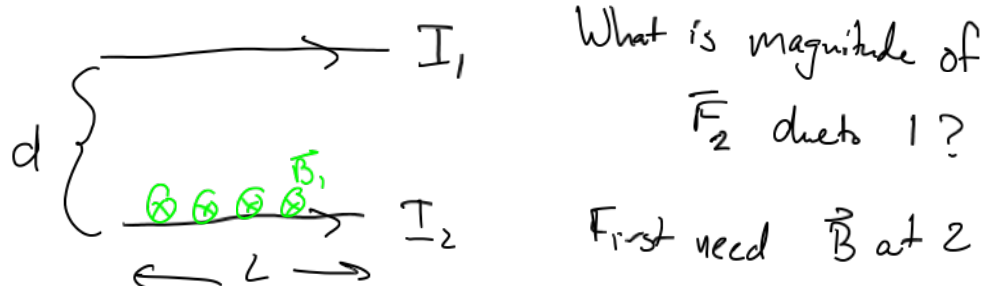
C.



D.

Sweet Chariot

Ponderable: Let me spring this on you



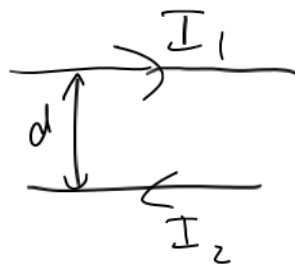
$$|\vec{B}| = \frac{\mu_0}{4\pi} \frac{2I_1}{d} \quad d \ll L$$

Now force on 2

$$|\vec{F}_2| = I_2 \Delta \vec{l} \times \vec{B}_1 = I_2 L B_1 \sin \theta$$

$$|\vec{F}_2| = \frac{\mu_0}{4\pi} \frac{2 I_1 I_2 L}{d}$$

direction? (on 2) up $\Rightarrow$ wires are pulled together

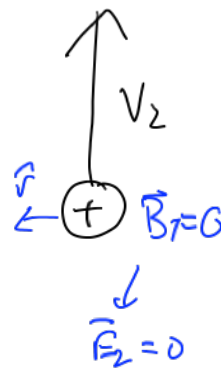
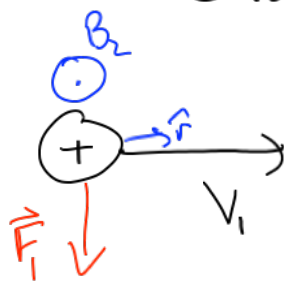


$$|\vec{F}_{21}| = \frac{\mu_0}{4\pi} \frac{2I_1 I_2 L}{d}$$

direction $\Rightarrow$ Wires pushed apart

Ponderable: Push me, will you?

Show It



$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q \vec{v} \times \vec{r}}{r^2}$$

$$\vec{F}_1 = q_1 \vec{v}_1 \times \vec{B}_2$$

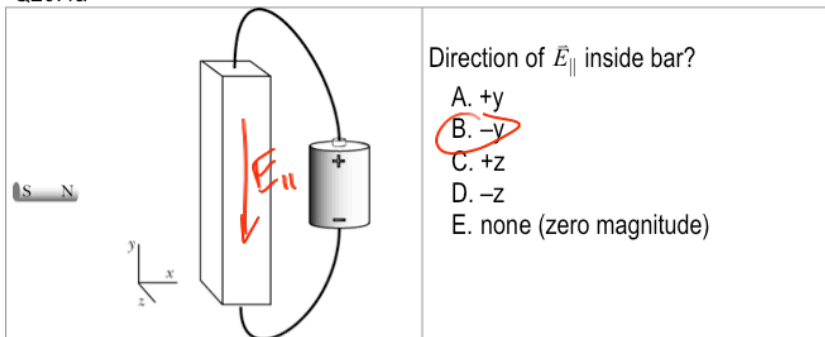
$$\Delta \vec{p} = \vec{F}_{\text{net}} \Delta t$$

$$\vec{F}_1 \stackrel{?}{=} -\vec{F}_2 \quad \underline{\underline{\text{no}}}$$

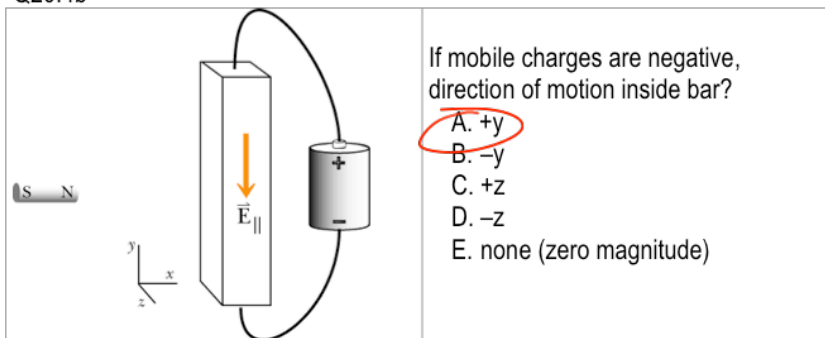
Newton's 3rd does not hold for mag forces

Ponderable: Hall Effect

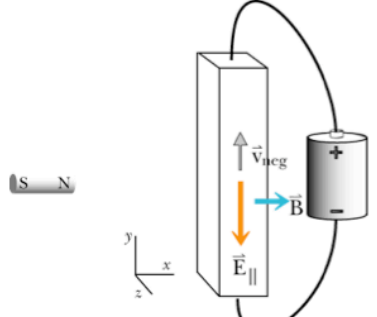
Q20.4a



Q20.4b



Q20.4c

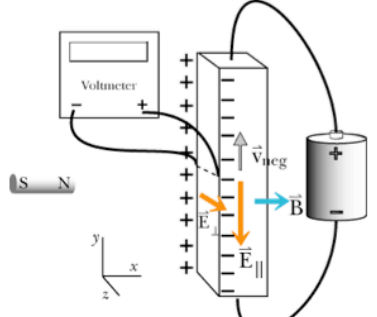


Direction of $\vec{F}_{\text{mag}}$ on moving negative charge?

- A. +y
- B. -y
- C. +z
- D. -z
- E. none (zero magnitude)

The diagram shows a horizontal rod on two vertical rails, connected to a battery. A magnetic field $\vec{B}$ points to the right. The rod moves to the right with velocity $\vec{v}_{\text{neg}}$. An induced electric field $\vec{E}_{\parallel}$ points downwards. A coordinate system shows y is vertical, x is horizontal to the right, and z is out of the page.

Q20.4d

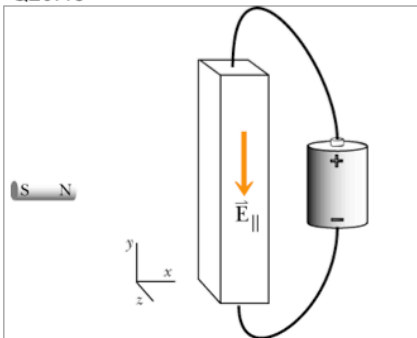


If mobile charges are negative, sign of voltmeter reading?
 (Voltmeter reads positive if + lead is connected to higher potential location)

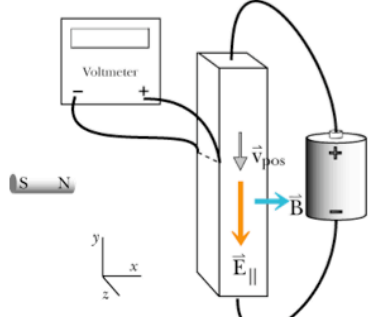
A. positive
 B. negative
 C. zero

The diagram shows a vertical rod with a battery connected to its ends. A voltmeter is connected to the rod with its positive lead at the top and negative lead at the bottom. A magnetic field $\vec{B}$ points to the right. An orange arrow $\vec{E}_\perp$ points downwards, and a blue arrow $\vec{E}_\parallel$ points upwards. A coordinate system shows y pointing up, x pointing right, and z pointing out of the page. The rod is marked with '+' signs on the left and '-' signs on the right.

Q20.4e

 The diagram shows a rectangular bar connected to a battery. To the left of the bar is a bar magnet with its South (S) pole on the left and North (N) pole on the right. A coordinate system is shown with the y-axis pointing upwards, the x-axis pointing to the right, and the z-axis pointing out of the page. Inside the bar, an orange arrow points downwards, labeled $\vec{E}_{\parallel}$. The battery is connected to the top and bottom of the bar, with the positive terminal at the top.	If mobile charges are positive, direction of motion inside bar? A. +y B. -y C. +z D. -z E. none (zero magnitude)
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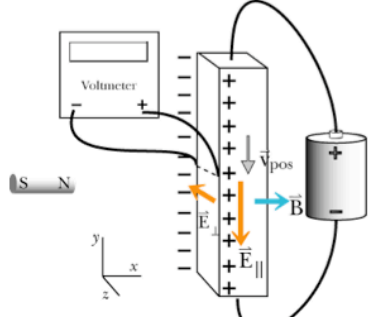
Q20.4f



If mobile charges are positive, direction of magnetic force?

- A. +y
- B. -y
- C. +z
- D. -z
- E. none (zero magnitude)

Q20.4g

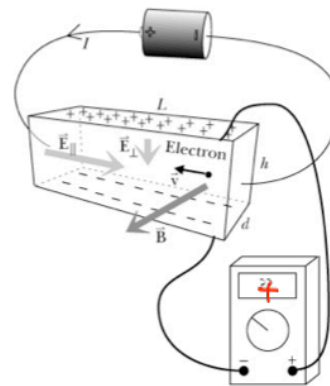
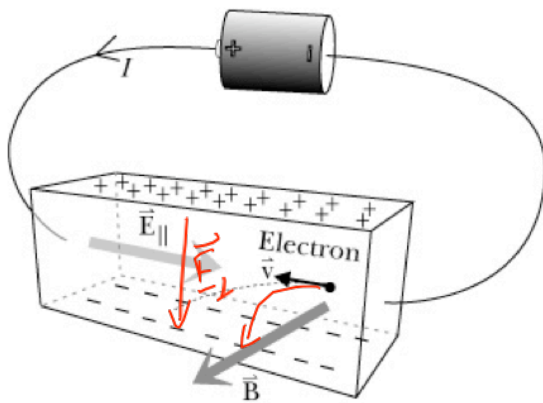


If mobile charges are positive, sign of voltmeter reading?
 (Voltmeter reads positive if + lead is connected to higher potential location)

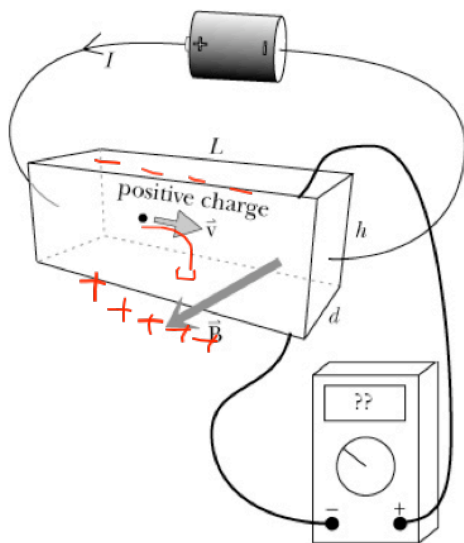
A. positive
 B. negative
 C. zero

will see sign of charges

Hall Effect



reads +



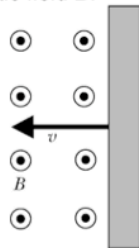
need -

There are materials
which have +
charge carriers

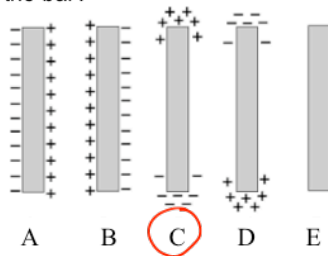
Ponderable: Motional emf

Q20.5a

A neutral copper bar is dragged at speed v through a region with magnetic field B .

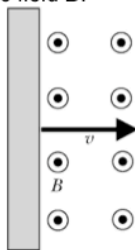


Which diagram best shows the state of the bar?

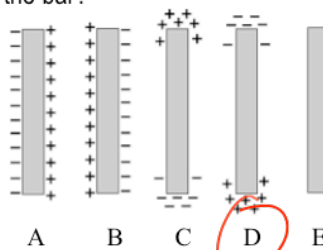


Q20.5b

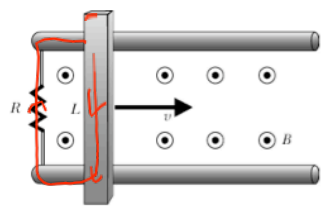
A neutral copper bar is dragged at speed v through a region with magnetic field B .



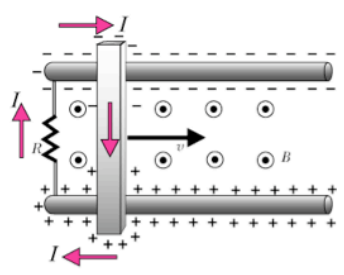
Which diagram best shows the state of the bar?



Q20.5c

 The diagram shows a horizontal rod of length L and resistance R on two parallel rails. A magnetic field B is directed into the page, indicated by dots in a grid. The rod is pulled to the right with a constant velocity v, as shown by an arrow. A red '+' sign is at the bottom left of the rod. Red arrows on the rod indicate a clockwise current flow.	Which direction will conventional current flow? A) Clockwise B) Counter-clockwise C) No current
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Q20.5e

 The diagram shows a horizontal rod of length ℓ and resistance R placed on two parallel horizontal rails. The rails are connected at the left end by a resistor R. A vertical rod is connected to the left end of the horizontal rod and the bottom rail. A magnetic field B is directed into the page, indicated by dots in circles. The rod is moving to the right with velocity v. Current I flows from the top rail, through the rod, and back to the bottom rail.	Current flows as shown. Is there a magnetic force on the entire bar? A) F_{mag} on bar is upward B) F_{mag} on bar is downward C) F_{mag} on bar is to the right D) F_{mag} on bar is to the left E) F_{mag} on bar = 0
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$$\vec{F} = I \vec{\ell} \times \vec{B}$$