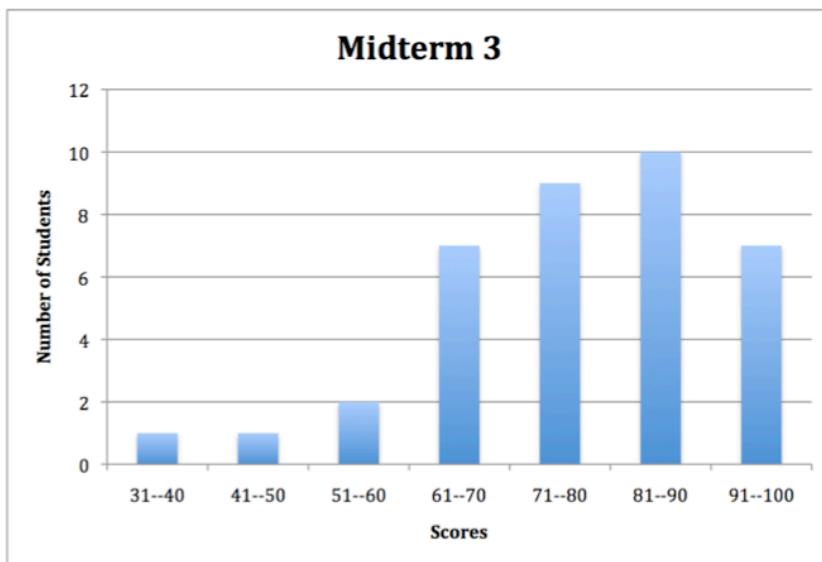


Apr 3

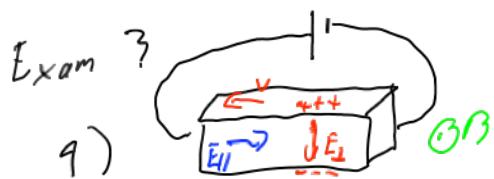
Get clickers



Mean: 77

Median: 80

Std Dev: 14



$$qvB = q\bar{E} = \tau \frac{\Delta V}{L}$$

$$V = \frac{\Delta V}{BL} = 0.01 \text{ m/s}$$

$$t = \frac{1}{V} = 18 \text{ s}$$

$$V = \mu \bar{E} \rightarrow \mu = \frac{V}{\bar{E}} = \frac{Vd}{\Delta V} = 0.0012$$

$$I = qnAv \rightarrow n =$$

7)



a) $\oint \vec{B} \cdot d\vec{l} = B_f l_r = 5,0 e^{-6} T \cdot m$

b) $\oint \vec{B} \cdot d\vec{l} = -B_f l_r = -5,0 e^{-6} T \cdot m$

c) $\oint \vec{B} \cdot d\vec{l} = 0$

$\oint \vec{B} \cdot d\vec{l} = -2 e^{-6} T \cdot m = \mu_0 I_{inc}$

$I_{inc} = 1,6 A$ \textcircled{R}

Discussion: Coulombic and Non-Coulombic Electric Fields

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r} \quad \text{Coulomb's law}$$

$$\hookrightarrow \oint \vec{E} \cdot \hat{n} dA = \frac{\sum q_i}{\epsilon_0} \quad \text{Gauss' Law}$$



$$\nabla \cdot \vec{E} = \rho / \epsilon_0$$

$\nabla \times \vec{E} = 0$
true for stationary charges

$$\Delta V_{\text{round path}} = 0 = - \oint \vec{E} \cdot d\vec{l}$$

Many charges

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{g \vec{V} \times \vec{r}}{r^2} \quad \text{Biot-Savart Law}$$

\hookrightarrow no "curly" part of \vec{E}

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \sum I_m \leftarrow \text{curly part of } \vec{B}$$

$$\oint \vec{B} \cdot \hat{n} dA = 0 \leftarrow \text{no divergence}$$

E field for
Stationary charges

has divergence
but no curvyness

B field

has curl but no divergence

$$\Delta V = - \oint \vec{E} \cdot d\vec{l} = 0$$

Coulombic E field
no curly E field

$$\Delta V_{\text{round}} = \oint_{\text{loop}} \vec{E} \cdot d\vec{l} = \frac{d\Phi_B}{dt}$$

Non-coulombic field

Φ_B is magnetic flux
through surface surrounded
by path took integral around



Flux can change in two ways

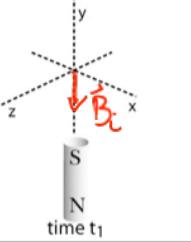
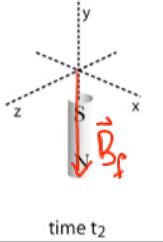
Change surface or change B

$$\Phi_B = \int_S \vec{B} \cdot \hat{n} dA$$

$$\oint_C \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \left[\int_S \vec{B} \cdot \hat{n} dA \right]$$

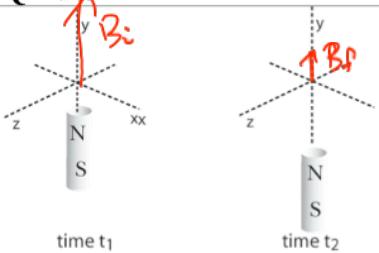
Clickers: Changing B Field

Q22.1a

 A 3D coordinate system showing a vertical z-axis pointing down, a horizontal x-axis pointing right, and a vertical y-axis pointing up. A bar magnet is positioned vertically along the z-axis. At the top (N pole) is a small grey circle with a black dot. At the bottom (S pole) is a larger grey circle with a black cross. A red arrow labeled \vec{B}_i points downwards from the S pole. Below the magnet is a label "time t_1 ".	 A 3D coordinate system identical to the first, showing the same axes and magnet orientation. A red arrow labeled \vec{B}_f points downwards from the S pole. Below the magnet is a label "time t_2 ".	<p>At the origin, what is the direction of $\Delta\vec{B}$?</p> <p>A) +y B) -y C) +z D) -z E) zero magnitude</p>
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$$\begin{array}{c} \vec{B}_i \\ \downarrow \\ \vec{\Delta B} \\ \downarrow \\ \vec{B}_f \end{array}$$

Q22.1b



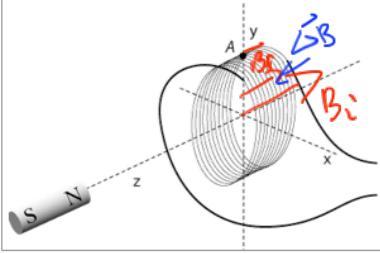
At the origin, what is the direction of $-\frac{\Delta \vec{B}}{\Delta t}$?

- A) +y
- B) -y
- C) +z
- D) -z
- E) zero magnitude

$$\begin{array}{c} \uparrow \\ B_i \end{array} \quad \downarrow \quad \frac{\Delta \vec{B}}{\Delta t} \quad \begin{array}{c} \downarrow \\ B_f \end{array} \quad - \frac{\Delta \vec{B}}{\Delta t} \quad \uparrow$$

Q22.1c

The magnet is moving in the +z direction, away from the coil.



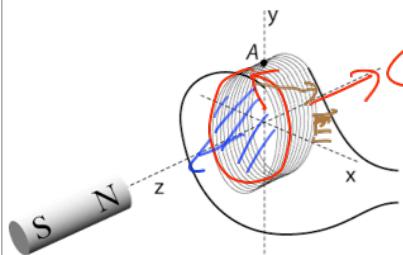
At the origin (inside the coil), what is the direction of $-dB/dt$?

- A) +y
- B) -y
- C) +z
- D) -z
- E) zero magnitude

$$\frac{d\vec{B}}{dt} \text{ in } \hat{z}$$
$$\hookrightarrow -\frac{d\vec{B}}{dt} = -\hat{z} d\omega$$

Q22.1d

The magnet is moving in the +z direction, away from the coil.



At location A, on the y-axis, inside the wire, what is the direction of the non-Coulomb electric field?

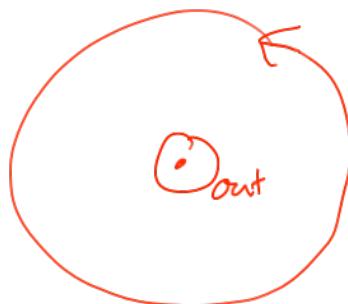
- A) +x
- B) -x
- C) +y
- D) -z
- E) zero magnitude

$$\oint \vec{E} \cdot d\vec{l} = - \frac{d\vec{B}}{dt}$$

↓ negative

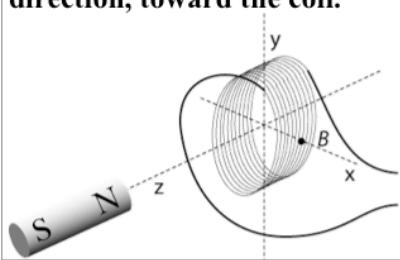
$$\hat{n} \cdot \left(- \frac{d\vec{B}}{dt} \right)$$

↓ +z o ↗ -z - #



Q22.1e

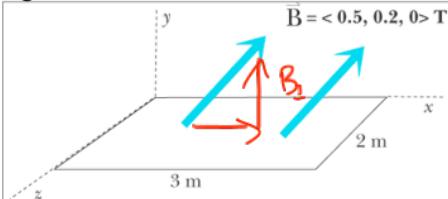
The magnet is moving in the $-z$ direction, toward the coil.



At location B, on the x-axis, inside the wire, what is the direction of the non-Coulomb electric field?

- A) +x
- B) +y**
- C) -y
- D) +z
- E) zero magnitude

Q22.2a



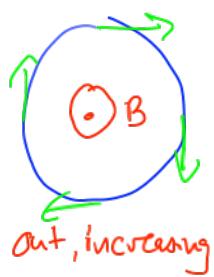
What is the magnetic flux through the rectangle?

- A) 0.2 Tm^2
- B) 0.5 Tm^2
- C) 1.2 Tm^2
- D) 3.0 Tm^2
- E) 4.2 Tm^2

$$\Phi_B = \int \vec{B} \cdot \vec{n} dA = \int B_z dA = B_z A = 0.2 \text{ T} \times 6 \text{ m}^2 = 1.2 \text{ T} \cdot \text{m}^2$$

Discussion: Faraday's Law

$$-\frac{d\Phi_B}{dt} = \text{Emf}$$

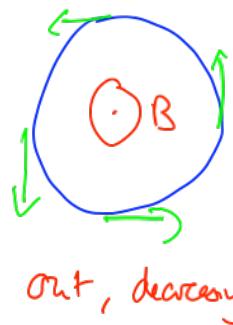


$$\frac{d\vec{B}}{dt} \oplus$$

$$-\frac{d\vec{B}}{dt} \ominus$$

$$\Phi_B = \int \vec{B} \cdot \vec{ndA}$$

$$\text{Emf} = \oint \vec{E} \cdot d\vec{l}$$



$$\frac{d\vec{B}}{dt} \ominus$$

$$-\frac{d\vec{B}}{dt} \oplus$$



$$\frac{d\vec{B}}{dt} \oplus$$

$$-\frac{d\vec{B}}{dt} \ominus$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \left[\int \vec{B} \cdot \vec{n} dA \right]$$

Tangible: Table Flux

$$B_{\parallel} = 2.0 \text{ e-5 T} \text{ in N direction}$$

$$B_{\perp} = 5.0 \text{ e-5 T down}$$

$$\Phi_B \text{ through table? } \int \vec{B} \cdot d\vec{A} = \pi R^2 B_{\perp} = 1.57 \times 10^{-4} \text{ T.m}^2 = \Phi_0$$

Consider copper wire $R = 0.5 \Omega$

flip over table in 2 seconds

What is I ?

$$\mathcal{E}_{\text{mf}} = -\frac{d\Phi_B}{dt} = -\frac{(-\Phi_0 - \Phi_0)}{2s} = \frac{2\Phi_0}{2s} = 1.57 \times 10^{-4} \text{ V}$$

$$\begin{aligned} I &= \frac{\mathcal{E}_{\text{mf}}}{R} \\ &= \frac{1.57 \times 10^{-4} \text{ V}}{0.5 \Omega} \\ &= 3.14 \times 10^{-5} \text{ A} \end{aligned}$$

Ponderable: Faraday's Law Exercises

Let There Be Light

$$B_{\text{sol}} = \frac{\mu_0 N I}{L} = \mu_0 n I$$

of turns
L
↑ length ↗
m # of turns

$$-\left(\frac{0 - \Phi_{B0}}{\Delta t}\right) = \mathcal{E}_{\text{ind}} = \frac{\Phi_{B0}}{\Delta t}$$
