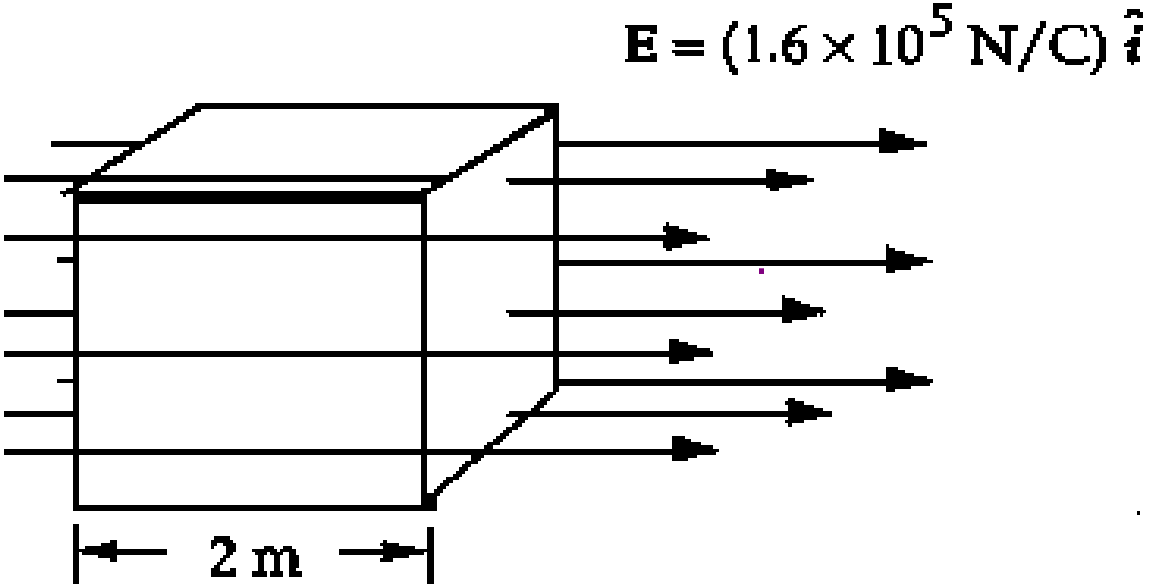
- Office hours this week:
    - W 4 - 6

- There *is* lab this week.

Clickers

- IT will collect them *here* at the end of the last class.

A cubical surface with no charge enclosed and with sides 2.0 m long is oriented with right and left faces perpendicular to a uniform electric field ***E*** of $(1.6 \times 10^5$ N/C) in the +x direction. The net electric flux ϕ_E through this surface is approximately



[✓ 1) zero]

2) $6.4 \times 10^5\ \mathrm{N \cdot m^2/C}$

3) $13 \times 10^5\ \mathrm{N \cdot m^2/C}$

4) $25 \times 10^5\ \mathrm{N \cdot m^2/C}$

5) $38 \times 10^5\ \mathrm{N \cdot m^2/C}$

Which of the following statements contradicts one of Maxwell's equations?

1) A changing magnetic field produces an electric field.
[✓ 2)] The net magnetic flux through a closed surface depends on the current inside.
3) A changing electric field produces a magnetic field.
4) The net electric flux through a closed surface depends on the charge inside.
5) None of these statements contradict any of Maxwell's equations.

Maxwell’s Equations – The Fundamental Laws of Electromagnetism

- Gauss’ Law
  - The total electric flux through a closed surface is proportional to the charge enclosed:

$$\oint_S \vec{\mathbf{E}} \bullet \hat{\mathbf{n}} \, dA = \frac{Q_{encl}}{\varepsilon_0}$$

- Gauss’ Law for Magnetism
  - The total magnetic flux through a closed surface is zero.
  - There are no magnetic charges.

$$\oint_S \vec{\mathbf{B}} \bullet \hat{\mathbf{n}} \, dA = 0$$

The Maxwell-Ampere Law

- The integral of $\vec{\mathbf{B}}\bullet d\vec{l}$ around a closed curve is proportional to the current piercing a surface bounded by the curve plus ε_0 times the time rate of change of electric flux through the surface.

$$\oint_C \vec{\mathbf{B}}\bullet \mathbf{d}\vec{\mathbf{l}} = \mu_0 \left(I_{encl} + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$$

$$\oint_C \vec{\mathbf{B}}\bullet \mathbf{d}\vec{\mathbf{l}} = \mu_0 \left(I_{encl} + \varepsilon_0 \frac{d}{dt} \int \vec{\mathbf{E}}\bullet \hat{\mathbf{n}}\, dA \right)$$

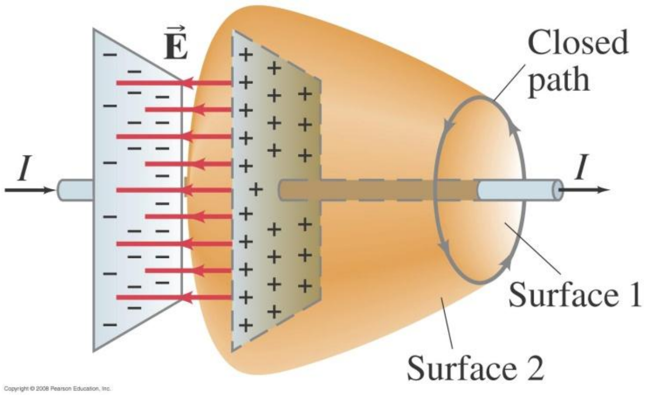


Figure 31.3

Faraday’s Law

- The integral of $\vec{\mathbf{E}}\bullet d\vec{l}$ around a closed curve is proportional the time rate of change of magnetic flux through a surface that is bounded by the curve.

$$\oint_{C}\vec{\mathbf{E}}\bullet d\vec{\mathbf{l}} = -\frac{d}{dt}\int \vec{\mathbf{B}}\bullet\hat{\mathbf{n}}\,dA$$

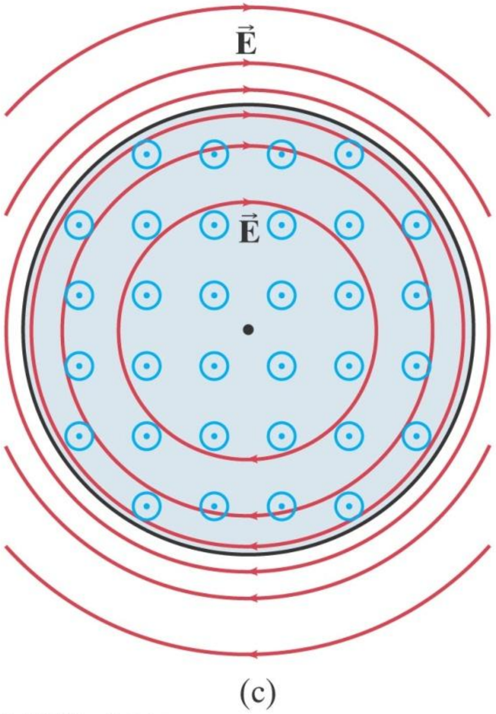
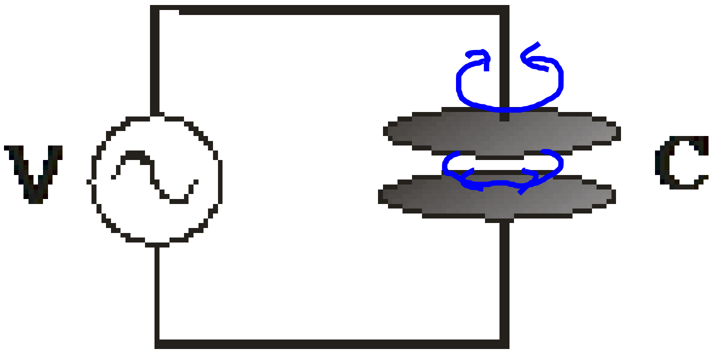
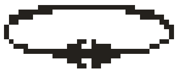


Figure 29.27c

An ac voltage is applied across a capacitor. Which figure best represents the magnetic field between the capacitor plates?




[✓ A]


B


C


D


E

Faraday’s and Maxwell-Ampere Laws

- A changing magnetic flux produces a curly electric field:

$$\oint \vec{\mathbf{E}}\bullet d\vec{\mathbf{l}} = -\frac{d}{dt}\int \vec{\mathbf{B}}\bullet\hat{\mathbf{n}}\,dA$$

- A changing electric flux produces a (curly) magnetic field:

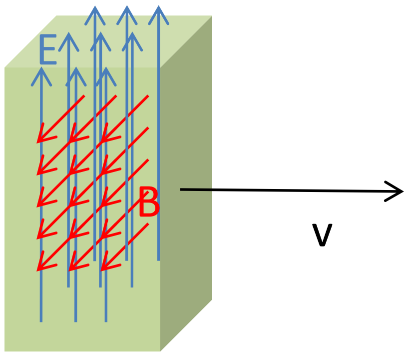
$$\oint \vec{\mathbf{B}}\bullet d\vec{\mathbf{l}} = \mu_0\left(I_{encl} + \varepsilon_0 \frac{d}{dt}\int \vec{\mathbf{E}}\bullet\hat{\mathbf{n}}\,dA \right)$$

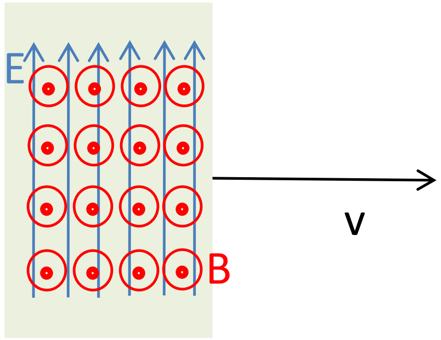
Self-sustaining fields

- Can electric and magnetic fields exist without any charges or currents around to produce them?
- Yes, but only if the fields are “moving” (i.e. changing:
  - Electromagnetic waves

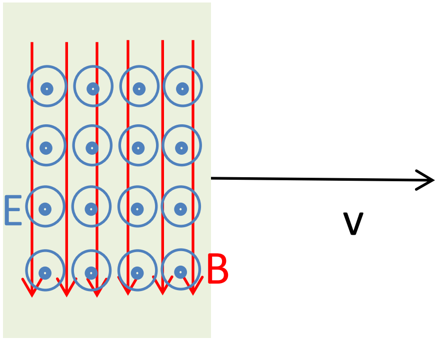
A moving "slab" of E and B fields

- Thin region in which there are uniform electric and magnetic fields.
  - No charges or currents in the vicinity of the slab.
  - Outside the slab, both fields are zero.
  - Inside the slab, E and B are perpendicular to each other.
  - Slab moves in a direction perpendicular to both fields.



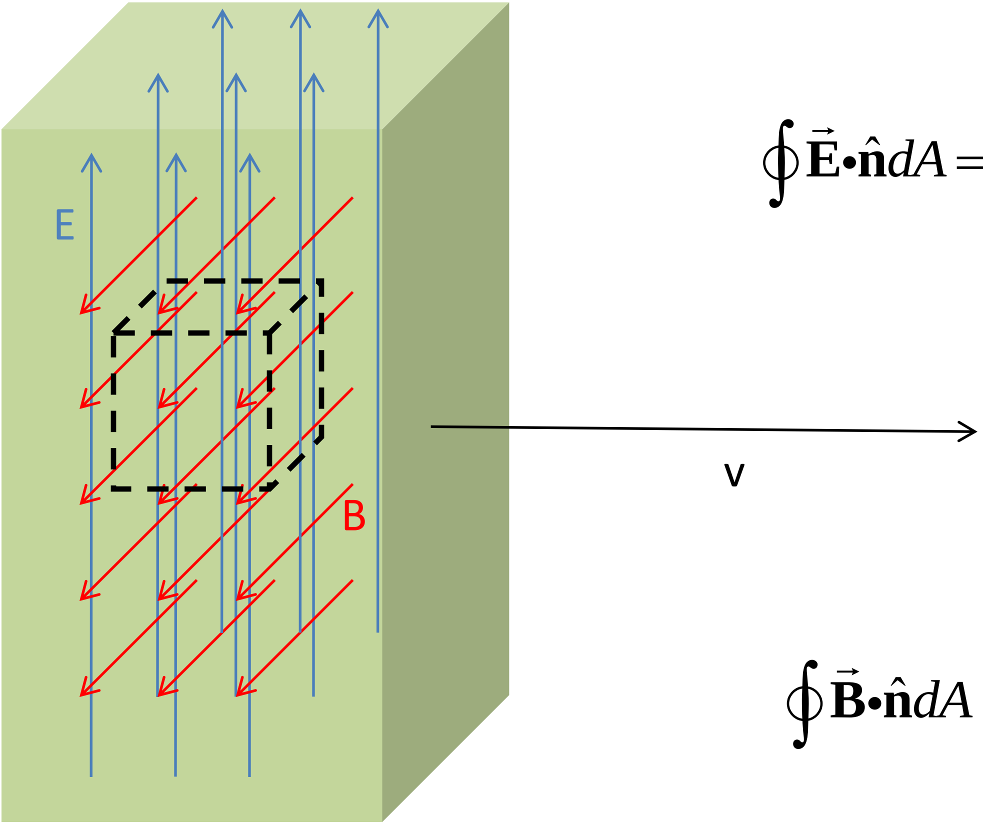


front view



top view

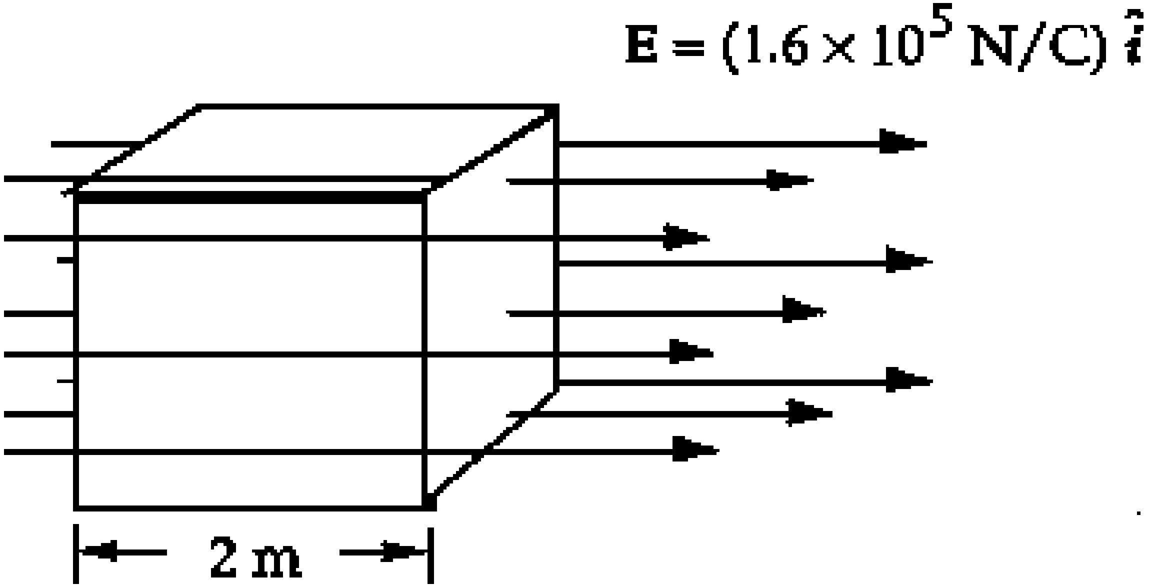
Slab obeys Gauss' Laws for E and B



$$\oint \vec{\mathbf{E}} \bullet \hat{\mathbf{n}} dA = \frac{Q_{encl}}{\varepsilon_0}$$

$$\oint \vec{\mathbf{B}} \bullet \hat{\mathbf{n}} dA = 0$$

A cubical surface with no charge enclosed and with sides 2.0 m long is oriented with right and left faces perpendicular to a uniform electric field ***E*** of (1.6 × 10^5 N/C) in the +x direction. The net electric flux ϕ_E through this surface is approximately



1) zero
2) $6.4 \times 10^5\ \mathrm{N \cdot m^2/C}$
3) $13 \times 10^5\ \mathrm{N \cdot m^2/C}$
4) $25 \times 10^5\ \mathrm{N \cdot m^2/C}$
5) $38 \times 10^5\ \mathrm{N \cdot m^2/C}$

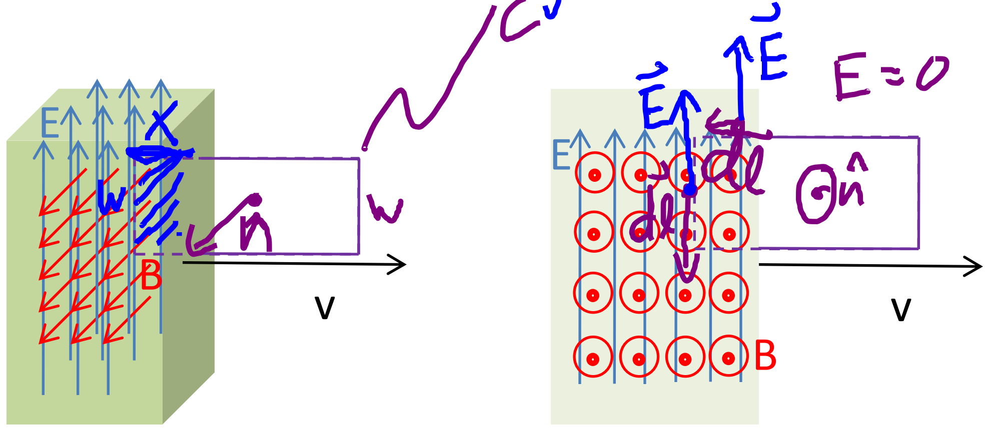
Does Slab obey Faraday's Law?

$$\oint_C \vec{E}\cdot d\vec{l} = \int_{\text{left edge}} \vec{E}\cdot d\vec{l} = -\int E\,dl = -E\int dl = -Ew$$

C

$$\Phi_B = Bwx$$

$$\frac{d\Phi_B}{dt} = Bw\frac{dx}{dt} = Bwv$$



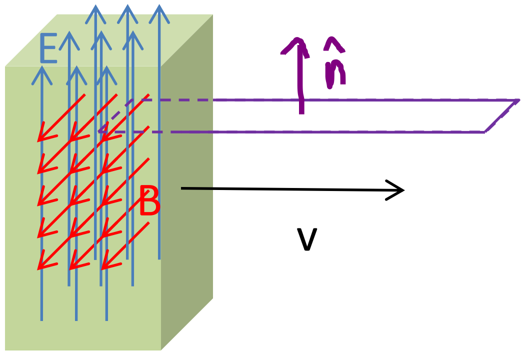
front view

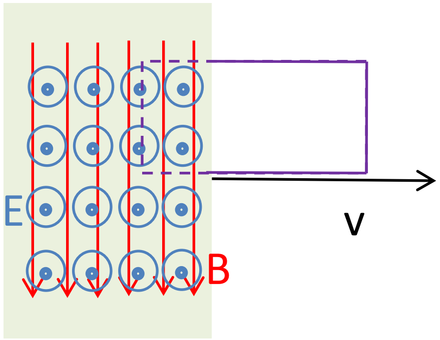
$$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\int_S \vec{B}\cdot\hat{n}\,dA$$

$$+E\cancel{w} = +B\cancel{w}v$$

$$\boxed{E = Bv}$$

Does Slab obey Maxwell-Ampere Law?





top view

$$\oint \vec{\mathbf{B}}\bullet d\vec{\mathbf{l}} = \mu_0\left(I_{encl} + \varepsilon_0 \frac{d}{dt}\int \vec{\mathbf{E}}\bullet\hat{\mathbf{n}}\,dA\right)$$