CHAPTER 31

PICO
OCTOBER 27
ALEX DIF

EM WAVES TRAVEL IN THE DIRECTION OF $\vec{E} \times \vec{B}$

SIMPLE
EXAMPLE:

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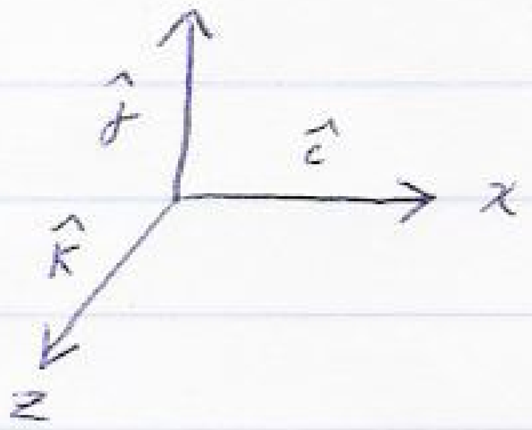

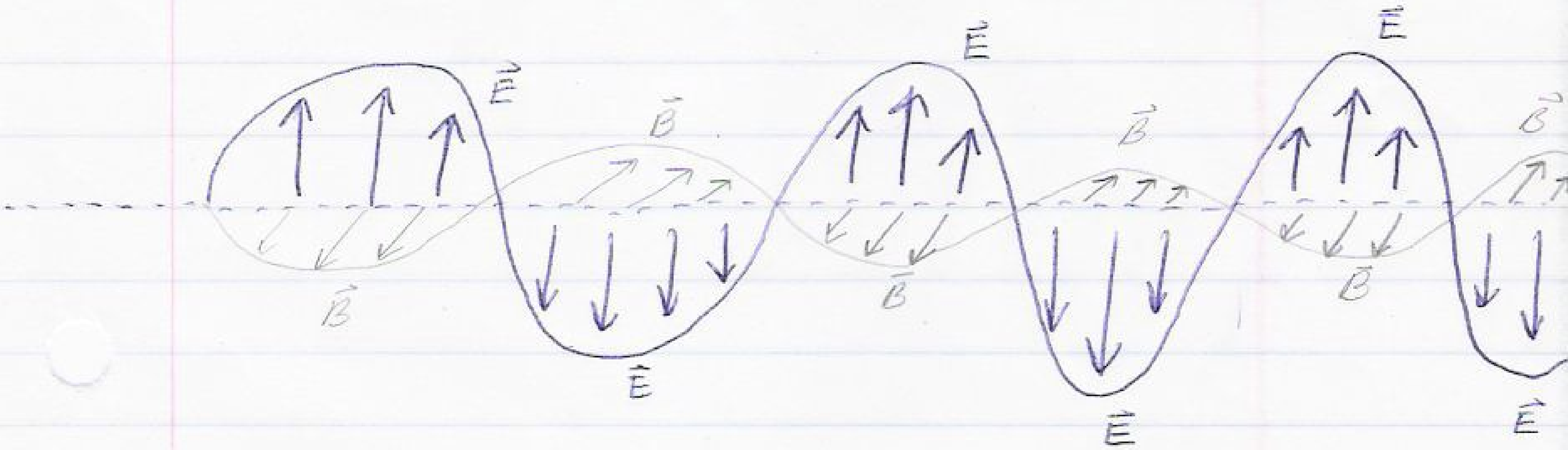

* NOTE *
take snapshots and waves
moves very fast.

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~ MAXWELL'S EQUATIONS ~

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① GAUSS' LAW: $\int_{\substack{\text{ENCLOSED}\\ \text{SURFACE}}} \vec{E}\cdot d\vec{A} = \dfrac{Q_{encl}}{\varepsilon_0}$

Φ_E

$-\dfrac{d\Phi_B}{dt}$

② FARADAY'S LAW: $\int_{\substack{\text{CLOSED}\\ \text{LOOP}}} \vec{E}\cdot d\vec{l} = \mathcal{E}_{induced} = \dfrac{-d}{dt}\int_{\substack{\text{surface}\\ \text{bounded by}\\ \text{loop}}} \vec{B}\cdot d\vec{A}$

RIGHT HAND RULE

③ AMPERE'S LAW: $\int_{\substack{\text{CLOSED}\\ \text{LOOP}}} \vec{B}\cdot d\vec{l} = \mu_0\left(I_{encl} + I_o\right)$

$I_o = \varepsilon_0 \dfrac{d}{dt}\int_{\substack{\text{surface}\\ \text{bounded}\\ \text{by loop}}} \vec{E}\cdot d\vec{A}$

④ GAUSS' LAW FOR MAGNETISM: $\int_{\substack{\text{CLOSED}\\ \text{SURFACE}}} \vec{B}\cdot d\vec{A} = 0$

when Q_{encl} & I_{encl} are 0.

① $\Phi_E = 0$

② $\oint \vec{E}\cdot d\vec{l} = -\dfrac{d\Phi_B}{dt}$

③ $\oint \vec{B}\cdot d\vec{l} = \mu_0\varepsilon_0 \dfrac{d\Phi_E}{dt}$

④ $\Phi_B = 0$

* MAXWELL'S EQUATIONS:

MATHEMATICALLY IMPLY THAT IN THE ABSENCE OF CHARGES & CURRENTS, $\vec{E}$ & $\vec{B}$ ARE WAVES THAT TRAVEL IN DIRECTION $\vec{E}\times\vec{B}$. AND SPEED $c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$ $\quad c = 3.00\times10^8\ m/s$

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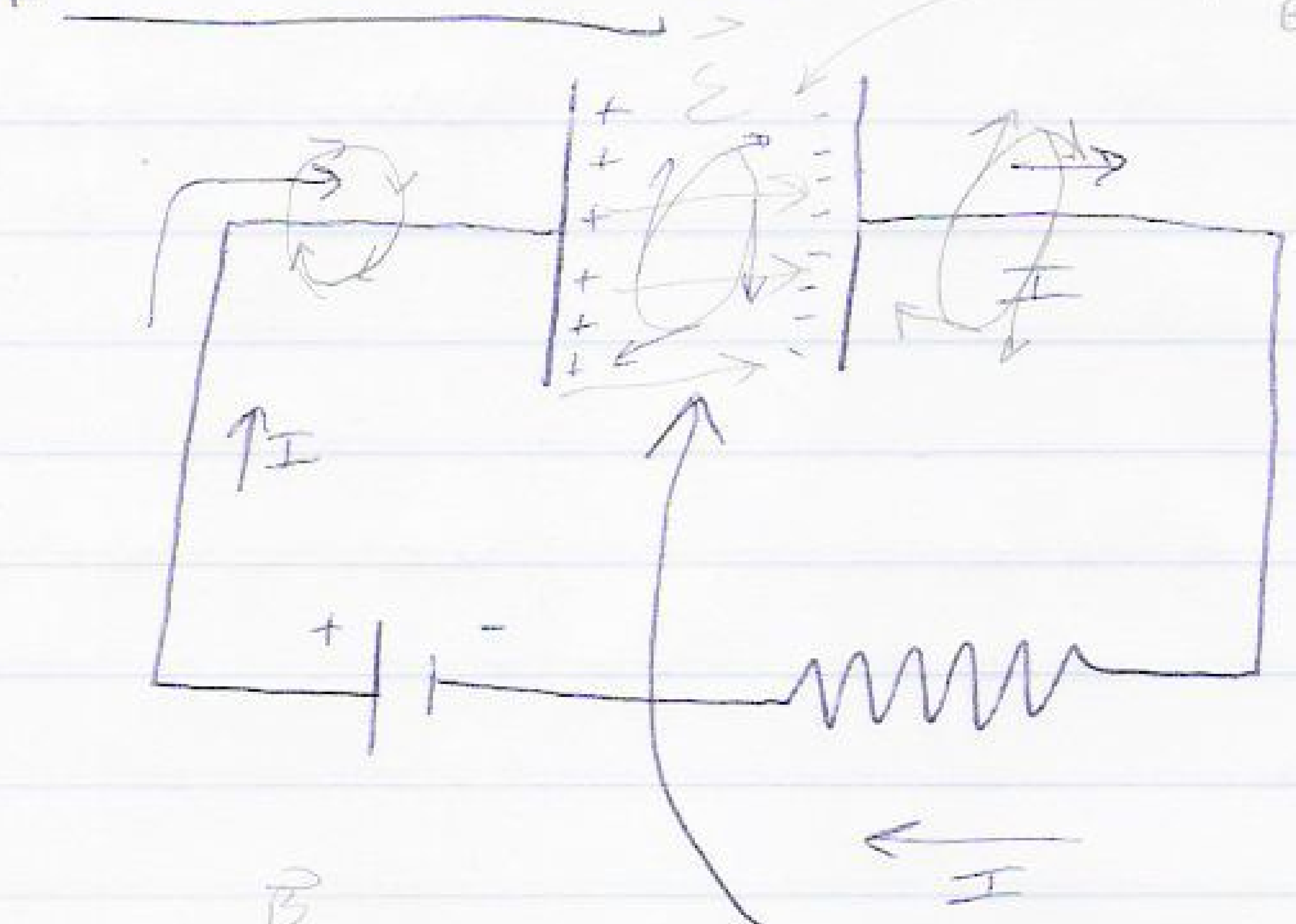
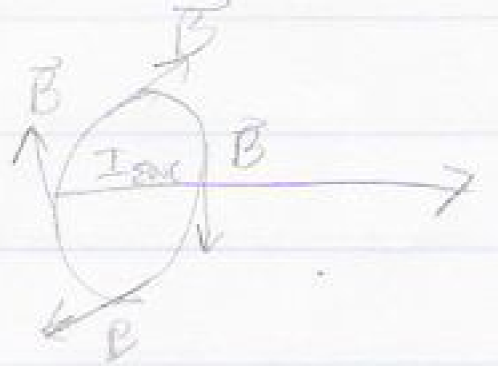
* CHARGING A CAPACITOR:

NO CURRENT BUT $\vec{E}$ IS THERE

CHANGE IN ELECTRIC FIELD

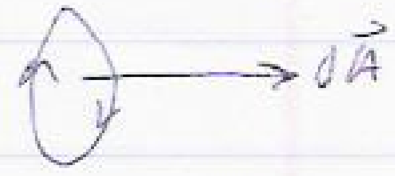


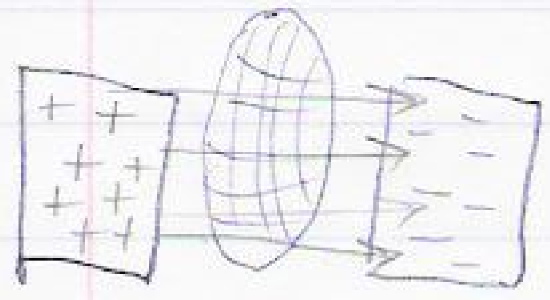


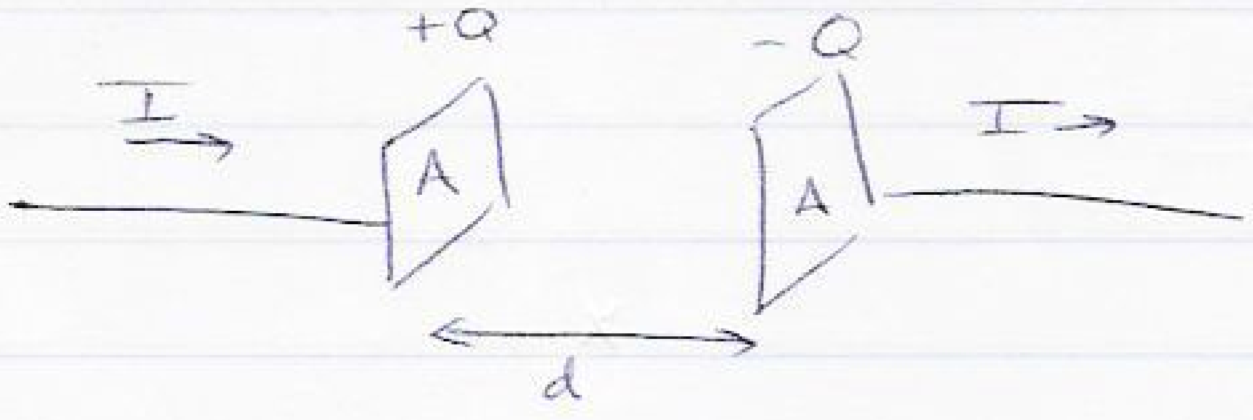
IN CENTER LOOP,

$$\int_{loop} \vec{B} \cdot d\vec{l} = \mu_0 I \text{ too}$$

$$I_D \text{ for a loop} = \epsilon_0 \cdot \frac{d}{dt} \int_{\substack{\text{surface}\\ \text{bounded}\\ \text{by loop}}} \underbrace{\vec{E} \cdot d\vec{A}}_{\text{right hand rule}}$$







$$I = \frac{dQ}{dt} = \frac{d}{dt}(CV) = \frac{d}{dt}(CV) = \frac{d}{dt}\left(\frac{\epsilon_0 A}{d} \cdot Ed\right)$$

$$C = \frac{Q}{V_{ab}}$$

$$C = \frac{\epsilon_0 A}{d} \ \& \ V_{ab} = -\int_a^b E\, dl = \int_a^b \vec{E}\, dl = Ed$$

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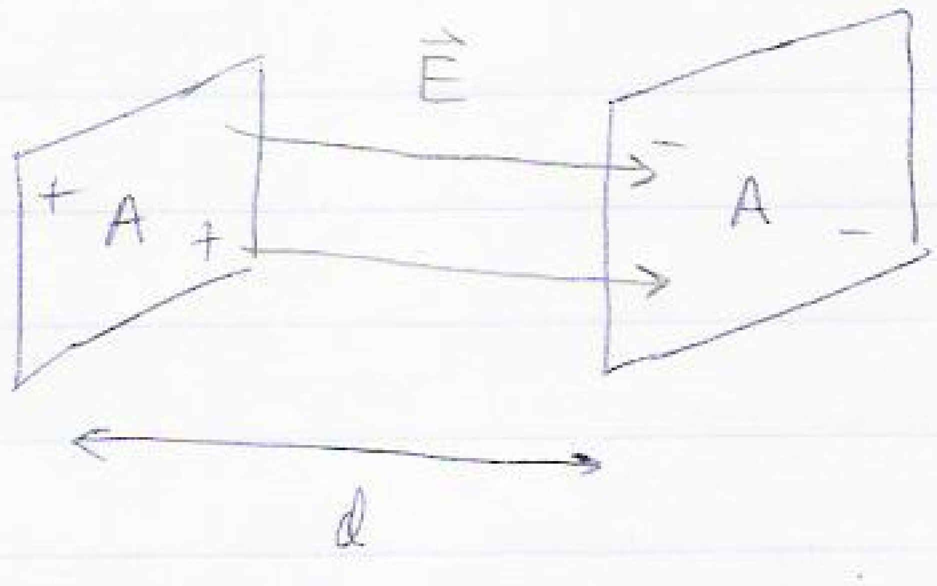
* ELECTRIC FIELDS STORE ENERGY

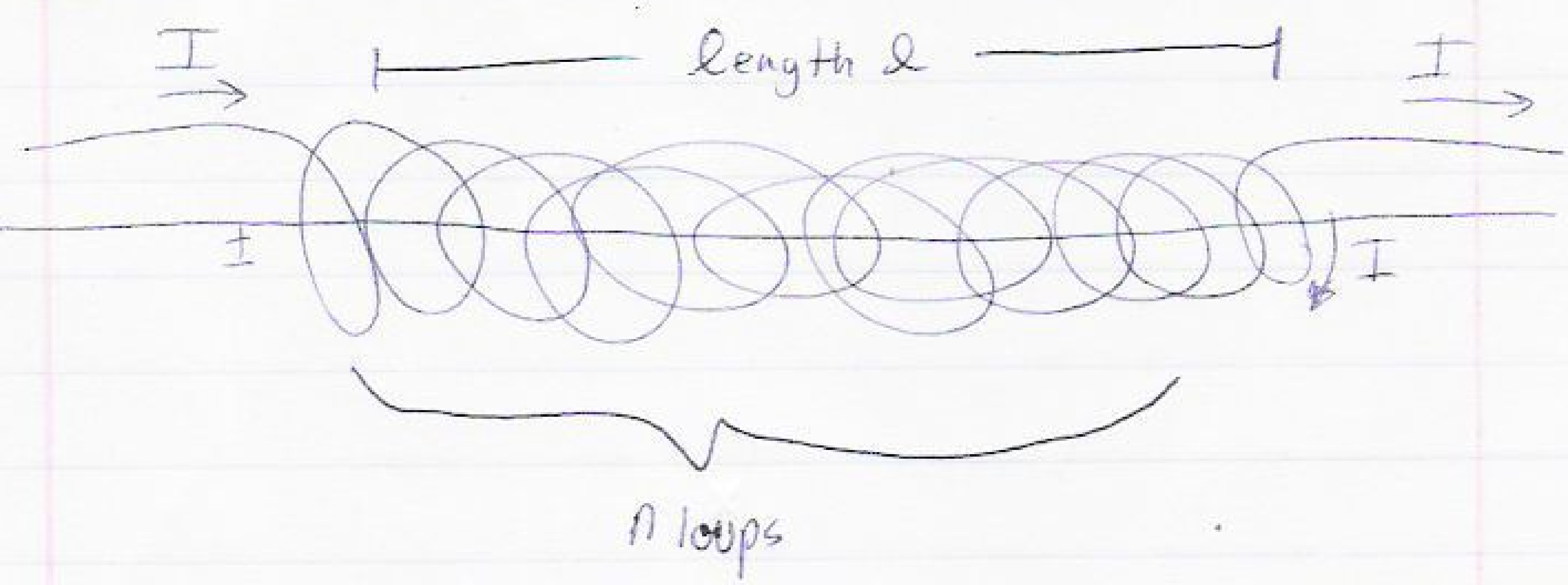
E.g. CAPACITOR (PARALLEL PLATE)



$$U = \frac{1}{2} C V^2 = \frac{1}{2}\left(\frac{\epsilon_0 A}{d}\right)\left(\mathcal{E} d\right)^2 = \frac{1}{2}\epsilon_0 A E^2 d$$

$$u = \frac{\text{ENERGY}}{\text{VOLUME}} = \text{ENERGY DENSITY} = \frac{U}{Ad} = \frac{1}{2}\epsilon_0 E^2$$

SOLENOID



$$B_{\text{INSIDE}} = n\mu_0 I = \frac{N\mu_0 I}{l}$$

current time t

$$U_{\text{ENERGY}} = \int_0^I \underset{\text{power}}{P}\, dt = \int_0^I V i\, dt = \int_0^I \frac{di}{dt} i\, dt = \int_0^I L i\, di = \frac{1}{2} L I^2 = \boxed{\frac{N^2 \mu_0 A I^2}{2l}}$$

$-\mathcal{E} = V_{ab}$

work needed to increase current from 0 to I

SELF INDUCTANCE

$$L = \frac{N\Phi_B}{I} = \frac{NBA}{I} = \frac{N(N\mu_0 I/\ell)A}{I} = \frac{N^2\mu_0 A}{\ell}$$

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$$= \frac{N^2\mu_0 A}{2\ell}\left(\frac{\ell B}{N\mu_0}\right)^2 = \frac{B^2 A\ell}{2\mu_0}$$

$$u = \frac{U}{A\ell} = \frac{B^2}{2\mu_0}$$

$$\boxed{\text{ENERGY DENSITY} = \frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}}$$

FOR A SIMPLE EM waves

$$\frac{1}{2}\epsilon_0 E^2 = \frac{B^2}{2\mu_0}$$

Therefore,

$$\mu_0\epsilon_0 E^2 = B^2$$

$$\frac{E}{c} = \underbrace{\sqrt{\mu_0\epsilon_0}}_{1/c}\, E = B$$

$$\boxed{\frac{E}{c} = B \quad \& \quad E = Bc}$$