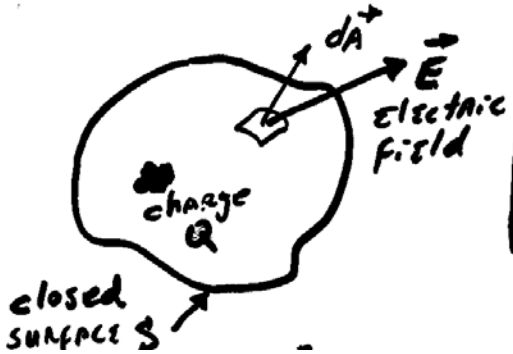
Maxwell Equations

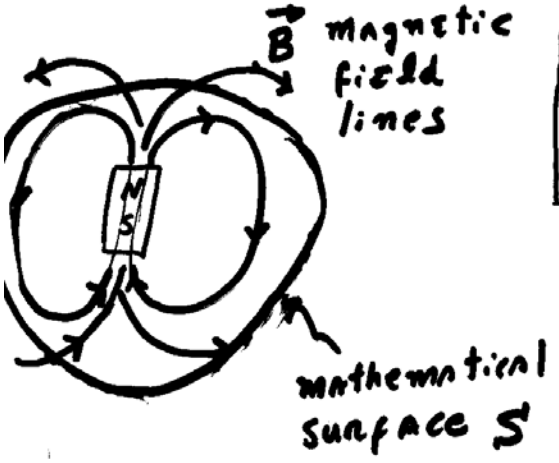
First Maxwell Eq.



$$\int_S \vec{E} \cdot d\vec{A} = \frac{Q_{inside}}{\epsilon_0}$$

ϵ_0 : permitivity of free-space

SECOND MAXWELL Eq.



$$\int_S \vec{B} \cdot d\vec{A} = 0$$

No magnetic monopoles have been observed (so far)

Third Maxwell Eq

$$\mathcal{E} = \oint_{\text{loop } \Gamma} \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\left(\int_S \vec{B} \cdot d\vec{A}\right)$$

where S is any open surface having the loop Γ as its boundary

$$\mathcal{E} = -\frac{d}{dt}\Phi_m$$

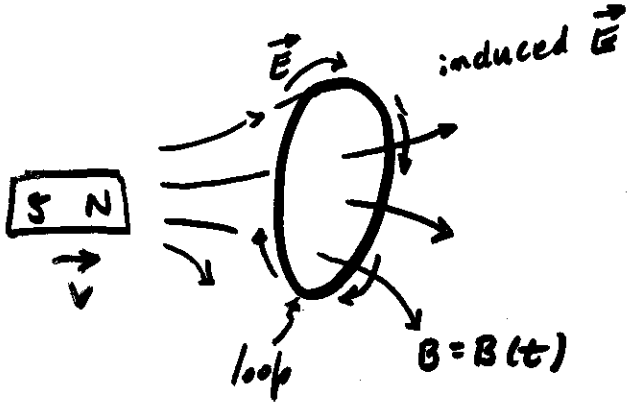
4th Maxwell's Eq.

It built upon Ampere's law

$$\oint_{\text{loop } \Gamma} \vec{B} \cdot d\vec{l} = \mu_0 i + \mu_0 \epsilon_0 \frac{d}{dt} \int_{\text{surface } S} \vec{E} \cdot d\vec{A}$$

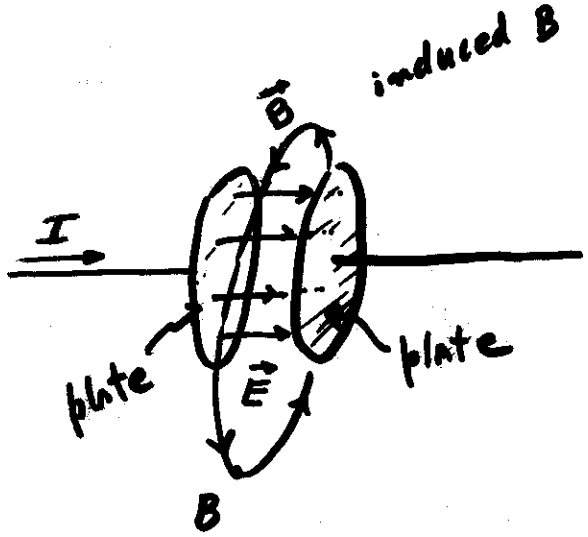
Generating electromagnetic waves

based on the time-dependent MAXWELL EQUATIONS



$$\int_{\text{loop}} \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\int_{\text{surface}} \vec{B}\cdot d\vec{A}$$

You have control over $\vec{B}(t)$ (move the magnet) $\Rightarrow$ to generate $\vec{E}$

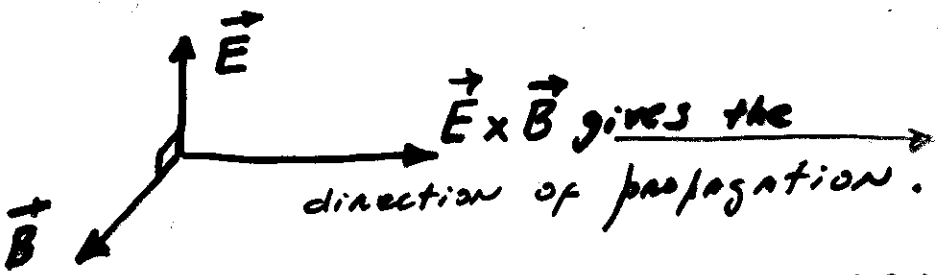


$$\int_{\text{loop}} \vec{B}\cdot d\vec{l} = \mu_0 I + \mu_0 \frac{d}{dt}\varepsilon_0 \int_{\text{surface}} \vec{E}\cdot d\vec{A}$$

You have control over $\vec{E}(t)$ (change the current) $\Rightarrow$ to generate $\vec{B}$

Notice:

- The previous two graphs show that $\vec{E} \perp \vec{B}$
- We will not do it here, but it can be mathematically justified that the propagation of electromagnetic can be pictured in the following way



TRANSVERSE WAVE

QUESTIONS

How do electromagnetic waves propagate?

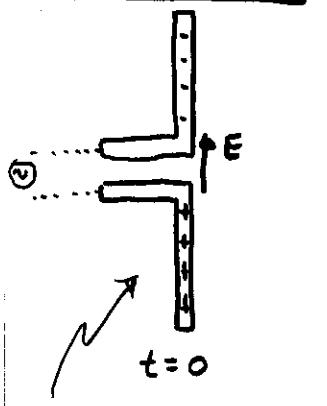
(Sound waves need "substance" to propagate. You can NOT hear in VACUUM. Do e-m waves need a medium to propagate?)

What is their speed?

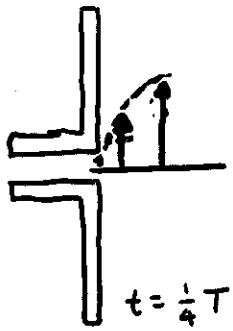
How to prove their existence?

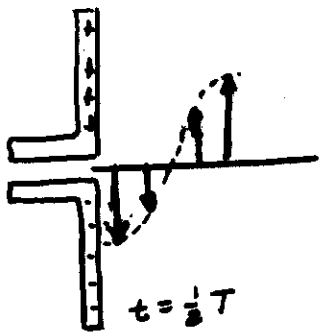
Electromagnetic waves

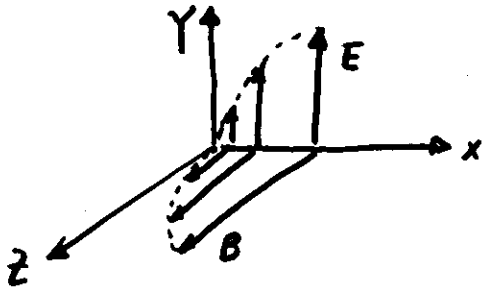
GENERATION

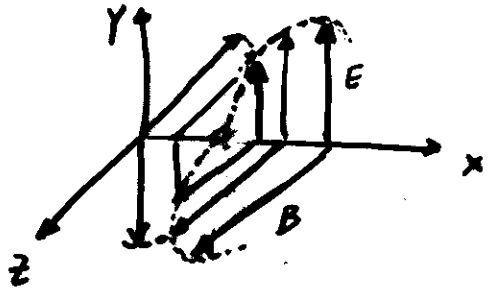


ANTENNA FED by an alternating-current generator

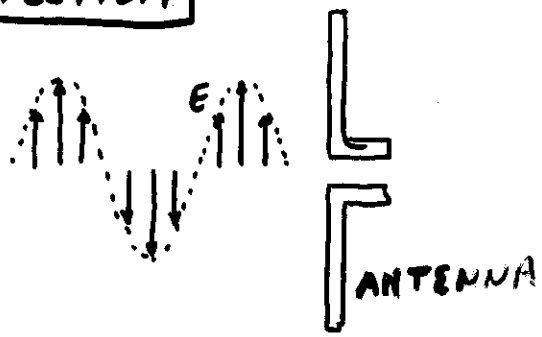








DETECTION



The alternating electric field of the wave produces an alternating current in the antenna

The alternating magnetic field of the wave produces an alternating magnetic flux in the loop antenna, i.e. an alternating e.m.f.