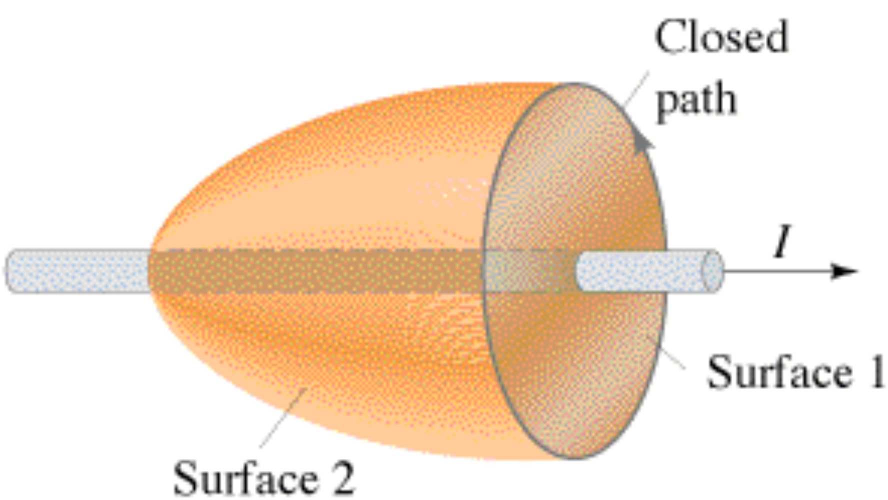
PHY385-H1F Introductory Optics

Class 4 – Outline: Sec. 3.3, 3.4

- Finishing Constraints on the EM-wave imposed by Maxwell's Equations
- Poynting Vector
- Irradiance
- Photons
- Radiation Pressure and Momentum
- Synchrotron Radiation
- Electric Dipole Radiation
- Emission

- Ampere's Original Law:

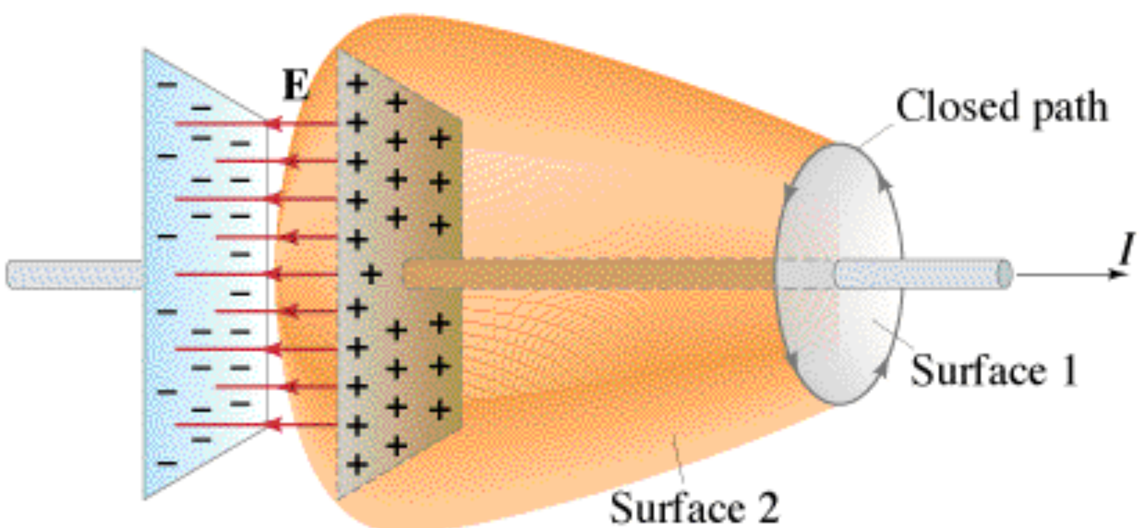
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{through}}$$



- Normally when we think of Ampere's law, we consider a closed path enclosing surface 1
- But we could have considered surface 2
- In this case, the current enclosed is the same as for surface 1
- The current flowing into any volume must equal that coming out, as long as the charge within that volume is constant.

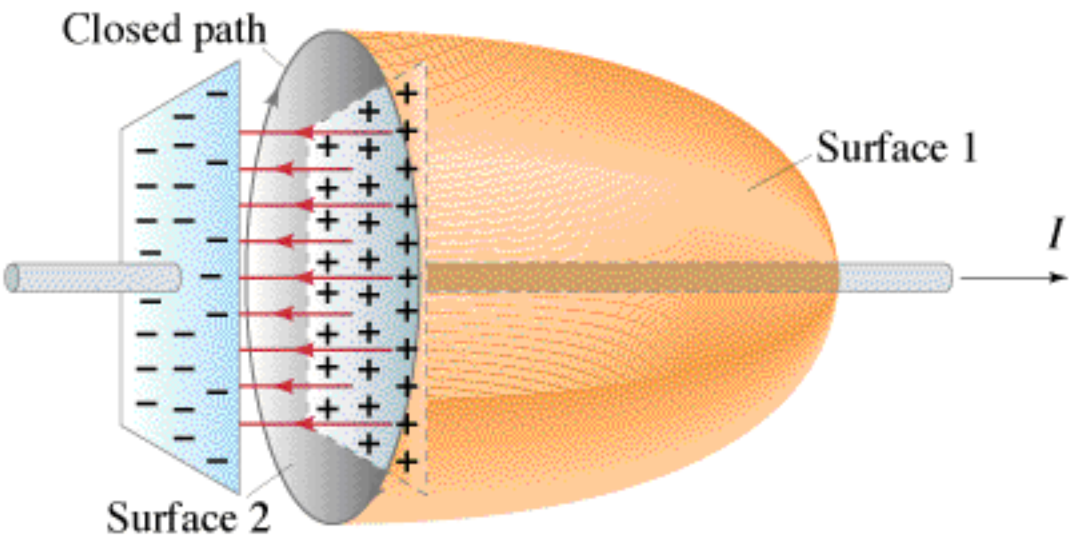
Maxwell's Paradox

- Suppose we have a charged capacitor and it begins to discharge



Surface 1 works, but surface 2 has *no current passing through*, yet there is a magnetic field around the closed path.

Maxwell's Paradox



Same problem here. Surface 1 works, but no current passes through Surface 2 – even though the closed path along which we must integrate the magnetic field is the same for both.

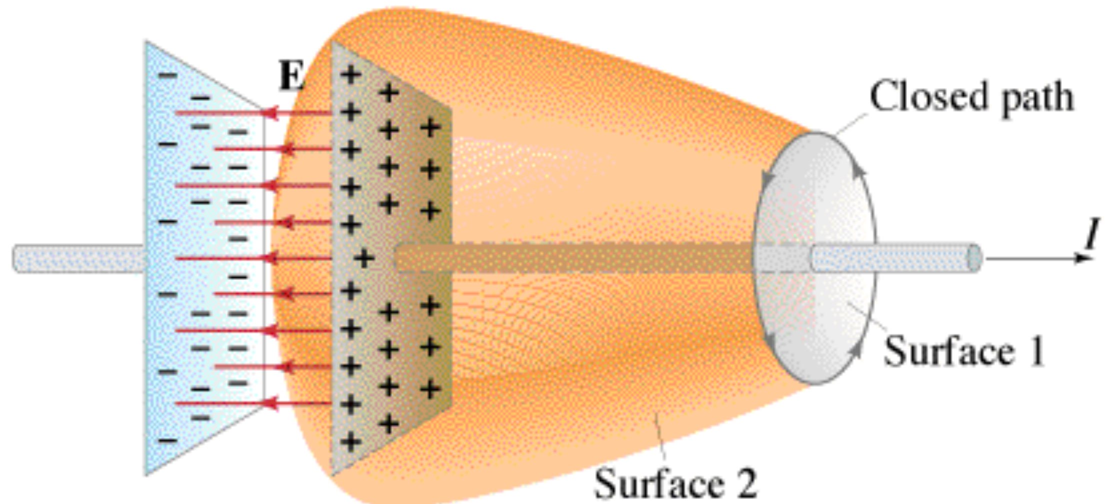
What is happening???

Ampere's Law – Complete Version

- While the capacitor is discharging, a current flows
- The electric field between the plates of the capacitor is *decreasing* as current flows
- Maxwell said the *changing electric field* is equivalent to a current
- He called it the **displacement current**
- Ampere's Law with Maxwell's correction is:

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{through}} + \mu_0 \varepsilon_0 \frac{\partial \Phi_E}{\partial t}$$

In-Class Task from Last time.. I asked:



1a. What is the current through surface 1? *I*

1b. What is the current through surface 2? *zero!*

1c. Should the loop integral of *B* around the closed path be the SAME or DIFFERENT for the two surfaces? *SAME*

2. How can Ampère's Law be applied to this situation? *You must include the displacement current (Maxwell's correction, related to d/dt of electric flux through the surface)*

Poynting Vector

- John Poynting
- 1884 published a paper describing a vector which is "pointing" in the direction of energy flow of an electromagnetic wave!
- This was 20 years after Maxwell first described electromagnetic waves.

John Henry Poynting

Poynting Vector

$$\vec{S} = \vec{E} \times \vec{H}$$

or

$$\vec{S} = \varepsilon_0 c^2 \left(\vec{E} \times \vec{B} \right)$$

Units: W/m^2

In a propagating sinusoidal electromagnetic plane wave of a fixed frequency, the Poynting vector oscillates, always pointing in the direction of propagation. The time-averaged magnitude of the Poynting vector is:

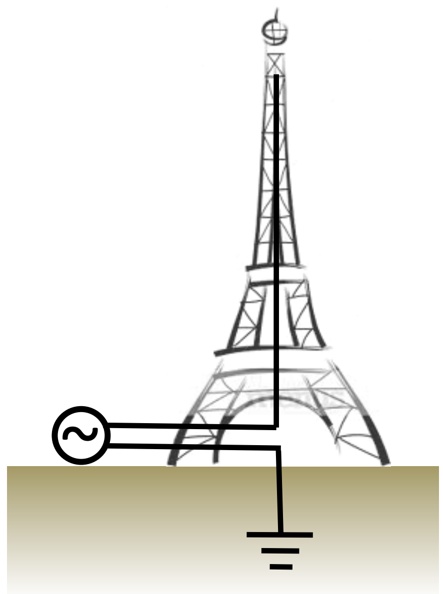
$$\langle S \rangle = \frac{1}{2\mu_0 c} E_0^2 = \frac{\varepsilon_0 c}{2} E_0^2$$

where E_0 is the amplitude of the electric field oscillations.

5-minute In-Class Task

- Please take out a piece of paper that you don't mind handing to me at the end
- WRITE YOUR NAME at the top of the piece of paper
- Discussion with your friends or me during this task is ***encouraged!***

Consider a big transmitting tower, which is aligned with the vertical $+z$ axis. Choose coordinates so that $+z$ is up, $+x$ is East, and $+y$ is North.



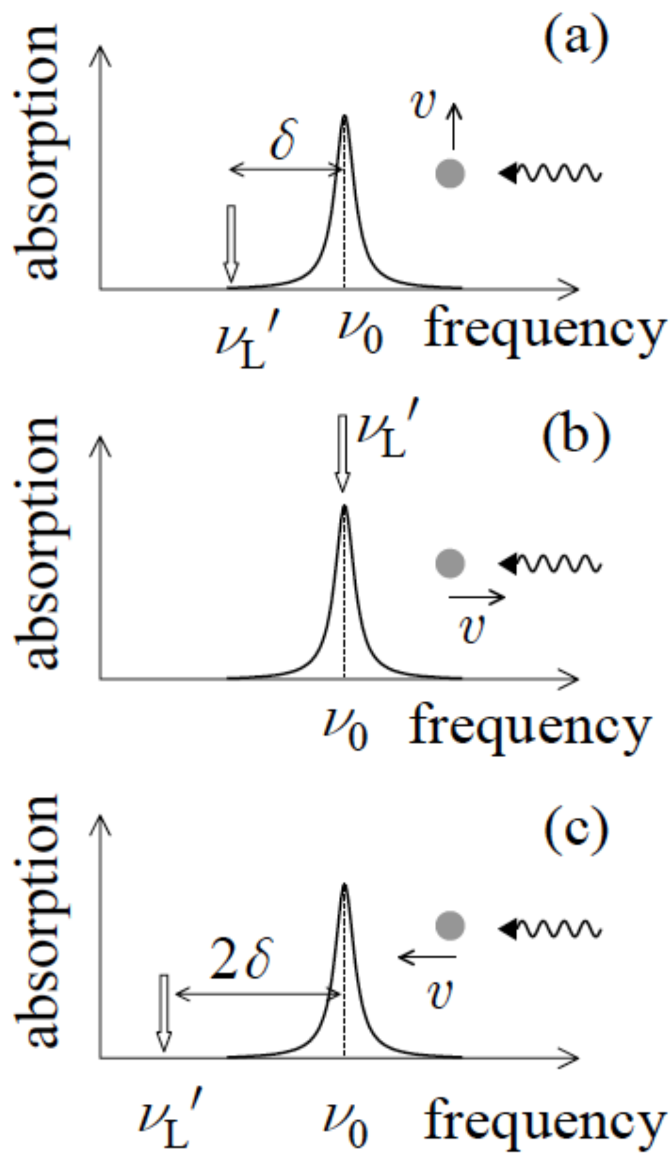
An AC generator is connected to the tower, sending a current up and down its length.

If you are in a car 1 km East of the tower:

1. Along which direction (x, y or z) will the electric field oscillate near your car?
2. Along which direction (x, y or z) will the magnetic field oscillate near your car?

Important note for our Monday tour of Professor Thywissen's Lab:

Doppler cooling mechanism



- absorption only for case (b)
- laser must be tuned below the transition
- frequency must be tuned as atoms cool