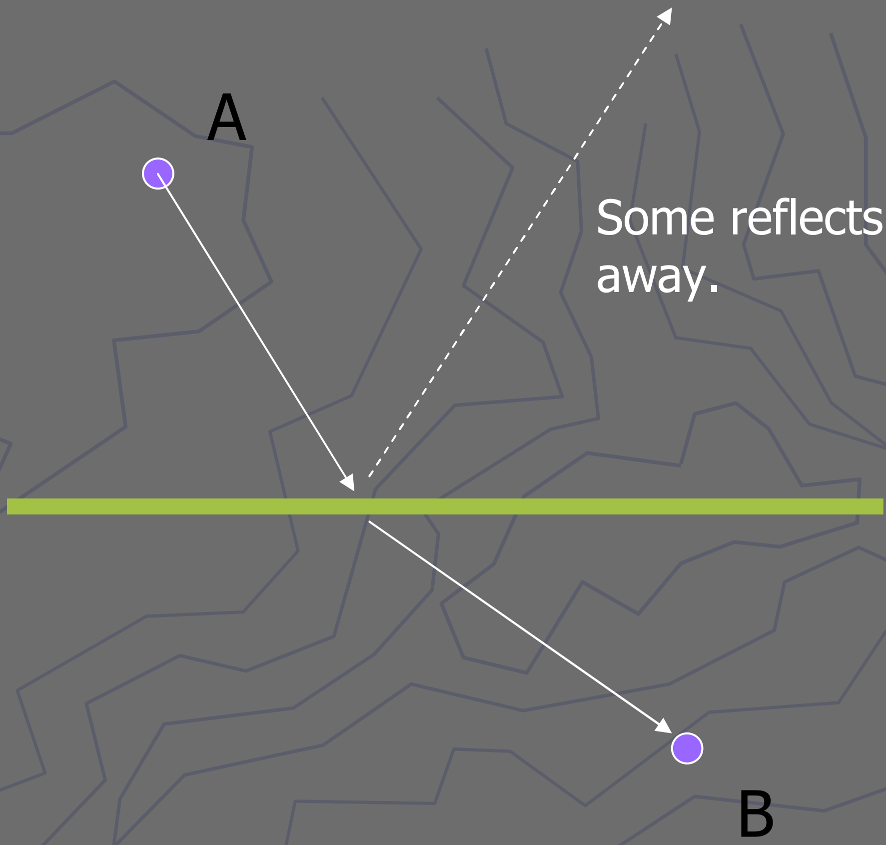
ElectroMagnetic Waves

Reflection and Refraction at Dielectric Boundarys

Dielectric Guided Waves

Remember Geometric Optics

- Huygen's Principle:
  - Light will minimize the optical path-length
  - Optical path length is one way of minimizing the time it takes for light to travel from 'A' to 'B' in two separate isotropic, uniform dielectric media.



I Know you have done this calculation.

Geometric Optics Questions

- Why does Light take the path of least time?
  - Put another way:
    - Why is there refraction?
    - Why is the angle of incidence equal to the angle of reflection?
- How much light gets reflected away at the interface?

- Geometric optics is unable to answer these questions.

Can the Theory of Electricity and Magnetism

Provide some of the answers?

What can J. C. Maxwell teach us?

Maxwell's Equations in Matter

$$\nabla \cdot \vec{D} = 0 \qquad \nabla \times E = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0 \qquad \nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t}$$

Linear Media

$$\vec{D} = \varepsilon \vec{E}, \qquad \vec{H} = \frac{1}{\mu} \vec{B}$$

Maxwell's Equations in Matter

$$\nabla\times\nabla\times\vec{E} = -\nabla\times\frac{\partial\vec{B}}{\partial t}$$

$$\nabla^2\vec{E} = \mu\varepsilon\frac{\partial^2\vec{E}}{\partial t^2}$$

$$\nabla\times\nabla\times\vec{H} = \nabla\times\frac{\partial\vec{D}}{\partial t}$$

$$\nabla^2\vec{B} = \mu\varepsilon\frac{\partial^2\vec{B}}{\partial t^2}$$

Wave Equations Result

Wave Energy and Power

Similar to free space as long as media are linear and isotropic.

Energy Density

$$u = \frac{1}{2}\left(\varepsilon E^2 + \frac{1}{\mu} B^2 \right)$$

Poynting Vector:

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

Maxwell's Equations in Matter

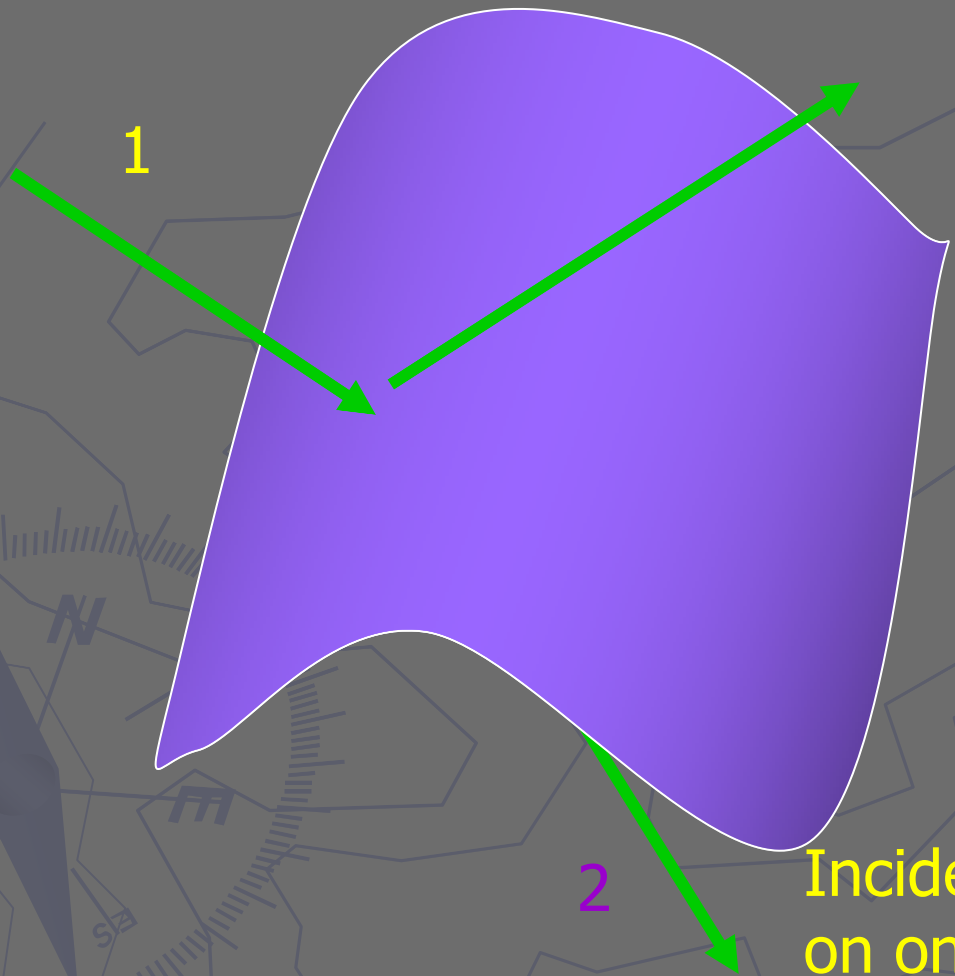
$$\nabla \cdot \vec{D} = 0 \qquad \nabla \times E = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0 \qquad \nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t}$$

Plane-wave Solutions

$$\vec{D} = \varepsilon \vec{E}, \qquad \vec{H} = \frac{1}{\mu} \vec{B}$$

Boundary between 1 and 2

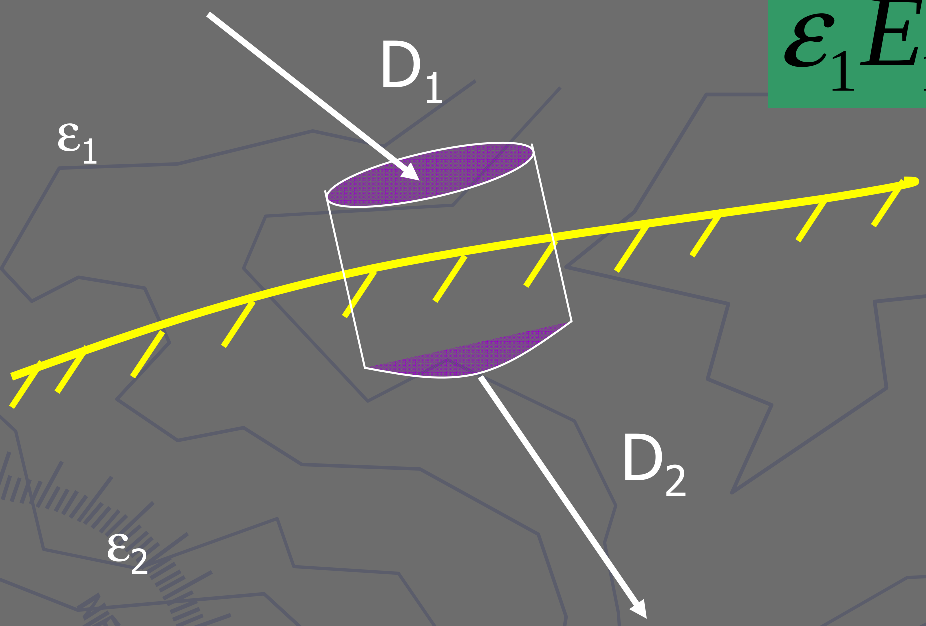


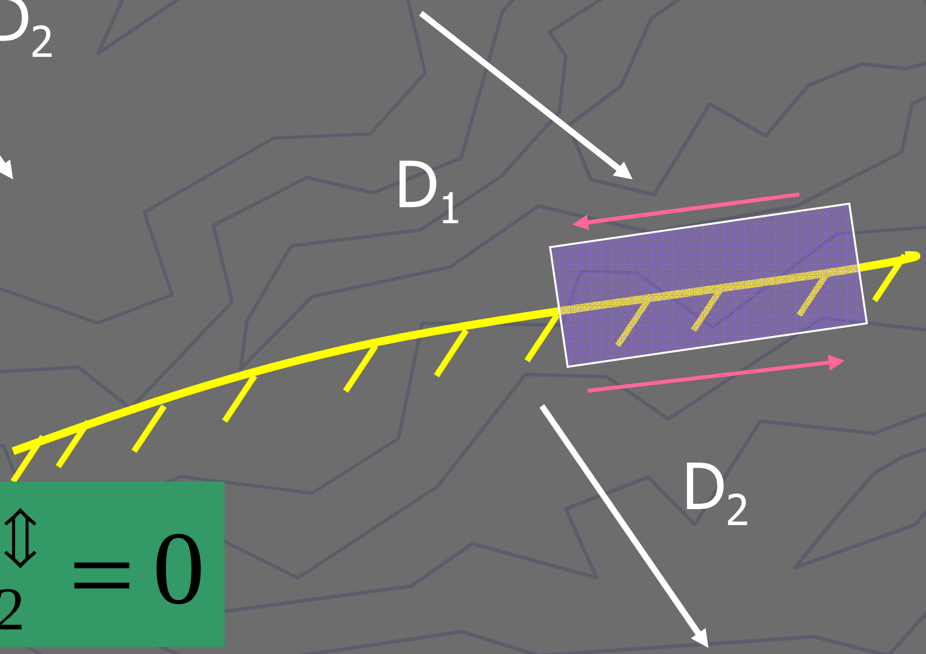
Incident and reflected waves on one side.

Transmitted waves on the other

Boundary Conditions: E-Field

$$\varepsilon_1 E_1^{\perp} - \varepsilon_2 E_2^{\perp} = 0$$

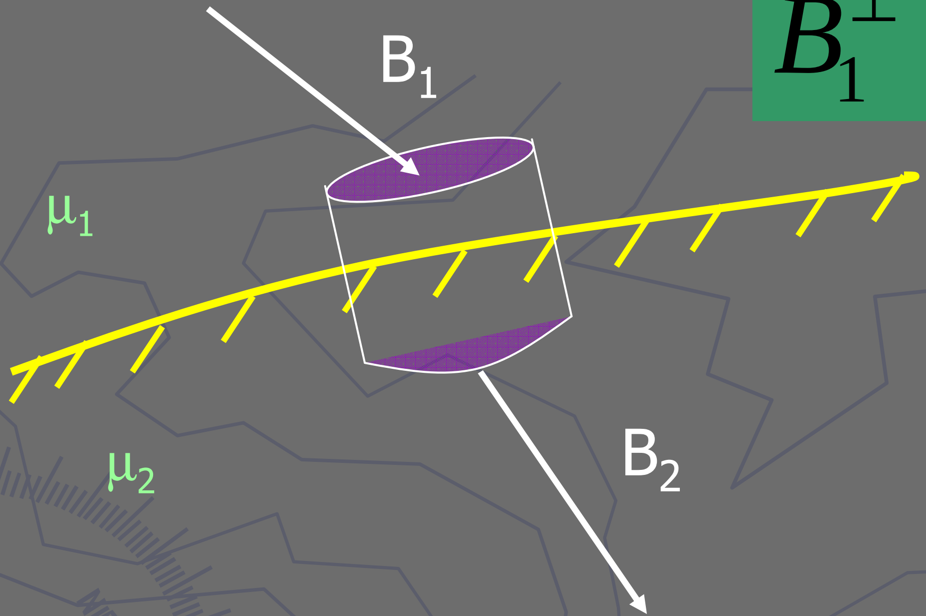


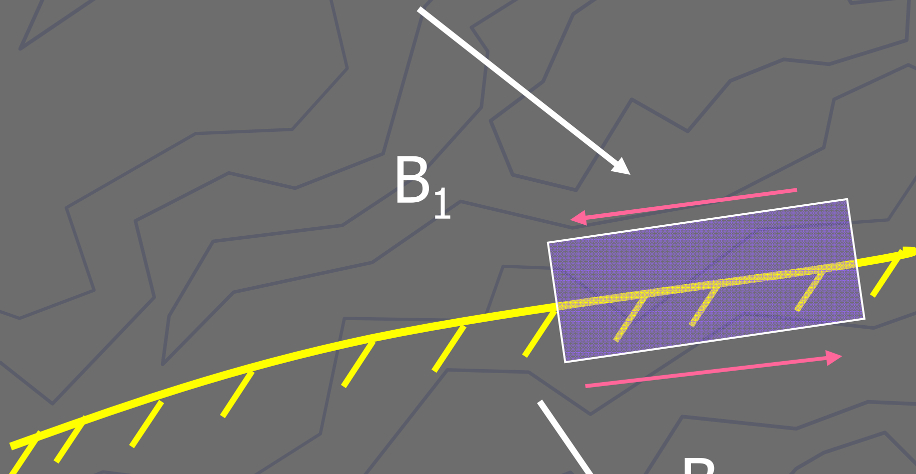


$$\vec{E}_1^{\Updownarrow} - \vec{E}_2^{\Updownarrow} = 0$$

Boundary Conditions: B-Field

$$B_1^{\perp} - B_2^{\perp} = 0$$

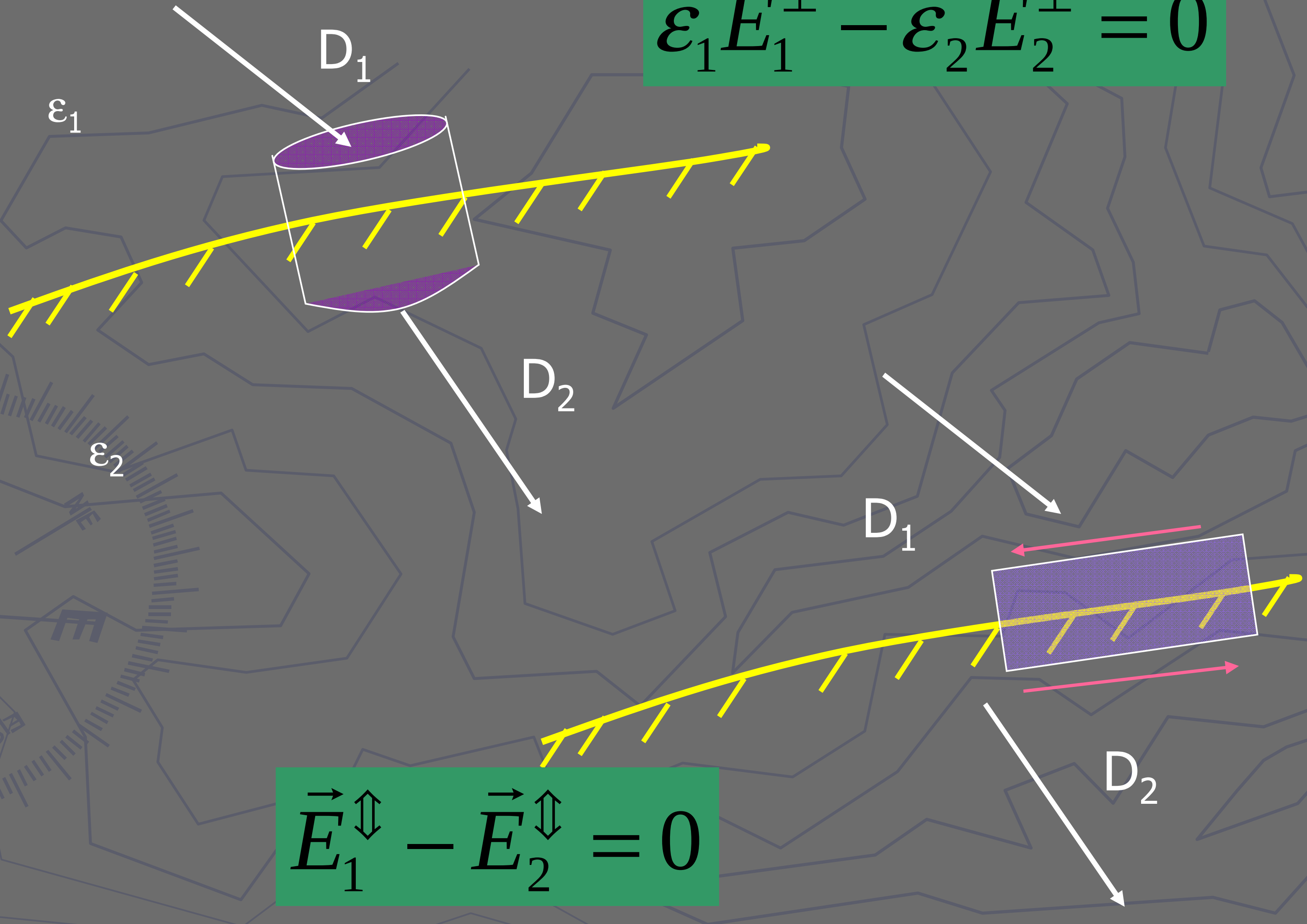




$$\vec{H}_1^{\Updownarrow} - \vec{H}_2^{\Updownarrow} = 0$$

Boundary Conditions: E-Field

$$\varepsilon_1 E_1^{\perp} - \varepsilon_2 E_2^{\perp} = 0$$



$$\vec{E}_1^{\Updownarrow} - \vec{E}_2^{\Updownarrow} = 0$$

Assume materials are essentially non-magnetic.

Meaning $\mu = \mu_0$

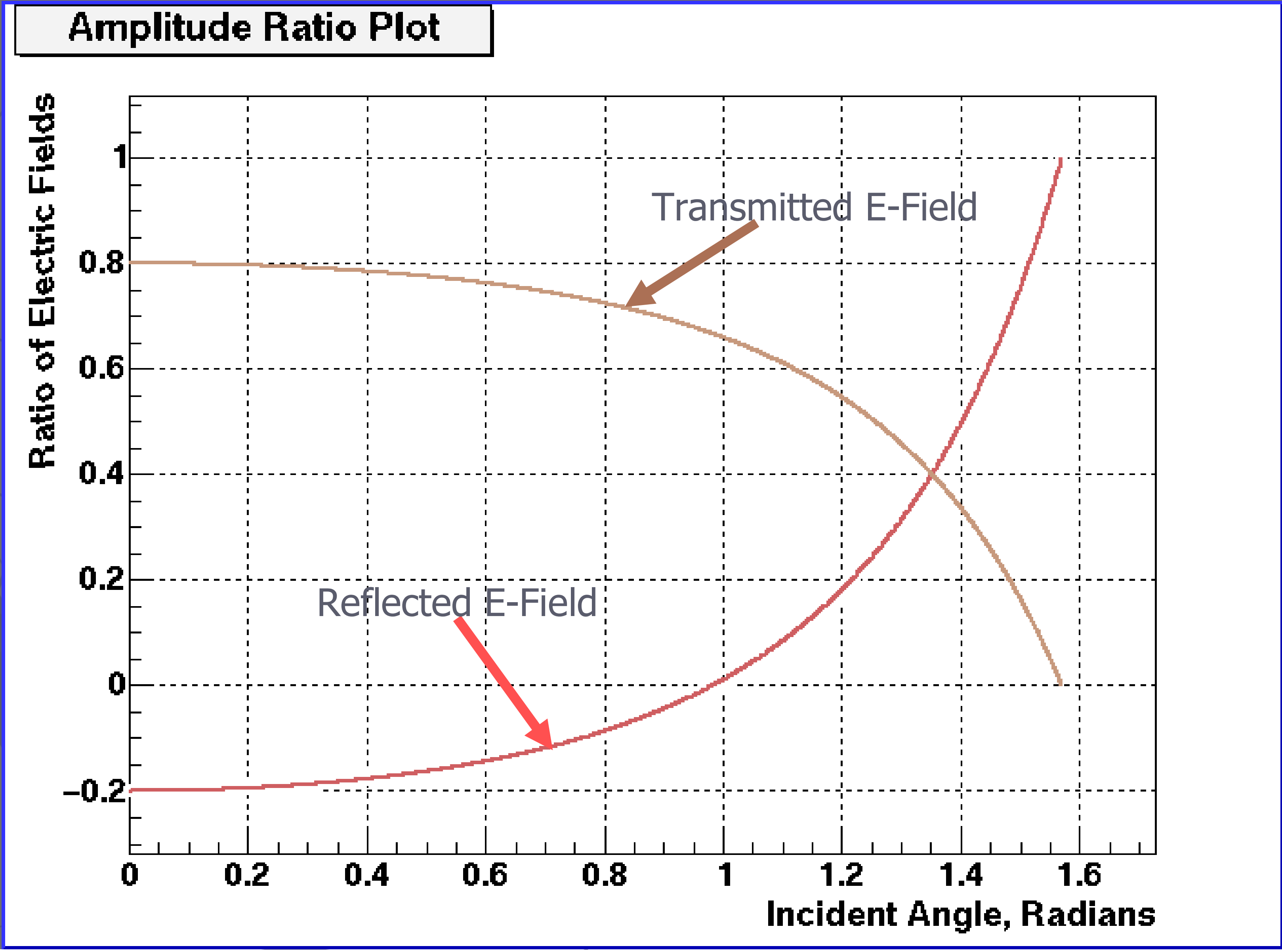
Board-work!

Show what these mean for normal and oblique incidence

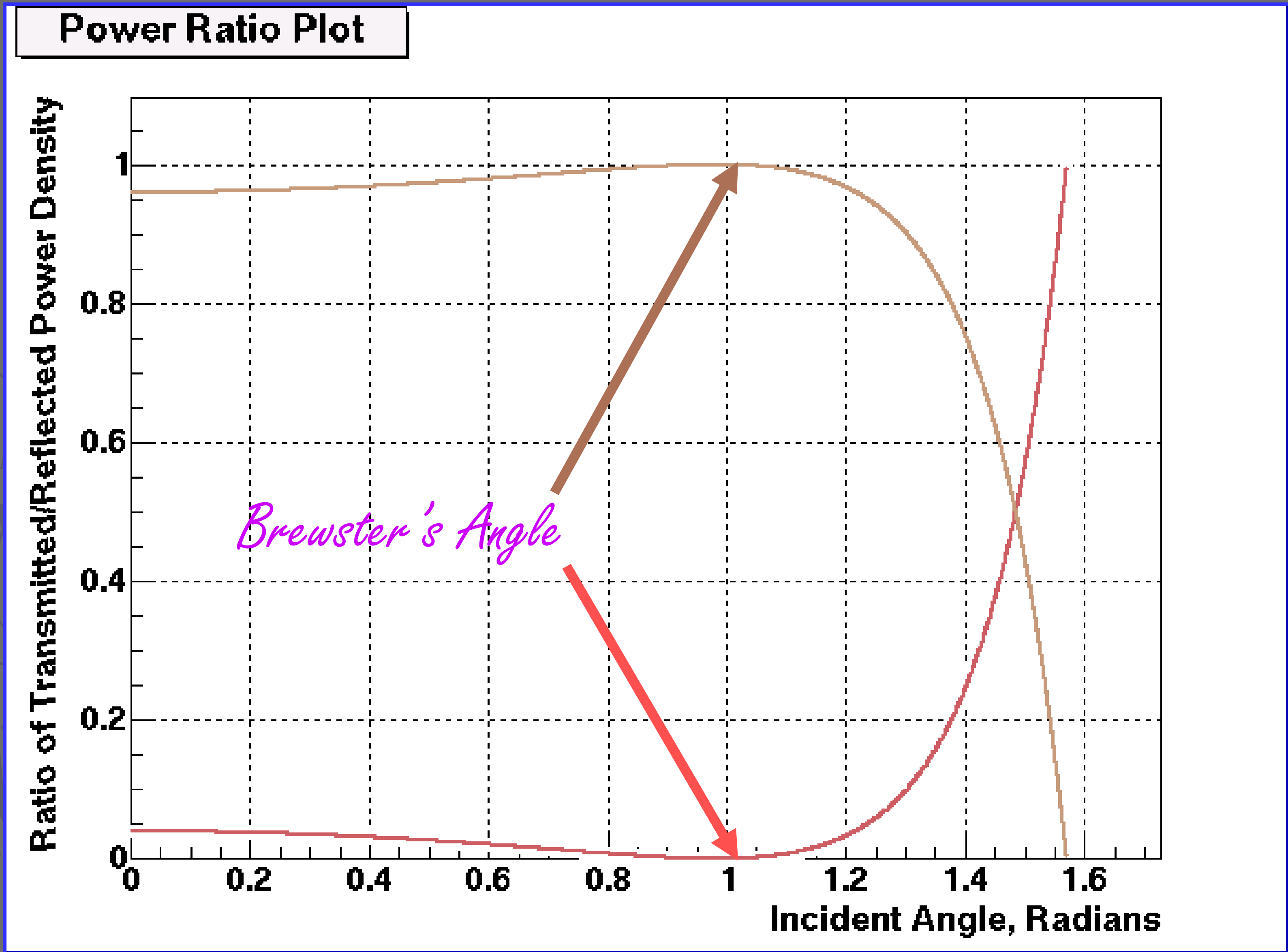
Leave up previous slide as reminder of Boundary conditions.

Ratio of Electric Fields

(& the magnetic fields too)



Ratio of Power Densities



This was the Hard Case

The other Polarization, with E entirely parallel to the interface, I leave to the Problem sets.

Summary

- Brewster's angle $\tan\theta = n_2/n_1$
- Electric field amplitude transmission and reflection ratios look a lot like our transmission like ratios.
- Total internal reflection
  - Produces an 'evenescent wave'
  - This wave does not propogate away from the boundary, only along it.