Quiz 3 Review

Wednesday, April 6, 2016 2:52 PM

WAVEGUIDE DEFINITION

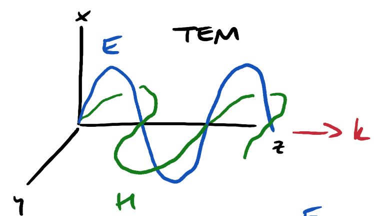
↳ structure that transmits EM waves and within the fields are confined to an extent

TYPES OF WAVEGUIDES

↳ transmission lines are waveguides

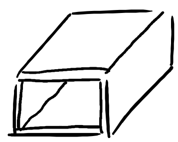
↳ transmission lines only propagate transverse electromagnetic waves, TEMs

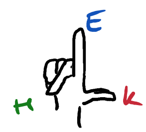
↳ waves in which both $\bar{E}$ & $\bar{H}$ are orthogonal to the direction of propagation



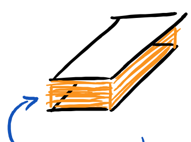
↳ rectangular waveguides

↳ cannot propagate TEM





↳ parallel plate waveguides

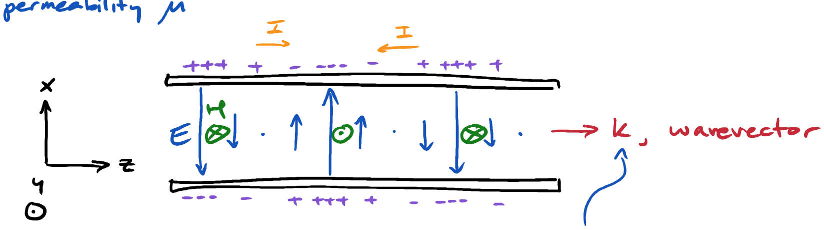


gap can be air or dielectric of permittivity ε', conductivity σ, and permeability μ

if you apply an AC voltage to the plates:

- electric field established b/w plates
- current flows in z direction
- magnetic field established in y direction

↳ forward travelling TEM in z



k gives direction of propagation

$$\boxed{\begin{aligned} \bar{E}_{sx}(z) &= \frac{V_s}{d} = \frac{V_o}{d} e^{-j\beta z} \\ \bar{H}_{sy}(z) &= \frac{I_s}{b} = \frac{V_o}{bZ_o} e^{-j\beta z} \end{aligned}}$$

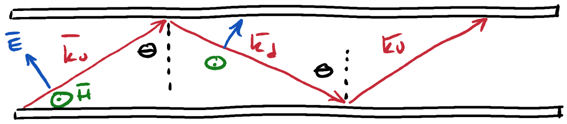
$$\boxed{|k| = 2\pi/\lambda}$$

where d is distance b/w plates &
b is width of waveguide into page

as frequency of applied AC voltage increases

↳ waves with $\bar{k}$ parallel to plate can stay, but

↳ waves begin to propagate with zig-zag direction due to reflections



$$\boxed{|\vec{k}_u| = |\vec{k}_d| = \omega\sqrt{\mu\varepsilon}}$$

$$\boxed{n = \sqrt{\varepsilon_r}}$$

if $\vec{k}_d$ interferes destructively with $\vec{k}_u$
wave will decay exponentially (evanescant wave)

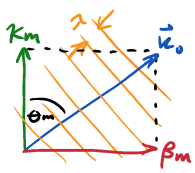
↳ only propagates if $\vec{k}_u$ & k_d constructively interfere
↳ all $\vec{k}_u$ waves in phase & all $\vec{k}_d$ waves in phase
↳ only true at certain angles of incidence, θ

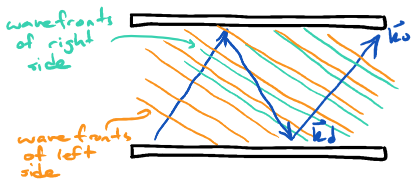
↳ THESE SPECIFIC ANGLES CORRESPOND TO A WAVEGUIDE MODE

↳ and only propagates if frequency ≥ cutoff frequency of mode
↳ TEM have no cutoff frequency, supported at any frequency

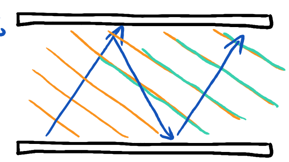
Modes → correspond to an angle of incidence at which all upward propagating waves are in phase

→ as frequency is raised, # modes increases





upward components not in phase
↳ decaying



upward components in phase
↳ propagating

$\vec{k}_u$ made of ⊥ components κ_m & β_m

$$\boxed{\beta_m = \sqrt{k^2 - \kappa_m^2}} \quad \boxed{\kappa_m = \frac{m\pi}{d}}$$

$$\boxed{v_p = \frac{\omega}{\beta_m}} \quad \boxed{\theta_m = \operatorname{acos}\left(\frac{m\pi}{kd}\right)}$$

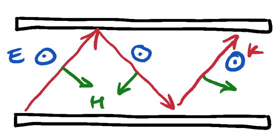
for upward components to be in phase, the phase shift over a round trip of κ_m must be an integer multiple of 2π

$$\boxed{2(\kappa_m d + \phi) = 2m\pi}$$

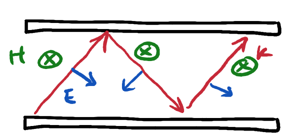
phase shift on reflection
mode #

with TE waves $\phi = \pi$
with TM waves $\phi = \emptyset$

TE waves
↳ E stays in same direction after reflection (s-polarized)



TM waves
↳ H stays in same direction after reflection (p-polarized)



↳ there are other polarizations b/w TE & TM cases
but these can be expressed as superpositions of TE & TM

Cutoff Frequency

$$\boxed{\omega_{cm} = \frac{m\pi c}{nd}}$$

$$\boxed{\lambda_{cm} = \frac{2\pi c}{\omega_{cm}} = \frac{2nd}{m}}$$

↳ for each mode there is a cutoff frequency, ω_{cm}

↳ if operating frequency, $\omega \geq \omega_{cm}$ mode will propagate

$$\boxed{\beta = \frac{n\omega}{c}\sqrt{1-\left(\frac{\omega_{cm}}{\omega}\right)^2}}$$

← if $\omega \geq \omega_{cm}$, β is real
if $\omega < \omega_{cm}$, β is complex