$E_{incident} = E_0 e^{-ikz}$

$E_{reflected} = \Gamma_0 E_0 e^{ikz}$

if Γ_0 is negative then $\bar{E}$ has changed the direction

$$\Gamma_0 = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \qquad \eta_1 = \left(\frac{\mu_1}{\varepsilon_1}\right)^{1/2}, \ \eta_2 = \left(\frac{\mu_2}{\varepsilon_2}\right)^{1/2}$$

for non magnetic media

$$\eta_1 = \sqrt{\frac{\mu_0}{\varepsilon_1}}, \quad \eta_2 = \sqrt{\frac{\mu_0}{\varepsilon_2}}$$

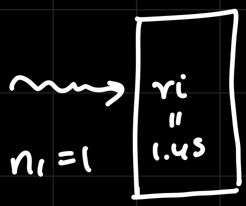
$$\Gamma_0 = \frac{\sqrt{\mu_0/\varepsilon_1} - \sqrt{\mu_0/\varepsilon_2}}{\sqrt{\mu_0/\varepsilon_1} + \sqrt{\mu_0/\varepsilon_2}} = \frac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}}$$

$$\frac{\sqrt{\varepsilon_{r_1}} - \sqrt{\varepsilon_{r_2}}}{\sqrt{\varepsilon_{r_1}} + \sqrt{\varepsilon_{r_2}}} \longleftarrow \quad = \frac{\sqrt{\varepsilon_0 \varepsilon_{r_1}} - \sqrt{\varepsilon_0 \varepsilon_{r_2}}}{\sqrt{\varepsilon_0 \varepsilon_{r_1}} + \sqrt{\varepsilon_0 \varepsilon_{r_2}}}$$

$$\downarrow$$

$$\boxed{\frac{n_1 - n_2}{n_1 + n_2}}$$

these n are not η (eeta)
this is refractive index



for non magnetic material

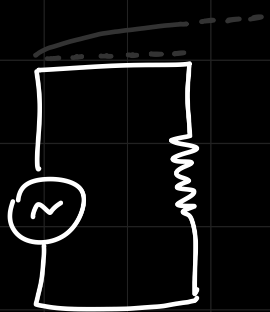
$$\Gamma_0 = \frac{n_1 - n_2}{n_1 + n_2} = -ve$$

and so, $\bar{E}_r$ = opposite to $\bar{E}_i$

Initial KVL/KCL problem

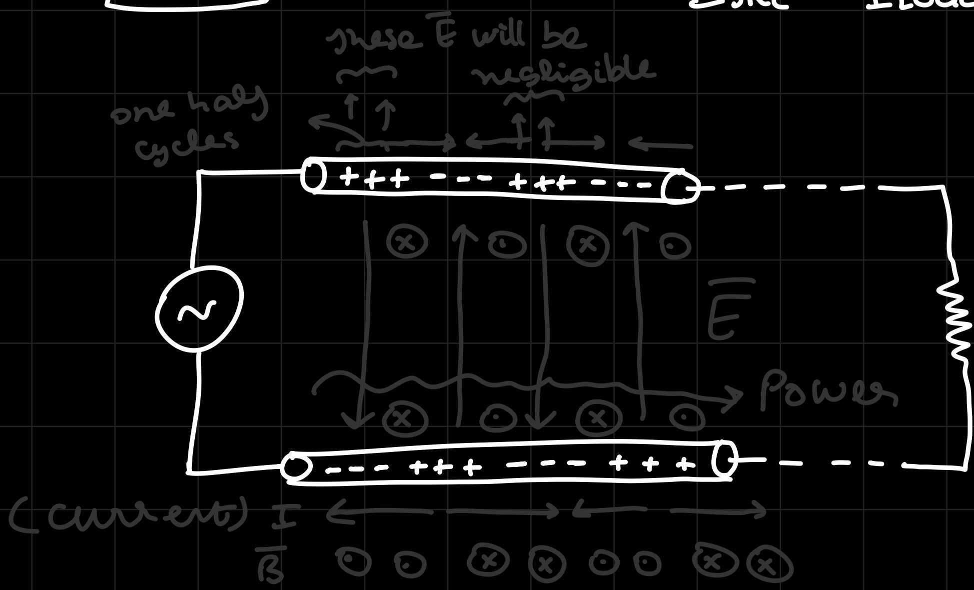
wavelength for freq = 50Hz → $\frac{3\times10^8}{50} = 6\times10^8$ cm

Since wavelength is very big, we can assume for a very small circuit that voltage remains constant along a R=0 line



but for very long ckts, we cannot assume:

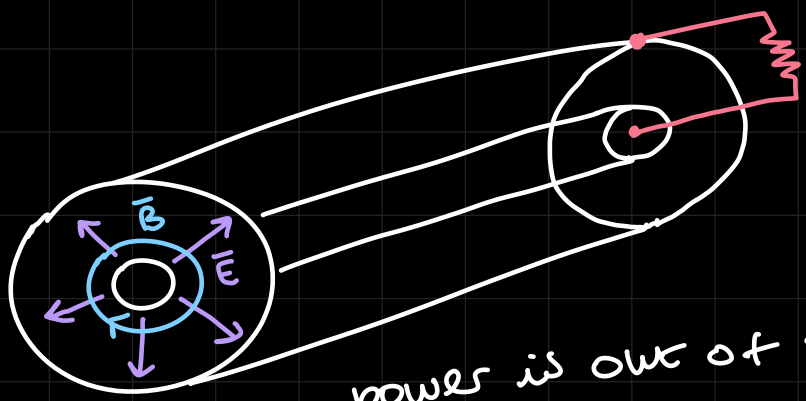
$V_{SRC} = V_{Load}$
$I_{SRC} = I_{load}$ } ×



$\bar{E} \times \bar{H}$ is almost zero outside the circuit because of $\bar{E}$

$(\bar{E} \times \bar{H})$ Power is held / concentrated within the 2 conductors and being guided from SRC → Load at all points because both $\bar{E}$ and $\bar{H}$ switch directions together.

Guided wave propagation



power is out of the screen ⊙

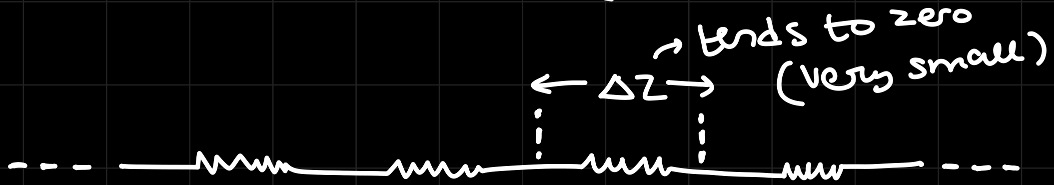
ERROR POSSIBLE: These conductors might not remain as PEC at higher frequency

Distributed Resistance (not lump resistance ×) throughout the conductors because not PEC

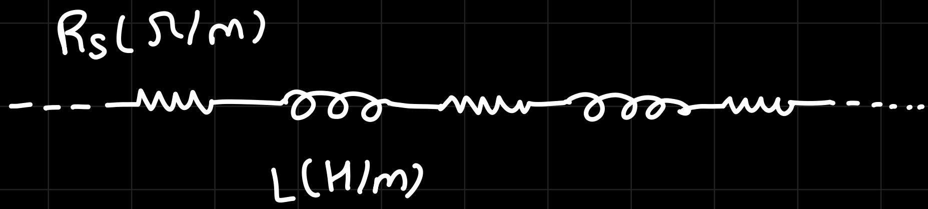
Assume that distributed resistance per unit length as R_s (Ω/m)

↳ not just r because distributed

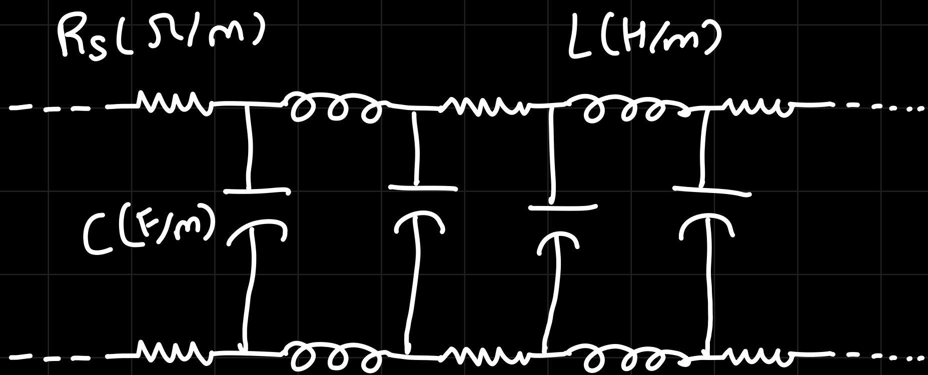
↓ series resistances



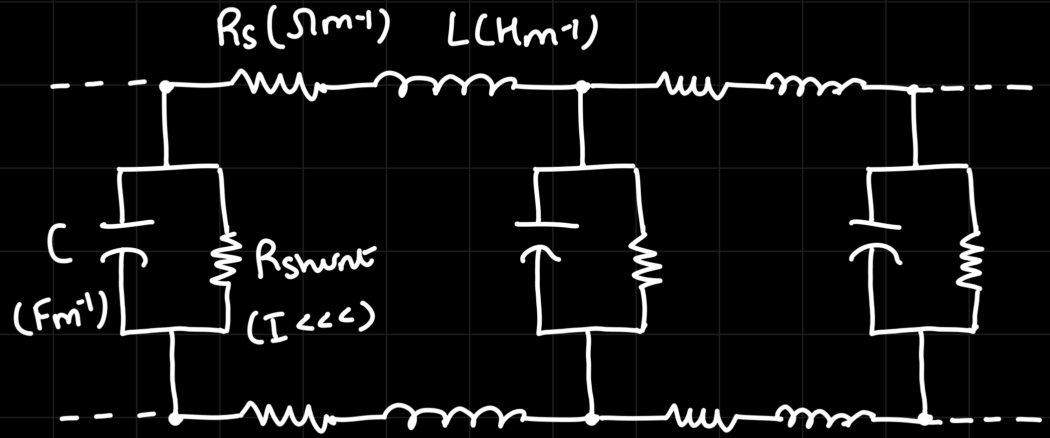
along with this we have inductance as well because of the $\bar{B}$

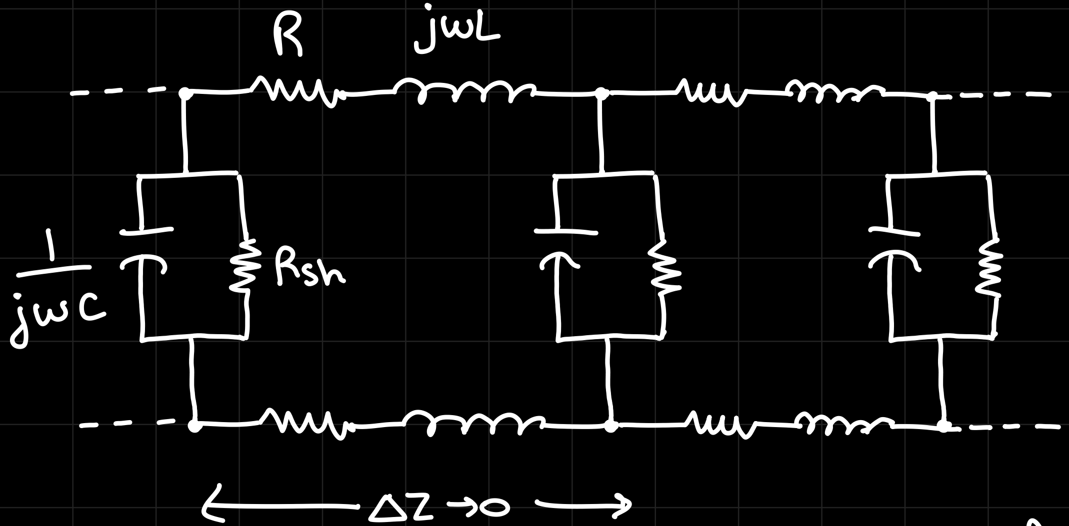


additionally, we also have distributed capacitance due to the $\bar{E}$



lastly, we have σ very small between the two conductors so that means very high resistance between them (dielectric medium) (leakage current)





<fig L>

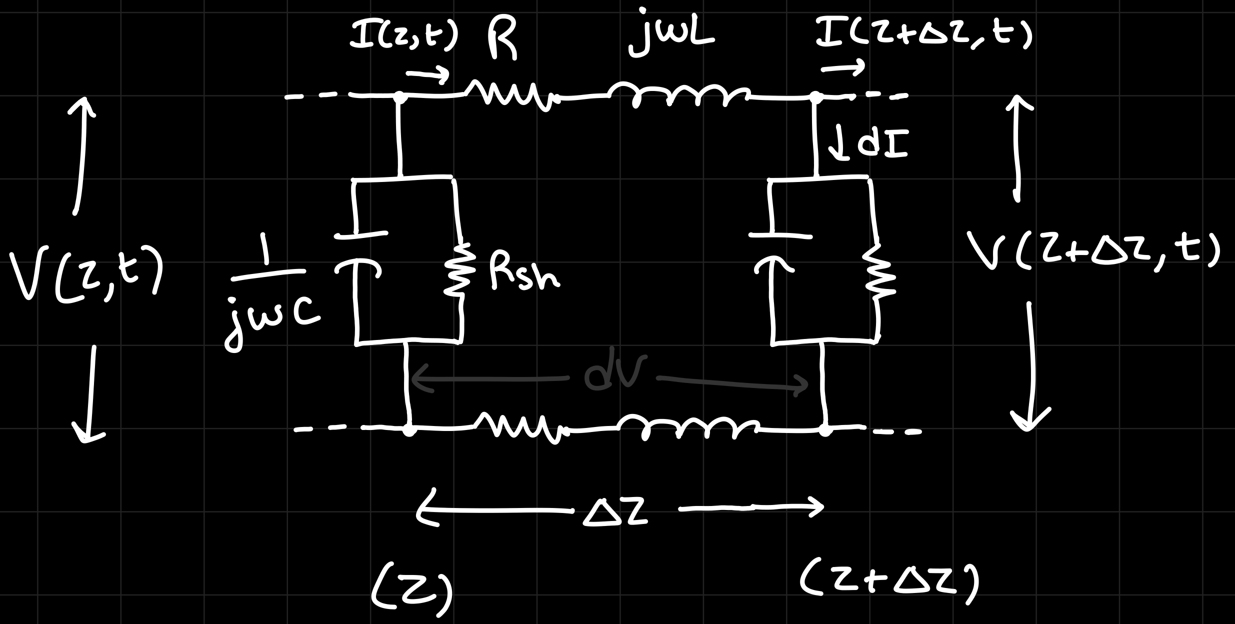
let $X = R + j\omega L$

(admittance) $Y = j\omega C + \frac{1}{R_{sh}} = (G + j\omega C)$

↳ very less because $R_{sh} >>>$

Since we have all these non-idealities, there must be some voltage drop and hence KVL / KCL would fail without considering these factors.

KCL/KVL fails for macroscopic circuitry but still work for <fig1> because $\Delta z \to 0$ (because distance very small)



$$V(z,t) - I(z,t)[R+j\omega L)\underbrace{\Delta z}_{} - V(z+\Delta z,t) = 0$$

because R and L are per unit values

$$-I(z,t)X\Delta z = V(z+\Delta z,t) - V(z,t)$$

$$\lim_{\Delta z \to 0} \frac{V(z+\Delta z,t) - V(z,t)}{\Delta z} = -XI(z,t)$$

$$\boxed{\frac{\partial V}{\partial z} = -X I(z,t)}$$

what about the current ?

$$I(z,t) = I(z+\Delta z,t) + dI$$

$$I(z+\Delta z,t) - I(z,t) = -dI$$

$$I(z+\Delta z,t) - I(z,t) = -VY\Delta z$$

$$\boxed{\frac{\partial I}{\partial z} = -VY}$$

now we find the wave equation
(requires 2nd derivation)

$$\frac{\partial^2 V}{\partial z^2} = -X\frac{\partial I}{\partial z} = -X(-VY) = V\cdot XY$$

note: $\left.\begin{matrix} X = R+j\omega L \\ Y = G+j\omega C \end{matrix}\right\}$ complex nums

$$\frac{\partial^2 V}{\partial z^2} - \gamma^2 V = 0$$

where $\gamma = \sqrt{XY}$

$\gamma = \left((R+j\omega L)(G+j\omega C)\right)^{1/2}$

(helmholtz eqn)

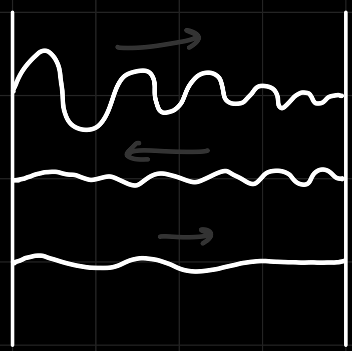
$\gamma = \alpha + j\beta$

general solⁿ:

$$V = V_+ e^{-\gamma z} + V_- e^{\gamma z}$$

$$V = V_+ e^{-\alpha z} e^{-j\beta z} + V_- e^{\alpha z} e^{j\beta z}$$

$$V(z,t) = V_+ e^{-\alpha z} e^{j(\omega t - \beta)z} + V_- e^{\alpha z} e^{j(\omega t + \beta)z}$$



continuous transmission
and reflection

Now, when will have lossless transmission
i.e. no attenuation in signal?

when $e^{-\alpha z}$ and $e^{\alpha z} = 0$

↳ $\alpha = 0$ i.e. γ = purely complex

so, $R = 0$ and $G = 0$

↳ series resistance = 0

↳ leakage current = 0 (R_{shunt} ↑↑↑)

so, $\gamma = j\beta = j\omega\sqrt{LC}$ → $\underline{\beta = \omega\sqrt{LC}}$

wavelength: $\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{\omega\sqrt{LC}} = \frac{1}{f\sqrt{LC}}$

and velocity → $\boxed{v = \frac{1}{\sqrt{LC}}}$

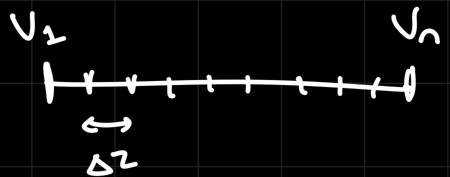
this is of the guided wave

quiz 3 and quiz 4 syllabus same
(open book) (closed book)

quiz 5 and quiz 6 syllabus : till today
(open book) (closed book)
30 mins 30 mins

PROJECT

{ finite difference method }



$\frac{V_{i+1} - V_i}{\Delta z}$ forward difference

$\frac{V_i - V_{i-1}}{\Delta z}$ backward difference

central difference (best)