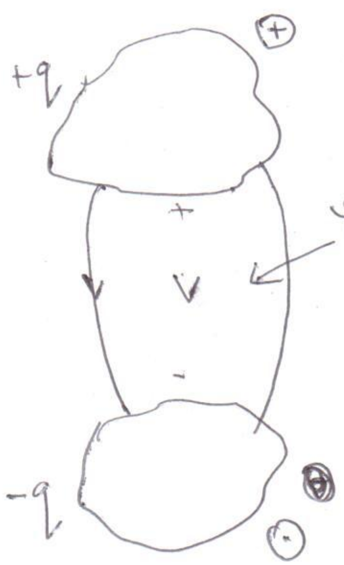
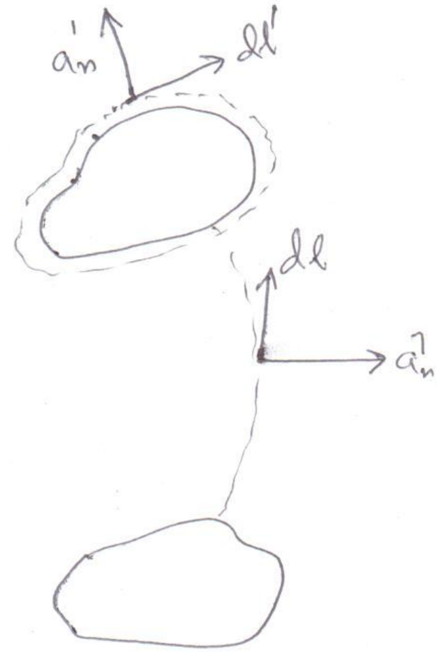
pul parameters.

Lecture 8:-
(2 cond Tx line: pul + Freq D)

$$l = \frac{\Psi}{I} \qquad c = \frac{q}{V} \qquad g = \frac{I_t}{V}$$



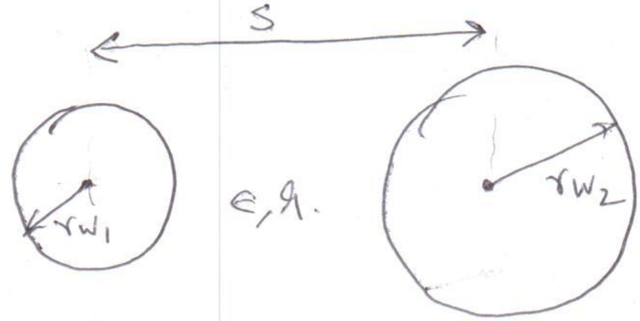


$$l = -\mu \frac{\int H_t \cdot a_n \, dl}{\oint H_t \cdot dl'}$$

$$c = \epsilon \frac{\oint \vec{E}_t \cdot a_n' \, dl'}{-\int \vec{E}_t \cdot dl}$$

$$g = \sigma \frac{\oint \vec{E}_t \cdot \vec{a}_n' \, dl'}{\int \vec{E} \cdot dl}$$

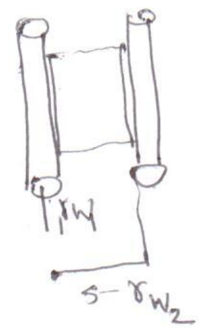
Case A: Cylindrical wires of different radii.



Now,

$$\oint H \cdot dl = I$$

$$\Rightarrow H = \frac{I}{2\pi r} \text{ outside the wire.}$$



Therefore, $\Psi_{\Delta z} = \iint B \cdot ds$

$$= \Delta z \int_{r_{w_1}}^{s - r_{w_2}} \frac{\mu I}{2\pi r} \, dr$$

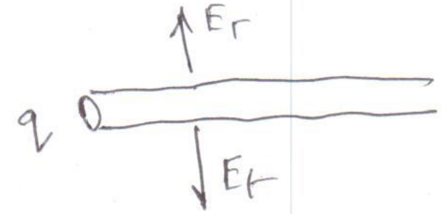
$$= \Delta z \frac{\mu I}{2\pi} \ln\left(\frac{s - r_{w_2}}{r_{w_1}}\right)$$

Other conductor:-

$$\Delta z \frac{\mu I}{2\pi} \ln\left(\frac{s - r_{w_1}}{r_{w_2}}\right)$$

$$\therefore\ l = \frac{\mu}{2\pi} \ln\left(\frac{s - r_{w_2}}{r_{w_1}}\right) + \frac{\mu}{2\pi} \ln\left(\frac{s - r_{w_1}}{r_{w_2}}\right)$$

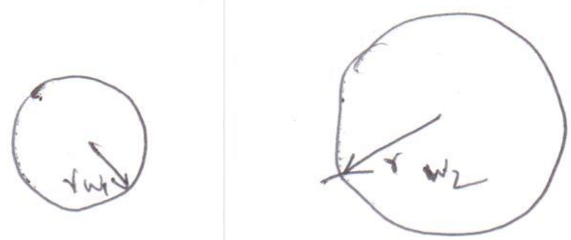
$$\Rightarrow\ l = \frac{\mu}{2\pi} \ln\left(\frac{(s - r_{w_1})(s - r_{w_2})}{r_{w_1}\, r_{w_2}}\right)$$



$$E_r = \frac{q}{2\pi \epsilon r}$$

$$\oint D \cdot ds = Q_{enc}$$

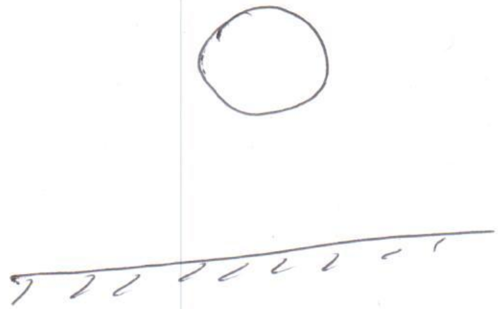
$$V = -\int E \cdot dl = \frac{q}{2\pi\epsilon} \ln\left(\frac{R_2}{R_1}\right).$$



$$V = \frac{q}{2\pi\epsilon} \ln\left[\frac{(s - r_{w_2})}{r_{w_1}}\right] + \frac{q}{2\pi\epsilon} \ln\left(\frac{(s - r_{w_1})}{r_{w_2}}\right)$$

$$C = \frac{q}{V} = \frac{2\pi\epsilon}{\ln\left(\frac{(s - r_{w_2})(s - r_{w_1})}{r_{w_1}\quad r_{w_2}}\right)}$$

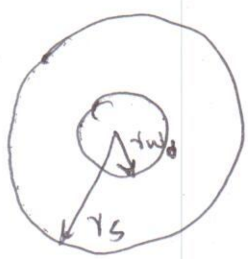
Case B :- wire on ground plane.



$$c = \frac{2\pi\epsilon}{\ln\left(\frac{2h}{r_w}\right)}$$

How do you get l and g?

Case C :- coaxial cable



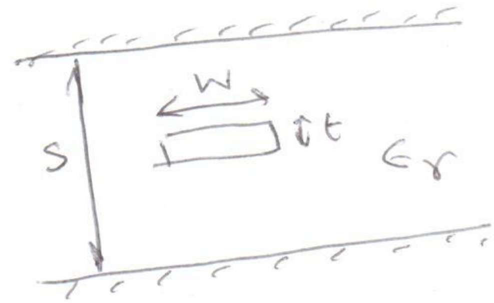
$$c = \frac{2\pi\epsilon}{\ln\left(\frac{r_s}{r_w}\right)}$$

$$l = \mu\epsilon\, c^{-1}$$

$$g = \frac{\sigma}{\epsilon} c$$

Case D :- PCB lines. (Refer Chap 4 : C. Paul)

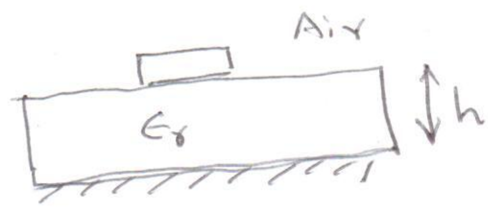
stripline



$$\ell = \frac{30\pi}{v_0}\,\frac{1}{\left[\frac{W_e}{s} + 0.441\right]}$$

$$\frac{W_e}{s} = \begin{cases} \frac{W}{s} & \frac{W}{s} \geq 0.35 \\ \frac{W}{s} - \left(0.35 - \frac{W}{s}\right)^2 & \frac{W}{s} \leq 0.35 \end{cases}$$

microstrip

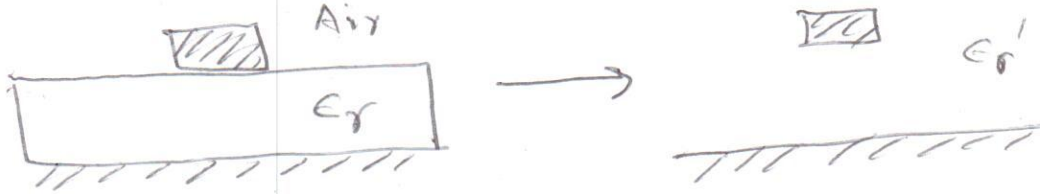


$$\ell = \frac{60}{v_0}\ln\left[\frac{8h}{W} + \frac{W}{4h}\right] \qquad \frac{W}{h} \leq 1$$

$$\frac{120\pi}{v_0}\left[\frac{W}{h} + 1.393 + 0.667\ln\left(\frac{W}{h} + 1.444\right)\right]^{-1} \qquad \frac{W}{h} \geq 1$$

What about C ?

$$\epsilon_r' = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12\frac{h}{W}}}$$



Skin effect Freq dependant pul.

$$\nabla \times E = -j\omega\mu H$$

$$\nabla \times \nabla \times E = -j\omega\mu\, \nabla \times H = -j\omega\mu\sigma E$$

$$\Rightarrow \nabla(\nabla \cdot E) - \nabla^2 E = -j\omega\mu\sigma E$$

$$\Rightarrow \nabla^2 E = j\omega\mu\sigma E$$

$$\frac{d^2 E_z}{dx^2} = j\omega\mu\sigma E_z.$$

$$\gamma^2 = j\omega\mu\sigma$$

$$E_z = E_0 e^{-\gamma x} \qquad \gamma = \sqrt{j}\sqrt{\omega\mu\sigma}$$

$$= E_0 e^{-x/\delta} e^{-jx/\delta} \qquad = \frac{1+j}{\sqrt{2}}\sqrt{\omega\mu\sigma}$$

$$J_z = J_0 e^{-x/\delta} e^{-jx/\delta} \qquad \delta = \frac{1}{\sqrt{\pi \mu f \sigma}}$$

Skin depth is a depth where $J_z = \frac{J_0}{e^1} = \frac{J_0}{2.7183}$

Surface impedance:-

$$Z_S = \frac{E_0}{J_{total}}.$$

$$J_{total} = \int_0^{\infty} J_z \, dx = \frac{J_0 \delta}{(1+j)}$$

$$Z_S = \frac{E_0}{J_0 \delta}(1+j) = \frac{1}{\sigma \delta}(1+j)$$

$$Z_S = R_S + j\omega L_i$$

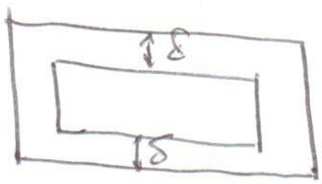
$$R_S = \frac{1}{\sigma \delta} \qquad \omega L_i = R_S.$$

example :-

What is the R ?

$$R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2 - \pi (r - \delta)^2}$$

$$\simeq \frac{\rho l}{2 \pi r \delta} \simeq \frac{\rho l \sqrt{\pi \mu f \sigma}}{2 \pi r}$$



$$R = \frac{\rho l}{A}. \quad R_{dc} = \frac{l}{\sigma w t}.$$

$$R = \frac{\rho l}{\left(tw - \left(tw - (t-\delta)(w-\delta)\right)\right)}$$

$$= \frac{\rho l}{\delta (t+w)} = \frac{l}{\sigma \delta (t+w)}$$