POWERUNIT

EM 2 Notes and Records

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Time Varying Fields — Lecture 1

$V_{emf} = -\frac{\partial \lambda}{\partial t}$, λ = Flux Linkage = Number of flux turns

$= -N \frac{\partial \psi}{\partial t}$, $\psi = \int B \cdot ds$

Area

μ = # of dipoles

- Ferromagnetic Material [Iron & Ferrite]
  - $\mu \uparrow$ Iron $\simeq$ 1500 – 3000

We Use Iron to sheild the magnetic field from the External field.

  - $\mu \uparrow\uparrow\uparrow$ Ferrite , Special characteristics: It's not a conducting material unless you suppress it on itself.

- What's a Dipole? an electron يدور حول النواة (nucron) & when it does that we get a $\vec{B}$

$B = \mu_0 H$ so $\psi = \int \mu H \cdot ds$

μ is permbility = مقدرة المادة على خطوط
المجال

→ forces against the source will induce the & -ve particles.
μ is the number of these particles.

- appling External magnetic field will rearrange and Aline to the External field applied [Aline the internal fields]

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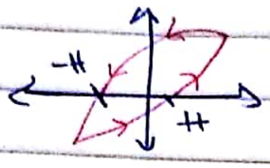
Each Dipole will generate internal field to support the External one.



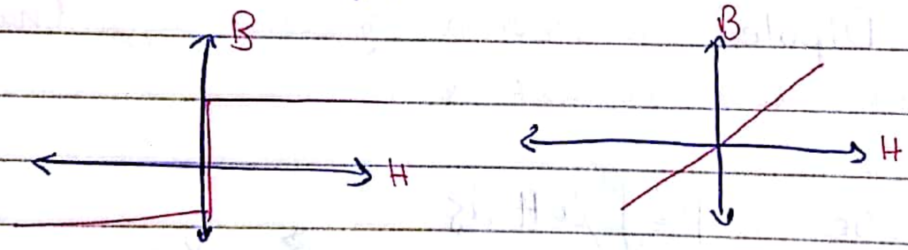
if $\mu\uparrow$ then the # of dipoles will increase.

In order to form the loop from $\boxed{-H}$ to $\boxed{H}$ we need T = period because once you remove the applied field, the material will try to go back to its original state & that takes time.

Losses of the Hystresses are function of frequency.
heat $\propto f^2$

also, μ is a function of frequency.

Ferrite reaches saturation very fast that's why we use air gaps to slow down the saturation.



with no airgaps — with airgaps.

Ferrite has less losses cause there's a free motion but no conducting pathes.

Ferrite's μ is very BIG!

Small area in the loop cause small losses
used in transformers → (عشان ما يسخنش كتير.)

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⊛ Iron is used to shield Magnetic lines
⊛ We tent Iron using كروم or قصدير
⊛ μ = ميل الماس

⊛ $\boxed{H}$ as Ac from $[-H , H]$

⊛ The Loop is a Representation [الشغل اللي بناخده] - [الشغل الناتج]
⇓
$\boxed{\text{equals Losses}}$

⊛ Thermal Energy is Another Representation for "Work".

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Lecture 2

$V_{emf} = -N \frac{d \int B \cdot ds}{dt} = -N \frac{d \int \mu_o H \, ds}{dt}$

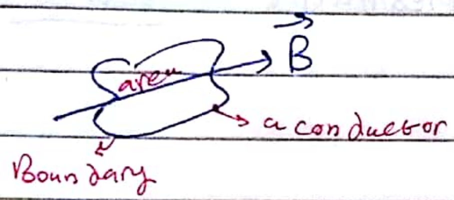
we can interchange between integration and differentiati because they are linear operation and Quantities.

$V_{emf} = -N \int \frac{\mu \, \partial H \cdot ds}{\partial t}$ [maxwell's equation]

$\int E \cdot dL$ so,

$V_{emf} = -N \int \frac{\mu \, \partial H}{\partial t} ds = -N \mu \int H_o \omega . \cos(\omega t) \, ds$

$= \boxed{-N \mu S H_o \omega . \cos(\omega t) = V_{emf}}$ memorize



Find V_{emf}

- To limit the boundry and to force charges to move in it.
  عشان السلك أو conductor عملنا Short circuit

- Electric field due to flux linkage.

$\Rightarrow H = H_o \sin(\omega t) \Rightarrow$ H لها current.

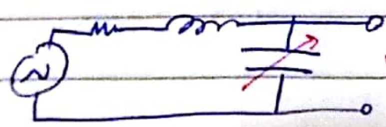
- The simplest oscillator is an eletron يدور around الذرة!

Hard Equations مستعصية eg $H_o(x, y, z) \Rightarrow$ space

$= \sinh^{-1}\left(\frac{x}{y^2+z^2}\right)$ ~~X~~ ملهاش.

- N # Must be High in order to recive waves.

- The reciver is a band pass filter. [resonance : $\frac{1}{2\pi\sqrt{LC}}$]



Vary cap to tune the resonance [channel]

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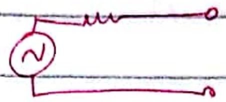
We usually work on resonance frequency so the equivalent circuit will become with resistance only.



Note: Expected Exam Question to find the operating frequency of a microwave with a certain specifications.

- كلما زادة السرعة يرتبط ال mass تتجاوب للزيادة فيها
- Higher speed ⟹ تكثر روابط ↑ ⟹ current will flow ↑ ⟹ Eddy current increased ↑ ⟹ more power losses ↑
- Small radious ⟹ Higher frequency.

Microwave oven operation.

- magnetron [two magnets with High magnetic fields]
- Tripler ⟹ Diode + capacitor
- electric field is applied
- Fillement [heater] → يحرر الالكترونات
- but the magnetic field that is applied is very High that keeps them spening.
- because of the mechanical Design they will spin in Groups (coheerent)
- we pick them up using a conductor / usually Ellu ذي ال Voltage
- Then that voltage is drove to the antenna which will be about 2.45 GHz ⟹ all the way to the microwave oven room.
- Useing Faraday's Cage to shield the room.

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Lecture 3

Time varying current is related to magnetic field that affects induction which is simply maxwell's equation.

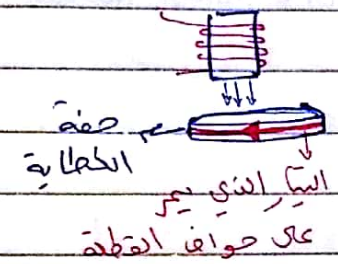
Volum current density ← $\vec{J} = \sigma \vec{\mathcal{E}}$ → Electric field
Conductivity

Applications on Faraday's law

1 Cap Sealing :-

الـControl عن ايتوريا لط The intencity in the coild سوف تقل.

$J \equiv A/m^2$

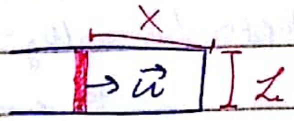


outer area is the largest So, $\mathcal{E} . dL$ ⇑ will increase and because the foil resistance is very low the power $P = I^2 R$ will increase as well. As heat will melt down the خاتمة ⇒ (اللي على العبوة)

Area ↑, Voltage drop ↑
μ ↑, High frequency
all of these case to intencify the magnetic field.

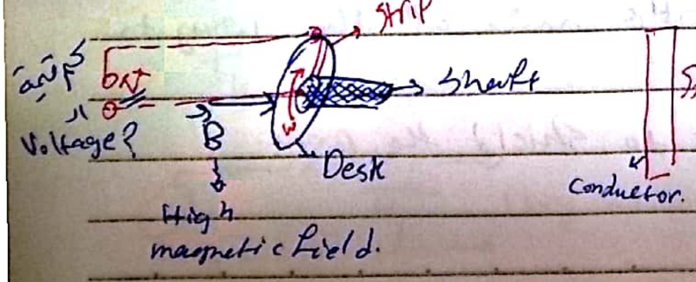
2 Electric breaking.

recall



$\phi = X . L$, $V = -B u L$
$u = \omega . r$, r: distance from center

so,,,



$$\int_0^R dv = \int_0^R r B u \, dL$$

$$\int_0^R dv = \int B \omega r \, dr \Rightarrow \boxed{V = \frac{\omega B r^2}{2}}$$

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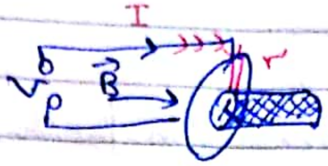
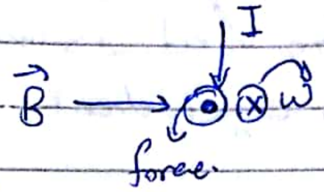
* if we were to find the current ??

$V = \frac{\omega B r^2}{2}$ $\otimes$ $\uparrow I = \frac{V}{\downarrow R}$ (Short circuit)



$\downarrow I$,, so force $\downarrow$

* magnetic field induced is always in the opposite direction of the source that caused it.
* the current will radially move in the Desk.
* if we have magnetic field + current = Force
Direction = $I \times B$

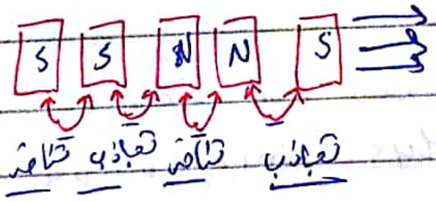


So, the Breaking will happen.
if $\underline{R}$ Load $\downarrow\downarrow$, Breaking force $\uparrow\uparrow$

$\otimes$ Examples:-
[1] shell: fly wheel [electric breaking system]
[2] Hybrid cars: (can Generate energy)

* to convert the [motor] load into a Generator, we must apply Force with higher speed than the field.
We usually use Ac Generators (Syncronous Generator)

[3] Linear motor.



So, it will move!
to change speed, change frequency
Related.

eg Lift the train upove Ground.

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Lecture 4

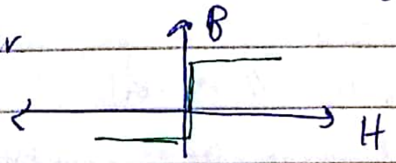
- ϵ_0 dipole reoriantation / # of $=$ Zero
- σ for instalation
- μ_r = for Ferrite is Largest

- $\mu_r \uparrow\uparrow$ (cciel,) $\longrightarrow$ $v \uparrow\uparrow$ (cciel,)
  Linearly [Like a Multiplication factor for both side Source & effected]
- $\mu_r \Rightarrow$ Used to intenaify the magnetic field lines [Flux]
- μ is nonlinear (problem) force for magnetic field بعكس ال electric field.

- μ is linear when the magnetic field is small.
- Real power (in thermal form) is equivalent to Losses
  "Resistance" but depends on frequancy. not a normal Resistance ((ohmic losses))

- When freeing electrons you increase conductivity
  # of free electrons $\uparrow$ $\leadsto$ conductivity $\uparrow$

- Breaking down due to Hug magnetic exterial field or force.
- Ferrite is Used in logic gates such as Schmitt trigger



Hystresses for Ferrite in this form X so we add airgaps in order to use it in transformers.

we can Amplify the Signal / Votage when we increase the turns Ratio.

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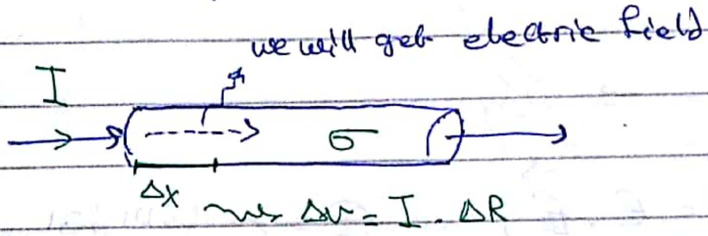
- It can also be used as a differentiator.
- σ = electron motion Representation.

- σ goes to Zero → R increases → insulator.
- σ goes to ∞ → R decreases → conductor.

- Any space or material will have $[\epsilon, \sigma, \mu]$
  ϵ ↓ electrons capability to Store energy.

- ϵ_0 can be obtained Statically by appling Different potentials

$$\boxed{E = \frac{\Delta V}{\Delta x}}$$



$$\boxed{\vec{J} = \sigma \vec{E}}$$

- كل تيار بيمشي داخل conductor or semi-conductor يعمل Electric field
داخل ال conductor, which is the basic idea for antenna.

- If we apply External field from $[+q \rightarrow -q]$ force will be generated to move $\vec{e}$.

- This is called polarization.

- When appling force distance between $\vec{e}$ & +ve charge change → balance will change → $\boxed{\text{polarization happen!}}$

[e.g. Liquid cristals]

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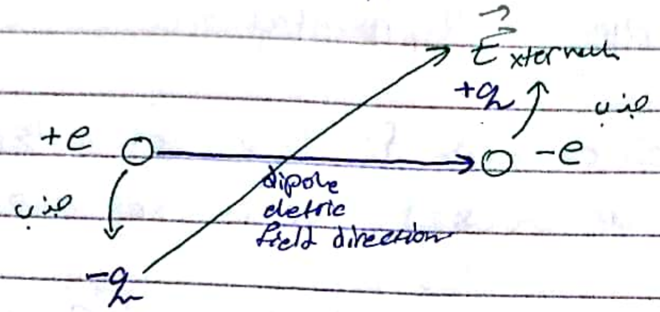
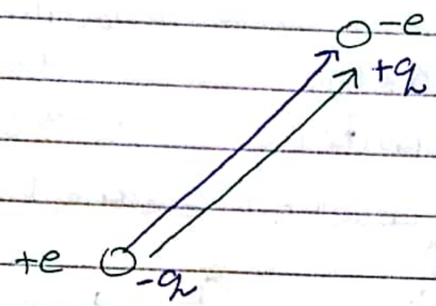
- Image ≡ Reflection of changes.
- Sensors are an application on electromagnetisime



⇓ [Reoriantation]



$\boxed{D = \epsilon . \vec{E}}$

↓ charge displacement

- ϵ = عدد ال dipoles اللي اتغير الاتجاه بتوعه

- Dielectric : $\epsilon_r > 1$, $\epsilon_r \uparrow\uparrow$ ⇝ electric field ↓↓
  ↳ when dipoles move استجابة ⇝ External field.

- Real Energy : when we apply work and bonds are broken!

$$\epsilon_r = \underbrace{\epsilon_r'}_{\text{real power loss}} + j\,\epsilon_r''$$

ϵ_r'' ⟶ mainly as a Resistance
can be seen in Microwave ovens
a charechterstic in water when we apply STRONG external field.

$$\mu_r = \mu_r' + j\,\mu_r''$$

μ_r'' ⟶ expressed in eddy currents [rare]

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Wave Equation

- $\oint E \cdot dL = -N \omega \sigma' \mu H_0 \cos(\omega t)$ ← Single harmonic case. ← Single point in Forrier domain.

- orthogonality:
  1. inner / dot product = Zero
  2. cross product direction (حسب قاعدة اليد اليمنى)

- Maxwell's Equation again.

$$\boxed{\nabla \times E = -\frac{dB}{dt}}$$

, ∇ = direction مشتقة بخصائص
↳ معدة !

→ For directive quantities.

e.g. $E = E_x \vec{a_x} = \underbrace{E_x(x,y,z,t)}_{\text{Value}} \underbrace{\vec{a_x}}_{\text{direction}}$

- Value could be a function of anything (in e.g., space x, y, z, t)

- If we hold these parameters (انثبتهم) E becomes a constant (Real Number).

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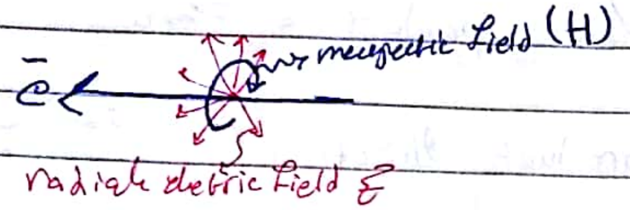
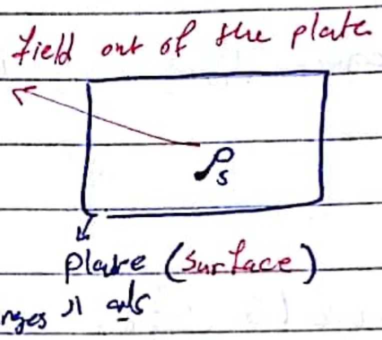
- Heat ≡ infrared radiation.

- For the same source (in space) electrical field and magnetic field are orthogonal.





- $\vec{\mathcal{E}} \propto \frac{1}{R^2} \propto q \propto \frac{1}{\epsilon_0}$

- charge (current element) ⇒ field ال Generation اصغر جزء بعمل

$$\boxed{dI = I \cdot dL}$$ شكله

- Simplest Maxwell's Equations

$$\boxed{\nabla \times \mathcal{E} = -\frac{dB}{dt}}$$

$$\boxed{\nabla \times H = J + \frac{dD}{dt}} \quad , \quad D = \epsilon \mathcal{E}$$

displacement

$$\hookrightarrow \boxed{\nabla \times H = J + \epsilon \frac{dE}{dt}}$$

also, $J = \sigma \cdot E$

$$\hookrightarrow \boxed{\nabla \times H = \sigma \mathcal{E} + \epsilon \frac{dE}{dt}}$$

- we propagate the electromagnetic waves in space.

For free space $\boxed{\nabla \times H = \epsilon \frac{dE}{dt}}$

- $\underbrace{\nabla}_{\text{Curl}} \underbrace{\times}_{\text{cross}}$ ⟺ It's a derivative for orthogonal stuff, also some sort of summation.

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- We Express cycling arguments in time and space

$E = E_0 \sin(\omega t - \beta r)$, How the electric field should look like

$\boxed{\text{direction of propegation}}$ = التي بتمشي فيه الموجة

$H = H_0 \sin(\omega t - \beta r)$, How the magnetic field should look like.

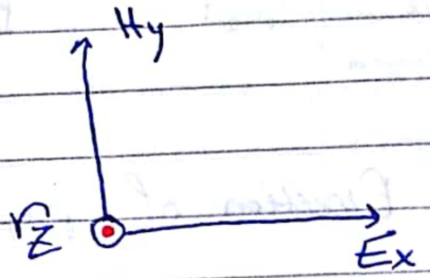
- $\omega \equiv$ frequncy in time $= \frac{2\pi}{T}$
- $\beta \equiv$ frequncy in space $= \frac{2\pi}{\lambda}$, λ is the period in space or wave length

Direction of propegation

$\vec{a_E} \times \vec{a_H} = \vec{a_r}$ e.g. if $E \rightsquigarrow \vec{a_x}$ & $H \rightsquigarrow \vec{a_y}$

$E = E_0 \sin(\omega t + \beta z)\, \vec{a_x}$

$H = H_0 \sin(\omega t + \beta z)\, \vec{a_y}$



- Electric field $\underset{\text{cross}}{\times}$ magnetic field

Gives you the direction of power carried on the electro magnetic wave.

$\rightsquigarrow$ because we send (power density) and Energy through transmission!

So $\vec{a_x} \times \vec{a_y} = \vec{a_z}$,

$\boxed{r = z}$ when we rewrite the answer in the argument we take the vector out

$H = H_0 \sin(\omega t + \beta \underset{\text{not } \vec{a_z}}{z})$

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plane wave in Free space

- $E = E_0 \sin(\omega t + \beta r)$
  $H = H_0 \sin(\omega t + \beta r)$ } => star ~~★~~

Origin of wave equation.

- $\nabla^2 E - \gamma E = 0$

  del operator.

- Realtion between E & H

$E = \eta\, H$, η (Caita) median cherechtersttcs impedance (could be complex)

[proportional to voltage signal] [proportional to current signals]

- Direction of propagation is a unit vector (r)

$E \times H = r$

- All waves can be approximated to (plane wave)
- How to achive plane wave? when the electric field is a stright line on a certain axis & the magnetic field is on a different orthogonal axis and they are both from the same source.

- From star ~~★~~ you can tell that H_0 & E_0 are much larger than the source.

- propagation direction tells us where the source's at.

- While the wave propagates it will lose power → lose H
  → lose E

boundary condition

- to creat electric field in a wire you need electric field on the outer space (air) surrounding this wire.
- to creat electric field outside the wire you need electric field inside it.

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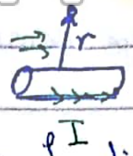
Boundary condition : the tangential component of the electric field is always continous.



power dinsity or Energy $\equiv$ WAtt/m^2

as A function of distance E_0 will decrease / reduced by $\frac{1}{r^2}$.

$\eta = \sqrt{\frac{\mu}{\epsilon}}$ (a real Quantity)

{ median charecterstics impeadance for free space. }

from Boisons Equation

$u = \frac{\omega}{\beta} = \frac{\frac{2\pi}{T}}{\frac{2\pi}{\lambda}} = \frac{\lambda}{T} = f.\lambda$ $\boxed{\text{Also}}$ $= \frac{1}{\sqrt{\mu.\epsilon}} = \frac{C_{\text{speed of light}}}{\sqrt{\mu_r \epsilon_r}}$

{ Speed of propegation }

$\hookrightarrow \mu = \mu_0 , \epsilon = \epsilon_0$ then u is maximum.

if we fix the {median / material / inviroment} then we fix the speed of propegation.

if we fix the frequncy {not a function of time/space} then we can measure λ

if we fix time { by taking more then one point at the same time } then electric field will be sinosoidal

Nyquist craiteria : to represnt a sinosidal you need at least two [2] points.

Remotly , we can measure the source by the electromagnetic waves

Transmitting Antenna — if we pass electric field in a wire this electric field will show up in air surranding the wire.

Receiving Antenna — and if there's an electric field out side the wire [in air] an electric field will be induced in the wire.

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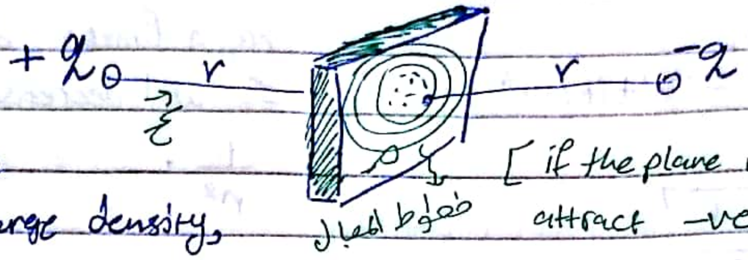
- whatever we see is basically $|\vec{E}| \equiv$ charge density.
  Charge density reflect the source [usually light]



(image theory)

- we only see the surface charge density, which is $\equiv$ تجمع ال charges على ال surface ال ds

[if the plane was +ve, it will attract -ve charges والعكس صحيح]

- Anything that Reflect images is a [conductor]
  وشدة الانعكاس تحدد ال conductivity
  ↳ [good conductor, semi conductor, ---]

$\boxed{\sigma, \epsilon, \mu}$ A function of frequency.

- $Z \neq$ Heat losses ال لا تمثل ⟺ هي مجرد تمثيل للعلاقة بين E & H ⟺ it's an impedance not a Resistance.
  nor Real power.

- Total Real power can be obtained from $E \times H$'s value
  indecates total power stored.

⊛ if Z was complex ⊛

⊛ Real part: (lossless)
will not desipate any real power

⊛ Imaginary part: (heat losses)
will consume power.

VERY IMPORTANT
عكس اللي بال circuits

- λ (wave Length) is measured in (meters).

- the $\boxed{\text{charge}}$ doesn't propegat but its effect does!
  [electromagnetic wave] ⟿ has weight [photons].

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$\vec{E}(x;t) \Rightarrow E_x(t) = E_0 \sin(\omega t - \beta z)\,\vec{a_x}$

$H(y;t) \Rightarrow H_y(t) = H_0 \sin(\omega t - \beta z)\,\vec{a_y}$

$E \times H = r$ propagation axis (+ve z-axis)

$E_0 = \eta H_0$ (in lossless median) , $\eta = \sqrt{\frac{\mu_0}{\epsilon_0}} = 120\pi = 377\,\Omega$

if $r = -\vec{z}$

→ $E = E_0 \sin(\omega t \pm \beta z)\,\vec{a_x}$

→ $H = H_0 \sin(\omega t \pm \beta z)\,\vec{a_y}$

Relation between (time) and (space) is speed.

$\lambda \cdot f = u$ (free space where $\mu = \mu_0$, $\epsilon = \epsilon_0$)

$\frac{1}{\sqrt{\mu_0 \epsilon_0}} = c$ (speed of light) $= 3 * 10^8$ (maximum)

Media types

1. free space [air, $\mu = \mu_0$, $\epsilon = \epsilon_0$]

→ even if there was no material at all, the electromagnetic field will be supported by the interaction between them. (air)

→ free space will not be affected by electric field nor magnetic field.

Theoritically we don't let the entinsity of electromagnetic field change the physical charecterstics of the material → يعني ما نحط electro magnetic حد such that يكسر روابط ويغير الـ material

→ so the field will be within normal field values.

Ex: $E = 10 \sin(2\pi \times 10^9 t - \beta z)\,\vec{a_x}$

$\lambda = \frac{3*10^8}{10^9} = 0.3\ m$, $H = \frac{10}{120\pi} \sin(2\pi \times 10^9 t - \beta z)\,\vec{a_y}$

$\beta = \frac{20\pi}{3}$, $u = \frac{\omega}{\beta}$, $\beta = \frac{\omega}{f \cdot \lambda}$

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⊛ We also need to find the power density:

$\vec{E} \times \vec{H}$ ⇝ magnitude only has the power density but the direction points in the propagation axis. Hence it is called a (pointing vector).

$$|P_D| = \frac{1}{2} E_{max} \cdot H_{max} \cdot \sin(\underset{\text{in between}}{\theta}) \quad (W/m^2)$$

in our case ⇝ plane wave they are orthogonal.

$$\boxed{|P_D| = \frac{1}{2} E_{max} \cdot H_{max}}$$

⊛ How to generate an electromagnetic wave?

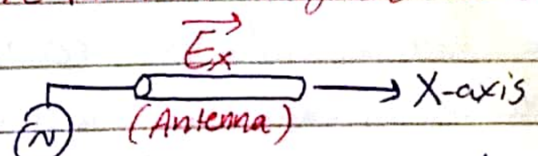
↳ from the boundry condition: [1] conductor

[2] time varying current will produce electric field in the conductor ⇝ so electromagnetic wave surrounding that conductor will be established!

⊛ if the current frequency was 1 GHz ⇝ the wave frequency will also be 1 GHz

& to change the wave frequency, the only way is to change the supply (current)'s frequency.

The function diagram for this case:-



↳ can support current & magnetic field

⊛ We can pick an electromagnetic wave from a steady step (sharp @ maximum component) using an antenna that is tuned at a certain impulse.

⊛ Pulse frequency contents are about (∞) A wide spectrum.

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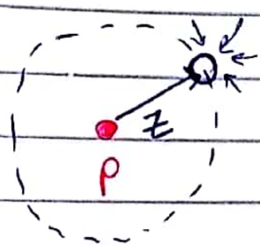
Antenna size (along with almost all electrical devices) depends on λ (meters) & can be controlled by frequency.
cause $\lambda = \frac{c}{f}$

$\boxed{\text{e.g}}$ for a station @ 801 KHz find: $\lambda = 371\ m$

- tower Hight $\Rightarrow \frac{\lambda}{4} \approx 91\ m$
- $\boxed{\text{tower Hight} * 2}$ = distances between towers $= \frac{\lambda}{2} = 182\ m$

Mainly, electromagnetic wave power depends on exactly How much you are sending and reciving (كم بتبعث وبتستقبل)

Calculating power at a certain point

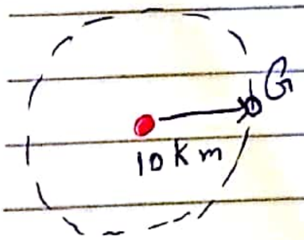


Find P??

$$P(z) = \frac{\text{Power transmitted}}{\text{distance}} = \frac{P_t}{4\pi \underbrace{r^2}_{(z)^2}} \ (w/m^2)$$

which implies $\boxed{P_D = \frac{1}{2} E_m \cdot H_m}$

Ex: if $P_t = 1$ watt, find P_D @ G:-



$$P(G) = \frac{1}{(10 * 10^3)^2 * 4 * \pi} = 795\ p\ (\text{watt}/m^2)$$

a very small value!

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POWERUNIT

Lecture 9

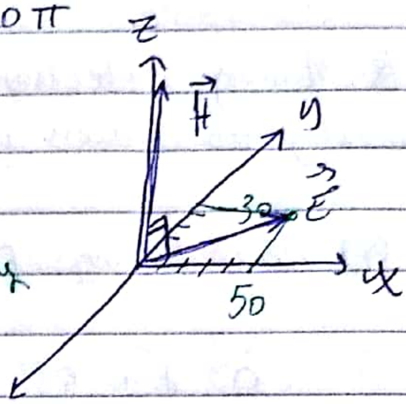
Ex.

$E = 50 \sin(w_0 t - 30\pi z)\vec{a_y} - 30 \sin(w_0 t - 30\pi z)\vec{a_x}$

* Find frequency * Draw the curl (Relation). * H?

* $H = \frac{50}{120\pi} \sin(w_0 t - 30\pi z)\vec{a_x} - \frac{30}{120\pi} \sin(w_0 t - 30\pi z)\vec{a_y}$

→ linear (two dependent component)



* $\vec{H}$ is orthogonal on Electric field.

Ex * give two orthogonal lines for the following in the same plane?

$a\vec{a_x} + b\vec{a_y}$

1) $-b\vec{a_x} + a\vec{a_y}$ } orthogonal
2) $b\vec{a_x} - a\vec{a_y}$

in phase, Same frequency, speed

Coherently, they vary as a function of time and space. (the two parts)

* if β was $+30\pi$ in the previous Example or they were not in phase or the direction of propagation was different, then they are not from the same Source and they are not components for the same wave.

* if $\vec{E}$ had (Same) x, y & z components then they are (from) the same wave and this is a vector represntation.

* if the Signals/waves were orthogonal then:

1. the dot product is equal to zero.
2. the cross product is equal to one.

} we use this when we have unknowns we "dot product" them them = 0, solve.

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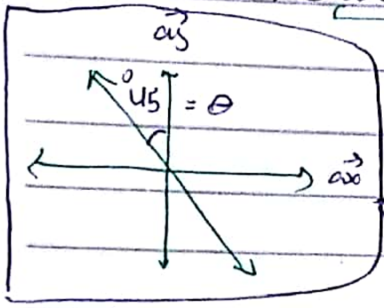
⊛ Polarization: Represents the trace of the tip of the electric field vector.

Why trace: it changes in space & time. (gives an argument of sine & cosine)

$$E = E_o \sin(\underbrace{\omega t - \beta r}_{\theta})\vec{a_r}$$



Because the argument doesn't affect anything

⊛ this obtaind line will not change if we change the values cause it's an argument.

⊛ the electric field will change on this line

⊛ called linearly polarized wave استقطاب خطي

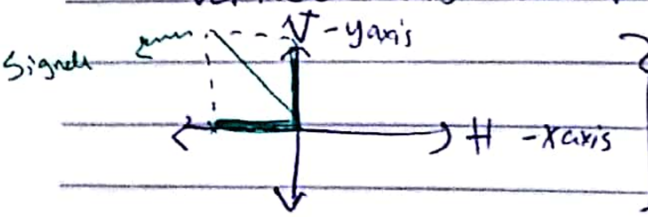
⊛ oriantation of reciving or transmitting antenna shape depends on the polarization so the tangential component of electric field outside goes in the conductor so we can recive it.

⊛ Waves in space can be supported if we give them two orthogonal parts $(\overset{\text{Horizontal}}{H}, \underset{\text{Vertical}}{V})$

⊛ if the angle θ between them is 90°, it (Antenna) will not recive anything

⊛ Inner product is the one that recives stuff, that's why the conductor of the Antenna should be orthogonal with the electric field lines.

⊛ Horizontal axis will recive (الامواج الموازية له).
Vertical axis will recive (الامواج الموازية له).



⇒ اذا سقطت الموجة بزاوية باخذ ال Inner product (cosine) والاسقاط للـ Signal على الـ two axis !

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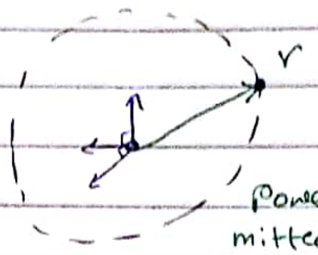
When $\sigma = 0$ then there is no attenuation due to conduction. Also, No drop in $\vec{E}$ (electric field) & No R (resistance) So No heat Losses.

Two types of Losses:

1. Due to destance
2. Due to media / material

Losses due to Destance :-



$$P_D = \frac{P_t \text{ transmitted}}{4\pi r^2}$$

Power Density

Power is transmitted radialy.

$$P_r = A_{eff} \cdot P_D$$

recived, effective Area

Attenuation due to space.

$$P_r = \frac{P_t \cdot A_{eff}}{4\pi r^2}$$

called (Link budjet) which is the relation between P_r & P_t

Losses due to material

$\sigma \neq 0$ (Lossy media)

$\rightsquigarrow \nabla^2 E - \gamma E = 0$ maxwell's / Laplace Equation

$\rightsquigarrow \gamma^2 = j\omega\mu(\sigma + j\omega\epsilon)$

$\rightsquigarrow \gamma = \alpha + j\beta$ $\rightsquigarrow$ same β from previous Lectures.

$$\rightsquigarrow \alpha = \omega \cdot \sqrt{\frac{\mu\epsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} - 1\right]}$$

$$\rightsquigarrow \beta = \omega \cdot \sqrt{\frac{\mu\epsilon}{2} \cdot \left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} + 1\right]}$$

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(3) Steady State Solution

direction of propagation

$$\vec{E} = E_o\, e^{-\alpha z} \sin(\omega_o t - \beta z)\, \vec{a_x}$$

- Now $e^{-\alpha z}$ ⇛ called the attenuation factor.

⇒ if there was no propagation, energy will decrease which cause more power Loss.

- Real power is lost as heat in the media ⇝ conduction path / current ⇝ infrared region.
- if α ↑↑ ⇝ Losses will ↑↑ ⇝ more heat ↑↑.
- (H) direction doesn't change

$$H = \frac{E_o}{\eta} e^{-\alpha z} \sin(\omega_o t - \beta z)\, a_y$$

- for the same wave, the sine argument is the same for $\vec{H}$ & $\vec{E}$

- Now what is η ??

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}} \Rightarrow |\eta| \angle \theta_\eta \Rightarrow |\eta| \cdot e^{j\theta_\eta}$$

take j to the denomenator ⇝ -j & the existing j will be gone.

$$\frac{\omega\mu}{-j\sigma + \omega\epsilon} \qquad \text{so, } \theta_\eta = \frac{1}{2} \tan^{-1}\left(\frac{\sigma}{\omega\epsilon}\right)$$

and $\frac{\sigma}{\omega\epsilon}$ is called the Loss tangent.

Which is one of the material's charecteristics!

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If $Z = 50\angle 20^\circ$

then there are Losses & we know that cause there is an angle & it's a complex Quantity

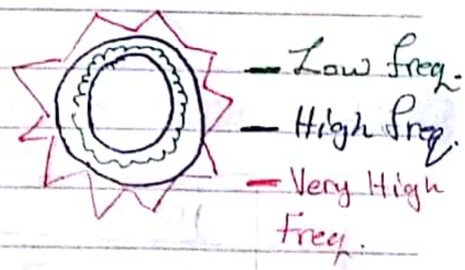
⊛ if $\boxed{\theta_Z}$ exist, How can we write H?

$$H = \frac{E_0}{|Z|} e^{-\alpha z} \sin(\omega t - \beta z \oplus \theta_Z)$$

constant phase shift due to medial material.

⊛ α Represnts the attenuation and it Usually appears at low frequncies, air that is close to earth (MF and below) (that's why it's called Surface wave propegation attenuation). at High frequncies, α is Almos gone.

⊛ The Higher the frequnay the straighten the propegation.



exists & ↓

ELF	0.3k - 3k
VLF	3k - 30k
LF	30k - 300k
MF	300k - 3M
HF	3M - 30M
VHF	30 - 300M
UHF	300M - 3G
EHF	3G - 90G

Why the $\boxed{3}$?!

because it's easire

⇒ with λ equation

$$\lambda = \frac{3 \times 10^8}{f}$$

At High freqnuey the Ionospher will reflect the wave (called sky wave)

⊛ UHF and apove, the wave will escape the ionosphere. [causes random rotation to the propegated waves]

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POWERUNIT

3 Perfect Conductor (μ & ε have no effect)

$\sigma \xrightarrow{\text{goes to}} \infty$

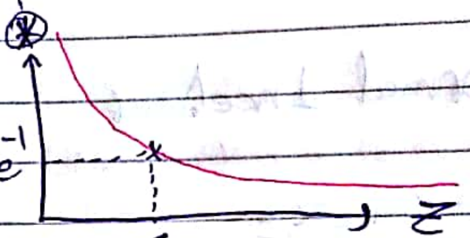
* The propegation of electric field in a conductor is zero.

There's differance between the propegation & existance of the electric field.

* When we apply current to a conductor, electric field exist to support the electric field that already exsist in the conductor, as for the wave propegation of the electric field, it is zero!

$$\vec{E} = E_o \, \underbrace{e^{-\alpha z}}_{\text{effective wieght}} \sin(\omega t_o - \beta z)\, \vec{a_x}$$

→ variable, function of z.



δ [delta = a small value
↳ skin depth

We say, @ δ the $\vec{E}$ on surface is e^{-1}. so,

$$\delta = \frac{1}{\alpha}$$

$$\alpha = \omega_o \sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2} - 1\right]}$$

Goes to ∞ — can be neglected — can be neglected

$$\therefore \approx \sqrt{\frac{\mu \sigma \omega}{2}} \quad \omega \to 2\pi f$$

$$\boxed{\alpha \simeq \sqrt{\pi \mu \sigma f}}$$

so,

$$\delta = \frac{1}{\alpha} = \frac{1}{\sqrt{\pi \mu \sigma f}}$$

⟷ Finding New α in conducting materials.

* Thin & thick conductors (expected Quiz Question)

- Thin: when it's comparable with the skin depth → نسبة قريبة من الرقم نفسه
- Thick: when it's about 5-2 times the value of the skin depth. لما تكون سمكها كبير بكتير

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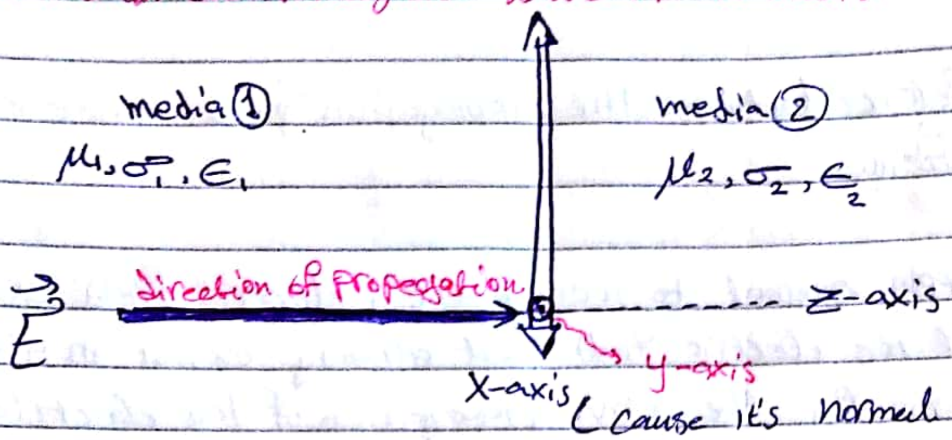
(*) Applications on thin & thick conductors: [Shielding]

(*) Incedents and Reflection (*)

if we had an electromagnetic wave in a media:-



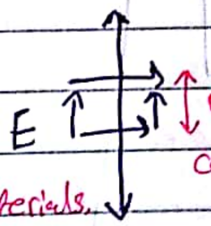
(cause it's normal على الفاصل بين ال two medias
↳ we call it "normal incedent")

(*) Normal Incedent

((The most important case • Applications ⇒ Transmission lines.))

$$\vec{E_1} = \vec{E_0}\, e^{-\alpha_1 z} \sin(\omega t - \beta_1 z)\,\vec{a_x}$$, in General !

The boundary conditions:



(*) differance in voltage drop causes current

⇝ tangential component is the boundary between the two materials.

⇝ the normal component is normal on the boundary.

((يعني انا عندي tangential component على الحدود
عليها مش بتكون ال normal component ((

The tangential component is Always continous.

$$E_{t_1} \Delta x = E_{t_2} \Delta x \text{ , so}$$

tangentiale

$$\boxed{E_{t_1} = E_{t_2}}$$

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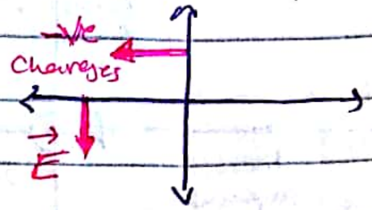
$D_{n_2} - D_{n_1} = \rho_s$ $\Rightarrow$ if perfect conductor then $\boxed{D_{n_2}}$ is Zero, so ρ_s is negative.

D ≡ flux lines (normal)

$\rho_s = -D_{n_1}$

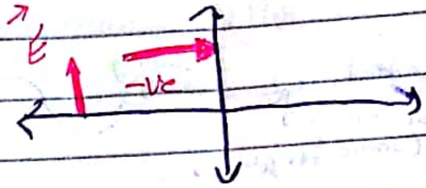
* ρ_s Represents the Reflecting image of the source of energy.

if $\vec{E}$ is direction



negative charges direction is as shown.

if $\vec{E}$ direction changes



* If we had a Dc current that is passing through a perfect conductor then the propagation is (Zero) and this happens in a very short time. Once we Apply External field the material Reconfigure its electrons in a period of time (Relaxation time)

الوقت لاعادة توزيع الالكترونات في ال material

When Relaxation time increases, Delay in Reflecting an image (surface charge density ρ_s) increases.

* for conductors, practically we say that there's no normal flux lines, because the relaxation time is very small, they are killed fast. That's why we don't draw them.

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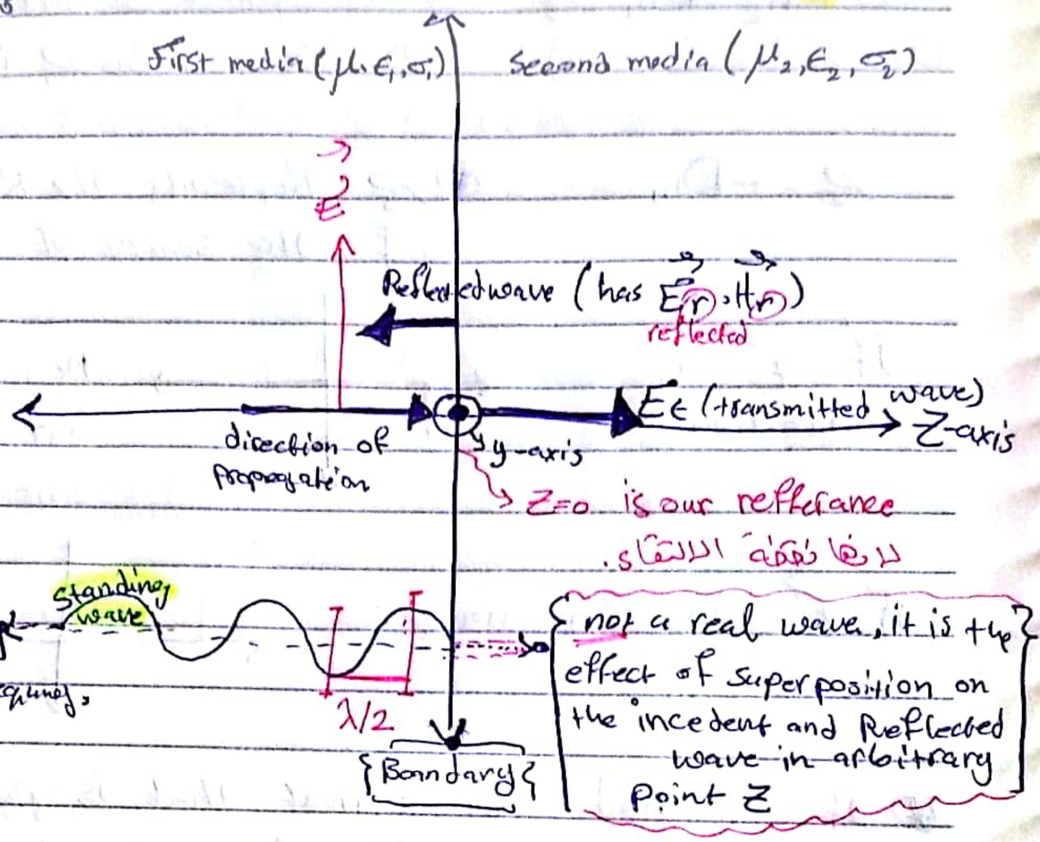
Figure X Lecture 13

* neglecting α:



{The total E_1 added two waves because they are coherent (same frequency).

{not a real wave, it is the effect of superposition on the incedent and Reflected wave in arbitrary point Z}

First media

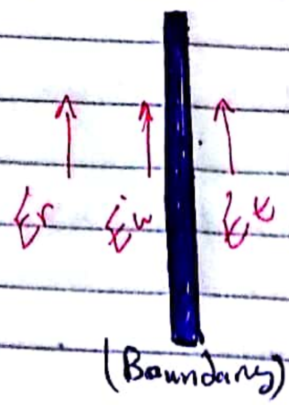
- $E_x = E_0 \sin(\omega_0 t - \beta z)\, \vec{a_x}$
- $H_y = \frac{E_0}{\eta} \sin(\omega_0 t - \beta z)\, \vec{a_y}$
- $\beta_1 \neq \beta_2$ (different medias)

Also, λ is different in differant media, so...

- $u_1 \neq u_2$ speed of propegation

$$u_1 = \frac{1}{\sqrt{\mu_1 \epsilon_1}} = \frac{c}{\sqrt{\mu_{r_1} \epsilon_{r_1}}}$$

- The vectorial sum at the right side equals The vectorial sum at the Left side.



Second media
after reflection

- $E_r = E_i * \Gamma$ ⇝ same direction
- $E_i \equiv$ incedent [الطاقة عند boundary]
- $\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$ could be complex

$\measuredangle$ the phase in (Γ complex) does a phase shift (delay) so, the Reference point changes.

continue...

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$E_i + E_r = E_t$

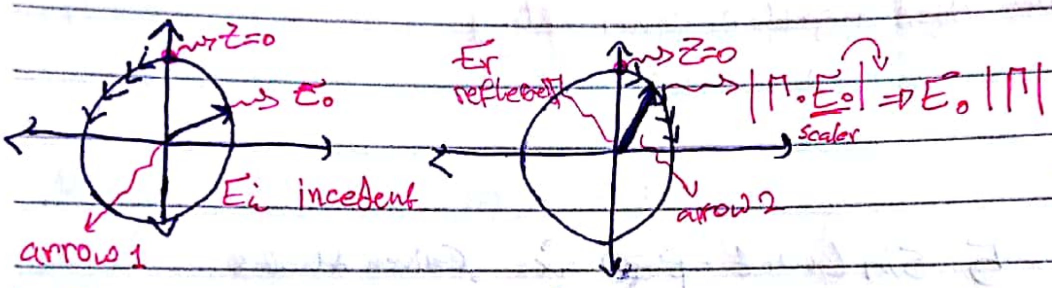
$E_i \underbrace{(1+\Gamma)}_{\tau} = E_t$, $\tau \equiv$ Transmission coefficient

$\boxed{\tau E_i = E_t}$ #

⊛ First material: $E_r = \Gamma E_o \sin(\omega_o t - \beta_1 Z)\vec{a_x}$

⊛ Second material: $E_t = \tau E_o \sin(\omega_o t - \beta_2 Z)\vec{a_x}$

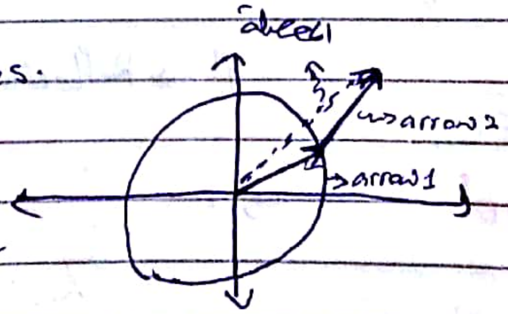
⇝ Note: all equations & Relations Applies on the boundary ONLY

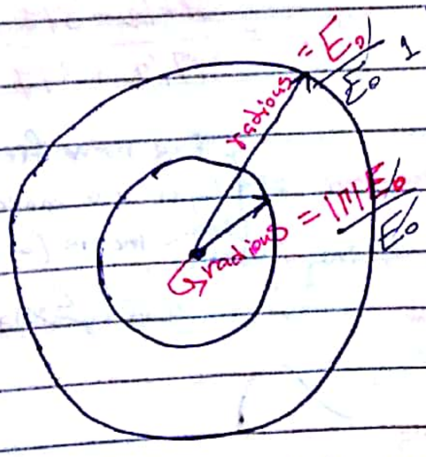


(Z in one direction) (when Z changes)

⊛ rotating around the unity circle is $\lambda = 2\pi$ in the Z-axis.

⇝ Adding the two circles: (vectorial sum)





⊛ in order for incedent to equal = 1 we devide by E_o for simplesity

⊛ $E_i + E_r = [E_1$ total in the first media]

E_1 is sinusoidal with double the original frequency. time & ω are constants and we fix time to t = Zero in order to remove its effect.

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E total:

$$\vec{E_i} + \vec{E_r} = E_1 \sin(\omega_0 t - \underbrace{2\beta}_{\text{double}} z)\, \vec{a_x}$$

⊛ Standing wave:

- called "Standing" cause it will not change its position or effect. It will remain in its position at the (graph) check Figure ✱.

→ Okay, then what exactly is it?!

∴ ((two waves added together coherently))

Example

$\vec{E_i} = \underbrace{5}_{E_0} \sin(\omega_0 t - \beta z)\, \vec{a_x}$, Given that:

$\mu_{r_1} = 1$, $\epsilon_{r_1} = 1$, $\sigma_1 = 0$

$\mu_{r_2} = 1$, $\epsilon_{r_2} = 4$, $\sigma_2 = 0$

Find:

→ $\eta_1 = \sqrt{\frac{\mu_1}{\epsilon_1}} = \eta_0 = 377\,\Omega$

→ $\eta_2 = \frac{\eta_1}{2}$

→ $u_1 = c = 3 \times 10^8$

→ $u_2 = \frac{c}{2}$

→ $\beta_1 = 20\pi$

$\lambda_1 f = c$

$\lambda_1 = \frac{3 \times 10^8}{3\,GHz}$

→ $\lambda_1 = 0.1\,m$

→ $\beta_2 = 40\pi$

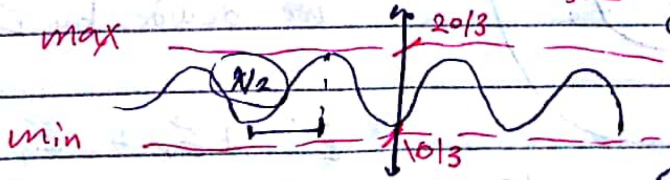
اصغر → $\lambda_2 = 5\,cm$

Γ → Reflection coefficient.

→ $\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{377/2 - 377}{377/2 + 377}$

$= -1/3$ (negative) ⇒ {if we move from light to more $\boxed{\text{dense}}$ media (-ve)} ← والسالب عكس

→ Draw the standing wave. (more free)



$\lambda/2 = 50\,cm$

⊛ maximum = $(1 + |\Gamma|) * E_0$

$= 4/3 * 5 = 20/3$

⊛ minimum = $(1 - |\Gamma|) * E_0$

$= 2/3 * 5 = 10/3$

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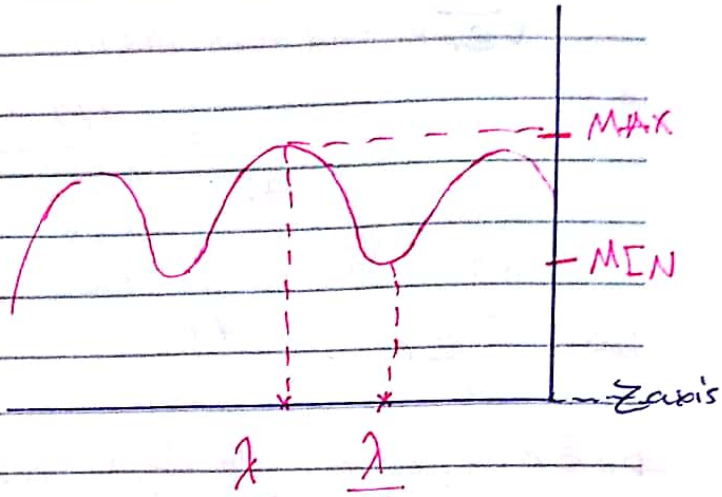
POWERUNIT

Lecture 14

Ex Given $\eta_1 = 100$, $\eta_2 = 200$, $\lambda = 10$ cm

$E_i = \underbrace{10}_{E_o} \sin(\omega_o t - \beta z)\vec{a_x}$.

Draw the standing wave:



- $MAX = (1+|\Gamma|) * E_o$
- $MIN = (1-|\Gamma|) * E_o$
- $\lambda/4 =$
- $\lambda/2 =$
- $|\Gamma| = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = 1/3$

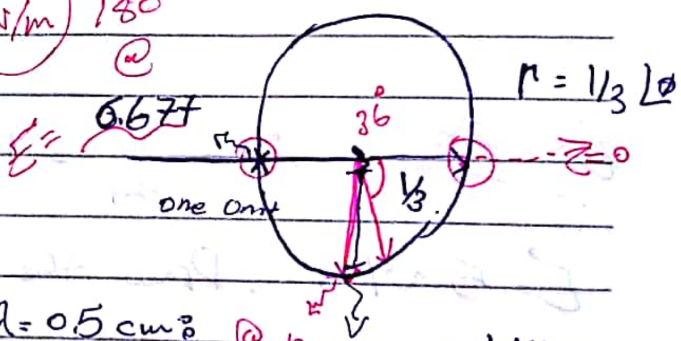
$MAX = (1+\frac{1}{3}) * 10 = 13.3$ V/m

$MIN = (1-\frac{1}{3}) * 10 = 6.67$ V/m

180 @

$\lambda/4 = 2.5$ cm

$\lambda/2 = 5$ cm



- Find Electric field Value @ $\lambda = 0.5$ cm:

we know that $\lambda = 2.5$ is @ 180° How on earth did we knew that?!

So $2.5 \rightarrow 180$

$0.5 \rightarrow X$

$X = \frac{180 * 0.5}{2.5}$

$X = 36°$

- Find the Value of Z @ 90° (Position):

SAME prosess

$2.5 \rightarrow 180$

$X \rightarrow 90$

$X = \frac{90° \cdot 2.5}{180}$, $X = 1.25$ cm

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- Find the speed of propagation

$$u = \frac{c}{\sqrt{\epsilon_r}}$$ ← find this first

we know $\eta_1 = \frac{\eta_0}{\sqrt{\epsilon_r}} = \frac{377\,\Omega}{\sqrt{\epsilon_r}} = 100$

from the Question

So, $\sqrt{\epsilon_r} = \frac{377}{100}$

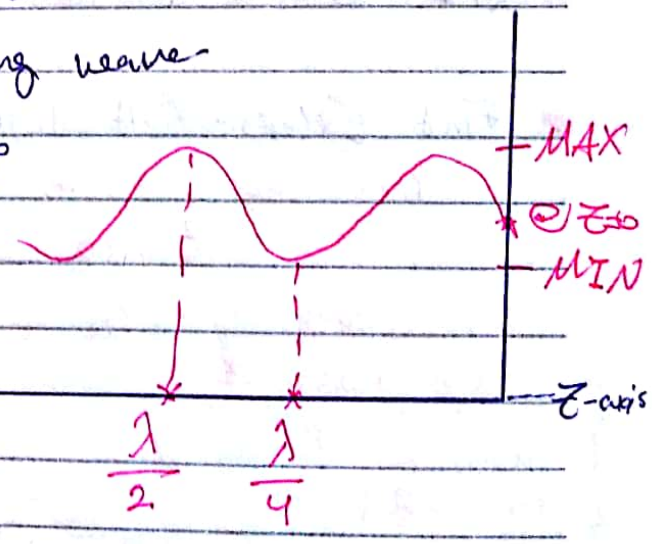
$\Rightarrow \sqrt{\epsilon_r} = 3.77$ which is $\gg 1$

$\Rightarrow u = \frac{c}{\sqrt{\epsilon_r}} = \frac{3\times10^8}{3.77} = 79.57\ M$

Example. Given $\eta_1 = 100$, $\eta_2 = 50 + j100$, $\lambda = 12\,cm$

$E = 5\ V/m$. Draw the standing wave.

$$\Gamma = \frac{-50 + j100}{150 + j100} = 0.62 \angle 82^\circ$$

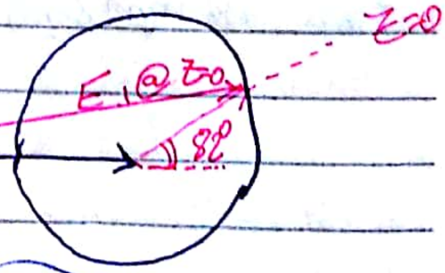


- MAX = 16.2 V/m
- MIN = 3.8 V/m
- $\lambda/4 = 3\,cm$
- $\lambda/2 = 6\,cm$

Find E @ z=0

$$= 10 * \sqrt{(1 + 0.62\cos(82))^2 + (0.62\cos(82))^2}$$ one unit

$= 12.4\ V/m$



Note: بيتكرر كل $\frac{\lambda}{2}$

POWERUNIT

Find E @ 13.2 cm

Answer ......

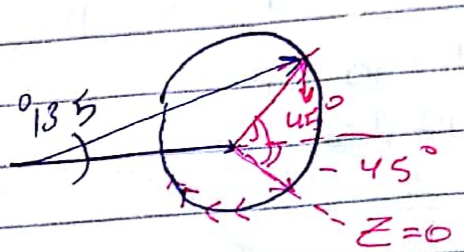
angle 75°

Ex →

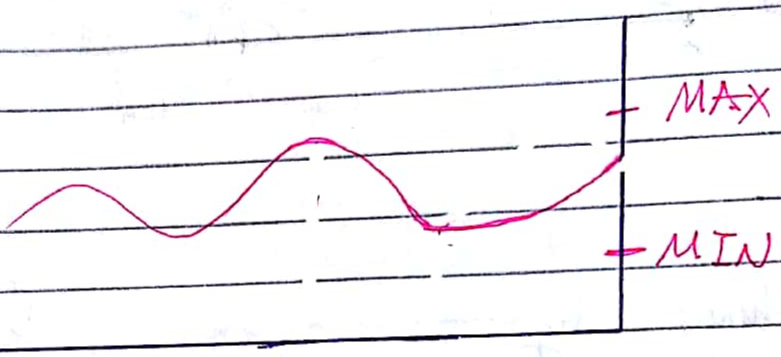
$\Gamma = 0.5 \angle -45$

$\lambda = 8\,cm$

$E_0 = 4\,V/m$



- $MAX = 6\,V/m$
- $MIN = 2\,V/m$
- $\lambda/4 = 2\,cm$
- $\lambda/2 = 4\,cm$



Matching point is: when the Reflection coefficient = zero.

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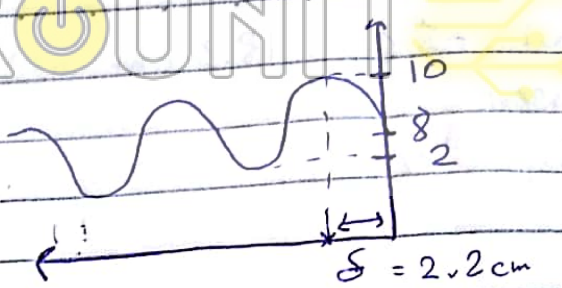
Ex $\lambda = 20$ cm

Find Γ?



$10 = (1+\Gamma)E_0$

$2 = (1-\Gamma)E_0$

$E_0 = \frac{2}{1-\Gamma}$, $E_0 = \frac{10}{1+\Gamma}$

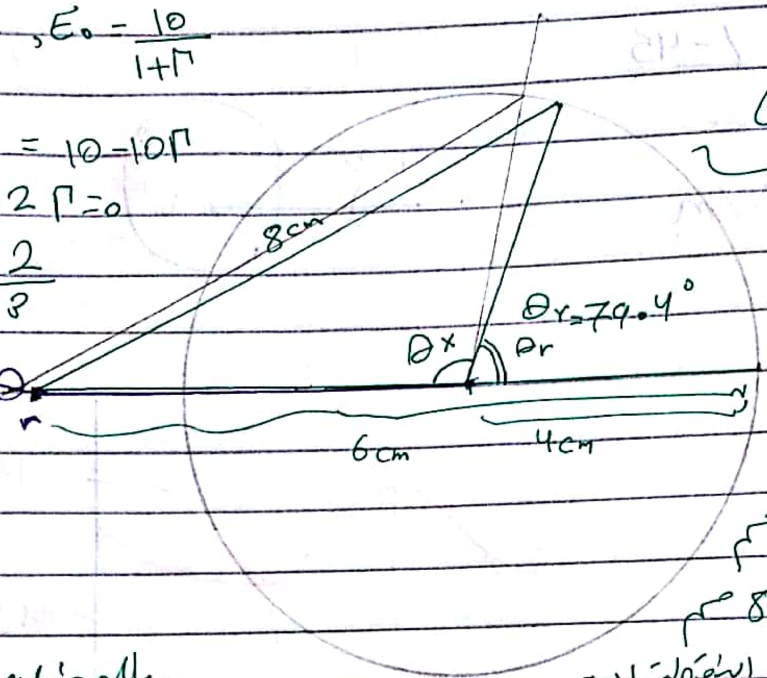
$2 + 2\Gamma = 10 - 10\Gamma$

$8 - 12\Gamma = 0$

$\Gamma = \frac{2}{3}$

Find θ_r

Graphically



ملحوظة:
رسمنا الـ6 سم
لين الـ Radius
والدائرة 4 سم
لين سنعرفنا الـ 6 سم
عطينا من المسافة 8 سم
وعلينا نبحث عن التقاطع اللي
كان معها مع المحيط للدائرة ووصلنا بينهم وقسنا الزاوية

Mathematically

Note: ما نعرف ولا رقم من وين اجا !!

$\rightarrow 8^2 - 6^2 + 4^2 = 2 * 8 * 4 \cos(\theta x)$

$64 = 52 - 64 \cos(\theta x)$

$\cos\theta_x = \frac{52 - 64}{64} \Rightarrow \theta_x = 100.8$

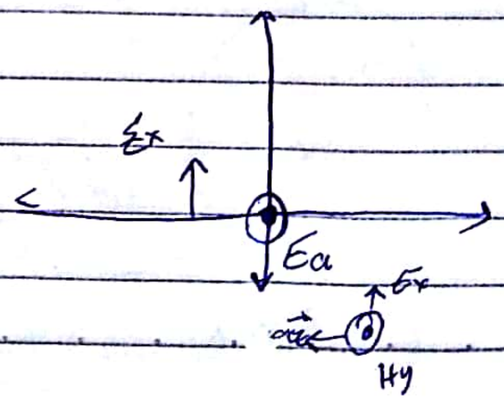
$180 - 100.8 = 79.1 \simeq 79.4$!!

$\theta_r * \frac{\lambda}{2} = 2.2 \text{ cm} = \delta$

$E_i = 5 \sin(w_0 t - \beta z)\vec{a_x} - 3 \sin(w_0 t - \beta z)\vec{a_y}$

$34 \sin(w_0 t + \beta z)\vec{a_E}$

$\vec{E}$ لـ Unit vector الـ اتجاه



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POWERUNIT

* $E_i = 5\sin(\omega_0 t - \beta_1 z)\,\vec{a_x}$
* $H_i = \dfrac{5}{\eta_1}\sin(\omega_0 t - \beta_1 z)\,\vec{a_y}$
* $E_r = \Gamma * 5\sin(\omega_0 t \pm \beta_1 z)\,\vec{a_x}$

  check?!
* $H_r = \dfrac{\Gamma}{\eta_1} * 5\sin(\omega_0 t + \beta_1 z)\,-\vec{a_y}$

if Γ (-ve) then $E_r \to -\vec{a_x}$, $H_r \to \vec{a_y}$

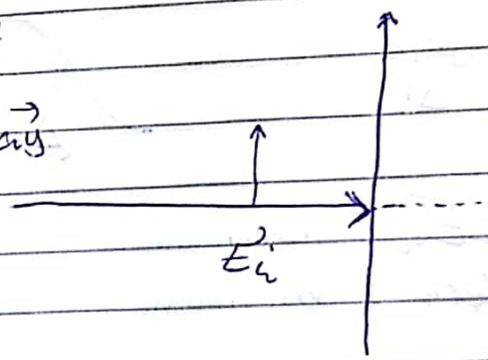
Ex: Continou the previous Example where the second material (media): $\Gamma = 0$, $\eta_1 = \eta_2$ (matching)

$\tau = (1+\Gamma)$

So $\tau = 1$ & $E_i = E_t \Rightarrow$ wave will continou straight

$E_t = \tau 5\sin(\omega_0 t - \beta_2 z)\,\vec{a_x}$

$H_t = \dfrac{\tau 5\sin(\omega_0 t - \beta_2 z)}{\eta_2}\,\vec{a_y}$



if the second material have $\mu = 2\mu_0$, $\epsilon = 2\epsilon_0$

then...

$\eta = \eta_0$ & β is doubled

but the speed $u = \dfrac{c}{2}$

Which means that you can change the speed of propegation and Also change the material but still have matching.

$\boxed{\text{V.I}}$ if we had a conductor $\eta_2 = 0$, $\underline{\underline{\Gamma = -1}}$

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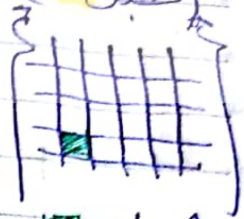
if the Second material is a conducting grid (شبكة) and the openings are smaller than $\frac{\lambda}{2}$, then we say that the grid is a good conductor (short circuit)



▨ $< \frac{\lambda}{2}$

$\Gamma = 1$

this means that we are coming out of the conductor toward the non-conducting material

nonrealistic

إن ال conductors لو فيه propagation.

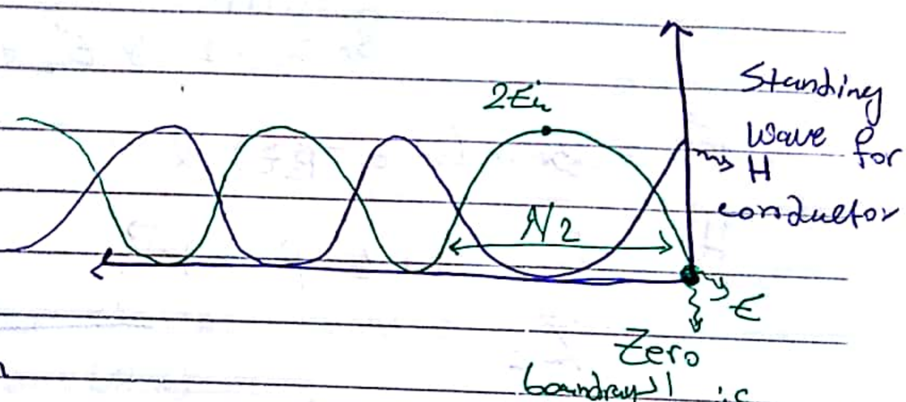
$\Gamma = -1$

this means that we are entering the conductor

و بحكي ايضاً انه ال Electric field الذي سقطها في جوا واله راجع عكسه.

Real case ↑

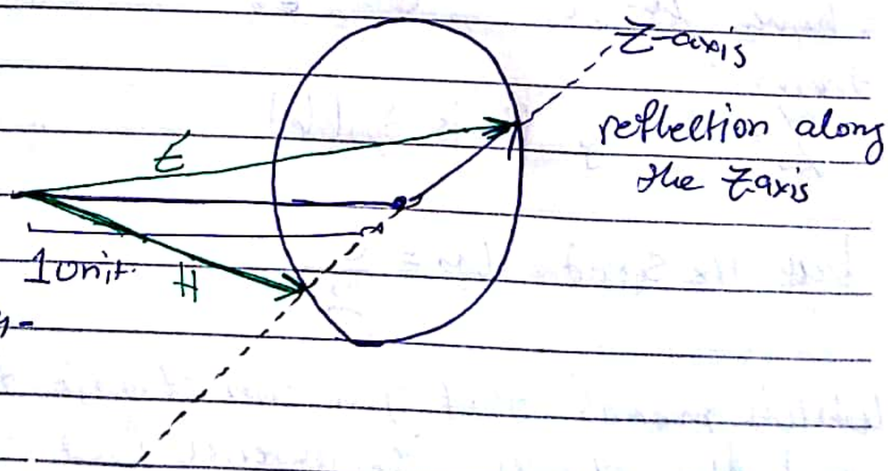
H عكس ال E



$2E_i \equiv$ maximum

Zero $\equiv$ minimum

$$\boxed{E = \eta H}$$



when E is max H is Min & Viceversa.

Homework ⇒ ReDo all Examples but this time inclued H Drawing & calculate its value

POWERUNIT

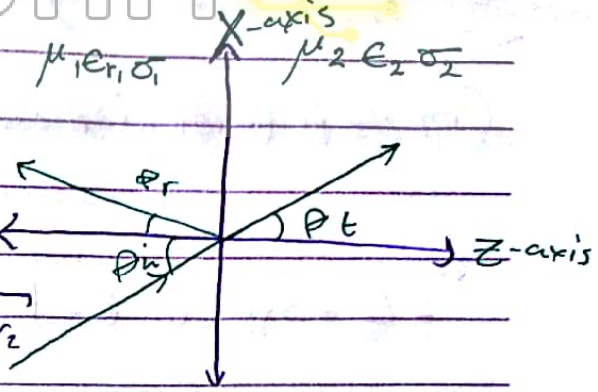
⊛ Oblique Incedent

$\theta_r = \theta_i$

from nill's law

$n_1 \sin(\theta_i) = n_2 \sin(\theta_t)$

where $n_1 = \sqrt{\mu_{r_1} \epsilon_{r_1}}$, $n_2 = \sqrt{\mu_{r_2} \epsilon_{r_2}}$



⇝ Two General cases are

⊛ ((perpendicular case)) ⊛

1) $$\Gamma_\perp = \frac{\eta_2 \cos\theta_i - \eta_2 \cos\theta_t}{\eta_2 \cos\theta_i + \eta_2 \cos\theta_t}$$

2) $$\tau_\perp = \frac{2\eta_2 \cos\theta_i}{\eta_2 \cos\theta_i + \eta_1 \cos\theta_t}$$

perpendicular on the plane that has the trace for two materials

يعني هو الحوريزة؟

incedent Electric field

⊛ ((parallel case)) ⊛

1) $$\Gamma_\parallel = \frac{\eta_2 \cos\theta_t - \eta_1 \cos\theta_i}{\eta_2 \cos\theta_t + \eta_1 \cos\theta_i}$$

2) $$\tau_\parallel = \frac{2\eta_2 \cos\theta_i}{\eta_2 \cos\theta_t + \eta_2 \cos\theta_i}$$

⊛ The point is to find E_r (reflected)

$(\Gamma_r \cdot E_i)$

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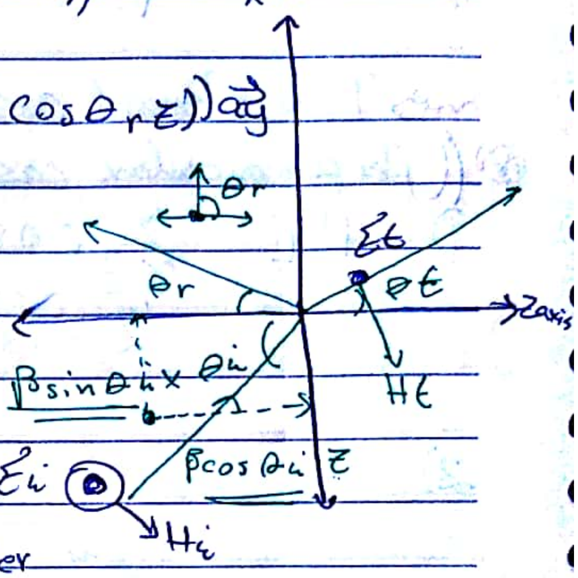
Example: $\mu_{r_1} = \mu_{r_2} = 1$ // $\epsilon_{r_1} = 1$, $\epsilon_{r_2} = 4$ // $\sigma = 0$

(On the perpendicular case) $E_i = E_o \sin(\omega_o t - \beta r)\,\vec{a_y}$

$\underline{\beta_r} \Rightarrow (\sin\theta_i x + \cos\theta_i z)$

$= E_o \sin(\omega_o t - \beta_1(\sin\theta_i x + \cos\theta_i z))$

$E_r = \Gamma_\perp E_o \sin(\omega_o t - \beta_1(\sin\theta_r x - \cos\theta_r z))\,\vec{a_y}$



→ $n_1 \sin\theta_i = n_2 \sin\theta_t$

→ $n_1 = \sqrt{\mu_{r_1}\epsilon_{r_1}}$, $n_2 = \sqrt{\mu_{r_2}\epsilon_{r_2}}$

→ $\sin\theta_i = 2\sin\theta_t$

● The second media is more dense so that θ_t (with z-axis) is smaller $\epsilon_{r2} > \epsilon_{r1}$

Using $\sin\theta_t = \dfrac{n_1}{n_2} \cdot \sin\theta_i = 1 \Rightarrow \sin^{-1}\left(\dfrac{n_2}{n_1}\right)$

$\dfrac{n_2}{n_1} > 1$, if $\theta_i = 30$ in this Example.

↳ $\sin^{-1}\left(\sin(30) * \frac{1}{2}\right)$

$= \sin^{-1}\left(\frac{1}{2} * \frac{1}{2}\right) \Rightarrow 14.5$

$E_t = E_o \tau_\perp \sin(\omega_o t - \beta_2(\sin\theta_t x + \cos\theta_t z))\,\vec{a_y}$

$H_i = \dfrac{E_o}{\eta_1} \sin(\omega_o t - \beta_1(\sin(\theta_i) x + \cos(\theta_i) z)) \cdot$ (unit vector) باتجاه ال θ_i

Unit vector باتجاه ال θ_i $\Rightarrow (-\cos\theta_i\,\vec{a_x} + \sin\theta_i\,\vec{a_z})$

$H_r = \dfrac{E_o \Gamma_\perp}{\eta_1} \sin(\omega_o t - \beta_1(\sin\theta_r x + \cos\theta_r z)) * $ (unit vector باتجاه)

(unit vector باتجاه ال H) $\Rightarrow (\cos\theta_r\,\vec{a_x} + \sin\theta_r\,\vec{a_z})$ ال H

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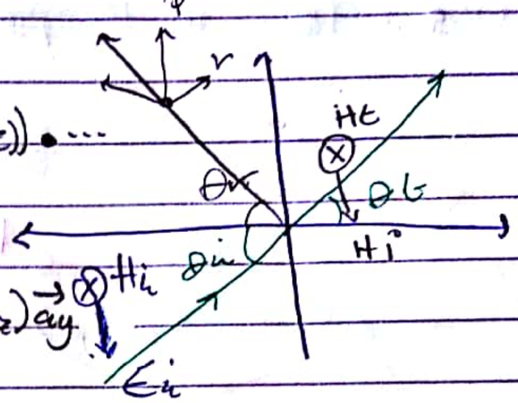
$$H_t = \frac{E_o \tau_\perp}{\eta_2} \sin(\omega_o t - \beta_2(\sin\theta_t x + \cos\theta_t z)) \cdot (\text{unit vector})$$

unit vector $\Rightarrow (-\cos\theta_t \vec{a_x} + \sin\theta_t \vec{a_z})$

Homework Redo the Example in the parallel case.

NOTE ⇒ اكمل انت



→ $E_i = E_o \sin(\omega_o t - \beta_1(\sin\theta_i x + \cos\theta_i z)) \cdot \ldots$

$\ldots (\cos\theta_i a_x - \sin\theta_i a_z)$

$$H_i = \frac{E_o}{\eta_1} \sin(\omega_o t - \beta_1(\sin\theta_i x + \cos\theta_i z)) \vec{a_y}$$

→ $E_t = E_o \tau_\parallel \sin(\omega_o t - \beta_2(\sin\theta_t x + \cos\theta_t z)) \cdot (\cos\theta_t a_x - \sin\theta_t a_z)$

$$H_t = \frac{E_o}{\eta_2} \tau_\parallel \sin(\omega_o t - \beta_2(\sin\theta_t x + \cos\theta_t z)) \vec{a_y}$$

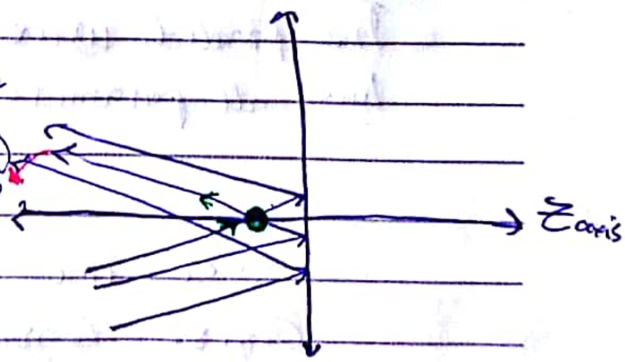
→ $E_r = E_o \Gamma_\parallel \sin(\omega_o t - \beta_1(\sin\theta_r x - \cos\theta_r z))(-\cos\theta_r a_x - \sin\theta_r a_z)$

$$H_r = \frac{E_o}{\eta_1} \Gamma_\parallel \sin(\omega_o t - \beta_1(\sin\theta_r x - \cos\theta_r z)) \vec{a_y}$$

⊛ StanDing Wave ⊛

$\theta_o = \theta_\Gamma + \Delta\theta \Rightarrow \Gamma_\perp e^{j\Delta\theta}$ = delay

$\vec{E_r a_y} = E_i \Gamma_\perp e^{j\Delta\theta}$



So $\omega t - \beta z$ ثابتة

⊛ wave front لل Electric field كل ال incedent تقاطع ال Reflected مع ال are coherant يعني نفس الطور و نفس ال phase

They are at the same frequency and the same plane/space.

→

POWERUNIT

(29) مزاوية الدوران Realatively as حسب الزاوية

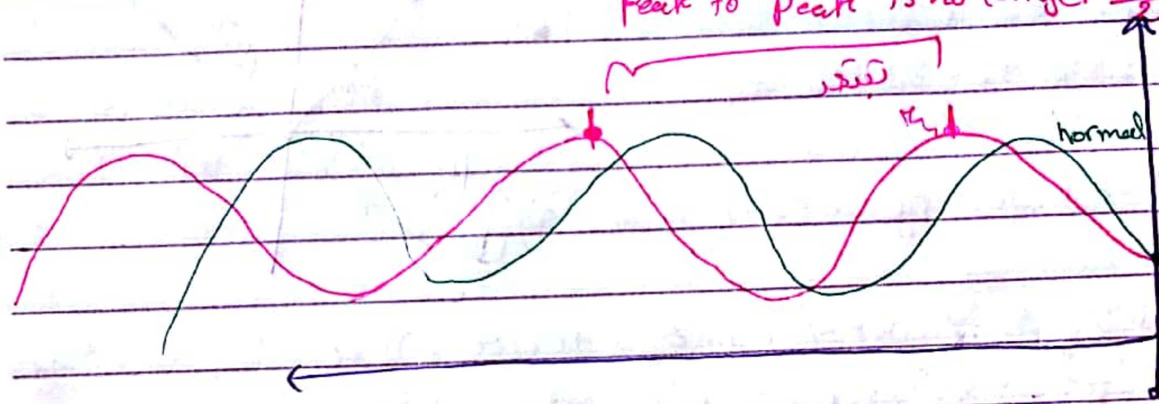
$\boxed{\Delta\theta} = 2\beta Z \cos\theta_i$

Zero $\theta_o = \theta_\Pi$ in the normal incedent

* $\theta_i = \theta_\Pi + \Delta\theta$

$\theta_o = 90°$ in the parallel case [No Reflection]

Peak to peak is no longer $\frac{\lambda}{2}$, $\frac{\lambda}{2\cos\theta_i}$



So It starts @ the same point then the decaying happen!

Z = 0 , $\theta_o = \theta_\Pi$, لما نغير الدوران تتغير سرعة
تتغير Z.

عشان هيك لما نبعد عن الـ wave وما بنعرف الـ source تبعها وين بجيب plane وبعمل اعمل فيه ميلان حتى احصل على الـ minimum.

The parallel wave at a constant Z has all parameters decreasing!

Lecture 17 is not written cause basically we didn't learn anything important but! If you're unpleased with that fact, the record for the lecture will be available. Go check it on your own!

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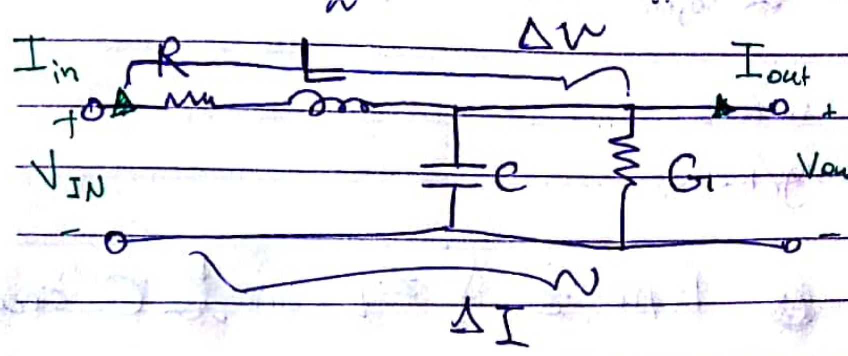
Transmission Line

Lecture 18

one Unit equivelant circuit model for transmission line.



$V_{out} = \Delta V$

$I_{out} = \Delta I$

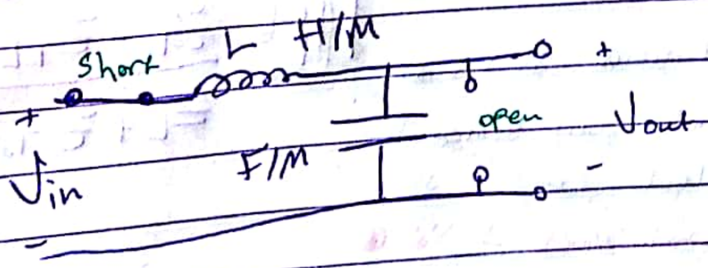
$\nabla^2 V - \gamma V = 0$

$V = V_0 \sin(\omega t - \beta X)$

No direction

لانه مصدر الطاقة موجودة بس قدّ

Lossless Transmission Line



$G = 0 \quad R = 0$

chanchteristic Impedance

$Z_{T.L} = \sqrt{\frac{L}{C}}$

Speed of propegation in T.L

$u = \frac{1}{\sqrt{L \cdot C}}$

$\lambda . f = u$

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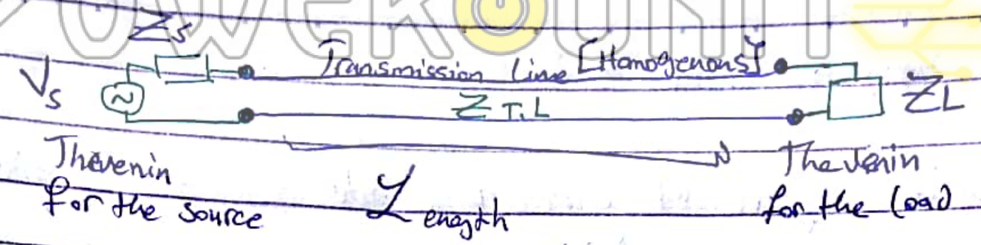
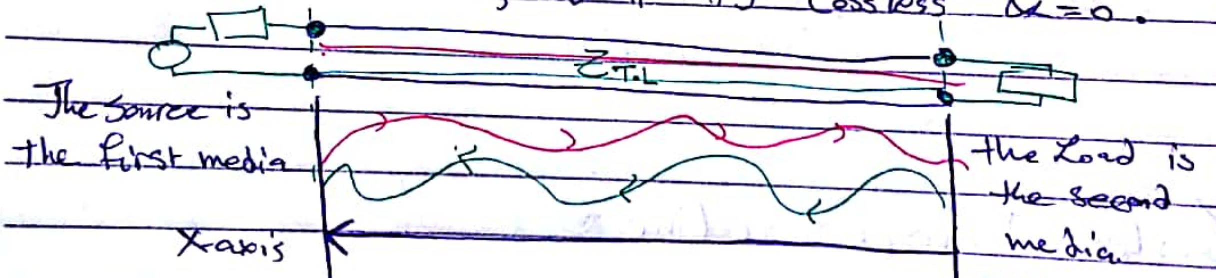


Small $\mathcal{L}$ = meters
L = Henry/meter

Beware!!
$\mathcal{L} \neq L$
بالتالي ما فيني أبدلهم

* Both Z_s & Z_L are LC circuits
* $Z_{T.L}$ is Real if it's lossless

* $Z_{T.L}$ فيها E مرفوعة لـ $-\alpha$ و X فيه α
attenuation factor, but if it's lossless $\alpha = 0$.



$$\boxed{\Gamma_s} = \frac{Z_s - Z_{T.L}}{Z_s + Z_{T.L}}$$

$$\boxed{\Gamma_L} = \frac{Z_L - Z_{T.L}}{Z_L + Z_{T.L}}$$

* اذا ال wave ماشية من ال load للsource بتشوف ال source كأنه ال load تبعها
* اذا ال wave ماشية من ال source لل load بتشوف ال load هو ال load تبعها.

* Maximum power transfer is when the wave (as a whole) is sent from the source to the load without reflecting back!
* We don't like waves/signals that reflects
* to avoid Reflection, $\Gamma_L = 0$ and this happens when $Z_L = Z_{T.L}$, called Matching.

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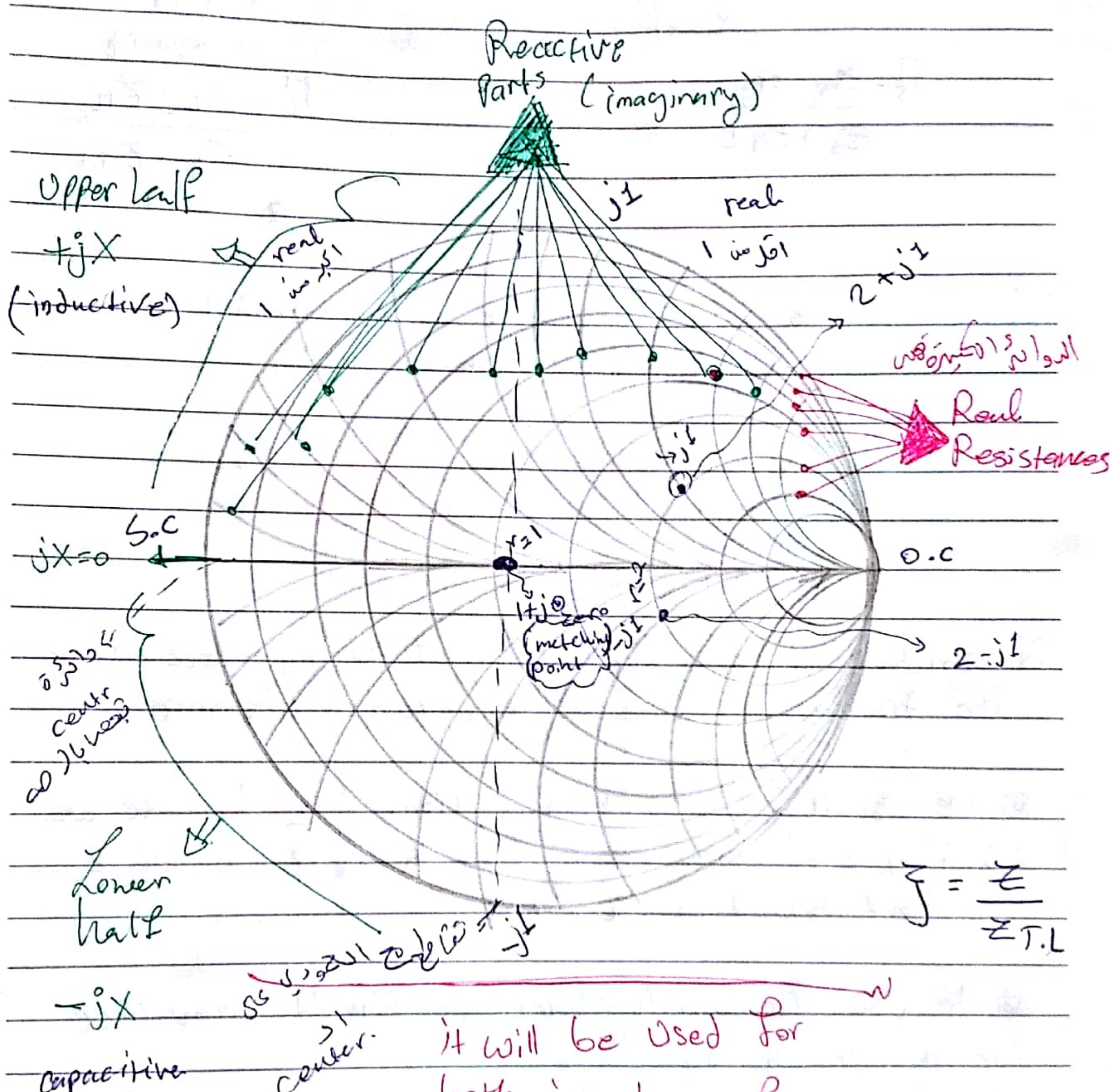
Smith chart

الدوائر الخارجية الكاملة للمستقيم



$$\zeta = \frac{Z}{Z_{T.L}}$$

it will be used for both impedances & addmitances

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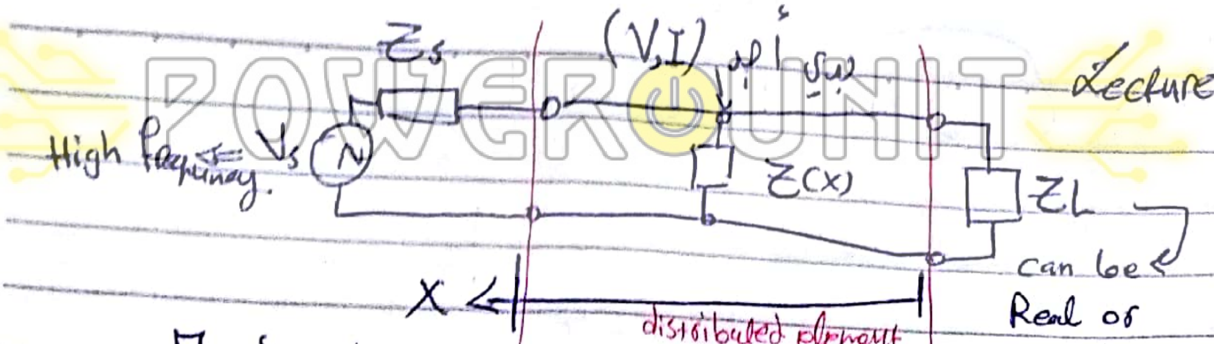

Z_L can be Real or Imaginary

$$\Gamma_s = \frac{Z_s - Z_{T.L}}{Z_s + Z_{T.L}}$$

$$\Gamma_L = \frac{Z_L - Z_{T.L}}{Z_L + Z_{T.L}}$$

* لا نستطيع التعامل معها كـ element منفصل بقطعة لوحدها.

* 0.1λ and above we will treat it as a distributed element.

* distribution of voltage & current is cyclic so to normalize things نرجع طول الـ T.L على λ.

* Smith chart is a Representation of the impedance along the transmission Line as a function of distance

* we usually starts analysis from Z_L because we know alot of information about it, but anywhere we start should be the same.

* to use the smith chart we should normalize for a certain impedance.

→ we normalize $Z_{T.L}$ using a normalization factor بقسم كل الـ impedances عليها.

→ Length of the T.L should also be normalized to λ

* capacitors and inductors will cause delays if the load in the second media isn't matched.

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® After delays & Reaching the Second media we will have Reflection.

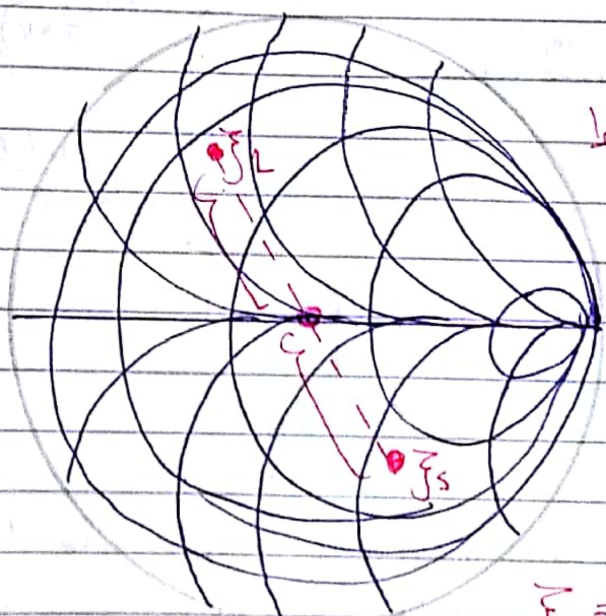
® Transient State: I can only see the effect in a specific time instant.

® Steady State: I see the effect every where along the Transmission Line @ any time

⟹ THE SMITH CHART IS ONLY FOR STEADY STATE ANALYSIS.

حيث أن ζ هي

$$\zeta = \frac{Z}{Z_{T.L}}$$



® اذا مديت خطاً من ζ_L لعند ال center ووصلته لـ ζ_s وكانت المسافة بينهما متساوية اذاً:

$$\zeta_s = \frac{1}{\zeta_L}$$

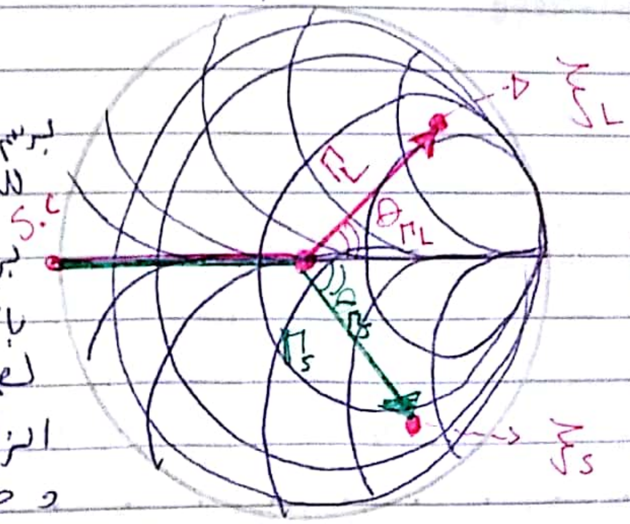
Ⓐ If I wanted to Draw $|\Gamma_L| \angle$ (بين ال +/-1) as a complex #

$|\Gamma_L| \angle \theta_{\Gamma_L}$

① برسم خط من عند ال S.C لل center

② برسم ال Vector قيمته $|\Gamma_L| \rightarrow$ باتجاه لـ ζ_L

③ الزاوية بين ال Vector و خط الصفر هي θ_{Γ_L}



نفس الخطوات لـ $|\Gamma_s| \angle \theta_{\Gamma_s}$

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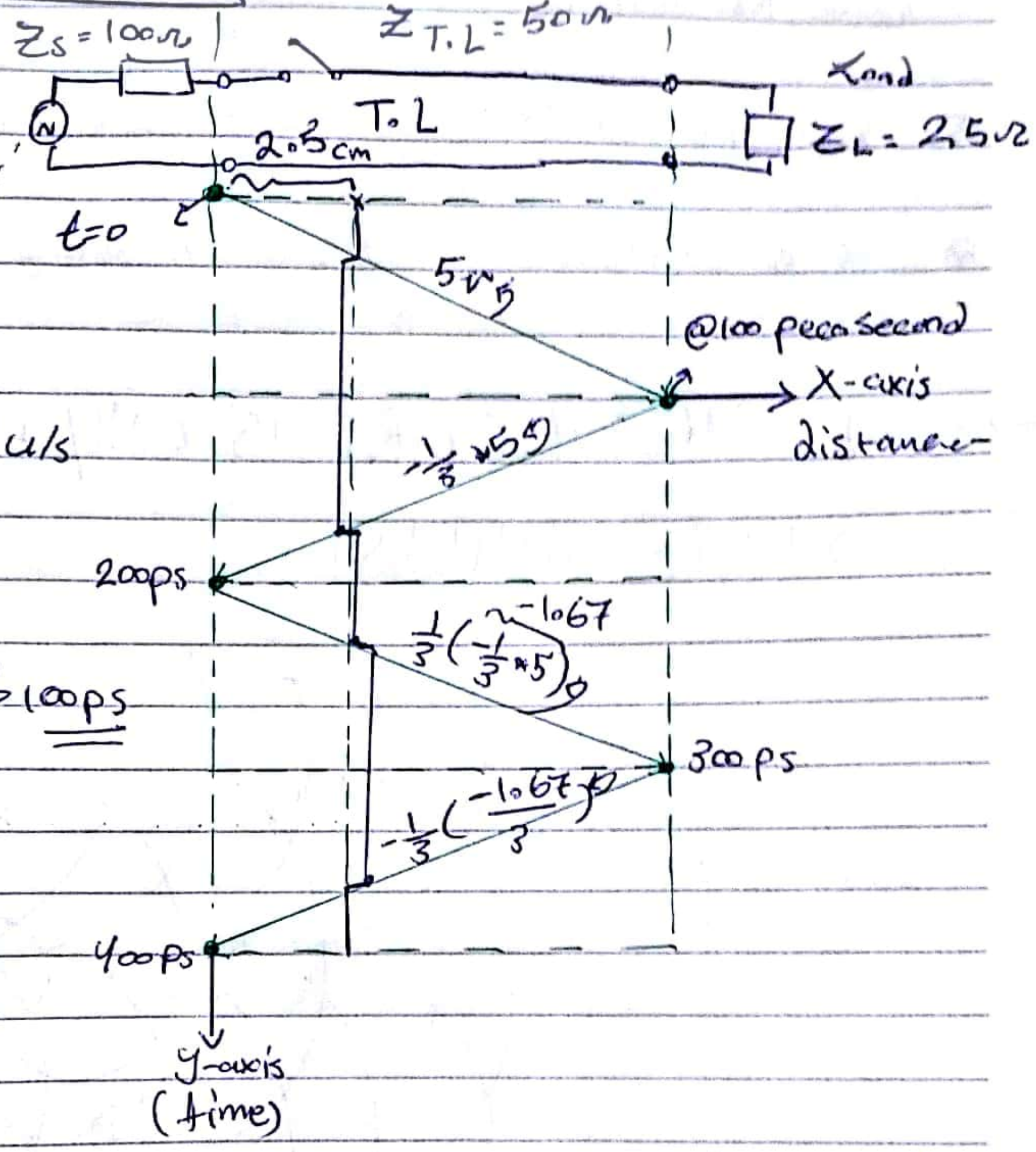
POWERUNIT

Transient Analysis

Example

$V_s = 15V$ (step)

not a Sinosoidal Voltage (Unit Step)



$u = \frac{c}{3} = 1\times 10^{8}$ m/s

$u = \frac{\text{distance}}{\text{Time}}$

$\Rightarrow$ Time $= 1\times 10^{-10} \Rightarrow$ 100ps

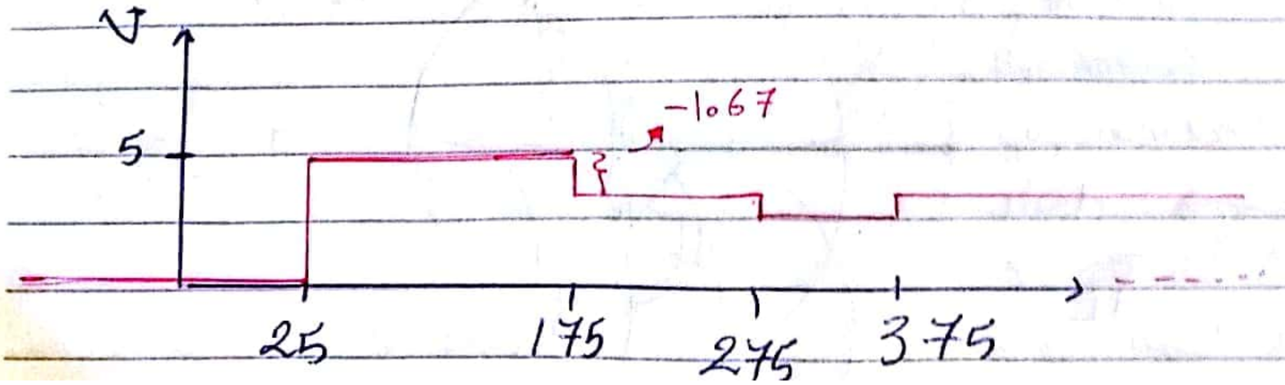
$\Gamma_{Load} = -\frac{1}{3}$

$\Gamma_{source} = \frac{1}{3}$

* Every time we reach a media we Must Multiply by its Reflection Coeffient (Γ)

نضرب ال wave ب Γ
تا ننسى الموضوع ده!

Draw the Voltage @ 2.5 cm



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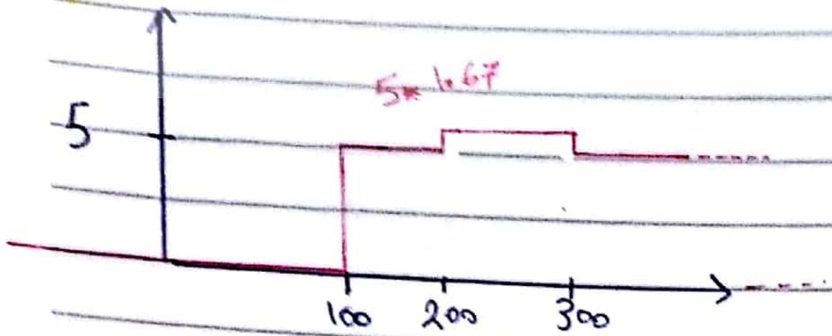
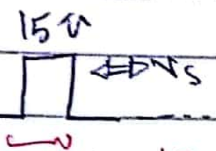
Draw the Voltage @ the Load

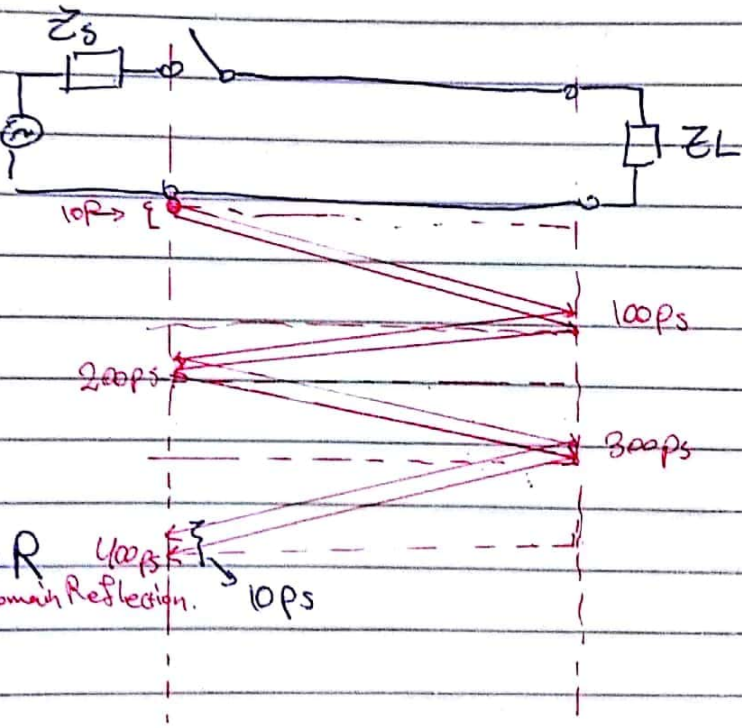


@ Steady State [OR] after a long time the Voltage will be @ the Load :

$$\frac{15 * 25}{125} = 3 \, v$$

INCASE OF PULSE :





Pulse width = 10ps

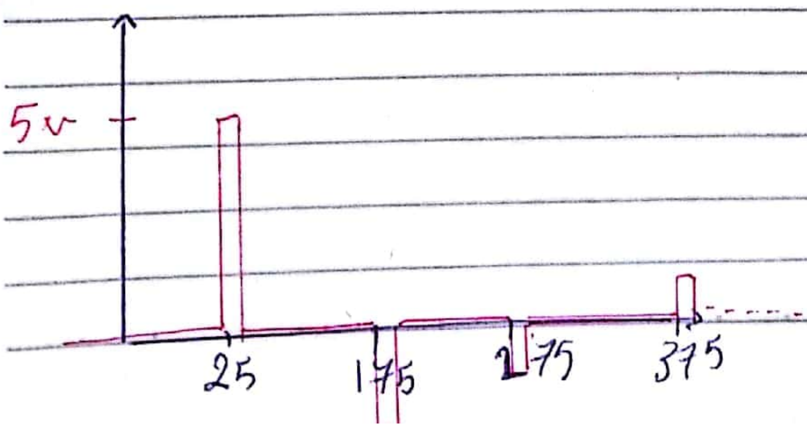
@ Steady state :

0 v

Zero

Application : OTDR

optical time domain Reflection.



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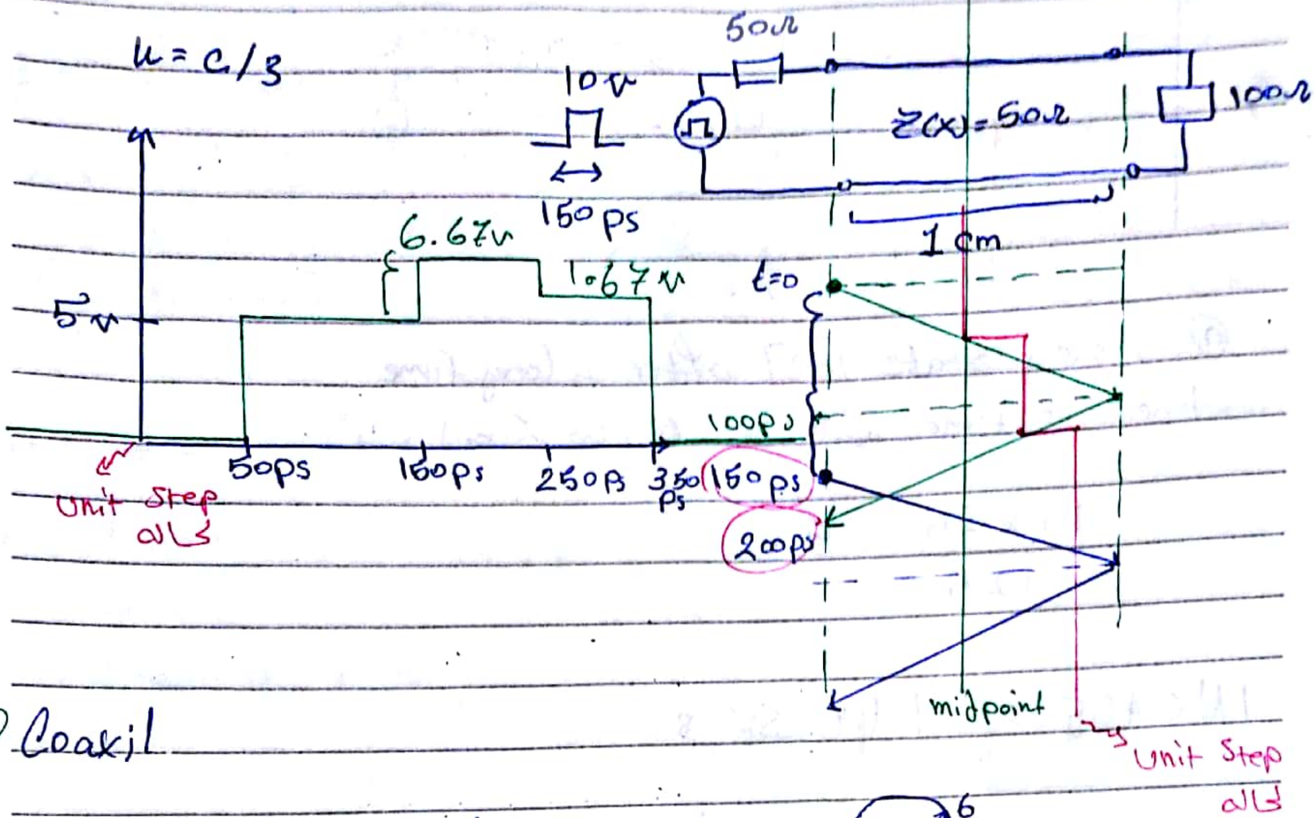
POWEROUNIT

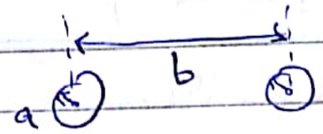
Quiz Draw the transient at mid point



Coaxil

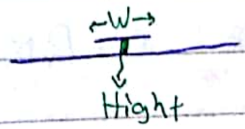
$$Z_{T.L} = \frac{138}{\sqrt{\epsilon_r}} \cdot \ln\left(\frac{b}{a}\right)$$, where

$$Z_{T.L} = \frac{276}{\sqrt{\epsilon_r}} \cdot \ln\left(\frac{b}{a}\right)$$, where



Micro Strip

$$Z_{T.L} = \frac{377}{\sqrt{\epsilon_r} \cdot \left(\frac{Width}{Hight} + 2\right)}$$, where



Total Delay = $\frac{Length}{Speed}$

$$u = \frac{1}{\sqrt{L.C}}$$

Speed of propagation

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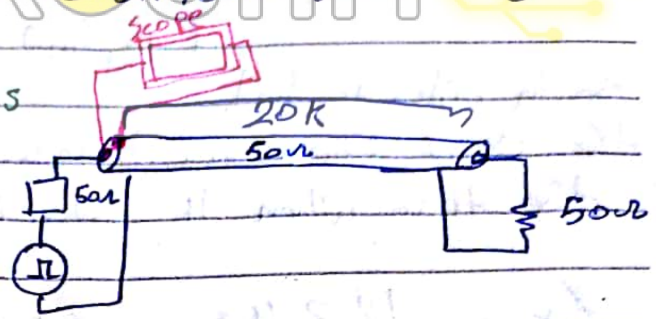
POWERUNIT

Ex assume DataRate: 1 Gbit/sec , $u = c/3$

Delay: $= \dfrac{20 \times 10^3}{1 \times 10^8} = 200\,\mu s$



Number of Stored bits in T.L $= \dfrac{200 \times 10^{-6}}{1 \times 10^{-9}} = 200k\,bit$

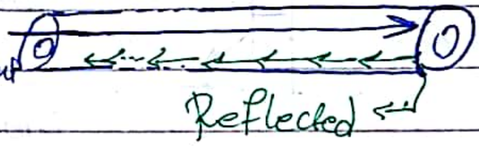
because

$\dfrac{1\ bit}{T_o} = 1$ nanoSec

The previous type of channel is called: Storage device - channel with memory.

Solution for the following problems caused by a channel with memory: ((Matching))

First problem



((Long Distances))

Inter symbol interfeance

Second problem

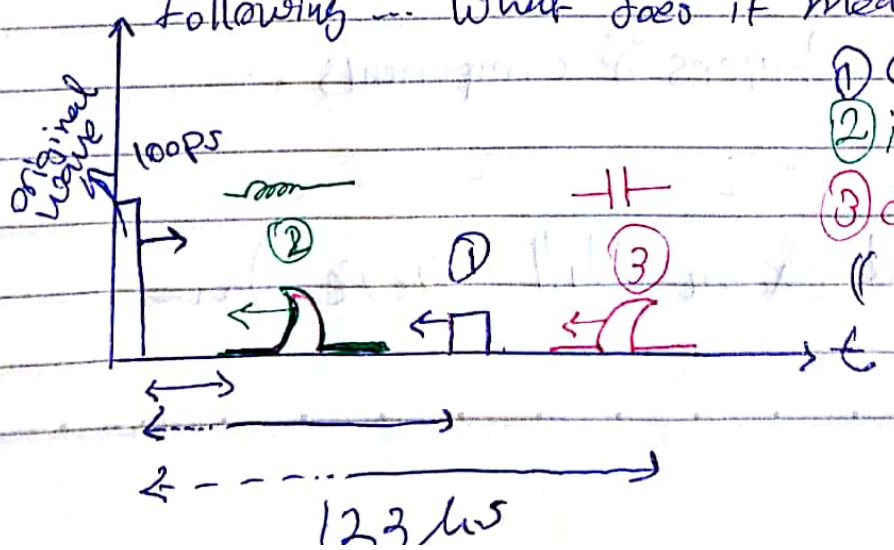
((Short distances))

Fading effect

If we added a Scope and we found the following ... What does it mean

1. General fault (problem)
2. inductive fault (deformation) قفلة
3. capacitive fault (cut) قطع

((1 & 2 & 3 أوامل))



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POWERUNIT

⊛ Now (123 μs) → هو زمن اللي راحت ورجعت فيه

(Round trip)

So in order to find the exact Location (distance) for the fault we need the time when it started to Reflect.

$$t_x = \frac{123\,\mu s}{2} = 61.5\,\mu s$$

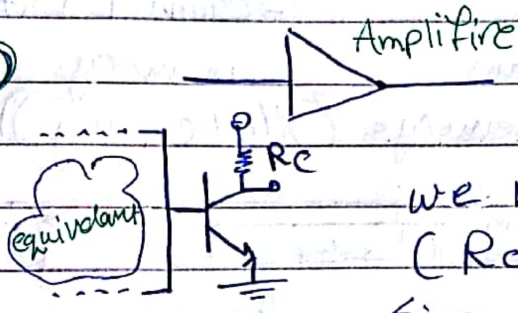
So $\underline{\underline{L_x}} = t_x * u^{\text{speed}}$

المسافة اللي يبعد عنها العطل...

$= 61.5\,\mu s * \frac{C}{3} = 6150\ m$

سرعة

⊛ Amplifire — What is the o/p impedance?



we need the o/p impedance (Rc + equivalent) to equal 50 Ω since the Load is 50 Ω to match up with it and avoid Reflection.

⊛ if the ||Voltage|| Reflection coefficient is (0.1) then the Reflected ||POWER|| is 1/100

⇒ Power = $(V)^2/R$

العشرة

⇒ This will damage devices & components.

~~ Mid exam till here ~~

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