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(1) Magnitude, $\vec{A} = A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z$, $|\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$

(2) Unit vector, $\hat{a}_A = \dfrac{\vec{A}}{|\vec{A}|} = \dfrac{A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z}{\sqrt{A_x^2 + A_y^2 + A_z^2}}$

(3) Scalar or dot $\vec{A}\cdot\vec{B} = |\vec{A}||\vec{B}|\cos\theta = AB\cos\theta$

(4) Vector or cross $\vec{A}\times\vec{B} = |\vec{A}||\vec{B}|\sin\theta = AB\sin\theta$

(5) Vector triple product, $\vec{A}\times(\vec{B}\times\vec{C}) = (\vec{A}\cdot\vec{C})\vec{B} - (\vec{A}\cdot\vec{B})\vec{C}$

(6) Scalar triple product $\vec{A}\cdot\vec{B}\times\vec{C} = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}$

(7) $\hat{a}_x\cdot\hat{a}_x = \hat{a}_y\cdot\hat{a}_y = \hat{a}_z\cdot\hat{a}_z = 1$

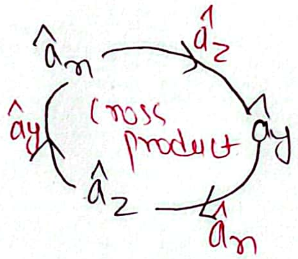
$\hat{a}_x\cdot\hat{a}_y = \hat{a}_y\cdot\hat{a}_z = \hat{a}_z\cdot\hat{a}_x = 0$

& similar case for $\underbrace{\hat{a}_\rho, \hat{a}_\phi, \hat{a}_z}_{\text{cyl}}, \underbrace{\hat{a}_r, \hat{a}_\theta, \hat{a}_\phi}_{\text{sph}}$

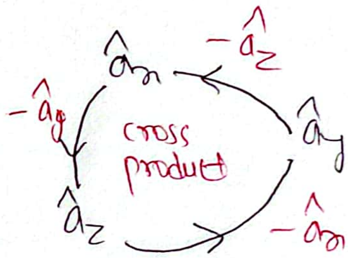
(8) $\hat{a}_x \times \hat{a}_y = \hat{a}_z$

$\hat{a}_y \times \hat{a}_z = \hat{a}_x$

$\hat{a}_z \times \hat{a}_x = \hat{a}_y$



Clockwise



Anticlockwise

(9) $\vec{dl} = dx\hat{a}_x + dy\hat{a}_y + dz\hat{a}_z$ (Rect.)

$\vec{dl} = d\rho\hat{a}_\rho + \rho d\phi\hat{a}_\phi + dz\hat{a}_z$ (cyl)

$\vec{dl} = dr\hat{a}_r + r d\theta\hat{a}_\theta + r\sin\theta d\phi\hat{a}_\phi$ (sph).

(10) $dv = dx\,dy\,dz$

$dv = \rho\, d\rho\, d\phi\, dz$

$dv = (r)(r\sin\theta)\,dr\,d\theta\,d\phi$

(11) $\vec{ds} = dy\,dz\,\hat{a}_x$

$dx\,dz\,\hat{a}_y$

$dx\,dy\,\hat{a}_z$

(12) $\vec{ds} = \rho\, d\phi\, dz\,\hat{a}_\rho$

$d\rho\, dz\,\hat{a}_\phi$

$\rho\, d\phi\, d\rho\,\hat{a}_z$

$\vec{ds} = r^2\sin\theta\, d\theta\, d\phi\,\hat{a}_r$

$r\sin\theta\, dr\, d\phi\,\hat{a}_\theta$

$r\, dr\, d\theta\,\hat{a}_\phi$

[Add, ρ with $d\phi$
(Note, $\rho = r\sin\theta$ (spherical))
Add, r with $d\theta$]

(11) Transformation

(a) Cyl. to Rect

$x = \rho\cos\phi$

$y = \rho\sin\phi$

$z = z$

(b) Rect to Cyl.

$\rho = \sqrt{x^2+y^2}$

$\phi = \tan^{-1}(y/x)$

$z = z$

[check quadrant to find 'ϕ']

(c) Sph. to Rect

$x = \underbrace{r\sin\theta}_{\rho}\cos\phi$

$y = r\sin\theta\sin\phi$

$z = r\cos\theta$

(d) Rect to sph.

$r = \sqrt{x^2+y^2+z^2}$

$\theta = \cos^{-1}\dfrac{z}{\sqrt{x^2+y^2+z^2}}$

$\phi = \tan^{-1}(y/x)$

I. $\phi = \tan^{-1}(y/x)$

II. $\phi = 180^\circ - \tan^{-1}(y/x)$

III. $\phi = 180^\circ + \tan^{-1}(y/x)$

IV. $\phi = 360^\circ - \tan^{-1}(y/x)$

[(x,y,z), $(-x,y,z)$, $(-x,-y,z)$, $(x,-y,z)$]

P.G.N.1

(e) Cyl. to sph

$\phi = \phi$

$r = \sqrt{x^2+y^2+z^2} = \sqrt{\rho^2+z^2}$

$\theta = \cos^{-1}(z/r) = \cos^{-1}\left(\frac{z}{\sqrt{\rho^2+z^2}}\right)$

(f) Sph. to cylindrical

$\phi = \phi$

$\rho = \sqrt{x^2+y^2} = r\sin\theta$

$z = r\cos\theta$

(12)

(a) $\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix}$

(b) $\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}$

(c) $\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \cos\theta\cos\phi & -\sin\phi \\ \sin\theta\sin\phi & \cos\theta\sin\phi & \cos\phi \\ \cos\theta & -\sin\theta & 0 \end{bmatrix} \begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix}$

(d) $\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \sin\theta\sin\phi & \cos\theta \\ \cos\theta\cos\phi & \cos\theta\sin\phi & -\sin\theta \\ -\sin\phi & \cos\phi & 0 \end{bmatrix} \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}$

(e) $\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin\theta & 0 & \cos\theta \\ \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix}$

(f) $\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \begin{bmatrix} \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \\ \cos\theta & -\sin\theta & 0 \end{bmatrix} \begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix}$

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(1) $\vec{F}_{12} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 |\vec{R}_{12}|^2} \hat{a}_{R12} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R_{12}^2}\left(\frac{\vec{R}_{12}}{R_{12}}\right)$ since, $\hat{a}_{R12} = \frac{\vec{R}_{12}}{|\vec{R}_{12}|} = \frac{\vec{R}_{12}}{R_{12}}$

(2) $\vec{E}_p = \frac{Q}{4\pi\varepsilon_0 R^2}\hat{a}_R = \frac{Q}{4\pi\varepsilon_0 R^2}\left(\frac{\vec{R}}{R}\right) = \frac{Q\vec{R}}{4\pi\varepsilon_0 R^3}$

(3) $\vec{E}_L = \frac{\rho_L}{2\pi\varepsilon_0 R}\hat{a}_R = \frac{\rho_L \vec{R}}{2\pi\varepsilon_0 R^2}$

(4) $\vec{E}_s = \frac{\rho_s}{2\varepsilon_0}\hat{a}_N$

(5) $\vec{D} = \frac{d\psi}{ds}\hat{a}_R$; $\psi = \oint_s \vec{D}\cdot\vec{ds}$; $\psi = Q$

(6) $\text{div}\,\vec{A} = \nabla\cdot\vec{A} = \lim_{\Delta V\to 0} \frac{\oint \vec{A}\cdot\vec{ds}}{\Delta V}$

(7) $\text{div}\,\vec{D} = \nabla\cdot\vec{D} = \lim_{\Delta V\to 0} \frac{\oint \vec{D}\cdot\vec{ds}}{\Delta V}$

(8) $\text{div}\,\vec{D} = \nabla\cdot\vec{D} = \rho_v$

(9) $\oint_s \vec{D}\cdot\vec{ds} = \int_{vol}(\nabla\cdot\vec{D})dv$

(10) $\vec{D} = \varepsilon_r\varepsilon_0\vec{E} = \varepsilon\vec{E}$ $(\because \varepsilon = \varepsilon_0\varepsilon_r)$

(11) $\vec{D} = \varepsilon_0\vec{E}$ (for free space)

(12) $V_{AB} = V_A - V_B = -\int_B^A \vec{E}\cdot\vec{dl} = -\int_{initial}^{final} \vec{E}\cdot\vec{dl}$

(13) $V_{AB} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$

(14) $\vec{E} = -\frac{dV}{dN}\hat{a}_N$

(15) $V_p = \frac{Q}{4\pi\varepsilon_0 R} + C$

(16) $V_L = -\frac{\rho_L}{2\pi\varepsilon_0}\ln(R) + C$

(17) $V_s = -\frac{\rho_s x}{2\varepsilon_0} + C$ or $-\frac{\rho_s y}{2\varepsilon_0} + C$, or $-\frac{\rho_s z}{2\varepsilon_0} + C$

(18) $\vec{E} = -\,\text{grad}\,V = -\nabla V$

(19) $V = \frac{Q}{4\pi\varepsilon_0}\frac{R_2 - R_1}{R_1 R_2}$

(20) $V = \frac{Q}{4\pi\varepsilon_0}\frac{d\cos\theta}{r^2}$

(21) $V = \frac{\vec{p}\cdot\hat{a}_r}{4\pi\varepsilon_0 r^2} = \frac{\vec{p}\cdot\vec{r}}{4\pi\varepsilon_0 r^3}$

(22) $\vec{E} = \frac{Qd}{4\pi\varepsilon_0 r^3}[2\cos\theta\,\hat{a}_r + \sin\theta\,\hat{a}_\theta]$

(23) $W_E = \frac{1}{2}\vec{D}\cdot\vec{E} = \frac{1}{2}\varepsilon_0 E^2$ $[\because w_E = \frac{dW_E}{dv}$

$W_E = \int \frac{1}{2}\vec{D}\cdot\vec{E}\,dv = \frac{1}{2}\int \vec{D}\cdot\vec{E}\,dv = \frac{1}{2}\int \varepsilon_0 E^2\,dv$

(24) $Q_3 V_{3,1} = Q_3 \frac{Q_1}{4\pi\varepsilon_0 R_{13}}$

(25) $\nabla\cdot(V\vec{D}) = V(\nabla\cdot\vec{D}) + \vec{D}(\nabla V)$

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26) $I = \oint \vec{J}\cdot d\vec{s}$ $\left[\because J = \frac{I}{A} = \frac{I}{s}\right]$

27) $\oint_s \vec{J}\cdot d\vec{s} = -\frac{dQ_i}{dt}$ [integral form of continuity eqn]

28) $\nabla\cdot\vec{J} = -\frac{\partial \rho_v}{\partial t}$ [Continuity equation in diff/point form]

29) $J = \sigma E$, $\boxed{\vec{J} = \sigma\vec{E}}$ → point form of ohms law

30) $\rho_v = \rho_0 e^{-\left(\frac{\sigma}{\epsilon}\right)t}$ [RTC]

31) Boundary condition Betn the Conductor & free space

$D_N = \rho_s$, $D_t = 0$, $E_t = 0$,

$D_N = \epsilon_0\epsilon_r E_N = \rho_s$

32) Boundary condition betn two perfect dielectric materials:-

→ $E_{t_1} = E_{t_2} \Rightarrow D_{t_1} = \frac{\epsilon_1}{\epsilon_2} D_{t_2} \Rightarrow D_{t_2} = \frac{\epsilon_2}{\epsilon_1} D_{t_1}$

$D_{N_1} = D_{N_2} \Rightarrow E_{N_1} = \frac{\epsilon_2}{\epsilon_1} E_{N_2}$

33) $\vec{D} = \epsilon_0\vec{E} + \vec{P}$

34) $\vec{P} = \chi_e \epsilon_0 \vec{E}$

35) $\epsilon_r = \chi_e + 1$

36) $C = \frac{Q}{V}$

37) $\nabla^2 V = -\frac{\rho_v}{\epsilon}$ [poisson's eqn]

38) $\nabla^2 V = 0$ [Laplace eqn]

39) Given V, $\vec{E} = -\nabla V$

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

$\vec{D} = \vec{D_s} = D_N \hat{a}_N$

$D_N = \rho_s$

$Q = \int \rho_s\, ds$

$C = \frac{|Q|}{V_0}$

40) $\nabla\cdot(V\vec{D}) = V(\nabla\cdot\vec{D}) + \vec{D}\cdot(\nabla V)$

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1) $d\vec{H} = \frac{I\, d\vec{l}\times\vec{R}}{4\pi R^3}$; $d\vec{H} = \frac{I\, d\vec{l}\times\hat{a}_R}{4\pi R^2}$ $\left(\because \hat{a}_R = \frac{\vec{R}}{|\vec{R}|} = \frac{\vec{R}}{R}\right)$

2) $\vec{H} = \oint \frac{I\, d\vec{l}\times\vec{R}}{4\pi R^3}$

3) $\vec{H} = \frac{I}{2\pi\rho}\hat{a}_\phi$ [In case of infinite]

4) $\vec{H} = \frac{I}{4\pi\rho}[\sin\alpha_2 - \sin\alpha_1]\hat{a}_\phi$

5) $\hat{a}_\phi = \hat{a}_I \times \hat{a}_\rho$

6) $\oint \vec{H}\cdot d\vec{l} = I_{enclosed}$ [Amperes circuital law for stead magnetic field

7) $\nabla\times\vec{H} = \vec{J}$ [point form of ampere circuital law]

8) $(\text{curl}\,\vec{H})_N = (\nabla\times\vec{H})_N = \lim_{\Delta S_N\to 0} \frac{\oint \vec{H}\cdot d\vec{l}}{\Delta S_N}$

9) $\oint \vec{H}\cdot d\vec{l} = \int(\nabla\times\vec{H})\cdot d\vec{s}$ [Stokes theorem]

10) $\phi = \int_s \vec{B}\cdot d\vec{s}$

11) $\vec{B} = \nabla\times\vec{A}$ {Vector Magnetic potential}

12) $\frac{\mu_0 I\, d\vec{l}}{4\pi R}$

Coaxial Cable cases

1) $a<\rho<b$; $\vec{H} = \frac{I}{2\pi\rho}\hat{a}_\phi$

2) $\rho<a$; $\vec{H} = H_\phi\hat{a}_\phi = \frac{I\rho}{2\pi a^2}\hat{a}_\phi$

3) $b<\rho<c$; $\vec{H} = \frac{I}{2\pi\rho}\left(\frac{c^2-\rho^2}{c^2-b^2}\right)\hat{a}_\phi$

4) $\rho>c$; $\vec{H} = 0$

13) Magnetic Boundary condition

$B_{N_1} = B_{N_2}$

$H_{N_2} = \frac{\mu_1}{\mu_2} H_{N_1}$

$H_{t_1} - H_{t_2} = K$

$\vec{H}_{t_1} - \vec{H}_{t_2} = \hat{a}_{N12}\times\vec{K}$

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

$B_{t_1} = \frac{\mu_1}{\mu_2} B_{t_2}$

$\mu = \mu_0\mu_r$

14) $\vec{F_e} = Q\vec{E}$

15) $\vec{F_m} = Q(\vec{v}\times\vec{B})$

16) $\vec{F} = \vec{F_e} + \vec{F_m} = Q[E + (\vec{v}\times\vec{B})]$

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① $emf = -\frac{d\phi}{dt} = -N\frac{d\phi}{dt}$ (for N turns)

$emf = \oint \vec{E}\cdot d\vec{l} = -\frac{d\phi}{dt}$

② $\vec{E} = \frac{\vec{F}}{q}$

$\vec{F} = q(\vec{v}\times\vec{B})$ | Motional emf $= \oint E_m \cdot d\vec{l} = \oint (\vec{v}\times\vec{B})\cdot d\vec{l}$

$\vec{E}_m = \vec{v}\times\vec{B}$

③ transformer emf $= -\frac{d\phi}{dt}$, $\phi = \int_S \vec{B}\cdot d\vec{s}$, so, transformer emf $= -\int_S \frac{\partial\vec{B}}{\partial t}\cdot d\vec{s}$

④ Net emf = (Motional) + (X-former emf) $= -\int_S \frac{\partial\vec{B}}{\partial t}\cdot d\vec{s} + \oint(\vec{v}\times\vec{B})\cdot d\vec{l}$

⑤ $\nabla\times\vec{H} = \vec{J} + \vec{G} = \vec{J} + \frac{\partial\vec{D}}{\partial t}$, $\vec{G} = \frac{\partial\vec{D}}{\partial t} = \vec{J}_d$

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

⑥ $\oint\vec{H}\cdot d\vec{l} = \int_S(\nabla\times\vec{H})\cdot d\vec{s} = \int_S \vec{J}\cdot d\vec{s} + \int\frac{\partial\vec{D}}{\partial t}\cdot d\vec{s} = I + I_d$

⑦ Maxwell's Equation

Point form (Diffⁿ form)	Integral form
$\nabla\cdot\vec{D} = \rho_v$ [time variant & invariant]	$\oint\vec{D}\cdot d\vec{s} = \int_v \rho_v dv$
$\nabla\times\vec{H} = J_c$ [time invariant]	$\oint\vec{H}\cdot d\vec{l} = \int_S\vec{J}_c\cdot d\vec{s}$
$\nabla\times\vec{H} = J_c + \frac{\partial\vec{D}}{\partial t}$ [time variant]	$\oint\vec{H}\cdot d\vec{l} = \int_S\left(\vec{J}+\frac{\partial\vec{D}}{\partial t}\right)\cdot d\vec{s}$
$\nabla\times\vec{E} = 0$ (time invariant)	$\oint\vec{E}\cdot d\vec{l} = 0$
$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$	$\oint\vec{E}\cdot d\vec{l} = -\int_S\frac{\partial\vec{B}}{\partial t}\cdot d\vec{s}$
$\nabla\cdot\vec{B} = 0$ (time variant & invariant)	$\oint\vec{B}\cdot d\vec{s} = 0$

[Phasor form → time variant conditions]

point (or Diffⁿ form)	Integral form
$\nabla\cdot\vec{D} = \rho_{vs}$	$\oint\vec{D}_s\cdot d\vec{s} = \int_{vol}\rho_{vs}dv$
$\nabla\times\vec{H}_s = \vec{J}_s + j\omega\vec{D}_s$	$\oint_S\cdot d\vec{l} = \int_S(\vec{J}_s + j\omega\vec{D}_s)\cdot d\vec{s}$
$\nabla\times\vec{E}_s = -j\omega\vec{B}_s$	$\oint\vec{E}_s\cdot d\vec{l} = -j\omega\int_S\vec{B}_s\cdot d\vec{s}$
$\nabla\cdot\vec{B}_s = 0$	$\oint_S\vec{B}_s\cdot d\vec{s} = 0$

Note:- step ① Add subscript 's'

② Replace $\frac{\partial}{\partial t}$ by $j\omega$

⑧ $\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} = -\mu\frac{\partial\vec{H}}{\partial t}$ ($\because \vec{B} = \mu\vec{H}$), $\mu = \mu_0\mu_r$

⑨ $\nabla\times\vec{H} = \frac{\partial\vec{D}}{\partial t}$ [for $\sigma = 0, J = 0$], $\nabla\times\vec{H} = \varepsilon\frac{\partial\vec{E}}{\partial t}$

⑩ Free space, $\sigma = 0$, $\varepsilon = \varepsilon_0$, $\mu = \mu_0$

⑪ Lossless/perfect/good dielectrics, $\sigma \ll \omega\varepsilon$; $\frac{\sigma}{\omega\varepsilon} \ll 1$, so $\sigma \simeq 0$, $\varepsilon = \varepsilon_0\varepsilon_r$, $\mu = \mu_0\mu_r$

⑫ Lossy/dissipative/imperfect dielectrics $\sigma \neq 0$, $\varepsilon = \varepsilon_0\varepsilon_r$, $\mu = \mu_0\mu_r$

⑬ Perfect or good dielectrics $\sigma \gg \omega\varepsilon$, $\frac{\sigma}{\omega\varepsilon} \gg 1$

$\sigma \simeq \infty$, $\varepsilon = \varepsilon_0$, $\mu = \mu_0\mu_r$

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P.N.Y

(14) $\gamma = \alpha + j\beta$

(15) $1\ Np = 8.686\ dB$

(16) $\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)}$

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

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

(19) $\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$

(20) Wave Eqn. in perfect dielectric

(i) $\vec{E}_x = E_{x0}\cos(\omega t - \beta z)\hat{a}_x$, $\vec{E}_{xs} = E_{x0}e^{-j\beta z}\hat{a}_x$

(ii) $\vec{H}_x = \sqrt{\frac{\epsilon}{\mu}}\, E_{x0}\cos(\omega t - \beta z)\hat{a}_y$, $\vec{H}_{ys} = \sqrt{\frac{\epsilon}{\mu}}\, E_{x0}e^{-j\beta z}$

(21) Wave eqn in free space

(i) $E_x = E_{x0}\cos(\omega t - \beta z)$

$\vec{E}_x = E_{x0}\cos(\omega t - \beta z)\vec{a}_x$

(ii) $H_y = \sqrt{\frac{\epsilon_0}{\mu_0}}\, E_{x0}\cos(\omega t - \beta z) = \sqrt{\frac{\epsilon_0}{\mu_0}}\, E_x$

$\vec{H}_y = \sqrt{\frac{\epsilon_0}{\mu_0}}\, E_{x0}\cos(\omega t - \beta z)\vec{a}_y = \sqrt{\frac{\epsilon_0}{\mu_0}}\, E_x \vec{a}_y$

(22) Wave Eqn in dissipative Medium

$\vec{E}_{xs} = E_{x0}e^{-\gamma z}\hat{a}_x$, $\vec{E}_x = E_{x0}e^{-\alpha z}\cos(\omega t - \beta z)\hat{a}_x$

$\vec{H}_{ys} = \frac{E_{x0}}{|\eta|}e^{-\alpha z} \cdot e^{-j(\theta + \beta z)}$, $\vec{H}_y = \frac{E_{x0}}{|\eta|}e^{-\alpha z}\cos(\omega t - \beta z - \theta)\hat{a}_y$

(23) Wave Eqn in perfect conductor

$\vec{E}_x = E_{x0}e^{-\alpha z}\cos(\omega t - \beta z)\hat{a}_x$ $[\theta = 45°]$

$\vec{H}_y = \frac{E_{x0}}{|\eta|}e^{-\alpha z}\cos\left(\omega t - \beta z - \frac{\pi^c}{4}\right)$

(24) Poynting's Theorem

$\vec{P} = \vec{S} = \vec{E}\times\vec{H} = E_x\hat{a}_x \times H_y\hat{a}_y = E_x H_y\hat{a}_z \Rightarrow \boxed{\vec{S} = S_z\hat{a}_z}$

$\nabla\cdot(\vec{E}\times\vec{H}) = -\vec{E}\cdot\nabla\times\vec{H} + \vec{H}\cdot\nabla\times\vec{E}$

(25) Losstangent

$\tan\theta = \frac{|\vec{J}_s|}{|\vec{J}_{ds}|} = \frac{|\sigma\vec{E}_s|}{|j\omega\epsilon\vec{E}_s|} = \frac{\sigma}{\omega\epsilon}$ $\boxed{\therefore \tan\theta = \frac{\sigma}{\omega\epsilon}}$

(26) skin depth,

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

$\alpha = \beta = \sqrt{\pi f\mu\sigma}$

(27) $\boxed{\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}}$; $\boxed{\Gamma = |\Gamma|e^{j\phi}}$ $\boxed{\Gamma = \frac{E_{x01}^-}{E_{x01}^+}}$ ⇒ Refn coeff

(28) $\boxed{\tau = \frac{E_{x02}^+}{E_{x01}^+}}$; $\boxed{\tau = \frac{2\eta_2}{\eta_2 + \eta_1}}$ ⇒ Transmission coeff

(29) $SWR = \frac{1+|\Gamma|}{1-|\Gamma|}$

(30) $\eta_{in} = \eta_1 \frac{[\eta_2 + j\eta_1\tan\beta_1 l]}{[\eta_1 + j\eta_2\tan\beta_1 l]}$ { i/p intrinsic impedance }

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(1) $Y = \sqrt{(R+j\omega L)(G+j\omega C)}$

(2) $Z_0 = \sqrt{\dfrac{R+j\omega L}{G+j\omega C}}$

(3) Lossless line ($R = G = 0$)

(4) Distortionless line ($\frac{R}{L} = \frac{G}{C}$)

case	Propn constant ($Y = \alpha + j\beta$)	Characteristic impedance ($Z_0 = R_0 + jX_0$)
General	$\sqrt{(R+j\omega L)(G+j\omega C)}$	$\sqrt{\dfrac{R+j\omega L}{G+j\omega C}}$
Lossless	$0 + j\omega\sqrt{LC}$	$\sqrt{\frac{L}{C}} + j0$
Distortionless	$\sqrt{RG} + j\omega\sqrt{LC}$	$\sqrt{L/C} + j0$

(5) $\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$; $\Gamma = |\Gamma| \angle \theta = |\Gamma| \angle \phi = |\Gamma| \angle \theta_\Gamma$

(6) $VSWR = \dfrac{V_{max}}{V_{min}} = \dfrac{1+|\Gamma|}{1-|\Gamma|}$

(7) $\tau = \dfrac{2Z_L}{Z_L + Z_0}$ [transmission coefficient]

(8) $Z_{in} = Z_0 \left[\dfrac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l} \right]$

(9) The voltage at anypoint on lossless Tx line is:-

$$V_p = (e^{-j\beta z} + \Gamma e^{j\beta z}) V_0^+$$

(10) Voltage is minimum when, $z_{min} = -\dfrac{1}{2\beta}[\phi + (2m+1)\pi]$, $m = 0, 1, 2 - - -$

(11) Voltage is max^m, when, $z_{max} = -\dfrac{1}{2\beta}(\phi + 2n\pi)$, $n = 0, 1, 2, - - -$

(12) Load admittance $(Y_L) = \dfrac{1}{Z_L}$

(13) $c = v = f\lambda \Rightarrow \lambda = c/f$, $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

(14) $v = \dfrac{1}{\sqrt{\mu\varepsilon}} = \dfrac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}} = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}} \cdot \dfrac{1}{\sqrt{\mu_r\varepsilon_r}} = \dfrac{c}{\sqrt{\mu_r\varepsilon_r}}$

(15) $f_c = \dfrac{v}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

(16) $v_g = v\sqrt{1 - \left(\frac{f_c}{f}\right)^2} = c\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$ = Group velocity

(17) $v_p = \dfrac{v}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} = \dfrac{c}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} \Rightarrow$ phase velocity

I. $P(x, y, z) = \tan^{-1}(y/x)$

II. $P(-x, y, z) = 180° - \tan^{-1}(y/x)$

III. $P(-x, -y, z) = 180° + \tan^{-1}(y/x)$

IV. $P(x, -y, z) = 360° - \tan^{-1}(y/x)$

Chap 1, $\phi = ?$

P. G. N. 6

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