Name: ________________________________ Student Number: _________

Formula Sheet

$\varepsilon_0 = 8.85\text{x}10^{-12}$ Fm^{-1}
$\mu_0 = 4\pi\ \text{x}10^{-7}$ Hm^{-1}

c = $3\text{x}10^{8}$ ms^{-1} (speed of light in vacuum)
intrinsic impedance of free space = 377 Ω

Maxwell's equations:

$\nabla \cdot E = \dfrac{\rho}{\varepsilon}$ $\quad \nabla \cdot B = 0$ $\quad \nabla \times E = -\mu \dfrac{\partial H}{\partial t}$ $\quad \nabla \times H = J + \varepsilon \dfrac{\partial E}{\partial t}$ $\quad B = \mu H$ $\quad J = \sigma E$

vector calculus identity: $\nabla \times \nabla \times A = \nabla(\nabla \cdot A) - \nabla^2 A$ Poynting vector: $S = E \times H$ $\quad S_{av} = \dfrac{1}{2}\mathrm{Re}\{E \times H^*\}$

Relations for a TEM wave: $k = \dfrac{2\pi}{\lambda}$ $\quad f\lambda = v$ $\quad v = \dfrac{\omega}{k} = \dfrac{1}{\sqrt{\mu\varepsilon}}$ $\quad Z = \sqrt{\dfrac{\mu}{\varepsilon}}$

Prototype TEM wave for conductor or lossy dielectric: $E = (E_0 e^{-\alpha z} e^{j(\omega t - \beta z)}, 0, 0)$

Good conductor (σ>>εω): $\alpha = \beta = 1/\delta$ $\quad \delta = \sqrt{\dfrac{2}{\mu\sigma\omega}}$ $\quad Z_m = e^{j\pi/4}\sqrt{\dfrac{\mu\omega}{\sigma}}$

Poor conductor (σ<<εω): $\beta = \omega\sqrt{\mu\varepsilon}$ $\quad \alpha = \sqrt{\dfrac{\mu}{\varepsilon}}\dfrac{\sigma}{2}$ Lossy dielectric($\varepsilon_c = \varepsilon e^{-j\phi}$): $\beta = \omega\sqrt{\mu\varepsilon}$ $\quad \alpha = \beta\dfrac{\phi}{2}$

Characteristic impedance of transmission line: $Z_0 = \sqrt{\dfrac{L}{C}}$ voltage reflection coefficient: $\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$

Coax cable: $Z_0 = \dfrac{\ln(b/a)}{2\pi}\sqrt{\dfrac{\mu}{\varepsilon}}$ microstrip line: $Z_0 = \dfrac{a}{W}\sqrt{\dfrac{\mu}{\varepsilon}}$ two-wire line: $Z_0 = \dfrac{\ln(b/a)}{\pi}\sqrt{\dfrac{\mu}{\varepsilon}}$

Snell's law: $n_i \sin\theta_i = n_t \sin\theta_t$ Brewster angle: $Tan\theta_B = \dfrac{n_2}{n_1}$ refractive index: $n = \sqrt{\varepsilon_r}$

Macroscopic Ampere's law: $\oint H \cdot dl = I_{enclosed}$ Waveguide modes: $\beta^2 = \mu\varepsilon\omega^2 - \dfrac{n^2\pi^2}{a^2} - \dfrac{m^2\pi^2}{b^2}$

$Z_{eff} = Z_0 \dfrac{Z_L + jZ_0\tan(kD)}{Z_0 + jZ_L\tan(kD)}$ quarter wave: $Z_{eff} = \dfrac{Z_0^2}{Z_L}$ half-wave: $Z_{eff} = Z_L$

Fresnel equations:

$T_\perp = \dfrac{2Z_2\cos\theta_i}{Z_2\cos\theta_t + Z_1\cos\theta_i}$ $\quad T_\parallel = \dfrac{2Z_2\cos\theta_i}{Z_2\cos\theta_i + Z_1\cos\theta_t}$ $\quad R_\parallel = \dfrac{Z_2\cos\theta_t - Z_1\cos\theta_i}{Z_2\cos\theta_t + Z_1\cos\theta_i}$ $\quad R_\perp = \dfrac{Z_2\cos\theta_i - Z_1\cos\theta_t}{Z_2\cos\theta_i + Z_1\cos\theta_t}$