EECE490U
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Mathematical Methods in Physical Electronics

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Topics (tentative)

Ch 1. Dirac Delta Function
Ch 2. Vector Analysis
Ch 3. Ordinary Differential Equations
Ch 4. Partial Differential Equations
Ch 5. Special Functions
Ch 6. Green's Functions
Ch 7. Integral Transforms

Model Equations

Maxwell's Equations in Classical Electrodynamics

$$\nabla \times \mathbf{E}(\mathbf{r},t) = \frac{\partial}{\partial t}\mathbf{B}(\mathbf{r},t)$$ Faraday's Law

$$\nabla \times \mathbf{H}(\mathbf{r},t) = \mathbf{J}(\mathbf{r},t) + \frac{\partial}{\partial t}\mathbf{D}(\mathbf{r},t)$$ (Generalized) Ampere's Law

$$\nabla \cdot \mathbf{D}(\mathbf{r},t) = \rho(\mathbf{r},t)$$ Gauss Law (Poisson's Equation)

$$\nabla \cdot \mathbf{B}(\mathbf{r},t) = 0$$ No Magnetic Monopole

$$\mathbf{F}(\mathbf{r},t) = q\left[\mathbf{E}(\mathbf{r},t) + \mathbf{v} \times \mathbf{E}(\mathbf{r},t)\right]$$ Lorentz Force

Schödinger Equation in Quantum Mechanics

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = H\Psi(\mathbf{r},t)$$ Schödinger Equation

$$H = -\frac{\hbar^2}{2m}\nabla^2 + V(\mathbf{r},t)$$ Hamiltonian Operator

The Importance of Vector Calculus

Original Maxwell's Equations (20 Scalar Equations)

$e+\frac{df}{dx}+\frac{dg}{dy}+\frac{dh}{dz}=0$	(1)	Gauss' Law
$\mu\alpha=\frac{dH}{dy}-\frac{dG}{dz}$ $\mu\beta=\frac{dF}{dz}-\frac{dH}{dx}$ $\mu\gamma=\frac{dG}{dx}-\frac{dF}{dy}$	(2)	Equivalent to Gauss' Law for magnetism
$P=\mu\left(\gamma\frac{dy}{dt}-\beta\frac{dz}{dt}\right)-\frac{dF}{dt}-\frac{d\Psi}{dz}$ $Q=\mu\left(\alpha\frac{dz}{dt}-\gamma\frac{dx}{dt}\right)-\frac{dG}{dt}-\frac{d\Psi}{dy}$ $R=\mu\left(\beta\frac{dx}{dt}-\alpha\frac{dy}{dt}\right)-\frac{dH}{dt}-\frac{d\Psi}{dz}$	(3)	Faraday's Law (with the Lorentz Force and Poisson's Law)
$\frac{d\gamma}{dy}-\frac{d\beta}{dz}=4\pi p'$ $\quad p'=p+\frac{df}{dt}$ $\frac{d\alpha}{dz}-\frac{d\gamma}{dx}=4\pi q'$ $\quad q'=q+\frac{dg}{dt}$ $\frac{d\beta}{dx}-\frac{d\alpha}{dy}=4\pi r'$ $\quad r'=r+\frac{dh}{dt}$	(4)	Ampère-Maxwell Law
$P=-\zeta p \quad Q=-\zeta q \quad R=-\zeta r$		Ohm's Law
$P=kf \quad Q=kg \quad R=kh$		The electric elasticity equation (**E** = **D**/ε)
$\frac{de}{dt}+\frac{dp}{dx}+\frac{dq}{dy}+\frac{dr}{dz}=0$		Continuity of charge

Heavyside's Maxwell's Equations (4 Vector Equations)

$$\nabla\times\mathbf{E}(\mathbf{r},t)=\frac{\partial}{\partial t}\mathbf{B}(\mathbf{r},t)$$

$$\nabla\times\mathbf{H}(\mathbf{r},t)=\mathbf{J}(\mathbf{r},t)+\frac{\partial}{\partial t}\mathbf{D}(\mathbf{r},t)$$

$$\nabla\cdot\mathbf{D}(\mathbf{r},t)=\rho(\mathbf{r},t)$$

$$\nabla\cdot\mathbf{B}(\mathbf{r},t)=0$$

Oliver Heaviside has coined many important terms currently used for electromagnetic material parameters: admittance, conductance, impedance, etc.