

## Symbols and Constants

$F$	force	$V$	electric potential
$Q$	charge	$\vec{A}$	vector potential
$\vec{E}$	electric field	$\rho$	charge density
$\vec{D}$	displacement field	$I$	current
$\vec{P}$	polarization field	$\vec{j}$	current density
$\vec{H}$	magnetic field	$\epsilon_R$	relative permittivity
$\vec{B}$	magnetic flux density field	$\mu_R$	relative permeability
$\vec{M}$	magnetization	$\epsilon_0 \approx 8.85 \times 10^{-12}$	F/m
		$\mu_0 = 4\pi \times 10^{-7}$	N/A <sup>2</sup>

## Vector Calculus

cross products

Cartesian	$\vec{a}_x \times \vec{a}_y = \vec{a}_z$	$\vec{a}_y \times \vec{a}_z = \vec{a}_x$	$\vec{a}_z \times \vec{a}_x = \vec{a}_y$
cylindrical	$\vec{a}_\rho \times \vec{a}_\phi = \vec{a}_z$	$\vec{a}_\phi \times \vec{a}_z = \vec{a}_\rho$	$\vec{a}_z \times \vec{a}_\rho = \vec{a}_\phi$
spherical	$\vec{a}_r \times \vec{a}_\theta = \vec{a}_\phi$	$\vec{a}_\theta \times \vec{a}_\phi = \vec{a}_r$	$\vec{a}_\phi \times \vec{a}_r = \vec{a}_\theta$

## Electrostatics

Coulomb's law  $\vec{F}_2 = \frac{Q_1 Q_2}{4\pi\epsilon_0 R^2} \vec{a}_{12}$

$\vec{E}$  of point charge  $\vec{E} = \frac{Q\vec{a}_r}{4\pi\epsilon_0 r^2}$

$\vec{E}$  of charge distribution  $\vec{E} = \int_V \frac{\rho(\vec{r}') dV'}{4\pi\epsilon_0 |\vec{r} - \vec{r}'|^2} \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|}$

Gauss's law

$$\epsilon_0 \oint_S \vec{E} \cdot d\vec{S} = Q_{\text{enclosed}}^{\text{total}} = \int_V \rho dV$$

$$\oint_S \vec{D} \cdot d\vec{S} = Q_{\text{enclosed}}^{\text{free}} = \int_V \rho_{\text{free}} dV$$

$$\oint_S \vec{P} \cdot d\vec{S} = -Q_{\text{enclosed}}^{\text{bound}} = -\int_V \rho_{\text{bound}} dV$$

relating  $\vec{E}$  to  $V$   $\vec{E} = -\vec{\nabla}V$

relating  $V$  to  $\vec{E}$   $V_{AB} = -\int_B^A \vec{E} \cdot d\vec{l}$

$V$ of charge distribution	$V = \int_V \frac{\rho(\vec{r}') dV'}{4\pi\epsilon_0  \vec{r} - \vec{r}' }$
capacitance	$C = Q/V$
parallel plate capacitor	$C = \frac{\epsilon_0 \epsilon_R A}{d}$ of dimensions $A$ and $d$
Poisson's equation	$\nabla^2 V = -\rho / \epsilon_0 \epsilon_R$
Laplace's equation	$\nabla^2 V = 0$
linear dielectrics	$\vec{D} = \epsilon_0 \epsilon_R \vec{E}$
boundary conditions	$E_T$ and $D_N$ continuous
energy	$W = \frac{1}{2} \int_V \vec{E} \cdot \vec{D} dV$

### Magnetostatics

law of Biot-Savart	$\vec{H} = \oint \frac{I d\vec{l} \times \vec{a}_R}{4\pi R^2}$
law of Biot-Savart	$\vec{H} = \int_V \frac{\vec{j} \times \vec{a}_R dV}{4\pi R^2}$
Ampere's law	$\oint \vec{H} \cdot d\vec{l} = I_{\text{enclosed}}$
inductance	$L = N\phi / I$
vector potential	$\vec{A} = \int_V \frac{\mu_0 \vec{j} dV}{4\pi R}$
relating $\vec{B}$ to $\vec{A}$	$\vec{B} = \vec{\nabla} \times \vec{A}$
linear materials	$\vec{B} = \mu_0 \mu_R \vec{H}$
boundary conditions	$H_T$ and $B_N$ continuous
energy	$W = \frac{1}{2} \int_V \vec{B} \cdot \vec{H} dV$

### Electromagnetics

Maxwell's equations	$\vec{\nabla} \cdot \vec{D} = \rho$	$\vec{\nabla} \cdot \vec{B} = 0$
	$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	$\vec{\nabla} \times \vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$