

# Engineering Electromagnetics

Mattia Fait

30 maggio 2025

## Indice

<b>1</b>	<b>Vector Algebra</b>	<b>3</b>
1.1	Scalars and Vectors . . . . .	3
1.2	Products of Vectors . . . . .	3
1.3	Fields . . . . .	3
1.4	Systems of Coordinates . . . . .	3
1.5	Position Vectors . . . . .	3
<b>2</b>	<b>Vector Calculus</b>	<b>3</b>
2.1	Integration . . . . .	3
2.1.1	Line Integrals . . . . .	3
2.1.2	Surface Integrals . . . . .	3
2.1.3	Volume Integrals . . . . .	3
2.2	Differentiation . . . . .	3
2.2.1	Gradient . . . . .	3
2.2.2	Divergence . . . . .	3
2.2.3	Circulation . . . . .	3
<b>3</b>	<b>Electric Field</b>	<b>3</b>
3.1	Charge . . . . .	3
3.2	Coulomb's Law . . . . .	3
3.3	Electric Field . . . . .	4
3.4	Electric Flux . . . . .	4
<b>4</b>	<b>Electric Potential</b>	<b>4</b>
4.1	Electrostatic Field . . . . .	4
4.2	Gauss's Law . . . . .	4
4.3	Electric Potential . . . . .	6
4.4	Materials in the Electric Field . . . . .	6
4.5	Interface Conditions . . . . .	6
4.6	Capacitance . . . . .	6
4.7	Energy in the Electrostatic Field . . . . .	6
<b>5</b>	<b>Boundary Value</b>	<b>6</b>
5.1	Poisson's Equation for the Electrostatic Field . . . . .	6
5.2	Laplace's Equation for the Electrostatic Field . . . . .	6

<b>6</b>	<b>Steady Electric Current</b>	<b>6</b>
6.1	Conservation of Charge . . . . .	6
6.2	Conductors, Dielectrics and Lossy Dielectrics . . . . .	6
6.3	Ohm's Law . . . . .	6
6.4	Power Dissipation and Joule's Law . . . . .	6
6.5	The Continuity Equation and Kirchhoff's Current Law . . . . .	6
6.6	Current Density as a Field . . . . .	6
6.7	Interface Conditions for Current Density . . . . .	6
<b>7</b>	<b>Static Magnetic Field</b>	<b>6</b>
7.1	Magnetic Field . . . . .	6
7.2	Biot-Savart Law . . . . .	6
7.3	Ampère's Law . . . . .	6
7.4	Magnetic Flux . . . . .	6
7.5	Static Magnetic Field . . . . .	6
7.6	Potential Functions . . . . .	6
<b>8</b>	<b>Magnetic Materials and Properties</b>	<b>6</b>
8.1	Magnetic Properties of Materials . . . . .	6
8.2	Magnetic Interface Conditions . . . . .	6
8.3	Inductance and Inductors . . . . .	6
8.4	Energy Stored in the Magnetic Field . . . . .	6
8.5	Magnetic Circuits . . . . .	6
8.6	Forces in the Magnetic Field . . . . .	6
8.7	Torque . . . . .	6
<b>9</b>	<b>Induction</b>	<b>6</b>
9.1	Faraday's Law . . . . .	6
9.2	Lenz's Law . . . . .	6
9.3	Motional Electromotive Force . . . . .	6
<b>10</b>	<b>Maxwell Equations</b>	<b>6</b>
10.1	Maxwell's Equations . . . . .	6
10.2	Time-Dependent Potential Functions . . . . .	6
10.3	Interface Conditions for the Electromagnetic Field . . . . .	6
10.4	Particular Forms of Maxwell's Equations . . . . .	6

# 1 Vector Algebra

## 1.1 Scalars and Vectors

## 1.2 Products of Vectors

## 1.3 Fields

## 1.4 Systems of Coordinates

## 1.5 Position Vectors

# 2 Vector Calculus

## 2.1 Integration

### 2.1.1 Line Integrals

### 2.1.2 Surface Integrals

### 2.1.3 Volume Integrals

## 2.2 Differentiation

### 2.2.1 Gradient

### 2.2.2 Divergence

### 2.2.3 Circulation

# 3 Electric Field

## 3.1 Charge

Line Charge Density

$$\rho_l = \lim_{\Delta l \rightarrow 0} \frac{\Delta Q}{\Delta l} \quad \left[ \frac{\text{C}}{\text{m}} \right]$$

Surface Charge Density

$$\rho_s = \lim_{\Delta s \rightarrow 0} \frac{\Delta Q}{\Delta s} \quad \left[ \frac{\text{C}}{\text{m}^2} \right]$$

Volume Charge Density

$$\rho_v = \lim_{\Delta v \rightarrow 0} \frac{\Delta Q}{\Delta v} \quad \left[ \frac{\text{C}}{\text{m}^3} \right]$$

## 3.2 Coulomb's Law

$$\vec{F} = k \frac{Q_1 Q_2}{r^2} \hat{r} \quad [\text{N}]$$

$$k = \frac{1}{4\pi\epsilon} \quad \left[ \frac{\text{Nm}^2}{\text{C}^2} \right]$$

### 3.3 Electric Field

$$\vec{E} = \lim_{Q \rightarrow 0} \frac{\vec{F}}{Q} \quad \left[ \frac{N}{C} \right]$$

### 3.4 Electric Flux

Electric Flux Density

$$\vec{D} = \vec{E} \quad \left[ \frac{C}{m^2} \right]$$

Electric Flux

$$\Phi = \int_S \vec{D} \cdot d\vec{s} \quad [C]$$

## 4 Electric Potential

### 4.1 Electrstatic Field

Postulates for the Electrostatic Field:

$$\begin{cases} \nabla \cdot \vec{E} = \frac{\rho_v}{\epsilon_0} \\ \nabla \times \vec{E} = 0 \\ \oint_S \vec{E} \cdot d\vec{s} = \frac{Q}{\epsilon_0} \\ \oint_C \vec{E} \cdot d\vec{l} = 0 \end{cases}$$

### 4.2 Gauss's Law

$$\oint_S \vec{D} \cdot d\vec{s} = Q \quad [C]$$

$$\oint_S \vec{E} \cdot d\vec{s} = \frac{Q}{\epsilon_0}$$

### 4.3 Electric Potential

Scalar Electric Potential

$$V_{ba} = \frac{W}{Q}$$



#### 4.4 Materials in the Electric Field

#### 4.5 Interface Conditions

#### 4.6 Capacitance

#### 4.7 Energy in the Electrostatic Field

### 5 Boundary Value

#### 5.1 Poisson's Equation for the Electrostatic Field

#### 5.2 Laplace's Equation for the Electrostatic Field

### 6 Steady Electric Current

#### 6.1 Conservation of Charge

#### 6.2 Conductors, Dielectrics and Lossy Dielectrics

#### 6.3 Ohm's Law

#### 6.4 Power Dissipation and Joule's Law

#### 6.5 The Continuity Equation and Kirchhoff's Current Law

#### 6.6 Current Density as a Field

#### 6.7 Interface Conditions for Current Density

### 7 Static Magnetic Field

#### 7.1 Magnetic Field

#### 7.2 Biot-Savart Law

#### 7.3 Ampère's Law

#### 7.4 Magnetic Flux

#### 7.5 Static Magnetic Field

#### 7.6 Potential Functions

### 8 Magnetic Materials and Properties

#### 8.1 Magnetic Properties of Materials

#### 8.2 Magnetic Interface Conditions

#### 8.3 Inductance and Inductors

#### 8.4 Energy Stored in the Magnetic Field

#### 8.5 Magnetic Circuits

#### 8.6 Forces in the Magnetic Field