High-Speed Electronics in Practice

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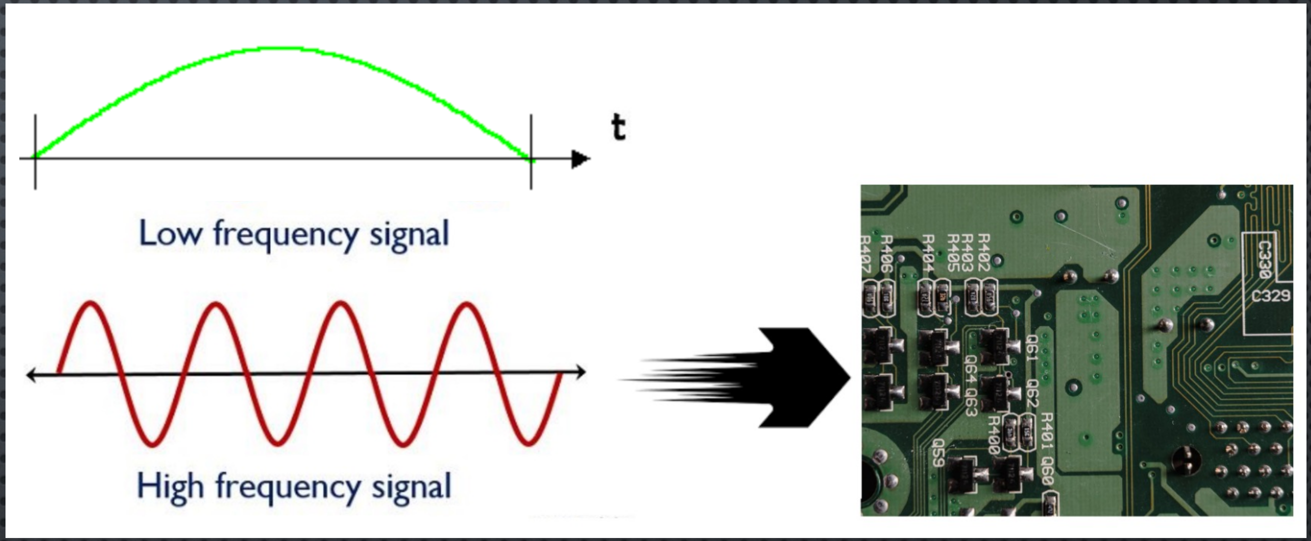
High-Speed Electronics?

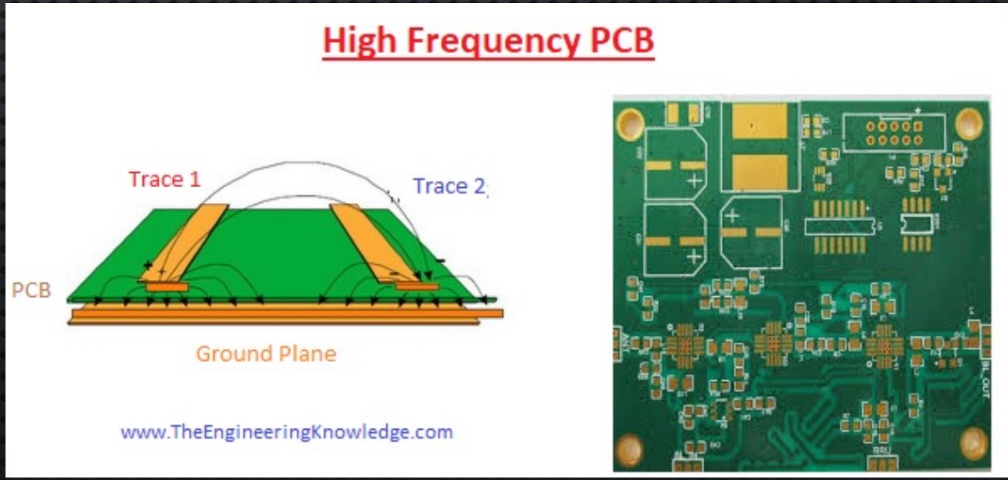
High-speed means high-frequency

When the signal frequency rises, the cycle shortens. In the cycle, to ensure enough time for the signal to maintain stability, the time for the signal to rise and drop has to be short. So this leads to high speed. In other words, high-frequency PCBs are also high-speed PCBs.

Example 1



Example 2



Target: High-speed digital and high-frequency analog electronic systems.

High-Speed Electronics in Practice

MM1. Introduction and Electric Field

Introduction

Lecturer:

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Course content (4 parts):

- Electrophysics
- Transmission line theory
- Electromagnetic compatibility
- Power supply strategies and types

17 minimodules (MM):

- Lectures 13
- Laboratory experiments 2
- Self study 2

Course plan:

Day	Date	Topic	Reading
Wed	6 Sep.	MMl: Introduction and Electric Field	QEM 1 - 47
Mon	11 Sep.	MM2: Current and capacity	QEM 41 -52
Wed	13 Sep.	MM3: Magnetic Field	QEM 57 -96
Mon	18 Sep.	MM4: Induction and magnetic material	QEM 76- 110
Wed	20 Sep.	MM5: Moment in Magnet Field	Transducere1 -26
Mon	25 Sep.	MM6: Exercise	Self study and finish exercise
Wed	27 Sep.	MM7: Impulse Propagation on Cables and Telegraph Equation	TL 1 -22
Mon	2 Oct.	MM8: ISQ and Measurement Report	Self study and Read slides
Wed	4 Oct.	MM9: Lab 1: Impulse propagation	Read instructions before lab1
Mon	9 Oct.	MMl0: Solution for Harmonic signals	TL 23 -38, 105 - 108
Wed	11 Oct.	MM 11: Standing Waves	TL 47 -49, 54 -58
Mon	16 Oct.	MM12: Smith Chart	TL 69 -89
Wed	18 Oct.	MM13: Cable Models and Power Ratio	TL 38 -44, 46 -48, 93 - 100
Mon	23 Oct.	MM14: Lab 2: Stub Matching	Read instructions before lab2
Mon	30 Oct.	MM15: EMC Part I	Read slides
Wed	1 Nov.	MM16: EMC Part II	Read slides
Mon	6 Nov.	MM17: Power Supply Strategies and Types	Read slides

Literature (please find them under the folder “literature” at AAU Moodle):

Plus some pages of different materials

Exam:

75%: Written exam, 3 hours for 3 questions (25% for each question), in Jan. 2024. You can bring the lecture notes (black board materials), slides, a calculator.

25%: 2 short reports of laboratory experiments

"Pass" means at least "2" or "50%"

Electric Field

Targets:

1. Read “Quasistatiske elektriske og magnetiske felter” (Page I – 47) (before or after the lecture)
2. Be able to calculate electric field at point charges (lecture)
3. Finish the exercise (after the lecture)

What is a field in general

In physics, a field is a region that has a value for each point in space and time. In the field, each point is affected by a force that can attract or repel it.

As one example, the objects fall on the ground because of the earth's gravitational force.

Field Types

Scalar field:

A function that associates a one-dimensional quantity with each point in space. Every point can be described by a single scalar number. No direction information.

For example: Temperature, humidity, density, pressure, electric charge

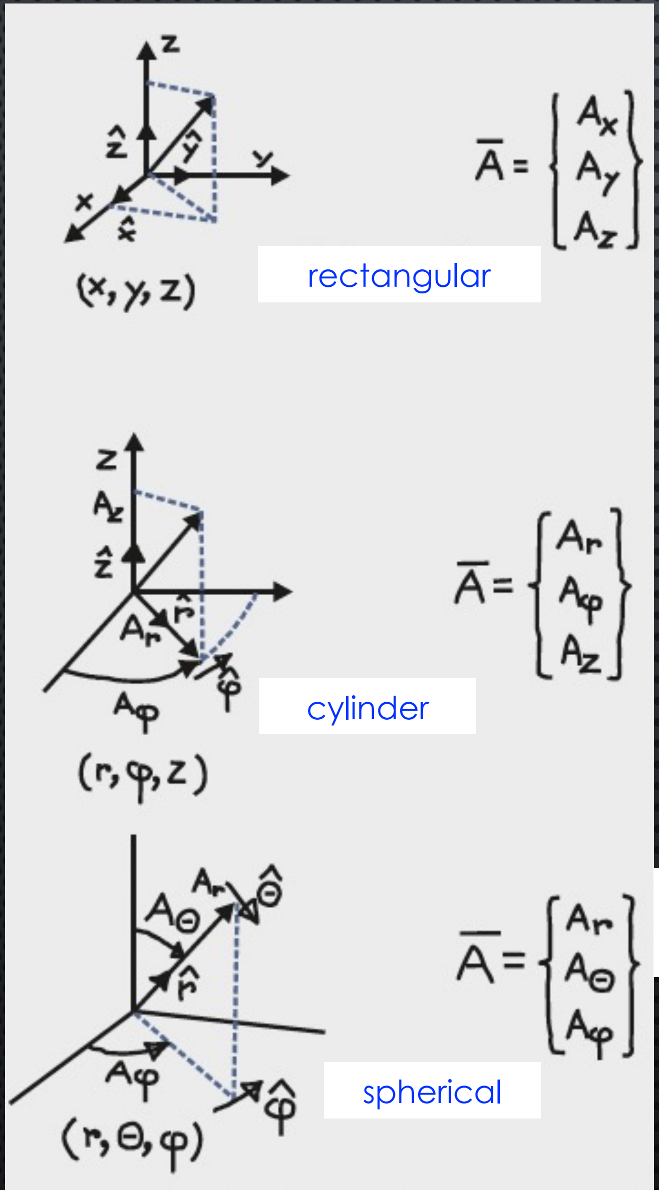
Vector field:

A function that associates a three-dimensional quantity with each point in space. For each point, e.g. a direction and a size (spherical coordinates) or 3 numbers (x, y and z coordinates). Have direction information.

For example: Temperature difference, water flow, gravitational field, Electric/magnetic field.

Blackboard (1)(2)(3)

Coordinate Systems for Fields



Planar symmetry

$$\bar{A} = A_x \cdot \hat{x} + A_y \cdot \hat{y} + A_z \cdot \hat{z}$$

Cylindrical symmetry, “cable”

$$\bar{A} = A_r \cdot \hat{r} + A_\varphi \cdot \hat{\varphi} + A_z \cdot \hat{z}$$

Spherical symmetry, “point source”

$$\bar{A} = A_r \cdot \hat{r} + A_\Theta \cdot \hat{\Theta} + A_\varphi \cdot \hat{\varphi}$$

The three types of coordinate systems are shown to the left.

The basic unit vectors in each system are orthogonal independent of the chosen point.

Coordinate Systems for Fields

Spherical

$$\begin{cases} x = r\sin\theta\cos\phi \\ y = r\sin\theta\sin\phi \\ z = r\cos\theta \end{cases}$$

$$\begin{cases} \hat{\mathbf{x}} = \sin\theta\cos\phi\,\hat{\mathbf{r}} + \cos\theta\cos\phi\,\hat{\boldsymbol{\theta}} - \sin\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{y}} = \sin\theta\sin\phi\,\hat{\mathbf{r}} + \cos\theta\sin\phi\,\hat{\boldsymbol{\theta}} + \cos\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{z}} = \cos\theta\,\hat{\mathbf{r}} - \sin\theta\,\hat{\boldsymbol{\theta}} \end{cases}$$

$$\begin{cases} r = \sqrt{x^2+y^2+z^2} \\ \theta = \tan^{-1}(\sqrt{x^2+y^2}/z) \\ \phi = \tan^{-1}(y/x) \end{cases}$$

$$\begin{cases} \hat{\mathbf{r}} = \sin\theta\cos\phi\,\hat{\mathbf{x}} + \sin\theta\sin\phi\,\hat{\mathbf{y}} + \cos\theta\,\hat{\mathbf{z}} \\ \hat{\boldsymbol{\theta}} = \cos\theta\cos\phi\,\hat{\mathbf{x}} + \cos\theta\sin\phi\,\hat{\mathbf{y}} - \sin\theta\,\hat{\mathbf{z}} \\ \hat{\boldsymbol{\phi}} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}} \end{cases}$$

Cylindrical

$$\begin{cases} x = s\cos\phi \\ y = s\sin\phi \\ z = z \end{cases}$$

$$\begin{cases} \hat{\mathbf{x}} = \cos\phi\,\hat{\mathbf{s}} - \sin\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{y}} = \sin\phi\,\hat{\mathbf{s}} + \cos\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{z}} = \hat{\mathbf{z}} \end{cases}$$

$$\begin{cases} s = \sqrt{x^2+y^2} \\ \phi = \tan^{-1}(y/x) \\ z = z \end{cases}$$

$$\begin{cases} \hat{\mathbf{s}} = \cos\phi\,\hat{\mathbf{x}} + \sin\phi\,\hat{\mathbf{y}} \\ \hat{\boldsymbol{\phi}} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}} \\ \hat{\mathbf{z}} = \hat{\mathbf{z}} \end{cases}$$

Divergence and Rotation

∇ **Nabla Symbol**

$$\mathbf{i}\frac{\partial}{\partial x} + \mathbf{j}\frac{\partial}{\partial y} + \mathbf{k}\frac{\partial}{\partial z}$$

Gradient

$$\nabla f$$

Change of f

Divergence

$$\nabla \bullet \bar{A}$$

Source field?

$\nabla \bullet \bar{A} = 0$ Source free

Rotation

$$\nabla \times \bar{A}$$

Conservative?

$\nabla \times \bar{A} = \bar{0}$ conservative

Divergence and Rotation

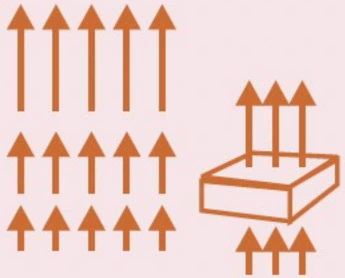
Divergence

- Place-differential.
- Describe the change in the field direction.
- A scalar.

$$\mathbf{DIV} = \frac{\mathbf{FLUX}}{\mathbf{VOLUMEN}}$$

$$\nabla \bullet \bar{\mathbf{A}} = \frac{\partial}{\partial x}A_x + \frac{\partial}{\partial y}A_y + \frac{\partial}{\partial z}A_z$$

$\nabla \bullet \bar{\mathbf{A}} \neq 0$

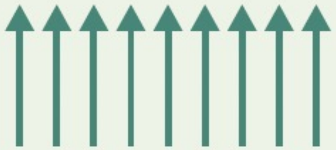


$\nabla \bullet \bar{\mathbf{A}} = 0$

Rotation

$$\mathbf{ROT} = \frac{\mathbf{CIRKULATION}}{\mathbf{AREAL}} \cdot \hat{\mathbf{n}}$$

$$\nabla \times \bar{\mathbf{A}} = \left(\frac{\partial}{\partial y}A_z - \frac{\partial}{\partial z}A_y\right) \cdot \hat{\mathbf{x}} + \left(\frac{\partial}{\partial z}A_x - \frac{\partial}{\partial x}A_z\right) \cdot \hat{\mathbf{y}} + \left(\frac{\partial}{\partial x}A_y - \frac{\partial}{\partial y}A_x\right) \cdot \hat{\mathbf{z}}$$



$\nabla \times \bar{\mathbf{A}} = \bar{0}$

$\nabla \times \bar{\mathbf{A}} \neq \bar{0}$

- Place-differential.
- Describe the change across the field direction.
- A Vector.

Divergence and Rotation

Three theorems

Gradient theorem

$$\int_{A\,C}^{B} \nabla f \cdot d\bar{l} = f(B) - f(A)$$

Potential field

Divergence theorem

$$\int_{V} \nabla \cdot \bar{A}\, dV = \oint_{S} \bar{A} \cdot d\bar{a}$$

Gauss theorem

Rotation theorem

$$\int_{S} \nabla \times \bar{A} \cdot d\bar{a} = \oint_{C} \bar{A} \cdot d\bar{l}$$

Stokes theorem

Electric Field Analysis

$\nabla \times \bar{E}$ **0 (conservative field)**

$\nabla \bullet \bar{E}$ **not 0 (source field)**

Blackboard (4)

Electric Field Analysis

Conservative field
(if one of the following is valid, all the others are valid.)

a. $\nabla \times \bar{A} = \bar{0}$ — Everywhere

b. $\int_{A\,C}^{B} \bar{A} \bullet d\bar{l}$ — Not depending on the path between A and B

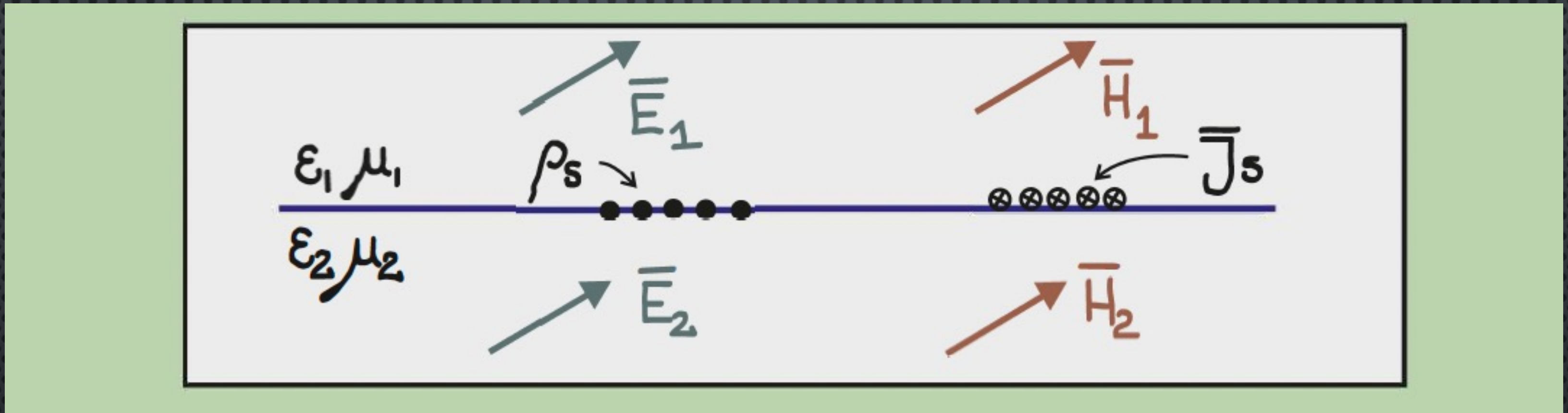
c. $\oint_{C} \bar{A} \bullet d\bar{l} = 0$ — For all the close circle

d. $\bar{A}$ is the gradient of a scalar $\bar{A} = \nabla V$

Blackboard (5)

Boundary Conditions

General case



Electric field

$$E_{t1} = E_{t2}$$

$$D_{n1} = D_{n2} + \rho_s$$

$$\varepsilon_1 E_{n1} = \varepsilon_2 E_{n2} + \rho_s$$

Magnetic field

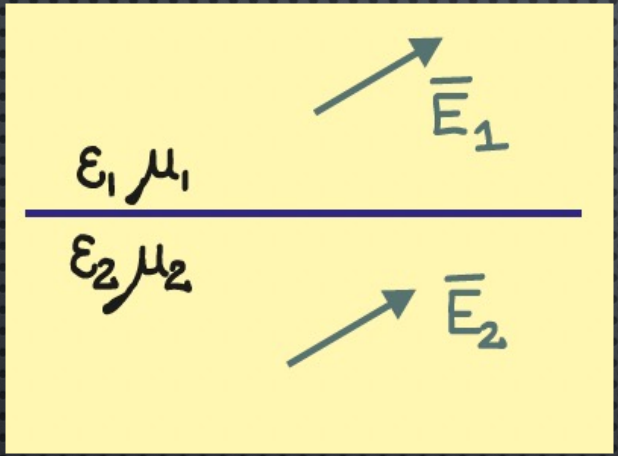
$$H_{t1} = H_{t2} + J_s$$

$$B_{n1} = B_{n2}$$

$$\mu_1 H_{n1} = \mu_2 H_{n2}$$

Boundary Conditions

Special case 1: electric field between two ideal dielectric materials



$$\rho_s = 0$$

Electric field

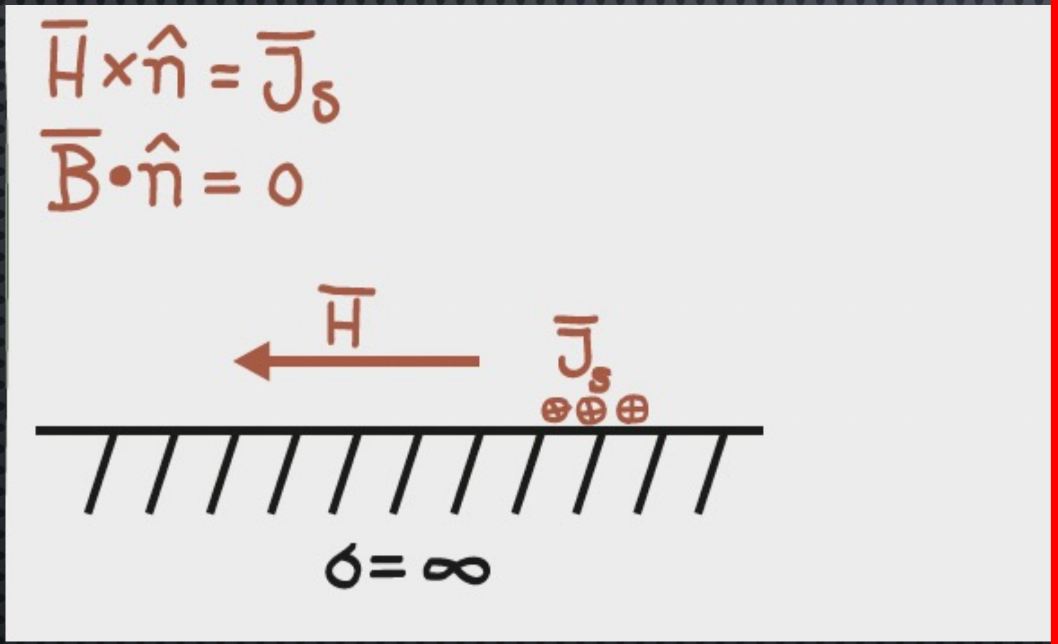
$$E_{t1} = E_{t2}$$

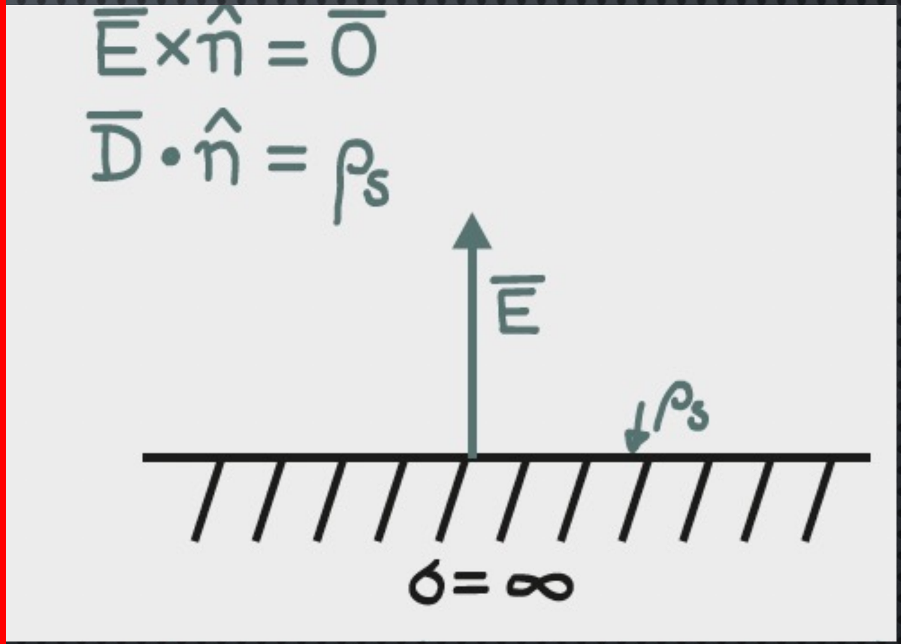
$$D_{n1} = D_{n2}$$

$$\varepsilon_1 E_{n1} = \varepsilon_2 E_{n2}$$

Boundary Conditions

Special case 2: electric field for ideal conductor





H-field are parallel with the surface and correspond to the linear surface current density

E-field are orthogonal to the surface and correspond to the surface charge density