Lesson 1
Introduction

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Sec. 1-1
Basics

1. What is EM
2. Why to study EM
3. Overview
4. Analysis of different types of EM problems

What is Electromagnetism (EM)?

- The study of electric charges at rest and in motion

Why to study EM?

- To understand the natural EM phenomena

  E.g. The “blue” sky (EM wave scattering), the lightening (discharge)

- To create EM devices to facilitate (and complicate) our lives

  E.g. The compass, motors, memories, solar cells

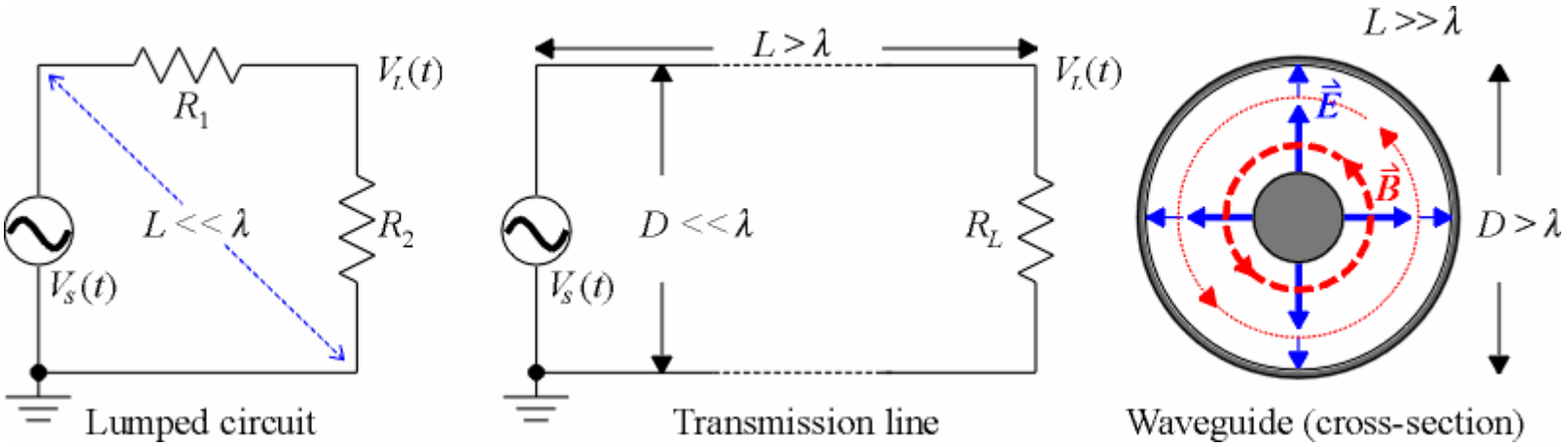
- To be an EE alumnus(alumna)

- To appreciate the beauty of the universal laws

Overview of EM

- Electric charges establish electric fields
- Moving charges become electric currents and create magnetic fields
- Timing-varying charges and currents cause the coupling between electric and magnetic fields such that they behave like “waves”

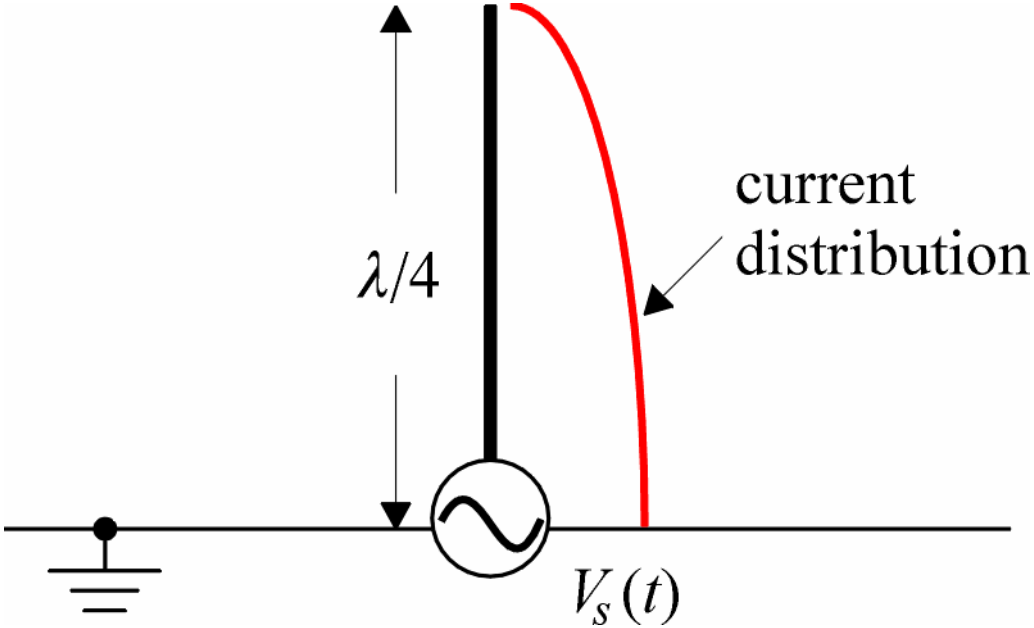
Types of EM problems



Analysis of EM problems

Conditions	Theory	Unknowns	Math tool	Description
$L << \lambda$	Lumped circuits Kirchhoff's laws	$V(t)$, $I(t)$	Ordinary differential equations (ODEs)	All points react to the source instantly
$L > \lambda$, $D << \lambda$	Transmission lines Kirchhoff's laws	$V(z,t)$, $I(z,t)$	Partial differential equations (PDEs)	Delay along the longitudinal (z) direction matters
$L >> \lambda$, $D > \lambda$	Waveguides Maxwell's equations	$\vec{E}(x,y,z,t)$, $\vec{H}(x,y,z,t)$	Full vectorial PDEs	Delay along the longitudinal (z), and transversal (x,y) directions matter

Example: Monopole antenna



- Lumped circuit theory: it's an "open circuit", no current can flow.
- EM theory: it may carry spatially nonuniform current.

Sec. 1-2
EM Model

1. Methodology
2. Our approach

Methodology

- Inductive(歸納) approach: Starting with observations of experiments, inferring laws and theorems (from particular phenomena to general principles)
- Deductive(演繹) approach: Starting with fundamental postulates, deriving particular laws and theorems, which can be verified by experiments

Our approach: Deductive

1. Defining the basic quantities:

(i) Electric charge q (e =1.6×10^{-19} C), volume charge density ρ (C/m^3)

(ii) Current I (C/s, or A), volume current density $\vec{J}$ (A/m^2)

(iii) Electric field intensity $\vec{E}$ (V/m): Electric force on a unit charge

(iv) Electric flux density $\vec{D}$ (C/m^2): Useful in studying electric field in materials

(v) Magnetic flux density $\vec{B}$ (T): Magnetic force on a charge moving with a given velocity

(vi) Magnetic field intensity $\vec{H}$ (A/m): Useful in studying magnetic field in materials

Our approach-2

2. Rules of operations:

   (i) Vector analysis

   (ii) Partial differential equations

3. Fundamental postulates: Maxwell equations and conservation of electric charges relate the source and field quantities. The solutions describe all the EM phenomena.