Lesson 01 Introduction

1.1 Basics

■ What is electromagnetics (EM)?

The study of electric charges at rest and in motion.

■ Overview of EM

Electric charges establish electric fields.

Moving charges form electric currents and magnetic fields.

Time-varying charges and currents cause the electric and magnetic fields are coupled in a way that they behave like “waves”.

■ Analysis of EM problems

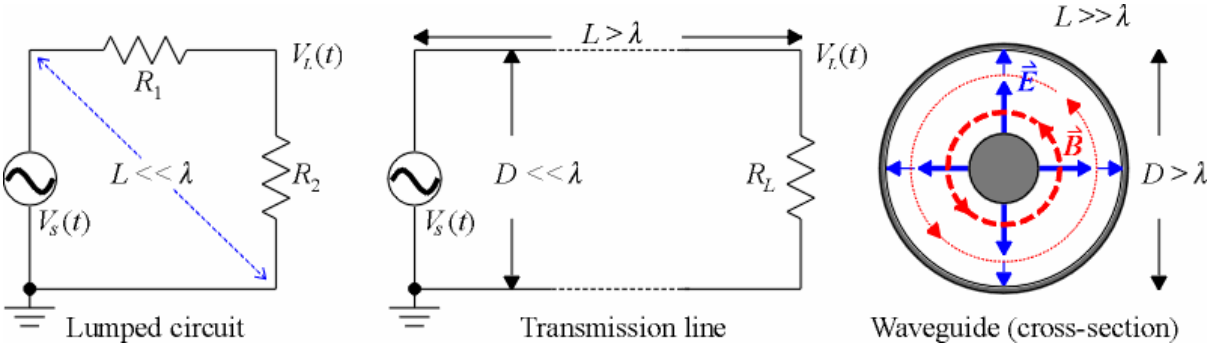

Fig. 1-1. Schematic diagram of different types of EM problems.

Tab. 1-1. Comparison among 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 exists
$L>>\lambda$, $D>\lambda$	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 exist

Example 1-1: A quarter-wave monopole antenna (Fig. 1-2) is regarded as an "open circuit" and cannot carry electric current according to the lumped circuit theory. However, the EM theory permits it carrying spatially nonuniform currents (DKC, Ch 11).

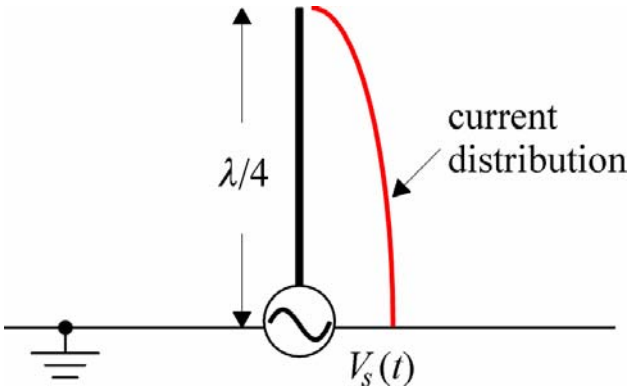

Fig. 1-2. A quarter-wave monopole antenna driven by a time-varying source may carry spatially nonuniform current.

1.2 Electromagnetic Model

■ Methodology

1) Inductive approach: starting with observations of experiments, inferring laws and theorems (from particular phenomena to general principles).

2) Deductive approach: starting with fundamental postulates, deriving particular laws and theorems, which can be verified by experiments.

We will take deductive approach to establish EM theory:

1) Defining the basic quantities: (i) Electric charge q (e=1.6×10^{-19} C), volume charge density $\rho = dq/dv$ (C/m^3). (ii) Current $I = dq/dt$ (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. Understand the meaning of physical quantities from their corresponding units.
2) Rules of operations: (i) Vector analysis (Lesson 5). (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.