Fundamentals of Electric Theory and Circuits

by

Sridhar Chitta

IK International Publishing House Pvt. Ltd.
4435-36/7, Ansari Road, Daryaganj
New Delhi – 110 002 (India)
Email: info@ikinternational.com Website: www.ikbooks.com
(2019)

The CD and contents

This book was initially conceived as a power point presentation with animations. Very few textbooks in electricity and magnetism use the power of the visual image to convey the principles of these two fascinating forms of pure energy and their fascinating twists and turns in circuits. The richness in the electric and magnetic processes is blurred in the seemingly meandering descriptions in several quality text books. A few visual aids are available but these are dispersed in so many locations on the internet that students find it difficult to piece together a meaningful knowledge base.

When I showed the presentation to a few colleagues, they felt enthused and suggested the preparation of a text book containing descriptions of several topics that cannot be discussed in detail in the presentation. The book's appeal would be enhanced with the power point presentation adding a new dimension to students' learning, engaging students not just through words, but also through visuals.

The power point presentation was developed on Windows "Office XP" Professional and uses the rich features of XP power point such as custom animation with entrance, emphasis, exit and motion paths.

Folder

Power_Point_Presentations

There are 12 parts to the Power Point presentation organized to correspond to the contents of the 10 chapters of the book. Also included are Power Point presentations with animations on the operation of a D.C Regulated Power Supply, Transformer coupled Audio Power amplifiers and the basic action of a Differential Amplifier which is the heart of an Operational Amplifier.

The presentation for the **first chapter** is covered in **3 parts:**

Chapter 1: Part 1: Number of slides: 115 (Automatic slide transition - 83 minutes)
Nature of the electric field; types of potential energy; electrostatic potential energy; conversion of energy; visualizing electric field at points in space; potential energy of electric fields; charge conservation and neutrality; dipoles; atomic and molecular dipoles; neutral atoms; visualizing a conductor and neutrality in metals; metallic structures; potentials in conductors and Seeing atoms.

Chapter 1: Part 2: Number of slides: 16 (Automatic slide transition - 8 minutes)
Effects of the electric field; polarization of atoms; electric field in metals and dielectrics; the induced dipole.

Chapter 1: Part 3: Number of slides: 65 (Automatic slide transition - 37 minutes)
Current; conductors, resistors; Action of a battery; Surfaces charges and conduction process; electric field inside metallic wires and current; The Drude Model and the Drift Speed of electrons; Mechanical battery simulates the action of a chemical battery; Visualizing current; Working definition of current.

Chapter 2: Number of slides: 106
Capacitors in circuits: Discharging and charging; visualizing the accumulation of charges on capacitor plates; Applying a pulse input to a capacitor-resistor combination; Applying a sinusoidal voltage to a capacitor; What is voltage ?; Conservative and non-conservative fields; Visualizing voltage and Working Definition of Voltage; Capacitance of a single conductor; Capacitance of the earth; Average electric field inside matter, conductors and dielectrics; Introduction to magnetic fields.

Chapter 3: Number of slides: 59
Discharge of a charged capacitor; A DC voltage applied to a charged capacitor and resistor; Applying a sinusoidal voltage to a charged capacitor and resistor and TINA simulation runs of voltage and current; sinusoidal voltage superimposed on a dc voltage and TINA simulation run; coupling ac signals to a common-emitter amplifier.

Chapter 4: Number of slides: 55
Where is the electrical energy ?; Is electric energy carried by individual electrons ?; Real burden of signal and energy transfer; Where is the energy?; Energy of a two-charge system; Energy in a circuit; Energy of electric and magnetic fields.

Chapter 5: Number of slides: 110
The Biot-Savart Law; Magnetic field of a moving charge; Magneto motive force and Magnetic Field strength; Magnetic field of a current; Faraday's Law; Solenoids and Inductors; Curly electric fields; Conservative and Non-conservative fields; Current in an inductive circuit to a sinusoidal input; inductor response to sinusoidal input of various frequencies; detailed view of current lagging the voltage in an inductor; sinusoidal input to a inductance (L) and resistor (R) combination; LR combination as a low-pass filter; currents without a voltage; producing high voltages using inductors; Seeing atoms.

Chapter 6: Number of slides: 72
Magnetic forces; Magnetic forces on a moving charge; Magnetic force on a current carrying wire; Magnetic forces do no work; who does the work when a current loop in a magnetic field suspends a mass; Action-at-a-distance vs. Aether theories; Birth of Classical Electrodynamics.

Chapter 7: Number of slides: 78
Faraday's Law ; The Magnetic Field; Faraday's Law applied to stationary coupled coils; Faraday's Law applied to moving coils; Faraday's Law or Lorentz Force Law ?; Motional emf; Generating emf in rotating machines; Unidirectional emf; Load of a Generator; Generators and Microphones; Energy conservation in Generators.

Chapter 8: Number of slides: 71
Motional emf; Motor current and back emf; Potential energy of magnetic moment; Charge and electrostatic potential energy; rotation and torque production in motors; How does the conductor move; Motor construction and mounting; Load Torque; Motor torque and effect of load torque on motor rpm and current; Motor and types of loads; Torque and speed characteristics of motor and loads; Start to Steady-state; Selection of motors; How do invisible lines of force carry Momentum and Energy ? Like moving objects ?; Magnetism as a relativistic effect.

Chapter 9: Number of slides: 69
Role of surface charges in operation of diodes; pn junction fabrication and formation of the transition (depletion) region; types of charge carriers in diodes; a diode in forward bias; potential and kinetic energies of electrons; increasing forward bias and large forward bias; a diode in forward bias; a diode as a rectifier; nonrectifying or ohmic contacts; a diode in reverse bias; current flow at the metal to semiconductor (n-type and p-type) material of a diode; peak inverse voltage ratings of diodes.

Chapter 10: Number of slides: 12
Animated slides showing Standing wave of antenna voltage and current; Receiving Antenna - Incident electromagnetic wave, Electric field in the antenna conductor, Standing wave of voltage and current, Current flow in radio receiver.

Regulated Power Supply: Number of slides: 76 (Automatic slide transition- 61 minutes)
DC Power supply, Transformer section; Construction and Step-down transformer operation; AC to DC rectification-Bridge rectifier, Capacitor Filter, Unregulated Voltage, Regulated Power Supply, Transistor operation, Transistor series-pass, Control of the series pass transistor voltage drop, Operation of the regulator: input voltage increase and input voltage decrease, Speed of operation of the series pass transistorized voltage regulator; IC fixed voltage regulator.

Transformer coupled Audio power amplifiers: Number of slides: 59 (Automatic slide transition – 29 minutes)
Drawback of connecting a load (a loudspeaker coil) directly to the collector of a transistor amplifier; Impedance mismatch and use of a transformer to match loads with transistor collector outputs; Construction and operation of Audio transformers; transformer operation; Reflected impedance of transformer; Derivation of reflected impedance equation; Loudspeaker construction and principle of operation; Impedance matching and Maximum Power Transfer; Determining turns ratio of an audio transformer for a transistorized Class A power amplifier.

Basic Action of a Differential Amplifier-Heart of the Opamp: Number of slides: 81
(Automatic slide transition – 39 minutes)
Principle of U-Tube Manometer (as an analogous action of a differential amplifier); Operational Amplifiers – Applications and Design, Opamp – Design Principle; Designing a Differential Amplifier; Differential-mode and Common-mode Action; Rejection of Common-Mode signals, Enhancements to Basic Design, FAQs.

Folder

Additional Practice Questions for all Chapters

The folder contains a pdf file set of questions for all chapters. The questions have been carefully selected from standard textbooks and from Ruth W. Chabay and Bruce A. Sherwood, *"Electric and Magnetic Interactions",* John Wiley, USA, 2011. The questions are aimed to stimulate visualization of practical aspects circuit processes and in spatial imagery related to electric and magnetic fields. Numerical problem solutions to several questions may be found in the textbooks referred.
Also included in this folder is an article "*Determining the Atomic Number and Avogadro's Number*" which describes how scientists found a reliable and accurate method by making use of the periodic table and experiments to estimate the number of atoms in various elements.

Folder

PDF_files

Instructions to view the ppts – pdf file
Contains detailed instructions on system requirements to view the ppts and the slide transitions.

Links_to_animations_articles – pdf file
Contains links to animations and articles on selected topics from the chapters nad appendices in the textbook that will enhance the learning experience.
The links may be copied and pasted in the URL box in internet webpages directly and viewed.

Recommended_books_for_libraries – pdf file
Contains a list of books the author recommends for Engineering and Science College Libraries. The selected books are meant to serve as a ready reference for both faculty and students and contain descriptions of the foremost theories of Electricity and Magnetism.

What_ is_e_in_diffl_equation_solutions – pdf file
Several times when we solve differential equations, we encounter '*e*' and we rarely stop to figure out what this strange looking constant is and what is its interpretation. It is really not such a difficult concept to understand as described in the article.

Growth of electric field – pdf file
Contains screen shots of growth of electric field around a dipole at various separation

distances

Potential around a pair of charges – pdf file
This file contains screen shots of the potential contours including equipotential surfaces of a pair of point charges. It shows the large potential variations near a point charge and which range in kilovolts. An example is provided that illustrates the existence of a potential in a region where there is zero electric field.

Simulation_super_ac_sig_on_dc_volt – pdf file
Contains detailed instructions to download simulation software and programming it for a demonstration of the superposition of ac signals on a dc voltage described in Chapter 3

RC phase shifters – pdf file
Phase shifts achieved by RC phase shifting networks are best demonstrated by the RC Phase shift oscillator. In this article, a simulation of the operation of the phase shift network is described using simulation software with 3 different simulations. Lastly, the simulation of a Phase shift Oscillator is described.

The speed of light waves in glass – pdf file
The speed of light is universally equal to c and therefore it would be wrong to state that light slows down in glass as is commonly explained in several textbooks. The article explains how light *apparently* slows down in glass.

Charge Densities and Continuity and Prop of em signals in wires – pdf file
In courses of electric circuits, transmission lines and electronic circuits, one frequently encounters different situations which involve visualizing the formation, motion and decay of volume and surface charge densities. Is the process steady as in the wires of a simple dc electrical circuit ? Is the process transient prior to reaching a steady-state ? Or is it a quasistatic situation ? Are the charges "excess" or are they the charges of the material itself or are the charges termed "excess" when they have migrated from other portions of the closed system comprising a circuit and all its elements. These aspects and the application of the conservation of charge principle to obtain the continuity equation are described in the first section of the paper.
The continuity equation for steady dc current in a wire is usually not described in circuit theory textbooks and the only exposure students get is in a course in semiconductor circuit theory when they learn the derivation and application of the continuity equation in semiconductors to obtain the mean distance of travel of carriers before recombining and so on.
Therefore, I have described in the first section the application of the conservation of charge principle to obtain the continuity equation for steady dc currents in conductors.

The second section describes a paper written by A. K. T. Assis on the propagation of em signals in straight wires which is based on a paper by Kirchhoff. Using modern notation Assis traces the steps followed by Kirchhoff in showing that signals propagate in straight wires under certain conditions at the velocity of light. The entire derivation is based on Weber's force law (without a field concept) which is an Action-at-a-distance theory based law.

Waveguide Attenuation and Impedance
The paper provides a discussion on the mechanism of *attenuation* of electromagnetic waves by waveguides at frequencies below cutoff (f_c) and using lumped-element equivalent circuits in filter theory describes an intuitive way to understand wave impedance.

MATLAB_programs_efield_thin_rod_and_invisible_tape - Word file

Programs - electric field due to charged thin rod

The electric field of a charged thin rod can be calculated by dividing the charge distribution into small pieces and finding the electric field at a point in space of each of these pieces. Then, by applying the Principle of Superposition of electric field, the resultant field at the point can be computed.
Two MATLAB programs that calculate separately the electric field due to a charged thin rod by this procedure is provided in the file.
The first program assumes that the rod is divided into 10 pieces and the second program assumes that the rod is divided into 100 pieces. The program can be directly copy pasted into the Command Window of MATLAB and run.
The number of slices and a few other parameters may be changed as indicated in the comments with the program. For larger and larger numbers of slices the computer results approach a constant value.

Program - electric field due to charged invisible tape

The electric field of a charged invisible tape can be calculated by dividing the charge distribution into small rectangular pieces and finding the electric field at a point in space of each of these pieces. Then, by applying the Principle of Superposition of electric field, the resultant field at the point can be computed.

A MATLAB program that calculates the electric field due to a charged invisible tape by this procedure is provided in the file. The program assumes that the tape is divided into 100 pieces. The program can be directly copy pasted into the Command Window of MATLAB and run.

Folder
Teacher's Guide

Prof. Härtel A qualitative approach to electricity A Guide to visualization of electrodynamics – pdf file

Contains a guide prepared by Prof. Hermann Härtel on the visualization of electrodynamics using symbols and images suitable for 1st and 2nd year students pursuing an undergraduate courses leading to a Degree in Electronics, Electrical Engineering and for undergraduate courses leading to a Degree of Science in Electronics.

Folder

Transmission Line Simulation Program

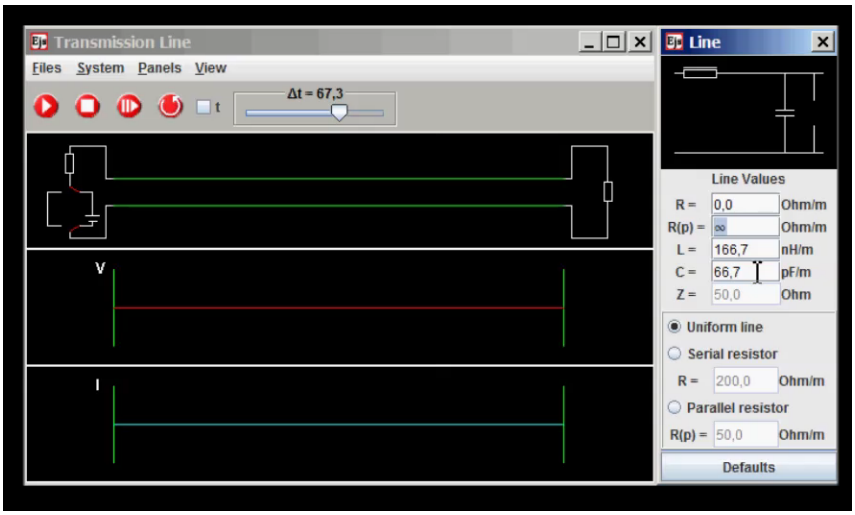
Contains a file “Transmission Processes in Linear Systems” which presents instructions to run simulations of a transmission line excited by sine waves, pulse trains and triangular waves. Also contains an executable jar file “TL” (Java based) to run the interactive animation of the simulation of a transmission line. The simulation program and the instructions were prepared by Prof. Hermann Härtel.

A video “User Guide” with voice over which describes the use of various menu commands and pop-up panels of the user interface is also included in the folder.

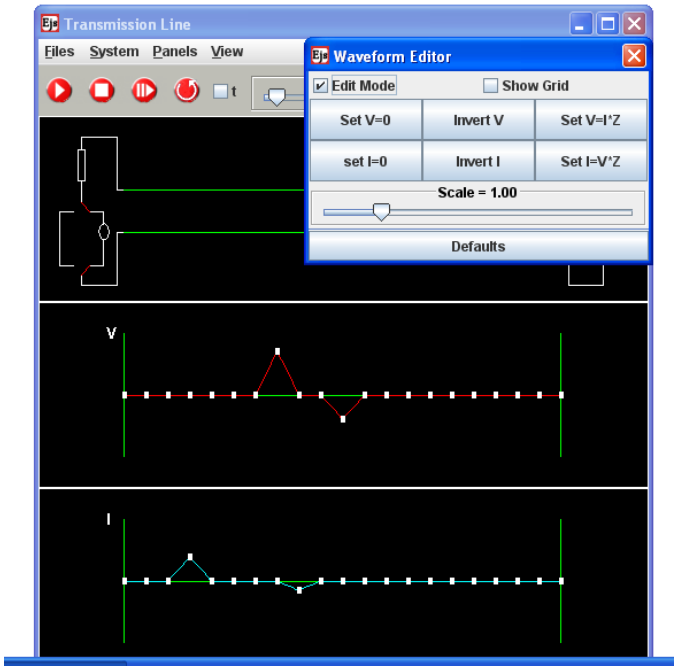
These files may also be viewed online here
1) Transmission Processes in Linear Systems
http://www1.astrophysik.uni-kiel.de/~hhaertel/TL/TL-tutorial/TL-uk.pdf
2) The simulation program is available for download by clicking “Simulation program TL.jar (zip-file for downloading)” in the webpage http://www1.astrophysik.uni-kiel.de/~hhaertel/index_e.htm
3) http://www1.astrophysik.uni-kiel.de/~hhaertel/Videos/TL-uk.mp4

Screen Shots of Simulation Program

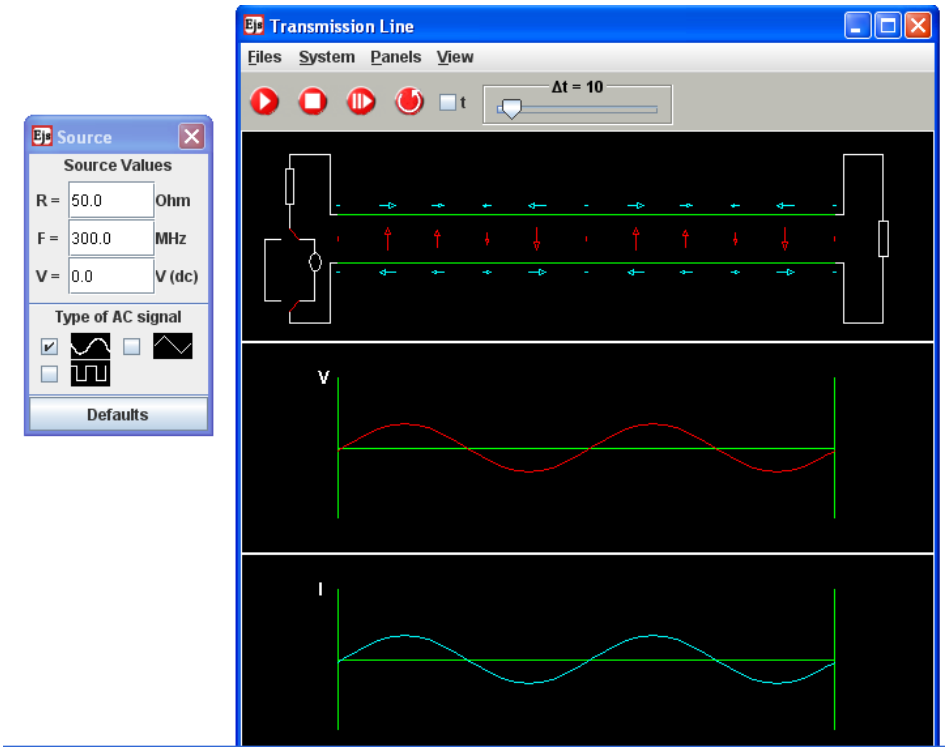
Setting up the Line parameters



Setting up initial conditions of the line



Line excited by a sinusoidal voltage generator



Folder
Videos by Prof Härtel

Contains a set of seven videos by Prof. Hermann Härtel that depict the field lines of a charge particle moving with uniform velocity, accelerating and in oscillatory motion.
Also contains a pdf file "Härtel Videos of charge particle in motion" which describes how the videos were made.

Dr. Hermann Härtel, using the basic ideas of Leigh Page's (Yale University) emission theory, which include relativity effects, developed an algorithm for preparing simulation programs to visualize processes of charged particles in uniform motion, accelerating and interacting with another particle, like those in the Berkeley Physics Course and many other similar processes. The program was developed at the IPN-Kiel, called XYZET in March-April 2017. The full set of seven videos is available in the folder "Videos by Prof Härtel".