Fundamentals of Electric Theory and Circuits

by

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Links to animations and webpage articles in the textbook

I viewed the animations in the Mozilla Firefox browser, since Google Chrome has stopped support for several animation files and Java based applets.
Some of the animations may need **Java** and this can be downloaded and installed in your computer. To do this, go to www.java.com and download (click the Free Java Download button), follow the instructions and install.

Whenever an animation requires Java it may prompt you to run in a dialog box and then you click "Run this time".
Sometimes you may need to configure Java to allow the animation to run, for example the wave particle animation in http://nagysandor.eu/Phys2000/waves_particles/wavpart2.html
To do this, after Java is installed, Click Start>Programs>Java>Configure Java. The Java Control Panel will open. Click the "Security" tab on the top and in that click "Edit Site List" then click "Add" and enter the URL http://nagysandor.eu. It is not necessary to enter the complete URL http://nagysandor.eu/Phys2000/waves_particles/wavpart2.html.
Entering nagysandor.eu would be sufficient.
If files have **broken links**, try **accessing these in web.archive.org.**
Some of the animations may require (Adobe) **Shockwave player** to run which may be downloaded from here http://get.adobe.com/shockwave/ and then installed. Some animations (especially the .dcr files) will require the software "**Shockwave for Director**". Some video files will play in **QuickTime Plug-in 7.7.3**.

Chapter 1

Section 1.1
1) *A Unified Treatment of Electrostatics and Circuits* by Ruth W. Chabay and Bruce A. Sherwood, Center for Innovation and Learning and Dept. of Physics, Carnegie-Mellon Uiversity, Pittsburgh, PA, 1999.
https://matterandinteractions.org/wp-content/uploads/2016/07/circuit.pdf
Can also be accessed through https://matterandinteractions.org/articles-talks/

Section 1.4
2) Videogame with charges – MIT, USA

http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/electrostatics/38-videogame/38-EMVideoGame320.html

Section 1.6
3) Electric field surrounds a charge
http://www.falstad.com/vector3de/

Section 1.7
4) The basic phenomena of electricity through simple experiments performed with low cost materials covers making electroscope, versorium, electric pendulum, bending a stream of water by static electricity and more.
Andre Koch Torres Assis, *The Experimental and Historical Foundations of Electricity*
http://www.ifi.unicamp.br/~assis/Electricity.pdf and
http://www.ifi.unicamp.br/~assis/Electricity-Vol-2.pdf

5) Electric Energy and potential
http://physics.bu.edu/~duffy/PY106/Potential.html
http://regentsprep.org/Regents/physics/phys03/apotdif/
Alternate sites: https://kaiserscience.wordpress.com/physics/electromagnetism/electric-fields-and-potential/
https://web.archive.org/web/20161120035609/http://regentsprep.org:80/Regents/physics/phys03/apotdif/

Section 1.9
6) CONSTANT ELECTRIC CURRENT AND THE DISTRIBUTION OF SURFACE CHARGES1 by Hermann Härtel, Guest scientist at Institute for Theoretical Physics and Astrophysics, University Kiel
http://www1.astrophysik.uni-kiel.de/~hhaertel/PUB/voltage_IRL.pdf

Section 1.10
7) Plotting charges and field lines – MIT, USA
http://ocw.mit.edu/ans7870/18/18.013a/textbook/HTML/chapter28/section04.html

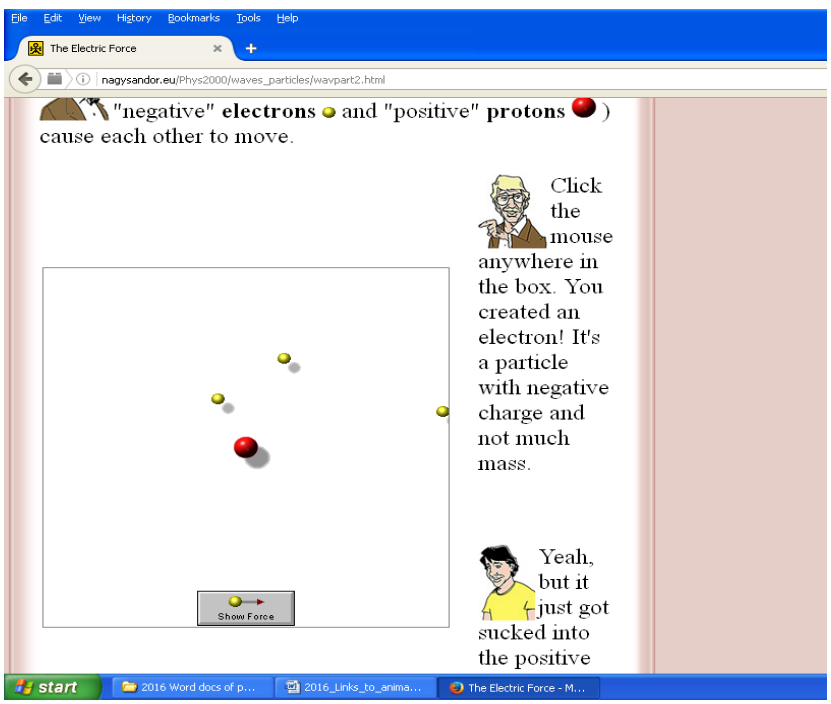
Another webpage link
http://www.falstad.com/vector3de/

In the first drop down list select "dipole"
In the second drop down list select "display field lines".
By default you will see the field lines between the dipole. Notice the electric field surrounding the dipole.
Now, **reduce** the "charge separation" by adjusting the scroll bar.
Notice how the field in the surroundings reduces until the field (resultant, of course, since the field due to a charge always exists) in the surroundings becomes zero.....like a neutral atom ! Of course in a real atom you can never make the field zero in the surrounding space assuming that the positive of the dipole is the nucleus and the negative charge of the dipole is the electron cloud of all the electrons of the atom.
Now again increase the "charge separation" by adjusting the scroll bar and note how the field grows in the surrounding. You have created an electric field (resultant of course) in

the surrounding space and a small tiny battery ! which has a voltage because potential difference between two points A and B in this field will be Integral E.dl moving between points B to A.
Link to a movie showing the growth of electric field in the space surrounding a pair of unlike charges (creating an electric dipole)
http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/electrostatics/14-PithBallsCreate/14-PithCreate_f127_320.html
http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/electrostatics/14-PithBallsCreate/PithCreate_640.mpg

8) For a nice introduction to field lines and flux
http://web.mit.edu/sahughes/www/8.022/lec02.pdf

Section 1.13
9) Making an atom –
http://web.archive.org/web/20060425113223/http://www.colorado.edu/physics/2000/waves_particles/wavpart2.html
http://nagysandor.eu/Phys2000/waves_particles/wavpart2.html



Original page http://www.colorado.edu/physics/2000/waves_particles/wavpart2.html here is shifted.

10) Potentials of charges –
http://web.archive.org/web/20100726004002/http://faculty.wwu.edu/vawter/PhysicsNet/Topics/ElectricPotential/PointCharges.html
Original page
http://faculty.wwu.edu/vawter/PhysicsNet/Topics/ElectricPotential/PointCharges.html
To view more, scroll down to the bottom and click on “Show Topics Menu Frames”.

Or, see the pdf file **"Potential around a pair of charges"** in the CD.

Section 1.15

11) **Volume charge densities in wires**

Comments
In Section 1.1 we learned there is a surface charge density in a wire in the steady-state. While Ohm assumed that with a DC current there is a uniform distribution of volume charge density throughout the body of the conductor, Kirchhoff (1850) showed that for DC currents in the steady-state, the excess charge can only exist at the surface of a conductor.

12) An experimental demonstration of the presence of surface charges in circuits
https://matterandinteractions.org/surface-charge-demo/.

Section 1.17
13) No net motion
http://freevideolectures.com/Course/2325/Solid-State-Devices-IIT-Madras/12

Section 1.18
14) Effect of raising the temperature on lattice ions
https://web.archive.org/web/20031121164042/http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/thermochem/eqilibrium-v1.html
https://web.archive.org/web/20110505231525/http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/thermochem/eqilibrium-v1.html
http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/thermochem/eqilibrium-v1.html

15) Animation - Atomic level views: shearing a metal, bending a metal and applying heat to a metal
To view an animation of metal shear (move), atoms slipping over, metal bending and when a metal's temperature is raised visit
http://www.pbs.org/wgbh/nova/wtc/meta-flash.html or
http://www.pbs.org/wgbh/nova/tech/structure-of-metal.html
and click "Launch Interactive".
Click the tabs "move", "slip", "bend" and then "heat" and with each tab window open click "apply force" to view how the atoms are shifted and vibrate with heat.
To raise the temperature in the tab "heat" move the cursor to the top + and bottom - of the Heat scale and change the amount of heat.

Section 1.19
16) video of Ball and Spring Model
https://www.youtube.com/watch?v=p6VeDd0ukXI&feature=youtu.be

For videos of lecture demos of Observing Surface Charge

https://matterandinteractions.org/videos-of-lecture-demos/
Click on "Observing surface charge". It will take you here
https://www.youtube.com/watch?v=U7RLg-691eQ&feature=youtu.be

View another video on surface charges by clicking "Charged straw near a high-voltage circuit". It will take you here http://www.astrophysik.uni-kiel.de/~hhaertel/PUB/straw.htm

17) Analogy between a water circuit and an electric circuit given under the supervision of Prof. Hermann Haertel in this link
Quite a few examples of water models can be found in textbooks with continuously running pumps to be used as analogy to the flow of free electrons within an electric circuit, but, *water models suffer in one important aspect*: the ratio between the kinetic energy of the flowing water and the size of the driving forces or pressure difference. In the *electric case this ratio is huge*.
http://www.astrophysik.uni-kiel.de/~hhaertel/PUB/syringe.htm

Section 1.24
18) animation at ionic level in a galvanic (electrochemical) cell
http://www.chembio.uoguelph.ca/educmat/chm19105/galvanic/galvanic1.htm
Follow the instructions in the webpage.

Section 1.25
19) Interactive surface charge and electric field configurations of isolated and grounded metal blocks, simple circuits and solenoids.
tinyurl.com/SurfaceCharge

Chapter 2

Section 2.2
1) Electric field of two charged plates
http://www.nickswebpage.com/cacci6_32112/phy-webpages/phy214/214workbook/4-Wkb3ch3c&schap%27s3&4.htm
2) Discharging a capacitor – a poster
https://matterandinteractions.org/wp-content/uploads/2016/07/SurfaceChargePoster.pdf
3) For a nice introduction to field lines and flux
http://web.mit.edu/sahughes/www/8.022/lec02.pdf

Section 2.7
4) Charging a capacitor
http://amasci.com/emotor/cap1.html

5) What is the mathematical constant 'e' ?
http://betterexplained.com/articles/an-intuitive-guide-to-exponential-functions-e/
The classic lecture by Prof. Gilbert Strang of MIT.
https://www.youtube.com/watch?v=oo1ZZlvT2LQ

Definitions and the number e
https://www.youtube.com/watch?v=8HpvEANFQ7Q
How they Invented Logarithms
https://youtu.be/FB3_BeukBBk
Logarithms: What problem was Napier trying to solve?
https://www.youtube.com/watch?v=cMA8m6upFPM
6) Ordinary Differential Equations and their solutions
Supplementary notes by Prof Haynes Miller, Department of Mathematics, MIT, USA
"Differential Equations are the language in which the laws of nature are expressed. Understanding properties of solutions of differential equations is fundamental to much of contemporary science and engineering."
http://ocw.mit.edu/courses/mathematics/18-03-differential-equations-spring-2010/readings/supp_notes/MIT18_03S10_sup.pdf

For a complete list of selected video lectures by Prof. Gilbert Strang of MIT, USA see the section "Mathematics video lectures" at the end of this file.

Section 2.8
7) Energy stored on a capacitor
http://230nsc1.phy-astr.gsu.edu/hbase/electric/capeng.html

Section 2.11
8) How the important identity $e^{j\theta} = cos(\theta) + j\,sin(\theta)$ came about
https://ccrma.stanford.edu/~jos/mdft/Proof_Euler_s_Identity.html

Section 2.13
High pass filter output waveforms- computer simulation generated
9) https://oceanpython.org/2013/03/11/signal-filtering-butterworth-filter/
10) http://archives.sensorsmag.com/articles/0203/33/main.shtml
11) http://stackoverflow.com/questions/7105962/how-do-i-run-a-high-pass-or-low-pass-filter-on-data-points-in-r

Section 2.14
12) Is a closed path necessary for charge to flow ?
http://amasci.com/emotor/cap1.html

Section 2.19
13) EMF, circuits and Kirchhoff's laws
http://ocw.mit.edu/high-school/physics/electric-circuits/steady-state-direct-current-circuits-batteries-resistors/8_022_fall_2004_lecture8.pdf

14) Lighting a fluorescent lamp using an electric field
View from the 42nd minute.
https://www.youtube.com/watch?v=5aQdZ26uR7E
Or search Lec 04: Electrostatic Potential and Electric Energy | 8.02 Electricity and Magnetism (Walter Lewin)

Else, visit http://web.mit.edu/smcs/8.02/

Section 2.21

15) Excess charges on a conductor
http://www.physicsclassroom.com/class/estatics/Lesson-2/Charging-by-Conduction

16) Current flow
http://amasci.com/miscon/voltage.html

17) Low *k* dielectric materials
http://www.sciencedirect.com/science/article/pii/S1369702104000537

18) Self and Mutual Capacitances
William R. Smythe, *Static and Dynamic Electricity*, McGraw Hill, 1950
https://ia800209.us.archive.org/18/items/StaticAndDynamicElectricity/Smythe-StaticAndDynamicElectricity.pdf

Section 2.26
19) Electric field of a charged capacitor
http://www.falstad.com/emstatic/index.html

20) Low *k* dielectric materials
http://www.sciencedirect.com/science/article/pii/S1369702104000537

Section 2.27
21) For a nice introduction to field lines and flux
http://web.mit.edu/sahughes/www/8.022/lec02.pdf

Chapter 3

Section 3.3
The webpages show how functions (periodic) can be represented using series, basically, you keep adding up small numbers (series) until it represents complicated functions.

1) Fourier Series
Any arbitrary waveform of engineering importance may be resolved into a Fourier spectrum. If the waveform is periodic, the spectrum will consist of a series of sines and cosines whose frequencies are all integral multiples of a fundamental frequency.
A Fourier series is a sum of sinewaves and cosinewaves of different amplitudes and frequencies whose summation can approximate any periodic function.
Check http://www.sosmath.com/fourier/fourier2/fourier2.html scroll down to view the animations seeing at the top of the animation box the no. of terms 'n' of the series and how as the number of terms increases the function is more accurately represented.
For another animation of the Fourier series representation of a step function (rather a periodic pulse train) visit

http://www.math.ubc.ca/~feldman/demos/demo3.html
For series animation of sin(x), visit
http://wims.unice.fr/wims/ and visit the Home Page
 a) click "Online Calculators and Plotters"
 b) click Animated Sequences
 c) click …"If you don't have a sequence ….try some Examples
 d) click on 2) example that of sinx ..see
 e) click back button of browser to go back to prev. page
 f) click on 10 terms: Fourier series: the development of a saw-tooth wave. See it with 10 terms or 50 terms
 g) click on 30 terms: And the development of a square wave. See it with 10 terms or 30 terms

Section 3.5

2) Superposition - Thevenin and Norton
http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-and-electronics-spring-2007/video-lectures/lecture-3/

3) How does a battery work
http://engineering.mit.edu/ask/how-does-battery-work

4) Voltage and Current Sources
https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-01-unified-engineering-i-ii-iii-iv-fall-2005-spring-2006/signals-systems/S5_mud.pdf

http://www.ee.sc.edu/personal/faculty/simin/ELCT102/13%20Voltage%20and%20Current%20sources.pdf

Notes on current sources in a communication (2006) by Prof. D.H. Johnson, Rice University, Houston, USA
An ideal current source produces electrons without needing a voltage. An ideal current source sitting on the table would spit electrons out into space! That's why the resistor is in parallel, to give the *electrons somewhere to go* AND *return them to the source.*

On more technical grounds, a high-resistance voltage source is more conveniently modeled as a non-ideal current source since it seems to be producing the same current (and not the same voltage) when different resistances (having values less than the source resistance) are attached.
(Italics are by Sridhar Chitta).

Chapter 4

Section 4.1
1) Bicycle wheel analogy
http://amasci.com/miscon/eleca.html#batt2

2) Waves – animation
http://www.glenbrook.k12.il.us/GBSSCI/PHYS/mmedia/waves/lw.html
See power point slide

Section 4.2
3) Batteries and generators " pump " electrons
http://amasci.com/miscon/eleca.html#batt2

4) Energy carried by moving electrons
http://www.st-andrews.ac.uk/~www_pa/Scots_Guide/audio/part6/page2.html

5) Analogy between a water circuit and an electric circuit given under the supervision of Prof. Hermann Haertel in this link
http://www.astrophysik.uni-kiel.de/~hhaertel/PUB/syringe.htm

6) Poynting Theorem and how it can be derived by manipulating Maxwell's equations to produce products of variables that have the dimensions and character of power or energy - David H. Staelin, MIT article *Electromagnetics and Applications*, 2011.
Section 2.7, Chapter 2, *Introduction to Electrodynamics*
http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-013-electromagnetics-and-applications-spring-2009/readings/MIT6_013S09_notes.pdf

7) Introduction to Elementary Particles
David J. Griffiths, *Introduction to Elementary Particles*", 2004 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim

8) Quantum electrodynamics
https://www.youtube.com/watch?v=YHTt6LGW9s0

9) Quantum Field Theory
https://www.youtube.com/watch?v=mBFDp-ppG6I

Section 4.3
10) In a circuit why are two wires needed
http://amasci.com/elect/elefaq1.html

Section 4.4
11) Igal Galili and Elisabetta Goihbarg, *Energy transfer in electrical circuits: A qualitative account*, Am. J. Phys., Vol. 73, No. 2, February 2005
Section 4.5
12) Simulations of charges in simple circuits
http://web.archive.org/web/20120115080730/http://galaxy.cofc.edu/circuits.html
or
http://www.colorado.edu/physics/phys3320/phys3320_sp12/AJPPapers/AJP_E&MPapers_030612/Preyer_SurfaceCharges.pdf

Section 4.7

13) Maxwell's Treatise on Electricity and Magnetism Vols. 1 and 2
Vol. 1
http://www.aproged.pt/biblioteca/MaxwellI.pdf
https://ia802302.us.archive.org/25/items/ATreatiseOnElectricityMagnetism-Volume1/Maxwell-ATreatiseOnElectricityMagnetismVolume1.pdf
Vol. 2
https://ia800304.us.archive.org/9/items/ATreatiseOnElectricityMagnetism-Volume2/Maxwell-ATreatiseOnElectricityMagnetismVolume2.pdf

14) Animations of waves – longitudinal waves without transport of matter
http://www.physicsclassroom.com/mmedia/waves/lw.cfm

15) Animations of em waves propagating from an oscillating dipole
Visit www.falstad.com and click in succession "Maths and Physics Applets" ->in electrodynamics - "2-D Electrodynamics applet-TE" and then in the applet window select Setup: Oscillating dipole and select 1 antenna source and then show Elines/B/j.
See the pulsations of the electric field and the radiation patterns.
You can also see the radiation pattern around a Setup Half-wave antenna.

16) Animations of travelling waves without the medium moving
http://phet.colorado.edu/sims/wave-on-a-string/wave-on-a-string_en.html
http://www.animations.physics.unsw.edu.au/jw/waves_superposition_reflection.htm

17) Demonstration of lighting an electric bulb by a receiving antenna
https://www.youtube.com/watch?v=Hd29jEaGERk

18) Doppler shift – frequency and wavelength of a wave like signal depends on the movement of the sender and receiver
http://www.aplusphysics.com/courses/regents/waves/regents_wave_phenomena.html
Folllow this link for a nice explanation with animation of the Doppler shift.
http://www.einstein-online.info/spotlights/doppler

19) An em wave travels slower than the speed of light in media other than free space with a change in wavelength without its frequency being affected
http://www.madsci.org/posts/archives/may98/893732585.Ph.r.html

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Chapter 5

Section 5.2
1) Magnetic field of a current line and current loop
http://www.falstad.com/vector3dm/
Field selection: Current line and Display: Field vectors or Field lines to view the magnetic field of a current line.

Field selection: Current loop and Display: Field vectors or Field lines to view the magnetic field of a current loop.

Section 5.5
Faraday's original "Experimental Researches in Electricity in 3 Volumes
2)
https://docs.lib.noaa.gov/rescue/Rarebook_treasures/QC503F211839_PDF/QC503F211839v1.pdf
https://docs.lib.noaa.gov/rescue/Rarebook_treasures/QC503F211839_PDF/QC503F211839v2.pdf
https://docs.lib.noaa.gov/rescue/Rarebook_treasures/QC503F211839_PDF/QC503F211839v3.pdf

Section 5.7
3) Magnetic field of a solenoid
http://www.falstad.com/vector3dm/
Field selection: Solenoid and Display: Field vectors or Field lines to view the magnetic field of a current line.

Section 5.8
4) Curly electric field associated with a changing magnetic field
http://www.glowscript.org/#/user/matterandinteractions/folder/matterandinteractions/program/22-Faraday-coil

5) More animations list
http://www.glowscript.org/#/user/GlowScriptDemos/folder/Examples/program/MatterAndInteractions

Section 5.9
6) Demonstration of non-conservative fields
https://www.youtube.com/watch?v=FUUMCT7FjaI
http://www.youtube.com/watch?v=G3eI4SVDyME
http://ocw.mit.edu/ans7870/hs/physics/8.02/8.02-s02-vl16.ram

7) Derivation of unequal voltages across a parallel circuit subject to a time-varying magnetic field
https://www.karmanotes.org/note/massachusetts-institute-of-technology/electricity-and-magnetism-358/lecsup315pdf

Section 5.19

Low- pass filter output waveforms- computer simulation generated
8) https://oceanpython.org/2013/03/11/signal-filtering-butterworth-filter/
9) http://archives.sensorsmag.com/articles/0203/33/main.shtml
10) http://stackoverflow.com/questions/7105962/how-do-i-run-a-high-pass-or-low-pass-filter-on-data-points-in-r

Section 5.22

11) **Volume charge density in wires and conductors**

Comments

In Section 1.1 we learned there is a surface charge density in a wire in the steady-state. While Ohm assumed that with a DC current there is a uniform distribution of volume charge density throughout the body of the conductor, Kirchhoff (1850) showed that for DC currents in the steady-state, the excess charge can only exist at the surface of a conductor.

I urge the reader to read the document "**Charge Densities and Continuity in Conductors and Semiconductors and The propagation of Electromagnetic signals in straight wires**" in the folder pdf_files before reading the rest of the comments below.

a) In the paper "On the motion of electricity in wires" Kirchhoff develops the theory of propagation of an electrical disturbance along a thin wire, available here
https://archive.org/stream/londonedinburghp13maga#page/392
This idea may be used to explain the presence of volume charge density changes inside wires during the initial transient when a circuit is made and hints at the presence of volume charge densities during the quasi steady-state in RC (Figs. 2.6) .and RL (Figs. 5.15 and 5.16) circuits. Their presence is hinted in transmission lines and antenna wires when excess charges move towards the surface as maybe seen in Section 5.22 (Figs. 5.36) and Section 10.10 (Fig. 10.27) in Chapters 5 and 10 in the book.
The volume density assumes significance in very low resistance wires of small lengths that can produce oscillating currents which transmit energy at near light speeds which is described in the paper "The Motion of Electricity in Conductors" in b) below.
When the resistance is large, the energy is transmitted not unlike the manner in which heat is conducted by a metal rod.

b) The paper by Kirchhoff "The Motion of Electricity in Conductors" (keep in mind that at the time of publishing the paper Kirchhoff assumed the Fechner hypothesis that current is due to movement of both positive and negative charges which we now know is due to movement of charges of one sign in wires) is translated to English by P. Graneau and A. K. T. Assis and is titled "Kirchhoff on the Motion of Electricity in Conductors" available here
https://www.ifi.unicamp.br/~assis/Apeiron-V19-p19-25(1994).pdf

It is recommended that Part c) be read after a discussion of the magnetic force of a current in Chapter 6 "Magnetic Forces".
c) Is there a distributed volume charge density in a line with DC current in the steady-state (alongwith surface charge densities) ?
In their book *The Electric Force of a Current - Weber and the surface charges of resistive conductors carrying steady currents*, Andre Koch Torres Assis and Julio Akashi Hernandes Ref.[37] write about a volume charge in a DC **steady-state** situation due to the Radial Hall Effect. In Section 6.4 Radial Hall Effect of their book, they prove it's existence quantitatively. This volume charge tends to *disturb the charge neutrality condition* inside the wires but note that the effect is very small.

However, as indicated in Chapter 7 of the book Ref [37], the presence of an external electric field due to volume charge density indicates that there is no shielding in a coaxial cable with a resistive outer conductor (sheath). It is important to realize this especially when dealing with interferences in telecommunication systems.
For a link to their book, see the file Recommeded_books_for_libraries in the pdf_files folder in the CD.

12) Animated view of TEM mode fields
https://en.wikipedia.org/wiki/Transmission_line
http://electronicsgurukulam.blogspot.in/2012/08/rectangular-waveguide-animation.html

13) Infinite line without a load
http://www.allaboutcircuits.com/vol_2/chpt_14/3.html

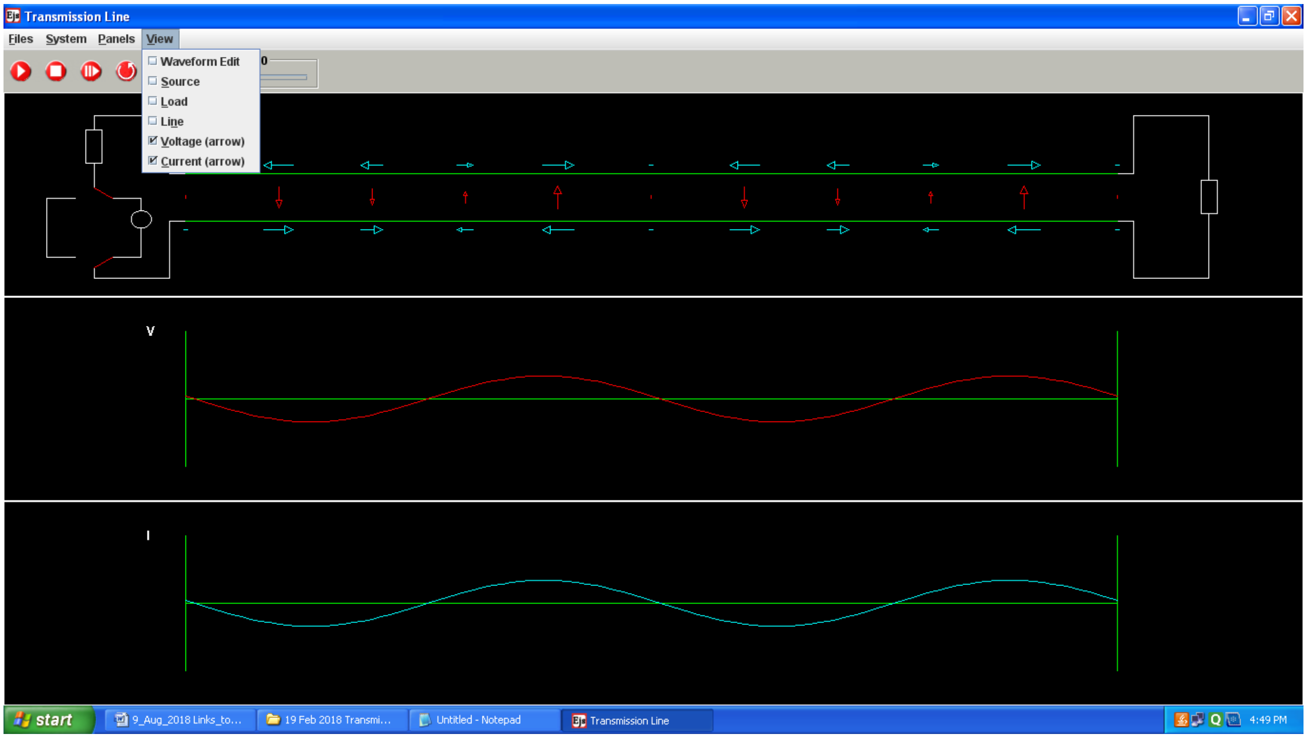
14) Incident and Reflected Waves in Transmission Lines – Standing waves in the sinusoidal steady-state
http://emlab.utep.edu/ee4347appliedem.htm
In Topic 4, Transmission Lines click on " Animation of VSWR with an open-circuit load" or, visit http://emlab.utep.edu/ee4347appliedem/TLStandingWave_open_logo.gif
Green = Incident wave; Gray = Reflected Wave, and Blue = the resultant standing wave.

Important Exercise: Set the load to open-circuit. Set the source voltage frequency to 35 MHz. Click "enter" after changing the frequency value so that the background changes from yellow to plain white which will ensure that the value is captured by the simulation program.
In the menubar click Panels and in the dropdown list select Voltage, Incident and Reflected. Then, click the play button in the toolbar.
In the initial transient after clicking the play button, it is important to see how the reflected wave begins *after* the incident wave reaches the end of the open-circuit line. The settings used in this exercise will be useful to view the voltages and currents of a half-wavelength dipole antenna that is described in Chapter 10.

15) Transmission line simulations – TL simulation

To view an interactive animation of the simulation of a transmission line,
Open the folder "Transmission Line Simulation Program" in the CD
i) Read the file "Applet Simulation of a Transmission Line"
ii) Read the transmission line processes described in the file "Transmission Processes in Linear Systems" in the CD.
iii) Run the java program TL in the folder "Transmission Line Simulation Program".

Below is a screen shot of a run with the radio buttons "Voltage (arrow)" and "Current (arrow)" enabled.



Or

i)visit http://www.astrophysik.uni-kiel.de/~hhaertel/TL/TL-doc/index.htm and suggested to download the "User guide (video)" or view online
ii) Next, visit http://www.astrophysik.uni-kiel.de/~hhaertel/TL/TL-tutorial/TL-uk.pdf and download the file "Transmission Processes in Linear Systems.pdf"
iii) Then visit http://www.astrophysik.uni-kiel.de/~hhaertel/TL/TL.zip and download the WinRAR zip file "TL"(reproduced here with permission from Hermann Haertel, University Kiel, Germany). Then right click select Extract files choosing the option for the extracted file location. Run the extracted Java file program
iv) Read the descriptions of the progress of the pulses (Chapter 2, Section 2.1.3 to 2.1.7) and follow the instructions to interactively set the Java applet (iii) to get a feel for the surface charge movements on a transmission line.

16) CGS system of units
https://en.wikipedia.org/wiki/Gaussian_units
https://en.wikipedia.org/wiki/Centimetre%E2%80%93gram%E2%80%93second_system_of_units

17) The Relaxation Time expression
http://web.hep.uiuc.edu/home/serrede/P436/Lecture_Notes/P436_Lect_07.pdf
http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-013-electromagnetics-and-applications-spring-2009/readings/MIT6_013S09_notes.pdf

18) Wires in Circuits – High-frequency effects
https://www.youtube.com/watch?v=O_up46ic3Do&index=8&list=PLYvv55hF1HIk3VZptrkXNhl6a3nkcwC-7

19) Displacement Curent - Transmission line model of a lumped capacitor
Before reading the article on Displacement Current, it would be instructive to read the topic "The Displacement Current", in Chapter 9, Maxwell's Equations and Electromagnetic Waves by Purcell (Ref.[22]).
Ivor Catt et al, *Displacement Current* - and how to get rid of it, Wireless World, December 1978, pdf page 51, pdf reader page 53
http://www.americanradiohistory.com/Archive-Wireless-World/70s/Wireless-World-1978-12.pdf

20) Transmission line effects in Integrated Circuits (ICs)
http://www.edn.com/design/analog/4340135/As-edge-speeds-increase-wires-become-transmission-lines
http://ecee.colorado.edu/~mcclurel/EDN_Transmission_Lines.pdf

Low *k* dielectric materials
http://www.sciencedirect.com/science/article/pii/S1369702104000537
http://en.wikipedia.org/wiki/Transmission_line#Short
http://www.antenna-theory.com/tutorial/txline/transmissionline.php#txline

21) Definitions of Attenuation
http://www.nist.gov/calibrations/upload/mn137.pdf
http://www.falstad.com/circuit/e-tl.html This is a simple circuit using a transmission line. The wave goes across the transmission line and is reflected at the other end, because the line is not terminated properly. This creates a standing wave on the line, which is a wave that oscillates but does not appear to travel. It is actually the combination of two waves (the initial wave, and the reflected wave) traveling in opposite directions.
In the scope, you can see that the peak voltage across the resistor doubles as soon as the wave is reflected, 4 nanoseconds after the oscillation starts. Click Next at the bottom of the webpage to view more simulations.

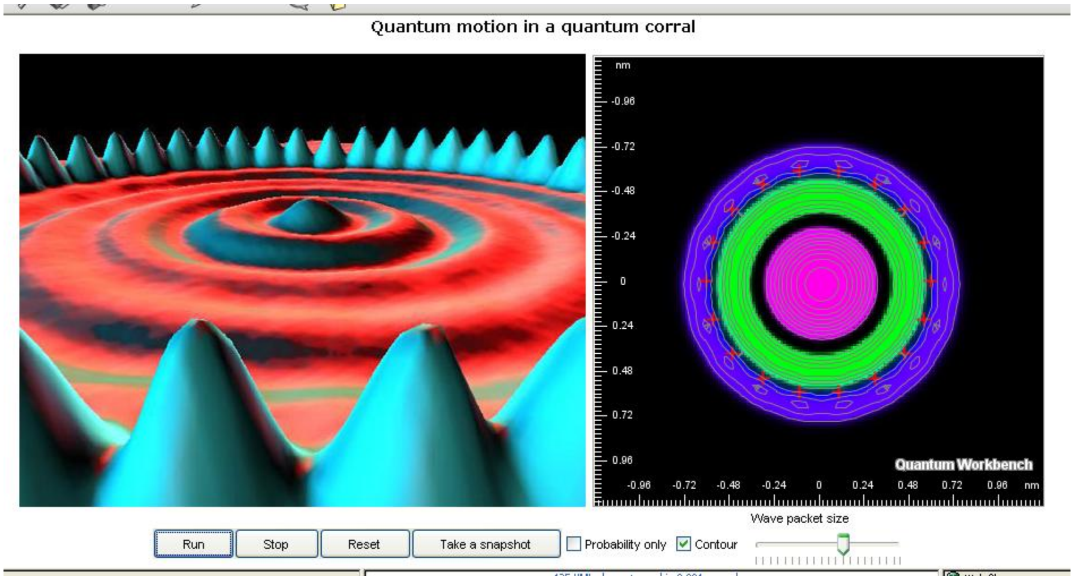
22) Albert A. Smith, *Radio Frequency Principles and Applications*, *The Generation, Propagation, and Reception of Signals and Noise*, Wiley-IEEE Press, 1998

Section 5.23

23) Quantum corral
http://web.archive.org/web/20170107155922/http://www.americanscientist.org/issues/pub/capturing-quantum-corrals
http://web.archive.org/web/20170402152647/http://researcher.watson.ibm.com/researcher/view_group.php?id=4245

24) How the image was made
http://www.phy.pku.edu.cn/~qhcao/resources/class/QM/eigler_circular_corral.pdf
http://www.almaden.ibm.com/vis/stm/lobby.html

25) For a 2D quantum dynamics simulation that shows the motion of an electron cloud in a circular corral setup.
http://mw.concord.org/modeler/showcase/quantum/corral.html



26) Seeing Atoms
https://www.nano.gov/nanotech-101/what/seeing-nano

27) Seeing Atoms – full article
https://nanohub.org/resources/3253

28) For *extracting individual atoms* (like the iron atoms that formed the Quantum Corral described in 21) to 24) from the native substrate, a tip-crash procedure is used and is described in the article here
https://arxiv.org/ftp/cond-mat/papers/0506/0506038.pdf

29) For a review the of *physics of quantum corrals* and relate the signal of the STM to the scattering properties of substrate electrons from atomic impurities supported on the surface read the article
https://arxiv.org/pdf/cond-mat/0211607.pdf

Chapter 6

Section 6.1

Longitudinal forces in current carrying wires
1) A.K.T. Assis and Marcelo Bueno, "*Longitudinal Forces in Weber's Electrodynamics*", International Journal of Modern Physics B, Vol. 9, No. 28 (1995), 3689-3696.

Tension in conductors
2) Peter Graneau, *Ampere Tension in Electric Conductors*, IEEE Transactions on Magnetics, VOL. MAG-20, NO. 2, MARCH 1984.

Section 6.5
3) Special situations to demonstrate magnetic forces do as much negative work as they do positive work so that they do no (net) work.

According to Prof. Bruce Sherwood, "Because the magnetic force on a moving charge is perpendicular to the velocity, the work done by a magnetic force is zero. However, in a multiparticle system it can happen that magnetic forces can *rearrange the energy* within the system, as long as these forces do as much negative work as they do positive work, so that the net work done is zero."
For a full description with an animation of the situation read the article **Magnetic forces do no (net) work** by Prof. Sherwood here https://brucesherwood.net/?p=191.

Section 6.6
4) Planck's Radiation Law and it's connection to Boltzmann's Law
The theory of electrons and its applications to the phenomena of light and radiant heat by H. A. Lorentz – (Pages 63 – 97)
https://archive.org/details/electronstheory00lorerich

5) A very useful and informative article on Action-at-a-distance theories
G. Burniston Brown, *A Theory of Action-at-a-Distance*, University College, University of London, 17th March 1955.
Proceedings of the Physical Society. Section B, Volume 68, Number 9
http://ritz-btr.narod.ru/brown-2.pdf

Chapter 7

Section 7.7
1) Unipolar induction and Weber's electrodynamics
A. K. T. Assis and D. S. Thober, Unipolar induction and Weber's electrodynamics, in: Frontiers of Fundamental Physics, M. Barone and F. Selleri (eds.), (Plenum Press, New York, 1994), pp. 409-414. Subject: We discuss unipolar induction and how it can be interpreted based on Weber's electrodynamics. We present predictions of the results of new experiments based on Weber's law.
https://www.ifi.unicamp.br/~assis/Unipolar-Induction-Weber-Law-p409-414(1994).pdf

Section 7.11
2) Generator construction
http://wind.morrisonprairie.com/windings.html

Section 7.14
3) Longitudinal waves (air molecules in motion) in open and closed pipes
http://www.miyazaki-catv.ne.jp/~yuasa1436/PlF4.htm

4) History of invention of the Klystron
http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-7731.pdf

Section 7.15
5) How mechanical motion alters electric or magnetic fields and converts mechanical to electrical power – David H. Staelin, MIT article *Electromagnetics and Applications*, 2011.
Section 6.3, Chapter 6, *Actuators and Sensors, Motors and Generators*
http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-013-electromagnetics-and-applications-spring-2009/readings/MIT6_013S09_notes.pdf

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Chapter 8

Section 8.3
1) 3D view of cross-product
http://www.glowscript.org/#/user/matterandinteractions/folder/matterandinteractions/program/17-cross-product

Section 8.10
2) How electrical power into motors could be transformed into mechanical power – David H. Staelin, MIT article *Electromagnetics and Applications*, 2011.
Section 6.3, Chapter 6, *Actuators and Sensors, Motors and Generators*
http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-013-electromagnetics-and-applications-spring-2009/readings/MIT6_013S09_notes.pdf

Section 8.23
3) Operation of DC motors
https://www.youtube.com/watch?v=LAtPHANEfQo
http://www.learnengineering.org/2014/09/DC-motor-Working.html

4) Operation of AC Induction motors
https://www.youtube.com/watch?v=LtJoJBUSe28
http://www.learnengineering.org/2013/08/three-phase-induction-motor-working-squirrel-cage.html

Section 8.24
5) How sound waves are produced by loudspeakers
http://www.mediacollege.com/audio/01/sound-waves.html

Section 8.27
6) Introduction to magnetism
http://www.regentsprep.org/Regents/physics/phys03/cintromag/
Alternate site: video or slideshow http://slideplayer.com/slide/2294032/

Section 8.28

7) Detecting bound currents - An experimental method used to detect bound currents
Alexander I. Korolev, *On the magnetic field of bound charges current*, arXiv:1307.2134 [physics.gen-ph]
https://arxiv.org/abs/1307.2134

8) Who does the work when the magnet picks up the clip ?
Before answering the question, let's see what Prof Sherwood writes about who does the work when two (neutral) objects like stars and two charged particles are attracted to each other (in his blog here https://brucesherwood.net/?p=277

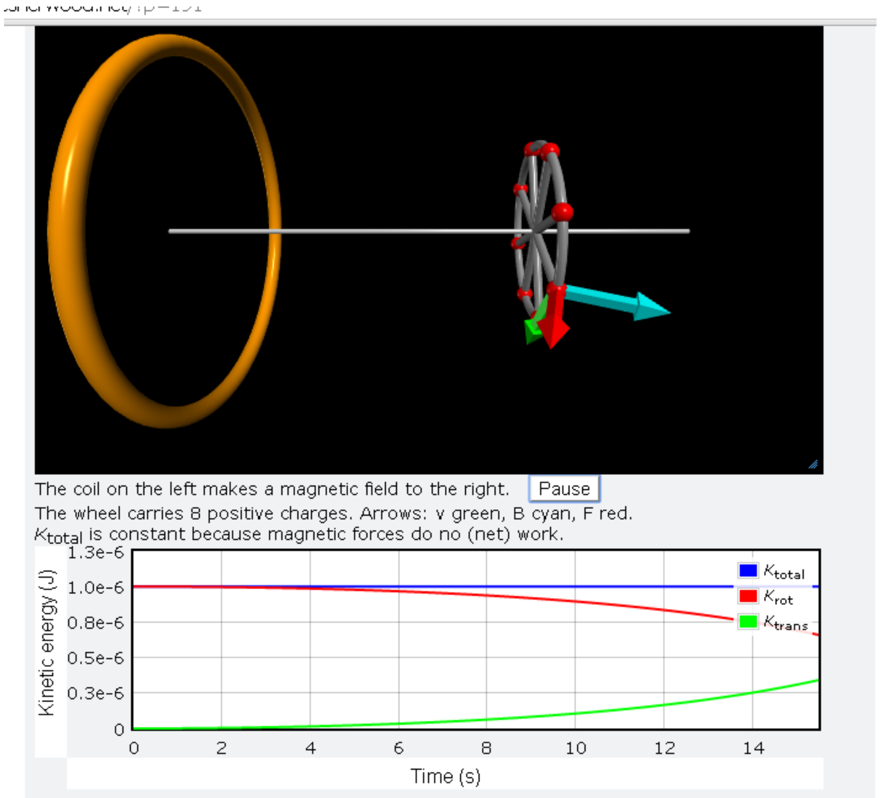
"Here is a brief summary of an argument presented in the mechanics section of our "Matter & Interactions" textbook that shows that it must be energy in the magnetic or electric or gravitational field that is the source of the increased kinetic energy. Consider two similar **stars A and B** far from each other, initially at rest. They accelerate each other, moving toward each other faster and faster. It is customary (and gives the correct results) to take the two stars as the system of choice and quantify the energy of the system (neglecting the constant rest masses) as kinetic energy plus gravitational potential energy of the two stars. The **change in the energy of the system plus the change in the energy of the surroundings is zero** (energy conservation). Since there is nothing in the surroundings, the change of kinetic energy plus change of potential energy is zero, from which we can calculate the final kinetic energy of the two stars.

If we choose star A as the system, the surroundings consist of star B. The kinetic energy of our chosen system, star A, increases, so for energy to be conserved the energy of the surroundings must decrease. However, the kinetic energy star B increases, not decreases. How can one deal with this paradox?

We state that there is energy in the "field," field being a concept to be introduced in the second-semester course, and we're even able to calculate the amount by which the field energy changes despite not even knowing what it is. Keep in mind that single objects don't have potential energy, **only pairs of interacting particles in a system have potential energy**. Therefore the change K in the kinetic energy of the system (star A) plus the change K in the kinetic energy of star B (part of the surroundings) plus the change in the field energy (also part of the surroundings) must be equal to zero, so the change in the field energy is -2K. We then comment that calculations based on the concept of potential energy give the correct result, but that in general there's an issue. The case of an **electron and a positron attracting each other is entirely similar to the two-star case**, but the field energy is associated with **electric** and magnetic fields."
For an example of energy conservation of charged particle interactions in an electric field, see the first part of "Electric Potential, Potential Difference and Potential Energy" at the end of Appendix A where the energy conservation principle is applied to the case of a **proton between the plates of a charged capacitor**.

Now, read the three articles (in Part 1, Part 2 and Part 3) below to understand who does the work in a magnetic interaction between a magnet and a metallic paper clip.

Part 1
Magnetic forces do no (net) work
https://brucesherwood.net/?p=191
Note you may need to enable Webgl in your browser to view the animation.



Part 2
Reciprocity of magnetic forces
https://brucesherwood.net/?p=307
Excerpt
The electric forces between the proton and electron exhibit "reciprocity." That is, the electric force that the proton exerts on the electron is equal in magnitude and opposite in direction to the electric force that the electron exerts on the proton.
……..
The magnetic force is quite different. The proton contributes zero magnetic field at the location of the electron and so no magnetic force acts on the electron, whereas the electron does contribute a nonzero magnetic field at the location of the proton, into the page, so there is a magnetic force on the proton, in the +y direction. The magnetic force does not have the property of reciprocity. To put it another way, the forces **do not obey Newton's third law**, which means that this "law" is not fundamental but rather a relationship that applies to electric and gravitational interactions but not to all types of interaction.
………..

Part 3
What energy is used by a magnet to attract another magnet?
https://brucesherwood.net/?p=277

9) Set of guidelines to modify traditional electricity and magnetism and circuits courses in engineering curriculum.
Sridhar Chitta, V. Kamaraju, Vedula Kavya, *Unifying Electric Theory and Circuits in Engineering Curriculum*, Intl Journal of Engineering Technology Science and Research, Volume 4, Issue 9, Sept. 2017, ISSN 2394 – 3386, online
http://www.ijetsr.com/images/short_pdf/1504360766_45-56-ieteh840_ijetsr.pdf

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Chapter 9

Section 9.3
1) Lattice ion movement in batteries and dry cells
http://www.science.uwaterloo.ca/~cchieh/cact/c120/electrolyte.html

2) Theory and Operation of dry cells
http://everything2.com/title/dry+cell

3) How a rise in temperature gives a more gradual occupation in states around the E_F level
http://jas.eng.buffalo.edu/education/semicon/fermi/functionAndStates/functionAndStates.html
http://oes.mans.edu.eg/courses/SemiCond/applets/education/semicon/fermi/functionAndStates/functionAndStates.html

Section 9.4
4) Non-uniform electric field in the transition region
http://jas.eng.buffalo.edu/education/pn/biasedPN2/BiasedPN2.html
http://web.archive.org/web/20170327235000/http://jas.eng.buffalo.edu/education/pn/biasedPN2/BiasedPN2.html

Section 9.6
5) Movement of holes in a lattice
http://www.ece.utep.edu/courses/ee3329/ee3329/Studyguide/Shockwave/Fundamentals/Demos/acceptor.html

6) Conduction by electrons and holes in extrinsic semiconductors-click the video lecture i in the page-Lecture 15 Introduction to Crystallography by Donald Sadoway in the course 3.091 in MIT, Mass. USA.

https://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-to-solid-state-chemistry-fall-2010/crystalline-materials/15-introduction-to-crystallography/

Section 9.9
7) Making Vo 'zero' by adjusting doping concentrations
http://jas.eng.buffalo.edu/education/pn/pnformation3/index.html
http://web.archive.org/web/20170328000334/http://jas.eng.buffalo.edu/education/pn/pnformation3/index.html
http://oes.mans.edu.eg/courses/SemiCond/applets/education/pn/pnformation/pnformation.html

8) The diode current is due to recombination
http://ecee.colorado.edu/~bart/book

Section 9.11
9) Current components of a p-n diode
http://web.eng.fiu.edu/~npala/Applets/education/pn/biasedPN/index.html
http://jas.eng.buffalo.edu/education/pn/biasedPN/index.html

10) Non-uniform electric field in the transition region
http://web.eng.fiu.edu/~npala/Applets/education/pn/biasedPN2/BiasedPN2.html
http://jas.eng.buffalo.edu/education/pn/biasedPN2/BiasedPN2.html
http://en.wikipedia.org/wiki/PN_junction

11) The electrostatic potential
http://academic.reed.edu/chemistry/roco/Potential/electrostatic_potential.html

Section 9.15
12) Fermi energy is positive
http://web.archive.org/web/20150421013249/http://people.duke.edu/~ad159/files/p112/27.pdf
http://web.archive.org/web/20040824021212/http://www.ph.utexas.edu/~phy317n/PHY317L/Lectures/Lecture20/L20examples.pdf

13) Majority of the electrons are separated from the top of the Fermi sea by much more than thermal energy - Fermi function and states
http://web.eng.fiu.edu/npala/Applets/education/semicon/fermi/functionAndStates/functionAndStates.html or
http://jas.eng.buffalo.edu/education/semicon/fermi/functionAndStates/functionAndStates.html

14) Partially filled states in metal
http://hyperphysics.phy-astr.gsu.edu/hbase/solids/fermi2.html

15) Electrostatic Potentials

http://academic.reed.edu/chemistry/roco/Potential/electrostatic_potential.html

16)
i) Biasing a bipolar transistor using dual polarity supply for direct coupling (without a coupling capacitor) of the signal generator to the first stage and also to a subsequent stage.
Lecture - 30 Cascading Amplifiers - Watch from the 36th minute.
http://www.nptelvideos.in/2012/12/electronics-for-analog-signal.html
or
https://www.youtube.com/watch?v=k7CI7B88gJE

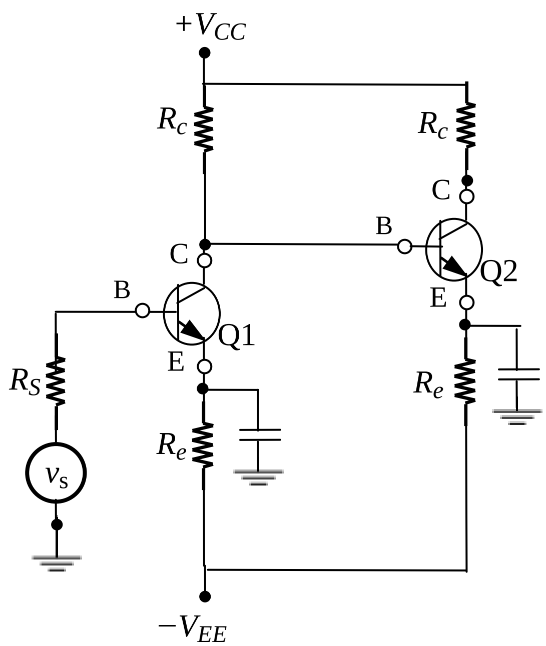


Fig. Biasing circuit of a bipolar transistor using dual polarity supply

ii) Drift voltage at input to amplifier
Lecture - 31 Cascading (Direct Coupling) - Watch from the 17th minute.
http://www.nptelvideos.in/2012/12/electronics-for-analog-signal.html
or
https://www.youtube.com/watch?v=nLEvB3aZrrs

Chapter 10

Section 10.3

1) Kink produced by an accelerated charge
http://www.glowscript.org/#/user/matterandinteractions/folder/matterandinteractions/program/23-radiate2D-fieldline-kink

2) Radiation by an accelerated charge
http://www.glowscript.org/#/user/matterandinteractions/folder/matterandinteractions/program/23-radiation-3D
3) Video – animation of accelerated charge by **Ruth W. Chabay**
https://www.youtube.com/watch?v=uVB3G_Edim4

4) video - animation of accelerated charge producing a kink in the electric field
http://videolectures.net/mit803f04_lewin_lec19/

Section 10.5
5) Why does light travel slower through glass or water than through a vacuum
http://www.madsci.org/posts/archives/may98/893732585.Ph.r.html

6) According to Prof. Bruce Sherwood "The "refractive index" is usually denoted by n, and it is common practice to say that "the speed of light in a medium with refractive index n is given by c/n where $c = 3\times10^8$ m/s". But in fact the speed of light is a universal quantity. Although it is very often *convenient to pretend that the speed of light is slower in glass*, that's just a calculational convenience — it's a misleading description of what's really going on. In fact, the refractive index and "speed of light" in glass is different for different frequencies of the sinusoidal radiation, because different frequencies of electric field affect the motion of the electrons differently in the glass".
Read the full article **The speed of light in a material** on the complex interaction between light and matter which makes light *apparently* slow down here https://brucesherwood.net/?p=95

Section 10.7
7) Radiation produced by a single dipole
http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/light/01-DipoleRadiation/01-Dipole_320.html

Section 10.8
8) Uniform electric field due to an infinite charged sheet
http://www.falstad.com/vector3de/ and in the Field Selection box choose "infinite plane" and the display to "Field vectors".

9) Simulation of electromagnetic radiation generated by an oscillating sheet of charge
http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/light/09-planewaveapp/09-planewaveapp320.html

Section 10.9
10) Faye Jan, "Copenhagen Interpretation of Quantum Mechanics", *The Stanford Encyclopedia of Philosophy* (Fall 2014 Edition), Edward N. Zalta (ed.)
https://plato.stanford.edu/archives/fall2014/entries/qm-copenhagen/

11) Claes Johnson, *Mathematical Physics of Blackbody Radiation*, Icarus iDucation 2012.

http://www.csc.kth.se/~cgjoh/ambsblack.pdf
Also see **Note** below.

12) Boya's article "The thermal radiation formula of Planck" discusses the assumptions made by Planck when deriving Planck's law and the distribution of energy in black body radiation
https://arxiv.org/pdf/physics/0402064.pdf

13) Clayton A. Gearhart's article "Planck The quantum and the historians" discusses how Planck's derivation was consistent with the continuous energies inherent in Maxwellian electrodynamics and Newtonian mechanics
http://faculty.csbsju.edu/cgearhart/pubs/PQH.pdf

14) Probability – Statistical phenomenon in Classical Randomness and Quantum Randomness and differences between them in Lecture 1 | Modern Physics: Quantum Mechanics (Stanford) by Prof. Leonard Susskind
https://www.youtube.com/watch?v=2h1E3YJMKfA

15) Planck's Radiation Law and it's connection to Boltzmann's Law
The Theory of Electrons by H. A . Lorentz – Pages 63 – 97
https://archive.org/details/electronstheory00lorerich

16) The origins of quantum electrodynamics
Victor F. Weisskopf, *Recent Developments in the theory of the electron*, Reviews of Modern Physics, Volume 21, Number 2, April 1949.
http://users.physik.fu-berlin.de/~kleinert/files/weisskopf.pdf

Note
According to Prof. Sherwood, the proper approach to model blackbody radiation would be to quantize the electromagnetic field and not the emitters. Read the full article here https://brucesherwood.net/?p=131 .

Section 10.l0
17) Radiation by a dipole
http://ocw.mit.edu/ans7870/8/8.02T/f04/visualizations/light/01-DipoleRadiation/01-Dipole_320.html

18) Folded Dipole
https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-661-receivers-antennas-and-signals-spring-2003/readings/ch3new.pdf

19) Incident and Reflected Waves in Transmission Lines – Standing waves in the sinusoidal steady-state
http://emlab.utep.edu/ee4347appliedem.htm
In Topic 4, Transmission Lines click on "Animation of VSWR with an open-circuit load" or, visit http://emlab.utep.edu/ee4347appliedem/TLStandingWave_open_logo.gif

Green = Incident wave; Gray = Reflected Wave, and Blue = the resultant standing wave.

Note: i) The standing voltage wave in the above utep webpage (gif) is different from the voltage wave in the slide #6 of the power point presentation of Chapter 10 in the CD (and the Fig. 10.33 in the Chapter 10 on Antennas) because of different line lengths.

Important ii) To view the standing wave voltage waveform as shown in Fig. 10.33 in Chapter 10, run the Transmission line simulations – Prof Haertel's TL simulation "TL" program.

a) Set the load to open-circuit.

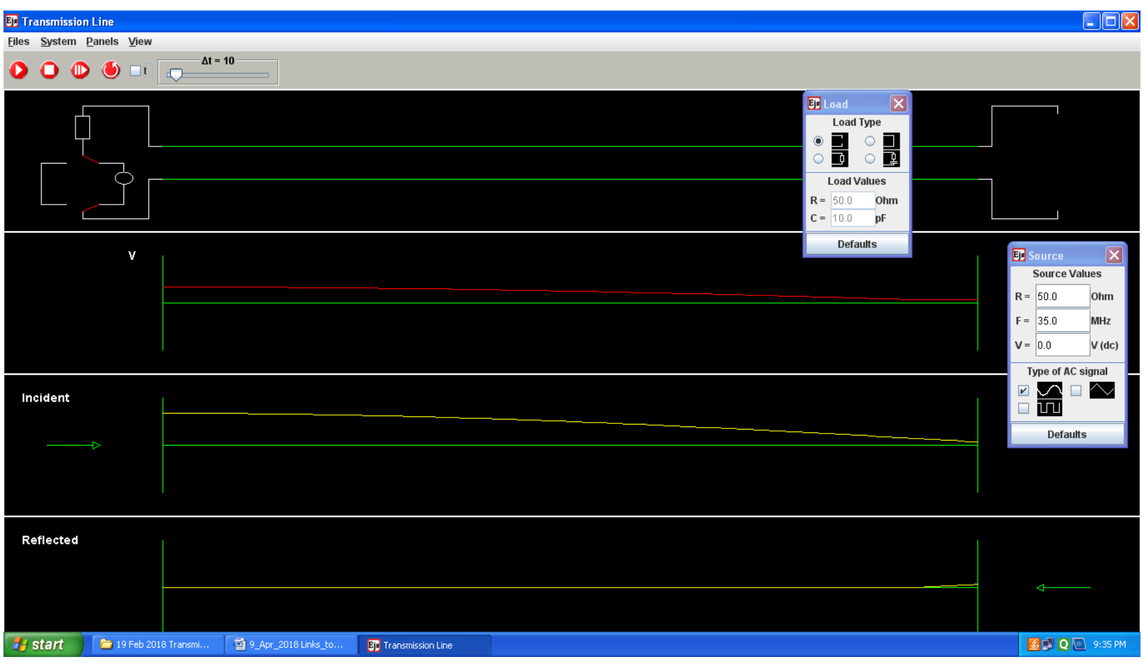
b) Set the source voltage frequency to 35 MHz. Click "enter" after changing the frequency value so that the background changes from yellow to plain white which will ensure that the value is captured by the simulation program.

c) In the menubar click Panels and in the dropdown list select Voltage, Incident and Reflected.

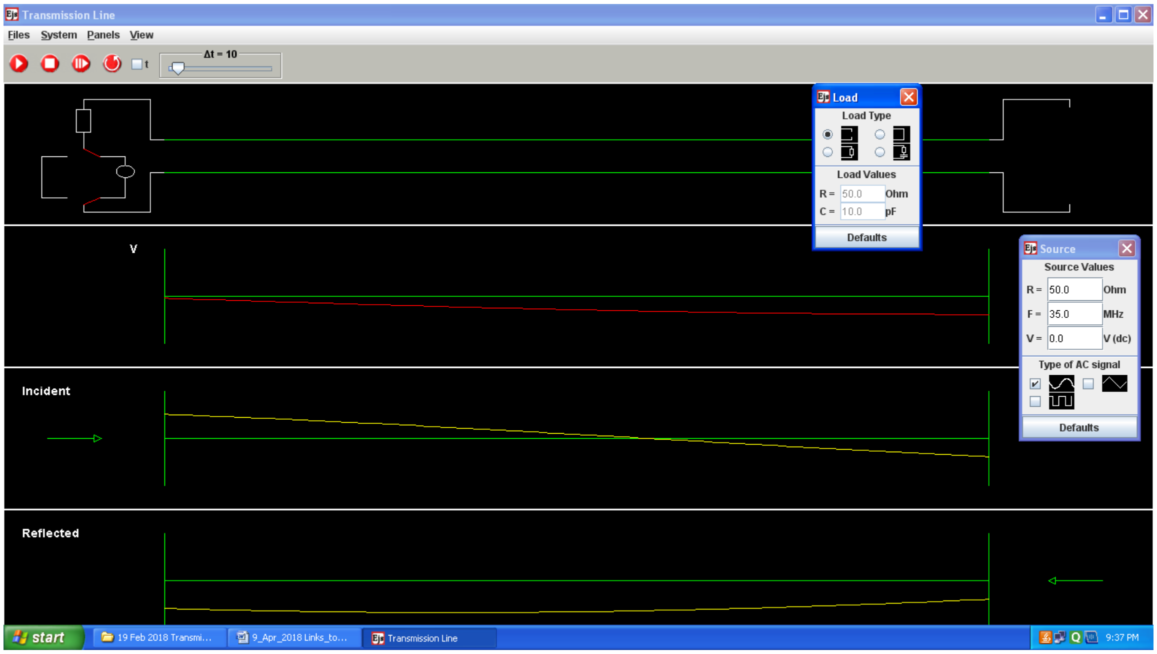
d) Then, click the play button in the toolbar.

In the initial transient after clicking the play button, it is important to see how the reflected wave begins *after* the incident wave reaches the end of the open-circuit line.

Shown below is a screen shot.



e) Then, observe the waveforms in the steady-state.



20) Standing waves of voltage and current
https://en.wikipedia.org/wiki/Dipole_antenna

21) Radiation Resistance
https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-661-receivers-antennas-and-signals-spring-2003/readings/ch3new.pdf

22) **Return loss and VSWR**
In a course in Antennas and Wave Propagation, the terms Return loss and VSWR are discussed. The following links provide information on what these terms mean and what their values represent in Antennas.
https://antennatestlab.com/antenna-education-tutorials/return-loss-vswr-explained
Excerpt: … *While it is true that poor (low number) return loss means that an antenna cannot radiate: It is NOT true that good return loss guarantees effective antenna radiation…*….
https://www.lsr.com/white-papers/understanding-antenna-design

For a **relation between Radiation Resistance and Reflection Coefficient** see
https://pdfs.semanticscholar.org/7639/afd0c305af2238d2f30ab621353587200d39.pdf

23) Demonstration of antenna lighting a bulb
https://www.youtube.com/watch?v=4xF1Fq2wB1I

24) John David Jackson, *Classical Electrodynamics*

Publisher: John Wiley & Sons; 3rd Revised edition edition (1998)
ISBN-10: 047130932X
ISBN-13: 978-0471309321
Available:
http://www.fisica.unlp.edu.ar/materias/electromagnetismo-licenciatura-en-fisica-medica/electromagnetismo-material-adicional/Jackson%20-%20Classical%20Electrodynamics%203rd%20edition.pdf/view

https://www.scribd.com/doc/48520397/Jackson-Classical-Electrodynamics-3rd-edition

Section 10.11
25) Waveguides -Theory transmitted powers and attenuation factors
http://www.ece.rutgers.edu/~orfanidi/ewa/ch09.pdf

26) Launching waves in a waveguide
http://www.radio-electronics.com/info/antennas/waveguide/waveguide-launchers-couplers-transitions.php

27) Wave propagation in waveguides
http://mason.gmu.edu/~jdilles/classes/ece305/ehwave.html
http://www.met.reading.ac.uk/clouds/maxwell/waveguide.html

28) Wave below cutoff frequency in waveguide
https://www.youtube.com/watch?v=FN2Ih6ntQFo

Section 10.12

29) Electric Field of a positive charge moving with constant velocity – depicted by field vectors
http://web.mit.edu/8.02t/www/802TEAL3D/visualizations/electrostatics/MovingChargePosElec/movingChargePosElec.htm

30) Electric Field of a negative charge moving with constant velocity – depicted by field vectors
http://web.mit.edu/8.02t/www/802TEAL3D/visualizations/electrostatics/MovingChargeNegElec/movingChargeNegElec.htm

31) Hartel's visualizations developed based on Leigh Page's Emission Theory velocity – depicted by massless moving elements whose loci are the lines of force
i) Field lines for a particle moving with high speed ii) The so-called bremsstrahlung
iii) Field lines for a rotating charge carrier iv) Field lines for an oscillating particle in 2D
v) Field lines for an oscillating particle in 3D vi) Field lines for an oscillating particle in 3D vii) cyclotron radiation
http://portia.astrophysik.uni-kiel.de/~hhaertel/Videos/videos-uk-fl.htm

32) Set of lectures introducing Relativity by Prof. Ramamurti Shankar, Yale University
https://www.youtube.com/watch?v=pHfFSQ6pLGU&index=12&list=PLFE3074A4CB751B2B

33) Introduction to Relativity, Lorentz Transformation, Four-Vector, Four-Vector in Relativity,
Full set of lectures by Prof. Ramamurti Shankar, Yale University beginning from Newton's laws
https://www.youtube.com/playlist?list=PLFE3074A4CB751B2B

34) Set of video lectures introducing Relativity by Prof. Leonard Susskind, Stanford University
Introduction to The Lorentz Transformation central to Relativity
https://www.youtube.com/watch?v=toGH5BdgRZ4&list=PL42DF98859D7B81B9&index=1
A full set of 10 lectures beginning from Special Relativity, use of vectors and spin in 3-D space, particle mechanics and ideas of momentum, fields and field theory (classical and quantum field theory), fields and particles, electromagnetism, where math and physics collide, electromagnetism and relativity including dynamics of electric and magnetic fields, plane electromagnetic waves.

Appendix A

1) Electric field of a charged disk
http://www.glowscript.org/#/user/matterandinteractions/folder/matterandinteractions/program/15-Edisk

2) Demo programs (GlowScript)
matterandinteractions.org/student

Appendix B

1) On the constitution of atoms and molecules by N. Bohr (1913)
http://www.ymambrini.com/My_World/MMJC211013_files/bohr_PhilMag_26_1_1913.pdf

2) The structure of the atom by E. Rutherford (1914)
https://ia801302.us.archive.org/22/items/McGillLibrary-97875-183/97875.pdf

3) Quantum mechanical model of hydrogen atom
http://dwb5.unl.edu/CHEM/Chemanim/BOHRQD/BOHRQD.html
For a visual representation of the wave and particle view of an electron visit
http://www.upscale.utoronto.ca/PVB/Harrison/Complementarity/Flash/ParticleWave.html
and a lecture on general wave particle duality which we should accept about electron (and matter behaviour) "It just is the fundamental nature of radiation, of light. You may think it is a contradiction because in your everyday experience you either see a wave or you see

a particle. But that is your everyday experience. And there are parts of nature that you cannot see every single day. And those deeper parts of nature have different rules. And you have to be *accepting* of those different rules. And so it is not a contradiction in terms.

", visit
http://www.youtube.com/watch?v=HT4sxODPR2Q or
http://ocw.mit.edu/courses/chemistry/5-112-principles-of-chemical-science-fall-2005/video-lectures/lecture-5-matter-as-a-wave/

For a lecture on wave-particle duality of matter ("why we dont see wave like behaviour in our day to day life" - 29th minute in the lecture)
http://www.youtube.com/watch?v=iWZDVWdtjMY
Also visit
http://www.youtube.com/watch?v=7nd6S6TQBTg

4) Animation-An electron as a point charge - a smoothly varying distribution of charge density-of electron position from probability data extracted from orbitals
http://www.av8n.com/physics/wavefunctions.htm#sec-animation
https://web.archive.org/web/20160403013223/http://www.av8n.com/physics/wavefunctions.htm

5) The binding energies of electrons (innermost to outermost)
http://www.chembio.uoguelph.ca/educmat/atomdata/bindener/elecbind.htm

6) Resultant electric field due to a pair of charges
http://ocw.mit.edu/ans7870/18/18.013a/textbook/HTML/chapter28/section04.html

7) Inquiring minds
http://www.fnal.gov/pub/inquiring/questions/bob.html

8) What is special about Metallic bonds ?
"A metal is *held together* by the strong forces of attraction between the positive nuclei and the *delocalised* electrons."
http://www.chemguide.co.uk/atoms/bonding/metallic.html

9) Vibration of lattice ions with temperature
http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/thermochem/eqilibrium-v1.html

10) Reciprocity of magnetic forces
https://brucesherwood.net/?p=307

Video lectures by Leonard Susskind

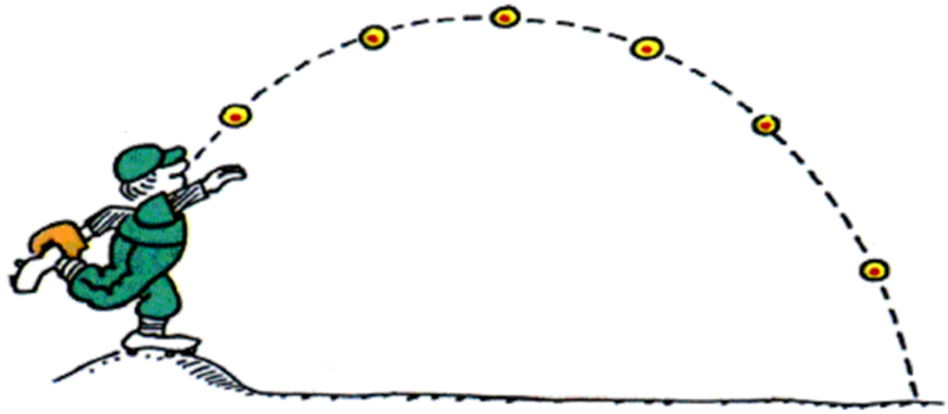
11) Introduction to the Lagrangian function, Relation between action and the Lagrangian; Euler-Lagrange equations and L = T–V
Lecture **3**, Classical Mechanics, Leonard Susskind, Stanford Univ., USA

https://www.youtube.com/watch?v=3apIZCpmdls
Situations when it is not possible that the Lagrangian is not separable into T and V;

Principle of Least Action, Relation between Symmetries and Conservation Laws; Laws determining Equilibrium
Lecture **4**, Classical Mechanics, Leonard Susskind, Stanford Univ., USA
https://www.youtube.com/watch?v=ojEwHlyty4Q

Here is a nice introduction to the Principle of Least Action (which should be read before reading about the Lagrangian and Hamiltonian) by Mark Eichenlaub, Physics Education Research Group, University of Maryland.

Suppose you are playing catch with someone. You throw the ball back and forth, and it goes in a path like this:



Why that particular path?

The throw is going to take, say, 1.5 seconds. During those 1.5 seconds, it turns out the ball wants to maximize its average height, but minimize its average speed.

To maximize height, you should go up as high as you can. Also, when you're at the highest point, you should go slowest. That way you take longer at the high points and they count for more in the average. As you go further down you should go faster so that it counts for less towards your average.

If you go too high, that involves lots speed, and you're trying to minimize speed. There's a trade off between going higher, which you like, and going faster, which you don't. When you mathematically work out the best possible solution, you get the parabola shape.

Height here means potential energy. Maximizing it is the same as minimizing its negative, so we could say we want to minimize kinetic energy (square of speed) and also minimize negative potential energy. Thus, the ball is minimizing the average of the quantity [kinetic energy - potential energy]. That quantity is called the Lagrangian.

This turns out to be a general rule for physics. When we get to a new situation, like a mass on a spring, all we have to do is change the potential energy function. We still minimize the same Lagrangian, and then we get the oscillatory motion of a mass on a spring. Or when talking about the solar system, we write the potential energy for gravity and we get the elliptical orbits of the planets out of it. (This was a large part of the motivation for the Lagrangian technique.)

In more-complicated situations like electromagnetism, we have to change the Lagrangian a bit so it's no longer just [kinetic energy - potential energy]. No problem, though. There's still a Lagrangian that works.

There is a really intriguing story behind why things should want to minimize a Lagrangian. It's told by Feynman in his book *QED* [The strange theory of light and matter]. In quantum mechanics, the ball actually takes all possible paths, but the paths can interfere with each other unless the Lagrangian is at a minimum. I highly recommend Feynman's book or the video lectures it's based on. http://vega.org.uk/video/subseri...

[QED The strange Theory of Light and matter https://www.academia.edu/8507722/QED_The_strange_theory_of_light_and_matter_by_Richard_Feynman]

Note: It is more accurate to say that the Lagrangian should be at a stationary point, which may or may not be a minimum. Minimum is fine for a layman's introduction, though.

Also read the public lecture by Young and Tong here http://www.phy.cuhk.edu.hk/events/public_lecture/pla/LA.pdf

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Equations of motion from the Lagrangian; Introduction to the Hamiltonian
Lecture **5**, Classical Mechanics, Leonard Susskind, Stanford Univ., USA
https://www.youtube.com/watch?v=lW9GJ0aiaNc

Electric and Magnetic Forces; Divergence, Curl and the notion of Vector Potential; Lagrangian from the action for a particle in a magnetic field and the equations of motion of the particle
Lecture **9**, Classical Mechanics, Leonard Susskind, Stanford Univ., USA
https://www.youtube.com/watch?v=WJn6h-6MMa8

Show that the Lagrangian for a particle in a magnetic field leads to the Lorentz Force Law; Notion of momentum; mechanical momentum and canonical momentum as derivative of the Lagrangian with respect to the velocity; Hamiltonian and an expression for energy of a particle moving in a magnetic field
Lecture **10**, Classical Mechanics, Leonard Susskind, Stanford Univ., USA
https://www.youtube.com/watch?v=bn5lKYHenSQ

12) The Coulomb Force And The Ampere Force by Parry Moon and Domina Eberle Spencer
http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=19B6CC2AEC55CA63310C9B8C43451526?doi=10.1.1.172.7550&rep=rep1&type=pdf

13) A Treatise on electricity and Magnetism by James Clerk Maxwell
Vol 1
https://ia800209.us.archive.org/28/items/electricandmagne01maxwrich/electricandmagne01maxwrich.pdf
or
https://ia802302.us.archive.org/25/items/ATreatiseOnElectricityMagnetism-Volume1/Maxwell-ATreatiseOnElectricityMagnetismVolume1.pdf

Vol 2
https://ia801404.us.archive.org/35/items/electricandmag02maxwrich/electricandmag02maxwrich.pdf
or
https://ia601501.us.archive.org/2/items/in.ernet.dli.2015.160612/2015.160612.A-Treatise-On-Electricity-And-Magnetism-vol-Ii.pdf

14) On the First Electromagnetic Measurement of the Velocity of Light by Wilhelm Weber and Rudolf Kohlrausch (2003)
http://www.ifi.unicamp.br/~assis/Weber-Kohlrausch(2003).pdf

15) Telegraphy Equation from Weber's Electrodynamics
http://www.ifi.unicamp.br/~assis/IEEE-Trans-Circuits-Systems-II-V52-p289-292(2005).pdf

16) Circuit Theory in Weber Electrodynamics by A. K. T. Assis
http://www.ifi.unicamp.br/~assis/Eur-J-Phys-V18-p241-246(1997).pdf

17) Introduction to Quantum Mechanics (Modern Physics)
https://www.youtube.com/watch?v=2h1E3YJMKfA

Appendix C

1) Surface voltage and field strength of insulators
http://incompliancemag.com/article/surface-voltage-and-field-strength-part-1-insulators/
http://web.archive.org/web/20130222064315/http://www.ce-mag.com/archive/01/09/mrstatic.html

http://web.archive.org/web/20180726144949/http://incompliancemag.com/article/surface-voltage-and-field-strength-part-1-insulators/

Appendix D

1) What is in a touch
http://www.worsleyschool.net/science/files/touch/touch.html
The original article no longer appears in the above website. The article in the Appendix is modified based on comments by Dr J.M. Clement, a leading physicist. See Fields and touch below.

2) For a nice animated description of a signal to a muscle
http://sdsu-physics.org/physics180/physics180B/p180b_images/17_p39_jumpingtheshark.gif

3) Fields and touch

https://web.archive.org/web/20100808132959/https://carnot.physics.buffalo.edu/archives/2010/2_2010/msg00129.html
https://web.archive.org/web/20100808134424/https://carnot.physics.buffalo.edu/archives/2010/2_2010/msg00132.html
https://web.archive.org/web/20100808131520/https://carnot.physics.buffalo.edu/archives/2010/2_2010/msg00133.html
https://web.archive.org/web/20100808132907/https://carnot.physics.buffalo.edu/archives/2010/2_2010/maillist.html#00132

Appendix E

1) Electrical potential energy and Electric potential – with animation
http://regentsprep.org/Regents/physics/phys03/apotdif/
Alternate site: https://kaiserscience.wordpress.com/physics/electromagnetism/electric-fields-and-potential/

Appendix F

1) Doppler shift – frequency and wavelength of a wave like signal depends on the movement of the sender and receiver- Animation
http://www.aplusphysics.com/courses/regents/waves/regents_wave_phenomena.html

Follow this link for a nice explanation with animation of the Doppler shift.
http://www.einstein-online.info/spotlights/doppler

2) Ampere's Force Law and details of the experiments of Ampere
Ampère's Electrodynamics – Analysis of the Meaning and Evolution of Ampère's Force between Current Elements, together with a Complete Translation of His Masterpiece: Theory of Electrodynamic Phenomena, Uniquely Deduced from Experience -Full text

http://www.ifi.unicamp.br/~assis/Amperes-Electrodynamics.pdf

3) Early Electrodynamics by R. A. R. Tricker
https://isidore.co/calibre/browse/book/4943

4) Exact differentials and path independence of integrals – See Eq. 5.31 in Page 61 of Inductance and Force Calculations in Electrical Circuits by Bueno and Assis.
https://math.libretexts.org/Core/Calculus/Vector_Calculus/4%3A_Integration_in_Vector_Fields/4.5%3A_Path_Independence,_Conservative_Fields,_and_Potential_Functions
See Theorem 3 "Looper property of conservative fields". Apply the component test for exactness using the variable r_j in place of *y*.

Interaction between objects and particles based on relative displacement, relative velocity and relative acceleration

5) Relational Mechanics and Implementation of Mach's Principle with Weber's Gravitational Force – Full text
http://www.ifi.unicamp.br/~assis/Relational-Mechanics-Mach-Weber.pdf

6) Surface charges introduced by Wilhelm Eduard Weber
The Electric Force of a Current - Weber and the surface charges of resistive conductors carrying steady currents (includes Weber's Force law – Full text)
http://www.ifi.unicamp.br/~assis/The-Electric-Force-of-a-Current.pdf

7) Comparing Weber's electrodynamics and Classical Electrodynamics
A K T Assis_ and H Torres Silva, *Comparison between Weber's Electrodynamics and Classical Electrodynamics*,Pramana Journal of Physics, September 2000,Vol. 55, No. 3 pp. 393–404
http://www.ifi.unicamp.br/~assis/Pramana-J-Phys-V55-p393-404(2000).pdf

8) Measurement of the value of *c*
Wilhelm Weber and Rudolf Kohlrausch, *On the First Electromagnetic Measurement of the Velocity of Light*,
http://www.ifi.unicamp.br/~assis/Weber-Kohlrausch(2003).pdf

9) Michelson-Morley experiment which discounted the existence of an aether and pointed to a length contraction
Animation of the experiment
http://galileoandeinstein.physics.virginia.edu/more_stuff/flashlets/mmexpt6.htm

10) An intuitive understanding of the Michelson-Morley experiment
http://galileo.phys.virginia.edu/classes/109N/lectures/michelson.html and click on "Detecting the Aether wind: the Michelson-Morley experiment".

11) The main assumption which led to the experimental setup - Michelson-Morley experiment

http://www.physicspages.com/2011/04/30/michelson-morley-experiment/
Main assumption: the aether was dragged by the earth at all times with speed v. Implication was that every mass dragged its own aura of aether along with it.
Failed experiment and conclusion: It was not the different times but the change in the length between the apparatus that made the times of the light pulses to remain the same leading to length contraction postulate of Special relativity. But that wasn't enough.

12) Michelson-Morley experiment: length contraction?
http://www.physicspages.com/2015/05/21/michelson-morley-experiment-length-contraction/
13) Result: Postulates of Special Relativity 1) No aether 2) Speed of light *c* is constant in all frames of reference. 3) Universality of time is abolished.
http://www.physicspages.com/2011/03/29/postulates-of-special-relativity/

14) Emisssion theory using massless moving elements (or so-called virtual particles)
Leigh Page, *The Emission Theory of Electromagnetism*
https://gsjournal.net/Science-Journals/Historical%20Papers-Mechanics%20/%20Electrodynamics/Download/3434
Also see Michelson-Morley experiment links above. And, the Eq. 16 of Appendix F which involved the Time-dilation equation of the Lorentz transformation set.

15) Leigh Page authored "*An Introduction to Electrodynamics from the standpoint of the electron theory*" earlier in 1922.
https://ia902604.us.archive.org/11/items/introductiontoel030885mbp/introductiontoel030885mbp.pdf
Another version is available here
https://ia800304.us.archive.org/34/items/anintroductiont03pagegoog/anintroductiont03pagegoog.pdf

16) Educational film (1960) on frames of reference by Profs. Patterson Hume and Donald Ivey – University of Toronto
https://www.youtube.com/watch?v=aRDOqiqBUQY

17) Inertial Vs. Non-inertial frames of reference
Video on Inertial and Non-inertial frames of reference of an object dropped in a train.
https://www.youtube.com/watch?v=Hb9okl-GuB8

18) Einstein's paper translated from the German "On the Electrodynamics of Moving Bodies"
https://www.fourmilab.ch/etexts/einstein/specrel/specrel.pdf
http://hermes.ffn.ub.es/luisnavarro/nuevo_maletin/Einstein_1905_relativity.pdf

19) Set of lectures introducing Relativity by Prof. Ramamurti Shankar, Yale University
https://www.youtube.com/watch?v=pHfFSQ6pLGU&index=12&list=PLFE3074A4CB751B2B

20) Introduction to Relativity, Lorentz Transformation, Four-Vector, Four-Vector in Relativity,
Full set of lectures by Prof. Ramamurti Shankar, Yale University beginning from Newton's laws
https://www.youtube.com/playlist?list=PLFE3074A4CB751B2B

21) A full set of 10 lectures beginning from Special Relativity, use of vectors and spin in 3-D space, particle mechanics and ideas of momentum, fields and field theory (classical and quantum field theory), fields and particles, electromagnetism, where math and physics collide, electromagnetism and relativity including dynamics of electric and magnetic fields, plane electromagnetic waves.
-by Prof. Leonard Susskind, Stanford University
Introduction to The Lorentz Transformation central to Relativity
https://www.youtube.com/watch?v=toGH5BdgRZ4&list=PL42DF98859D7B81B9&index=1

22) Derivation of the magnetic force as an electrical process based on the relativistic approach
http://oyc.yale.edu/physics/phys-201/lecture-15#ch3

23) **Is magnetism simply a relativistic effect of the electric field** ? Not necessarily. In a few places in the text we had stated that the magnetic field is a relativistic *effect of the electric field*, and in a few places simply that magnetism is relativistic.
According to Prof. Bruce Sherwood it is incorrect to think that "magnetic fields are merely electric fields seen from a different reference frame". He offers several examples that show that magnetic fields are not merely the result of changing the reference frame. For example, "a *stationary* electron or proton or neutron acts like a magnetic dipole and produces a magnetic field, and there is no inertial reference frame in which that magnetic field is zero"[31]. For more examples, read the article **What is Light? What are Radio Waves?** here https://brucesherwood.net/?p=127&

24) The origin of Quantum Electrodynamics and Quantum Field Theory
It is "necessary not only to quantize material particles, but also the *electromagnetic field*"
Victor F. Weisskopf, MIT, Cambridge, Recent Developments in the theory of the electron, Reviews of Modern Physics, Volume 21, Number 2, April 1949
http://users.physik.fu-berlin.de/~kleinert/public_html/files/weisskopf.pdf

25) Peter Graneau gives an account of Professor A. K. T. Assis' work on inertia, which confirms Newton's belief in instantaneous action at a distance.
Peter Graneau, *The Riddle of Inertia*, Electronics world + wireless world, Jan 01 1990, V 96 No. 1647 Page 60
http://gsjournal.net/Science-Journals/Journal%20Reprints-Mechanics%20/%20Electrodynamics/Download/3306

Teacher's Guide (Available in CD)

Hermann Härtel, *A Qualitative Approach to Electricity: A Guide to Visualising Eletrodynamics using symbols and images*, 2017

1) Emisssion theory using massless moving elements (or so-called virtual particles)
Leigh Page, *The Emission Theory of Electromagnetism*, 1924
https://gsjournal.net/Science-Journals/Historical%20Papers-Mechanics%20/%20Electrodynamics/Download/3434

2) Kink in the electric field Accelerating and moving with constant velocity and decelerating charge and then oscillating charge
Watch from 16th minute
https://www.youtube.com/watch?v=6lb040GCs2M&index=149&list=PLERGeJGfknBR3pXCPlV3bgb_qHCSNOdBf
https://www.youtube.com/watch?v=6lb040GCs2M&index=29&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j

3) Accelerated charge
https://www.youtube.com/watch?v=oH7WRKglKNk

4) The theory of transmission lines applied to the charging of capacitors
Ivor Catt et al, *Displacement Current* - and how to get rid of it, Wireless World, December 1978, pdf page 51, pdf reader page 53
http://www.americanradiohistory.com/Archive-Wireless-World/70s/Wireless-World-1978-12.pdf

Power Point Presentations

Regulated Power Supply

1) Transformer Theory section in Electrical Power System and Transmission Network
http://www.sayedsaad.com/fundmental/
click "Transformer Theory" in left panel of "Electrical Fundamental Dep."

2) Capacitors – Types and Uses
http://www.learnabout-electronics.org/ac_theory/capacitors01.php

3) NPN transistor common-emitter Amplifier – Interactive animation
https://ngsir.netfirms.com/englishhtm/Amplifier.htm

Basic Action of a Differential Amplifier-Heart of the Opamp

Biasing methods of Differential Amplifiers

1) *Chapter12:Differential amplifiers*,
https://wiki.analog.com/university/courses/electronics/text/chapter-12

2) A. C. Van Der Woerd and A. C. Pluygers, *Biasing a Differential Pair in Low-Voltage Analog Circuits: A Systematic Approach*, Analog Integrated Circuits and Signal Processing 3, 119-125 (1993), © 1993 Kluwer Academic Publishers, Boston

Common-mode signals and differential-mode signals
3) *Common Mode Signals vs. Differential Mode Signals*
http://www.we-online.com/web/en/passive_components_custom_magnetics/blog_pbcm/blog_detail_electronics_in_action_44030.php

4) tutorial
TUTORIAL *2045Understanding Common-Mode Signals*,
https://www.maximintegrated.com/en/app-notes/index.mvp/id/2045

5) Charles Kitchin, *Avoiding Op Amp Instability Problems In Single-Supply Applications*, Analog Dialogue, Mar 2001, Vol. 35
http://www.analog.com/en/analog-dialogue/articles/avoiding-op-amp-instability-problems.html

Transformer coupled Audio power amplifiers

1) Audio Transformers by Bill Whitlock, Jensen Transformers, Inc
http://jensen-transformers.com/wp-content/uploads/2014/09/Audio-Transformers-Chapter.pdf

2) Audio Transformer Design Manual by Robert G. Wolpert
http://www.dissident-audio.com/Transfos/Papers/Wolpert_Audio_Xfmr_Design_Manual.pdf

3) Testing a power supply – Noise (Part 2) by Robert Hanrahan
https://www.edn.com/design/power-management/4411821/Testing-a-power-supply---Noise--Part-2--

Mathematics Video Lectures

Calculus lectures by Prof Gilbert Strang, MIT, USA (except * lectures)
It is recommended that these lectures be viewed in the sequence below.

Big picture of Calculus
https://www.youtube.com/watch?v=UcWsDwg1XwM

Big Picture - Derivatives
(When Algebra ends and Calculus begins)
https://www.youtube.com/watch?v=T_I-CUOc_bk

About Limits and Continuous functions
https://www.youtube.com/watch?v=kAv5pahIevE&spfreload=5
Which functions grow faster than others
https://www.youtube.com/watch?v=WU1m2QQrlho
Growth rates and log graphs
https://www.youtube.com/watch?v=WU1m2QQrlho
Linear approximations Newton's method
https://www.youtube.com/watch?v=U0xlKuFqCuI
Power series
https://www.youtube.com/watch?v=N4ceWhmXxcs
*__How they Invented Logarithms__
https://youtu.be/FB3_BeukBBk
*__definitions and the number e__
https://youtu.be/8HpvEANFQ7Q
The exponential function
https://www.youtube.com/watch?v=oo1ZZlvT2LQ
Derivative of sinx and cosx - Circular motions
and Why do we need radians
https://www.youtube.com/watch?v=FtQl1gAo12E
Complex Numbers Part Imaginary, but Really Simple
https://www.youtube.com/watch?v=Jkv-55ndVYY

Inverse functions f ^-1 (y) and the Logarithm x = ln y
https://www.youtube.com/watch?v=I_ril7ToAi4
Derivatives - Product Rule and Quotient Rule
https://www.youtube.com/watch?v=5ZpqI8zz1HM
Chains f(g(x)) and the Chain Rule -
Bonus: What is the curve of sin x and sin 3x ?
What is the difference between the two ?
https://www.youtube.com/watch?v=yQrKXo89nHA

Max Min derivative
https://www.youtube.com/watch?v=tBBJ2TSTa1Q&spfreload=5
Derivatives of ln y and sin ^-1 (y)
https://www.youtube.com/watch?v=cRsptYEK1G4

Overview of Differential Equations
https://www.youtube.com/watch?v=ghjOS7Q82s0

Big Picture: Integrals
https://www.youtube.com/watch?v=2qxY859dzzQ
Integrating Factor for Constant Rate
https://www.youtube.com/watch?v=MJUjSKew4nQ
Integrating Factor for a Varying Rate

https://www.youtube.com/watch?v=qJOQOkJ7rI8

Second Order Equations
https://www.youtube.com/watch?v=xCCeV-glFdM
Method of Undetermined Coefficients
https://www.youtube.com/watch?v=mKYlNJhK_2o
Variation of Parameters
https://www.youtube.com/watch?v=0f15AVSQ770

Response to Complex Exponential
https://www.youtube.com/watch?v=kIT2uMxYh6M

Solution for Any Input
https://www.youtube.com/watch?v=0r2L3wTqkBc

Computational Science and Engineering I, Lecture 1
https://www.youtube.com/watch?v=CgfkEUOFAj0
Computational Science and Engineering I, Lecture 2
https://www.youtube.com/watch?v=-agCn_nWztQ