Introduction to Electromagnetism

S. R. Zinka
zinka@vit.ac.in

School of Electronics Engineering
Vellore Institute of Technology

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Outline

1 Introduction
2 Syllabus
3 Methods of Evaluation
4 Text Books & References
5 Resources
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1. Introduction
2. Syllabus
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Atmospheric Attenuation of Electromagnetic Waves

Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).

Visible light observable from Earth, with some atmospheric distortion.

Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).

Radio waves observable from Earth.

Long-wavelength radio waves blocked.
Founding Fathers
James Clerk Maxwell (1831-1879)

\[\nabla \times E = -\frac{\partial B}{\partial t}\\
\nabla \cdot D = \rho_e\\
\nabla \times H = J_e + \frac{\partial D}{\partial t}\\
\nabla \cdot B = 0
\]

“In 1865, Maxwell unified the two distinct theories electricity and magnetism into a single super-theory electromagnetism and proved that optics is a sub-field of this super-theory”

Most profound and the most fruitful that physics has experienced since the time of Newton - Albert Einstein
Henrich Rudolf Hertz (1857-1894)

“In 1888, Hertz experimentally demonstrated the existence of electromagnetic waves”

It’s of no use whatsoever ... this is just an experiment that proves Maestro Maxwell was right ... we just have these mysterious electromagnetic waves that we cannot see with the naked eye. But they are there - Henrich Rudolf Hertz
Jagadish Chandra Bose (1858-1937)

“In 1894, Bose ignited gunpowder and rang a bell at a distance using electromagnetic waves proving that communication signals can be sent without using wires.”

The invisible light can easily pass through brick walls, buildings etc. Therefore, messages can be transmitted by means of it without the mediation of wires - J. C. Bose
Guglielmo Marconi (1874-1937)

“made the first public transmission of wireless signals on 27 July 1896”
Guglielmo Marconi (1874-1937)

Marconi overseeing his assistants using a kite to raise the antenna
Hendrick Antoon Lorentz & Albert Einstein

- Lorentz took the electrodynamics theory further into microscopic level and laid foundation for the special theory of relativity (STR)
- Later in 1905, Einstein formulated STR in its full extent

For me personally Lorentz meant more than all the others I have met on my life’s journey - Albert Einstein
Paul Maurice Dirac

\[ \nabla \times \mathbf{E} = -J_m - \frac{\partial \mathbf{B}}{\partial t} \]
\[ \nabla \cdot \mathbf{D} = \rho_e \]
\[ \nabla \times \mathbf{H} = J_e + \frac{\partial \mathbf{D}}{\partial t} \]
\[ \nabla \cdot \mathbf{B} = \rho_m \]

“expanded electrodynamics to a more symmetric form, including magnetic as well as electric charges”

One could perhaps describe the situation by saying that God is a mathematician of a very high order, and He used very advanced mathematics in constructing the universe - Paul Dirac
<table>
<thead>
<tr>
<th>Introduction</th>
<th>Syllabus</th>
<th>Methods of Evaluation</th>
<th>Text Books &amp; References</th>
<th>Resources</th>
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**Why Do We Need To Study this Course?**
Any pile of tin with a transmission line exciting it may be called an antenna. It is evident on physical grounds that such a pile of tin does not make a good antenna, and it is worthwhile to search for some distinguishing characteristics that can be used to differentiate between an ordinary pile of tin and one that makes a good antenna.  

\footnote{Volume 8 of the MIT Radiation Laboratory series, *The Principles of Microwave Circuits*}
A Few Applications
Introduction to Electromagnetism

Wi-Fi

Radio

Mobile Phone

Microwave Oven
Air Traffic Control (ATC)

Weather Forecasting
Satellite Communication & Remote Sensing

Missile Surveillance & Tracking
A Few Microwave Components
Rect to Circular Transition

Coaxial to Microstrip Transition

E Plane Tee

H Plane Tee
Magic Tee

Waveguide Directional Coupler

Microstrip Filter

Waveguide Filter
Helical Antenna

Horn Antenna

Microstrip Patch Antennas

Parabolic Reflector Antenna
A Very Famous Horn Antenna!
Are we going to study all these devices? ... 😞
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# Electrostatics

<table>
<thead>
<tr>
<th>Topics/Sub-Topics</th>
<th>No. of Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate systems: Cartesian, Cylindrical, and Spherical</td>
<td>2</td>
</tr>
<tr>
<td>Divergence, Gradient, and Curl - Divergence theorem and Stroke’s theorem</td>
<td>2</td>
</tr>
<tr>
<td>Coulomb’s law - Electric field intensity - Field due to line, sheet, and volume charge - Electric flux density</td>
<td>3</td>
</tr>
<tr>
<td>Gauss Law - Applications of gauss law - Energy density in a electrostatic filed</td>
<td>2</td>
</tr>
<tr>
<td>Energy expended in a moving charge in an electric field - Potential - Potential gradient</td>
<td>2</td>
</tr>
<tr>
<td>Current and current density – Related problems</td>
<td>1</td>
</tr>
<tr>
<td>Metallic conductors, their properties, and conductors Boundary conditions – Related problems</td>
<td>2</td>
</tr>
<tr>
<td>Method of images – Related problems</td>
<td>1</td>
</tr>
<tr>
<td>Semiconductors and dielectrics Properties - Boundary conditions</td>
<td>2</td>
</tr>
<tr>
<td>Capacitance, Poisson’s equations - Laplace equations and uniqueness theorem – Related problems</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong> ≈ 20p</td>
<td></td>
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</tbody>
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## Magnetostatics

<table>
<thead>
<tr>
<th>Topics/Sub-Topics</th>
<th>No. of Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biot-Savart’s law, Ampere’s circuital law - Magnetic flux and flux density</td>
<td>3</td>
</tr>
<tr>
<td>Scalar and vector magnetic potentials - Problems</td>
<td>1</td>
</tr>
<tr>
<td>Steady state magnetic field laws, Force on a moving charge – Problems</td>
<td>1</td>
</tr>
<tr>
<td>Magnetic boundary conditions</td>
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<tr>
<td>Potential energy and forces on magnetic material – Problems</td>
<td>1</td>
</tr>
<tr>
<td>Lorentz force and Faraday’s law - Related problems</td>
<td>1</td>
</tr>
<tr>
<td>Displacement current - Inductance and mutual inductance – Problems</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total ≈ 9p</strong></td>
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</tbody>
</table>
## Time Varying Electromagnetic Fields

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<thead>
<tr>
<th>Topics/Sub-Topics</th>
<th>No. of Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxwell’s equations in point form and integral form – Related problems</td>
<td>2</td>
</tr>
<tr>
<td>Wave motion in free space</td>
<td>1</td>
</tr>
<tr>
<td>Wave motion in perfect dielectrics, lossy dielectrics - Problems</td>
<td>1</td>
</tr>
<tr>
<td>Poynting vector and power calculations - Related problems</td>
<td>2</td>
</tr>
<tr>
<td>Retarded potential (Qualitative study)</td>
<td>1</td>
</tr>
<tr>
<td>Propagation in good conductor – Related problems</td>
<td>2</td>
</tr>
<tr>
<td>Polarization : Horizontal, vertical, linear, elliptical and circular</td>
<td>2</td>
</tr>
<tr>
<td>Normal incidence at a plane conducting boundary, Oblique incident</td>
<td>1</td>
</tr>
<tr>
<td>Dielectric Boundary conditions</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>≈ 13p</strong></td>
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Methods of Evaluation

- Assignments (10%)
- Simulation based mini-project (10%)
- CAT-I & CAT-II (30%)
- Term End Examination (50%)
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Text Books & References

- Mathew O Sadiku “Elements of Electromagnetics”, Oxford University Press, 2003 [S1]
- D. K Cheng “ Field Wave Electromagnetics”, Addison Wesley, 2001 [C1]
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Opensource Softwares

- Ubuntu (or any other flavor of Linux)
- Python (an alternative to MATLAB)
- Lyx (with Jabref)
- Inkscape (with Textext)
- WWW