

BASIC PHYSICS OF ELECTRICITY AND MAGNETISM

APPLICATIONS IN MEDICAL IMAGING SYSTEMS

Fauzyah Aprillia, S.Tr.T., M.Sc.



Basic Physics of Electricity and Magnetism

Fauzyah Aprillia, S.Tr.T., M.Sc.

PT BUKULOKA LITERASI BANGSA

Anggota IKAPI: No. 645/DKI/2024



Basic Physics of Electricity and Magnetism

Author : Fauzyah Aprillia, S.Tr.T., M.Sc.
ISBN : 978-634-324-040-2 (PDF)
Editor : Lia Anggreani Napitupulu, S.S.
Layouter : Lia Anggreani Napitupulu, S.S.
Cover Designer : Novikean Keysah Sanisri

Publisher

Penerbit PT Bukuloka Literasi Bangsa

Distributor: PT Yapindo

Kebon Jeruk Business Park Complex, Block INo. 21, Jl. Meruya Ilir Raya No. 88, Meruya Utara Village, Kembangan District, West Jakarta Administrative City, DKI Jakarta Province, Postal Code: 11620

Email : penerbit.blb@gmail.com

Whatsapp : 0878-3483-2315

Website : bukuloka.com

© Copyright is protected by law.

Valid for 50 (fifty) years from the first publication of the work.

It is prohibited to quote or reproduce any part or all contents of this book without written permission from the publisher. Criminal sanctions apply for violations of Article 2 of Law Number 19 of 2002 concerning Copyright.

Anyone who intentionally and without rights performs actions as referred to in Article 2 paragraph (1) or Article 49 paragraph (1) and paragraph (2) shall be sentenced to imprisonment for at least 1 (one) month and/or a minimum fine of Rp1,000,000.00 (one million rupiah), or a maximum imprisonment of 7 (seven) years and/or a maximum fine of Rp5,000,000,000.00 (five billion rupiah).

Anyone who intentionally distributes, broadcasts, exhibits, circulates, or sells to the public any copyrighted work or related rights products resulting from infringement as referred to in paragraph (1) shall be sentenced to a maximum imprisonment of 5 (five) years and/or a maximum fine of Rp500,000,000.00 (five hundred million rupiah).

PREFACE

Praise be to God Almighty for His grace and blessings, so that the book entitled *Basic Physics of Electricity and Magnetism* can be prepared and presented to readers. This book discusses the fundamental concepts of electricity and magnetism in a clear, systematic, and accessible manner, helping readers understand electric charge, electric fields, current, circuits, magnetic forces, and the close relationship between electricity and magnetism in everyday life.

Written in a simple yet engaging style, this book is intended for the general public who wish to broaden their knowledge of basic physics. As a book offered for public readership, it is expected to serve as a useful reading material for anyone interested in understanding the principles of electricity and magnetism in a light and practical way.

May this book enrich readers' knowledge, encourage curiosity, and help them realize that electricity and magnetism are not merely concepts in physics, but essential parts of modern life, present in technology, household devices, communication systems, and many activities around us.

Jakarta, Juni 2026

Editorial Team

TABLE OF CONTENTS

PREFACE	iii
TABLE OF CONTENTS	iv
Chapter 1: Introduction to Physics in Medical Radiology	1
1.1 Definition of Medical Physics	1
1.2 Role of Electricity and Magnetism in Radiology	6
1.3 Scope of Study.....	11
1.4 Relationship with Medical Imaging Technology	19
Chapter 2: Basic Concepts of Electric Charge and Electric Fields	35
2.1 Electric Charge	35
2.2 Coulomb's Law	47
2.3 Electric Field	51
2.4 Electric Potential Energi.....	54
Chapter 3: Current, Voltage, and Resistance.....	68
3.1 Electric Current	68
3.2 Electric Voltage	73

3.3 Resistance	84
3.4 Ohm's Law	88
3.5 Electric Power	102
Chapter 4: Basic Components of Electrical Circuits	110
4.1 Resistors	110
4.2 Capacitors	117
4.3 Inductors	123
4.4 Voltage Sources	127
4.5 Component Characteristics	131
Chapter 5: Electrical Circuit Analysis	136
5.1 Series Circuits	136
5.2 Parallel Circuits	143
5.3 Kirchhoff's Laws	152
5.4 Combination Circuits	156
5.5 Applications in Medical Equipment	161
Chapter 6: Direct Current (DC) and Alternating Current (AC)	173
6.1 Characteristics of DC	173

6.2 Characteristics of AC	180
6.3 Sinusoidal Waveforms	189
6.4 Impedance	197
6.5 Power Factor.....	205
Chapter 7: Transformers and High Voltage Systems	210
7.1 Transformer Principles	210
7.2 Step-up and Step-down Transformers.....	219
7.3 High Voltage Systems	227
7.4 Electrical Safety	233
Chapter 8: Electrical Principles in Radiology Equipment.....	255
8.1 Radiology Electrical Systems.....	255
8.2 X-ray Generators	264
8.3 Control Systems	275
8.4 Protection and Safety.....	278
Chapter 9: Working Principles of X-ray Tubes.....	290
9.1 Structure of X-ray Tubes	290
9.2 Thermionic Emission	296

9.3 Electron Acceleration	303
9.4 Electron Interaction with Target.....	306
9.5 X-ray Production	310
Chapter 10: Digital Imaging Systems.....	320
10.1 Basic Imaging Concepts	320
10.2 Digital Detectors.....	327
10.3 Analog-to-Digital Conversion.....	331
10.4 Image Quality	334
10.5 Noise and Resolution.....	338
Chapter 11: Basic Concepts of Magnetism.....	343
11.1 Magnetic Fields	343
11.2 Magnetic Forces	350
11.3 Magnetic Properties of Materials	353
11.4 Electromagnets	357
Chapter 12: Electromagnetic Induction and MRI Applications	370
12.1 Electromagnetic Induction	370
12.2 Faraday's and Lenz's Laws	377

12.3 Magnetic Resonance.....	380
12.4 Principles of MRI Operation	384
12.5 Clinical Applications of MRI	390
AUTHOR PROFILE	395
REFERENCES.....	396

REFERENCES

- Alexander, C. K., & Sadiku, M. N. O. (2021). *Fundamentals of electric circuits* (7th ed.). McGraw-Hill Education.
- Barker, G. J. (2020). *Introduction to functional magnetic resonance imaging* (3rd ed.). Cambridge University Press.
- Brady, A. P., Bello, J. A., & Derchi, L. E. (2020). Radiology in global health: Strategies, implementation, and applications. *European Radiology*, 30(5), 2597–2606.
- Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2021). *The essential physics of medical imaging*. Wolters Kluwer.
- Callister, W. D., & Rethwisch, D. G. (2020). *Materials science and engineering: An introduction*. Wiley.
- Chapman, S. J. (2021). *Electric machinery fundamentals* (6th ed.). McGraw-Hill Education.
- Creswell, J. W., & Creswell, J. D. (2021). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.
- Griffiths, D. J. (2017). *Introduction to electrodynamics*. Cambridge University Press.
- Halliday, D., Resnick, R., & Walker, J. (2020). *Fundamentals of physics* (11th ed.). Wiley.

- Horowitz, P., & Hill, W. (2020). *The art of electronics* (3rd ed.). Cambridge University Press.
- International Electrotechnical Commission (IEC). (2022). *Electrical installation safety standards and protection principles*. IEC.
- Kuffel, E., Zaengl, W. S., & Kuffel, J. (2020). *High voltage engineering fundamentals*. Butterworth-Heinemann.
- Levitt, M. H. (2020). *Spin dynamics: Basics of nuclear magnetic resonance*. Wiley.
- Maxwell, J. A. (2020). *Qualitative research design: An interactive approach*. Sage Publications.
- McBee, M. P., Awan, O. A., Colucci, A. T., *et al.* (2021). Deep learning in radiology. *Academic Radiology*, 28(1), 23–29.
- McRobbie, D. W., Moore, E. A., Graves, M. J., & Prince, M. R. (2021). *MRI from picture to proton* (3rd ed.). Cambridge University Press.
- National Fire Protection Association (NFPA). (2023). *Electrical safety in the workplace standards*. NFPA.
- Nilsson, J. W., & Riedel, S. A. (2020). *Electric circuits*. Pearson.
- Ogata, K. (2020). *Modern control engineering*. Pearson.
- Oppenheim, A. V., & Willsky, A. S. (2020). *Signals and systems*. Pearson.
- Sedra, A. S., & Smith, K. C. (2021). *Microelectronic circuits* (8th ed.). Oxford University Press.
- Seeram, E. (2019). *Digital radiography: Physical principles and quality control*. Springer.

- Serway, R. A., & Jewett, J. W. (2018). *Physics for scientists and engineers*. Cengage Learning.
- Serway, R. A., and Jewett, J. W. Physics for Scientists and Engineers. Tenth edition. Cengage Learning.
- Tipler, P. A., & Mosca, G. (2020). *Physics for scientists and engineers*. W. H. Freeman.
- Webster, J. G. (2020). *Medical instrumentation: Application and design* (4th ed.). Wiley.
- Westbrook, C., Roth, C. K., & Talbot, J. (2020). *MRI in practice* (5th ed.). Wiley.

Basic Physics of Electricity and Magnetism offers a clear and engaging exploration of the fundamental principles behind electricity and magnetism. Readers are introduced to essential concepts such as electric charge, electric fields, current, voltage, simple circuits, and magnetic phenomena that appear in everyday life.

Written in an accessible and well-structured style, this book helps readers understand how electricity and magnetism shape modern technology, from household appliances to communication devices. This book is sold for the general public, especially for anyone who wishes to broaden their scientific knowledge and appreciate the role of physics in today's world.

ISBN 978-634-324-040-2 (PDF)



9 786343 240402