Adult Basic Education

Science

Physics 3104C

Magnetic Fields, Matter and Energy

Study Guide

Prerequisite: Physics 3104B

Credit Value: 1

Text: *Physics: Concepts and Connections*. Nowikow et al; Irwin, 2002

Physics Concentration

Physics 1104
Physics 2104A
Physics 2104B
Physics 2104C
Physics 3104A
Physics 3104B
Physics 3104C

Table of Contents

To the Student

I. Introduction to Physics 3104C

In this course you will study magnetic forces and the magnetic fields around magnets. You will learn how magnetic fields can induce electricity. This is the basis behind electric generators and transformers. The course will also introduce you to the revolution in Physics that took place in the twentieth century (Quantum Mechanics). It will require an understanding of physics concepts from many previous courses.

In addition to this Study Guide you will also need a scientific calculator.

II. Use of Science Study Guides

Before beginning this course, ensure you have the text and any other resources needed *(see the information in the Introduction to this course for specifics)*.

As you work through the Study Guide, you will see that it is divided according to the Units listed in the Table of Contents. When you open a unit it will have the following components:

To the Student

Reading for this Unit:
Here you will find the chapters, sections and pages of the text you will use to cover the material for this unit. Skim the sections of the textbook, look at the titles of the sections, scan the figures and read any material in the margins. Once you have this overview of the unit, you are ready to begin. Do not be intimidated by the content. You will work through the text, section by section, gaining knowledge and understanding of the material as you go.

References and Notes	Work to Submit
This left hand column guides you through the material to read from the text. Read any highlighted notes that follow the reading instructions. The symbols ►► direct you to the questions that you should complete when finished a reading assignment..	You come across three (3) headings in this right hand column. **Writing:** This section comprises your notes for the unit. Here you will find either written questions or references to specific questions or problems from your text. You may want to write out each question followed by the answer. This material should be checked by your instructor before moving on to the next unit. Mathematical problems should have their solutions checked as you go. **Laboratory:** This section indicates if there is a Lab that should be completed for the unit. Let the instructor know in advance that you will be ready for the lab. A lab report should be submitted for each Lab. Your instructor will provide guidelines as to how s/he wants the report written. **Assignment:** This section indicates if there is an assignment that should be completed for the Unit. The information in the "References and Notes" column will indicate how you obtain the assignment. These assignments frequently relate the science content to technology, society and the environment.

III. Recommended Evaluation

Written Notes	10%
Labs/Assignments	20%
Test(s)	20%
Final Exam *(entire course)*	50%
	100%

The overall pass mark for the course is 50%.

Unit 1 - Magnetic Fields

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit:	*Physics: Concepts and Connections:*	
	Chapter 15:	Section 15.1: page: 628
		Section 15.2: pages: 629-630
		Section 15.3: pages: 630-632

References and Notes	Work to Submit
	Writing:
Read page 628 of Section 15.1 ▶▶	1.1 What is a lodestone?
	1.2 What two characteristics distinguish magnetic fields from electrostatic and gravitational fields.
	1.3 For each of (a) gravitational, (b) electric and (c) magnetic fields, list the object that creates the field and the object that responds to the field.
Read pages 629-630 of Section 15.2 ▶▶	1.4 Explain what domains and magnetic dipole are.
	1.5 State the domain theory.
	1.6 What does the term ferromagnetic mean?
	1.7 State the Law of Magnetic Forces.
	1.8 Explain magnetic induction in terms of domain theory.

Unit 1 - Magnetic Fields

References and Notes	Work to Submit
Read pages 630 to 632 of Section 15.3 ▶▶	1.9 What is a test compass? 1.10 How can iron filings be used to map magnetic fields? 1.11 Sketch a diagram to show the magnetic field lines around (a) a bar magnet and (b) the earth.

Unit 2 - Electromagnetic Induction

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*
Chapter 15: Section 15.4: pages 633-637
Section 15.5: pages 639-640; 648
Chapter 16: Section 16.1: pages 670-671,
Lab. 16.1: pages 691-692

References and Notes	Work to Submit
	Writing:
Read page 633 of Section 15.4. ▶▶	2.1 State Oerstad's Principle.
Study Figure 15.12 on page 634 ▶▶	2.2 State left hand rule #1.
	2.3 Complete Problem 1 and 2 on page 638.
Read "Magnetic Character Revisited" on pages 634-635 ▶▶	2.4 Define and give an example of (a) paramagnetic and (b) diamagnetic materials.
Read pages 635-637 ▶▶	2.5 What is an electromagnet? How is it created?
Use Figure 15.15 and 15.16 to help answer 2.6.	2.6 What happens to the magnetic field lines when current flows through a coiled conductor?
Refer to Table 15.3 ▶▶	2.7 What factors affect the strength of an electromagnetic?
	2.8 What is magnetic permeability?

Unit 2 - Electromagnetic Induction

References and Notes	Work to Submit
	2.9 How does the magnetic permeability of iron compare to copper?
Refer to Table 15.4 ▶▶	2.10 Briefly describe one (1) application of electromagnets.
Read page 639 of Section 15.5 ▶▶	2.11 What is the motor principle?
Read page 640 ▶▶	2.12 What four (4) parameters affect the size of the force resulting from the interaction of two (2) magnetic fields? 2.13 When is the magnetic force at (a) maximum and (b) minimum?
Read page 648 of Section 15.5 ▶▶	2.14 What four (4) parameters affect the size of the magnetic force on an individual charge? 2.15 When is this magnetic force on the charges at (a) maximum and (b) minimum?
Read Section 16.1, pages 670-671 ▶▶	2.16 What is Faraday's law of electromagnetic induction? 2.17 How is alternating current created using a coiled conductor and a magnet? 2.18 Sketch and describe how Faraday's iron ring apparatus functions. 2.19 Define transformer (use glossary).

Unit 2 - Electromagnetic Induction

References and Notes	Work to Submit
	Laboratory:
Let your instructor know you are ready for Lab #1 on pages 691-692 ▶▶	2.20 Complete and submit to your instructor Core Lab #1: Electromagnetic Induction
	Assignment:
Read in Appendix A: "Physics of Cell Phones" for your assignment ▶▶	2.21 Complete and submit to your instructor Questions 1, 3 and 5 on page 125.

Unit 3 - Quantum Mechanics

The objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*
Chapter 17: Unit F: pages 694-695
Section 17.1: page 697
Section 17.2: pages 697 - 701
Section 17.3: pages 702 - 706
Section 17.4: pages 707 - 710
Section 17.5: pages 710 - 711
Section 17.6: pages 712 - 719

References and Notes	**Work to Submit**
	Writing:
Read Unit F, Introduction, page 694-695. ▶▶	3.1 List four (4) discoveries that resulted in the end of classical physics.
Read page 697 of Section 17.1 ▶▶	3.2 What is another name for quantum theory?
	3.3 What is quantum theory?
	3.4 What are two (2) characteristics of light that the wave theory of light could not explain.
	3.5 What are two (2) properties of subatomic particles that the wave theory of light could not explain?
Read page 698 of Section 17.2 ▶▶	3.6 Is the brightness of a light source related to its penetrating power?
	3.7 What part of sunlight causes damage to the skin?

Unit 3 - Quantum Mechanics

References and Notes	Work to Submit
Read page 699 to page 701 ▶▶	3.8 What are quanta?
Read the sidebar on page 699 ▶▶	3.9 Write Planck's equation in terms of frequency. Explain what each variable represents.
A photon is a particle of light. The energy of a beam of light is concentrated in these particles.	3.10 Write Planck's equation in terms of wavelength. Explain what each variable represents.
We have seen light filaments glow white and toaster elements glow red. The temperature of the object affects the wavelengths of light emitted from a heated object.	3.11 Refer to the seven regions of the electromagnetic spectrum shown in Figure 10.9. (a) Which region has the highest energy associated with it? (b) Which has the lowest energy?
^{0}C + 273 = Kelvin (K)	3.12 What is an electron volt?
Wein's Law requires temperature to be in Kelvin not Centigrade	3.13 What is black body radiation?
0^{0}C = 273K	3.14 Refer to Figure 17-8A, what did wave theory predict would happen to the flux (flowing out) of photons at shorter wavelengths?
25^{0}C = 298K	
850K = 577 ^{0}C	3.15 Refer to Figure 17.8B. According to Planck's black body equation, what happens to the flux (flowing out) of photons as an object heats up?
	3.16 State Wein's Law in words and as an equation.
	3.17 Convert 125 ^{0}C to Kelvin.
	3.18 Convert 1000K to ^{0}C.
	3.19 Solve Problems 1 and 2 on page 702.

Unit 3 - Quantum Mechanics

References and Notes	**Work to Submit**
Read page 702 of Section 17.3 ▶▶	3.20 What is the photoelectric effect?
Read pages 703 - 706 of Section 17.3 ▶▶	3.21 Using Figure 17.11A, explain why lower energy photons of light do not cause electron emission from a metal's surface?
	3.22 What is the work function?
	3.23 Using Figure 17.11B explain the effect of high energy photons on electron emission from a metal's surface?
Use Table 17.1 on page 704 for these questions ▶▶	3.24 Calculate the energy E (in eV) associated with (a) x-rays whose wavelength is 10^{-10}m (b) visible light whose wavelength is 550nm (c) radiowaves whose wavelength is 10^{2}m.
	3.25 Complete Problems 24 and 28 on page 732.
Read Section 17.4 pages 707-709 ▶▶	3.26 Describe Compton's experiments.
Do not worry about the mathematical problems here, you are not responsible.	3.27 What did Compton's work show about photons?
Read pages 710 to 711 of Section 17.5 ▶▶	3.28 What did de Broglie propose about matter and light waves?
Again you are not responsible for the mathematical problems.	

Unit 4 - Model of the Atom

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections*
Chapter 17: Section 17.6: pages 712-719

References and Notes	Work to Submit
	Writing:
Read page 712 and 713 of Section 17.6, pages to "The Conservation of Energy" ▶▶	4.1 What is observed when the spectrum of hydrogen gas is examined?
These series correspond to electron transitions.	4.2 What does the Bohr model say about energy emissions and electrons?
Bohr's model is limited to ***one*** *electron systems.*	4.3 How does Bohr explain the fact electrons do not fall into the nucleus?
	4.4 Explain the presence of the Lyman, Balmer and Paschen series in the spectrum of hydrogen. (Discuss this with your instructor).
Read page 718 of Section 17.6 ▶▶	4.5 What other atoms or ions can Bohr's model be applied to?
	4.6 Why can the Bohr model only apply to one electron system?
	4.7 What is meant by the wave-particle duality of light?
	4.8 What is the principle of complementarity?
	4.9 Using Figure 17.24, summarize the behaviour of light that can be explained by (a) the wave theory and (b) the particle theory?

Unit 5 - Nuclear Reactions

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*
Chapter 18: Section 18.1: page 738
Section 18.2: pages 741-742

References and Notes	Work to Submit
	Writing:
Read the Introduction to Section 18.1 on page 738 ▶▶	5.1 Why is electrical energy consumption continually increasing?
Read page 741 of Section 18.2 ▶▶ *A periodic table is found on page 805 of the text. Note: For each element the atomic number (Z) is above the symbol.*	5.2 Define each of the following: (i) nucleus (ii) proton (iii) neutron (iv) nucleons (v) atomic number (Z) (vi) atomic mass number (X) (vii) number of neutrons (N)
Read pages 742-743 of Section 18.2 ▶▶	5.3 Complete Problems 36, 37, and 42 on page 773. 5.4 What are isotopes? (Use the glossary). 5.5 What is the equation that relates energy and mass? 5.6 What is a mass defect? 5.7 What is a mass difference?
Read pages 744-746 ▶▶	5.8 What is radioactivity? 5.9 Why are the nuclei of some elements radioactive?

Unit 5 - Nuclear Reactions

References and Notes	Work to Submit
	5.10 What is transmutation?
	5.11 What is ionizing ability?
	5.12 What is an alpha (α) particle?
	5.13 What is the general equation for alpha decay?
	5.14 Complete Problem 2 on page 751.
*Read page 747 "Beta Decay" and "**β**⁻ Decay" to the end of page 748* ▶▶	5.15 When one atom of $^{32}_{15}P$ decays by β emission, an atom of $^{32}_{16}S$ is formed. The difference in mass is 8.4 x 10^{-4}μ. How much energy is released by the one atom?
	5.16 What is β^- decay?
	5.17 What is the general equation for β^- decay?
	5.18 Complete Problem 3 on page 751.
	5.19 What is positron emission?
	5.20 Complete Problem 4 on page 751.
Read pages 749-750 ▶▶	5.21 How is electron capture different from β^+ decay?
	5.22 What is gamma decay?
Read pages 751-752 of Section 18.4 ▶▶	5.23 What is half-life ?

Unit 5 - Nuclear Reactions

References and Notes	Work to Submit
	5.24 What is the equation for radioactive decay? Explain what each variable represents? 5.25 Complete Problems 1 and 2 on page 754. 5.26 Complete Problems 56 and 58 on page 775.

Unit 6 - Nuclear Energy

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit:	Physics: Concepts and Connections:		
	Chapter 18:	Section 18.5:	pages 754-761
		Section 18.6:	pages 761 - 768
		Section 18.7:	pages 768-769

References and Notes	Work to Submit
	Writing:
Read pages 754-761 of Section 18.5 ▶▶	6.1 Where does the heat energy in nuclear reactions come from?
	6.2 What is nuclear fission?
	6.3 Explain how controlled nuclear reactions are used in nuclear reactors.
	6.4 What is binding energy?
	6.5 What is nuclear fusion?
	6.6 Complete Problems 1 and 2 on page 760.
Read pages 761-768 of Section 18.6 ▶▶	6.7 What does the term CANDU represent?
	6.8 Explain how the CANDU reactor produces electricity.
	6.9 Describe three (3) safety systems on the CANDU reactor.
Read Section 10.7 on pages 768 - 769 ▶▶	6.10 Summarize the arguments for and against nuclear energy.

Appendix A

The Physics of Cellular Telephones

Outcomes:

1. Identify questions, analyze, compile and display evidence and information to investigate the development over time of a practical problem, issue or technology.

2. Explain Oersted's Principle.

3. Analyze qualitatively and quantitatively electromagnetic induction by both a changing magnetic flux and a moving conductor.

4. State Faraday's law of magnetic induction.

5. Analyze and evaluate, from a variety of perspectives, using a variety of criteria, the risks and benefits to society and the environment of a particular application of scientific knowledge and technology.

6. Identify, analyze and describe examples where technologies were developed based on scientific understanding, their design and function as part of a community's life and science and technology related careers.

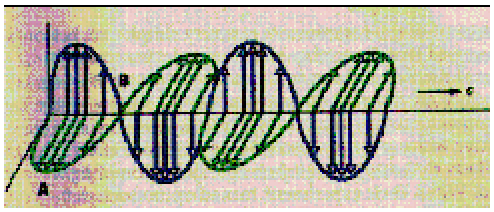
Introduction

What does the name Marconi mean to you? If you live in this province, probably quite a bit. In 2001 Newfoundland and Labrador celebrated the 100th anniversary of the reception of the first transatlantic wireless message at Signal Hill by Guglielmo Marconi. This signal was sent from Poldhu, England on December 12, 1901. In the 1890's Marconi had invented and developed the wireless telegraph to send messages over large distances. At the age of twenty-seven, his success on Signal Hill marked a turning point in world-wide communication. Marconi's work laid the foundation for the development of today's cellular telephones. Marconi though, could not have imagined the enormous impact his work would have on future generations. The number of people using cellular telephones has risen dramatically during the past decade. "Experts estimate that by 2005 there will be over 1.26 billion wireless telephone users worldwide" (Cellular Telephone Use and Cancer). Neither could Marconi have imagined the possible health risks currently associated with wireless communication – risks attributed to electromagnetic fields.

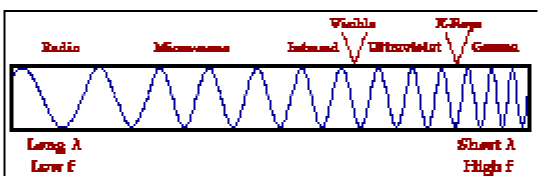
Theory

Electromagnetic Fields

By the time you leave for school in the morning you have already been exposed to a number of electromagnetic fields – from your blow dryer to your toaster to your microwave. What are these electromagnetic fields and where do they come from? A 'field' exists in a region of space surrounding an object. We cannot necessarily see a field, but we can observe the effects of its presence. A dropped object, for example, is drawn towards the earth because of the pull of the earth's gravitational field. Oersted found that a magnetic field is produced around a wire carrying an electric current. Faraday found conversely that an electric field is induced by a changing magnetic field. Maxwell extended Faraday's and Oersted's work by hypothesizing that a *changing* electric field would also produce a magnetic field. Maxwell went on to say that if a changing magnetic field produces an electric field, that electric field is itself changing. This changing electric field would then produce a changing magnetic field, and so on. The net result of the interaction of these changing fields was a 'wave' of electric and magnetic fields travelling through space. These waves are called electromagnetic waves. They are transverse waves where the electric and magnetic fields are perpendicular to each other and to the direction of travel.



At point A the electric and magnetic fields associated with the wave are at maximum strength and at point B the fields are at minimum strength. Electromagnetic waves are waves of fields, not of matter as are water waves. It is because they are fields that electromagnetic waves can travel in empty space at the speed of light. It is interesting to note that Heinrich Hertz did not experimentally detect electromagnetic waves until 1887 – eight years after Maxwell's death. Electromagnetic waves have since been detected over a wide range of frequencies known as the electromagnetic spectrum.



Radio frequency (RF) radiation is one of the several types of electromagnetic radiation. It is the type of radiation emitted by cellular telephones.

Cellular Telephones and Electromagnetic Radiation
There are many different types of cellular telephones available to consumers. They all convert voice into impulses that are transmitted over radio waves at frequencies ranging from about 800 to 2100 megahertz. Moving charges in the transmitting radio antenna create electromagnetic waves that radiate away from the antenna (and can be picked up by a receiving antenna). All cellular telephones emit non-ionizing radio frequency radiation. This is different from ionizing radiation produced by X-ray machines, which can present a health risk at certain doses. According to the National Cancer Institute, the level of exposure to radio frequency radiation depends on the amount of cellular telephone traffic, the quality of transmission; how far the antenna is extended, and the size of the handset.

The main source of radio frequency energy is the cell phone antenna. The closer the antenna is to the head, the higher the exposure to radio frequency radiation. The intensity of the electromagnetic wave actually changes $\frac{1}{r^2}$ as (where r represents distance).

The antenna would be closest to the person's head in a hand-held cellular phone since the antenna is actually in the handset.

The intensity of the radio frequency radiation also depends on the power level of the signal sent to and from the nearest base station. Each zone in a particular geographic region has its own base station. When a call is made from a cell phone, a signal is sent to this base station. The base station then sends the call through a switching center where it is transferred to another base station, another cell phone or to the local land line system. The farther a cell phone user is from the base station, the more power is required to maintain the connection. This will increase the amount of radio frequency radiation for the user. It should also be noted that digital phones (which operate at different frequencies and power levels) are believed to emit less radiation than the older analog versions.

Health Risks
"Amazing, fast-paced, ever-evolving technology is progress. But progress often comes with a price. The price might be negative effects on our health" (Cell Phones and Electromagnetic Health Hazards). Recently there has been concern that the use of cell phones (particularly hand-held models) may be linked with loss of memory, Parkinson's disease, headaches and even cancer. This concern has prompted several studies, particularly on the link between cell phone use and cancer. Overall, most of these studies do not support such a link. However, based on the fact that cellular telephones have been available for a relatively short period of time, it would be premature to conclude that there is no link between cellular telephone use and cancer. It is important to continue the research, addressing the effects of long-term cell phone use as well as the differences between analog and digital technologies. Slesin (2002) notes that a, "lack of studies about the adverse effects of EMF's may also prevent us from finding beneficial effects" (p. 2). In the meantime, preventative measures can be taken at least regarding

cell phone use. Consumers can purchase a device called a 'Wave Buster' which claims to absorb up to seventy percent of electromagnetic fields from cell phones (due to its ceramic composition). The Wave Buster has two pieces – one that attaches near the antenna and the other over the speaker. In the absence of such a device, users can limit cell phone use or switch to a phone with a headset where there is more distance between the antenna and the user. It is your responsibility to take EMF exposure into your own hands. "As more evidence uncovers the truth about EMF's, it's prudent to protect you and your family, while enjoying all that technology has to offer" (Cell Phones and Electromagnetic Health Hazards, p. 2).

Conclusion

Electromagnetic fields surround us constantly – whether they be from cell phones or microwaves or television sets. Moreover, the number of EMF sources are growing rapidly. Unfortunately "the entire effect of multiple electromagnetic fields on human physiology is not completely understood" (Electromagnetic Fields and your Health). Since the adverse effects of exposure to EMF's appear to arise slowly, the consequences of living in a world filled with EMF's may not be known for many years. Until then we can only continue the exploration begun in part by Marconi.

Questions

1. What is an electromagnetic wave?
2. An electromagnetic field is measured at a distance ' r ' away from the source. How will the electromagnetic field change at a distance ' $2r$ ' from the source?
3. What is the difference between ionizing and non-ionizing radiation?
4. Research: What are some other kinds of electromagnetic radiation?
5. Research: How does the digital cellular telephone differ from the analog phone?

References

Cell phones and electromagnetic health hazards. Available: http://www.ecomall.com/greenshopping/magnet.htm.

Cellular telephone use and cancer. Available: http://cis.nci.nih.gov/fact/3_72.htm.

Deley, T. (2002) Electromagnetic fields on a power trip. Available: http://www.mindfully.org/Health/EMF-Electrictro-MagneticFeb02.htm.

Electromagnetic fields and your health. Available: http://www.clarus.com/shared/emf2.shtml.

Electromagnetic radiation: How safe are cell phones, cell towers, power lines and household appliances? Available: http://members.nyas.org/events/section/mtg_02_0212.html.

Giancoli, D.C. (1998). *Physics*. Prentice-Hall Canada Inc.: Toronto.

Swedish review of cell phone studies finds no 'consistent evidence' of cancer link. (2002). Available: http://www.nlm.nih.gov/medlineplus/news/fullstory_9485.html.

Wavebuster against the electromagnetic waves from cell phones. Available: http://uk.gsmbox.com/news/mobile_news/all/54169.gsmbox.

Activities

Activity 1: (taken from Deley, 2002)

Purpose: To measure electromagnetic fields in the home.

Materials: Gaussmeter

Background: Electromagnetic radiation is measured in Gauss or milligauss. Deley states that people living in urban areas average 3 milligauss while those in rural areas average 1 milligauss. Generally, electromagnetic fields drop to naturally occurring levels at around 3 feet from the source (except around power lines).

Procedure: Students will use the gaussmeter to measure the electromagnetic fields around cell phones and other home appliances. Take measurements in several different rooms and at different distances from the same object. Students could then graph electromagnetic field against distance to observe the relationship between the two.

Activity 2: Radio Wave Transmission
For a simulation and some information on how a radio wave is transmitted, go to: http://www.pbs.org/wgbh/aso/tryit/radio/.