

ELECTROMAGNETIC RADIATION

# Electricity and Alagnetism

Project PHYSNET Physics Bldg. Michigan State University East Lansing, MI

# ELECTROMAGNETIC RADIATION

by R. Young

1. I	Introduction	1
2. I	Procedures	1
Ack	gnowledgments	1

ID Sheet: MISN-0-515

# Title: Electromagnetic Radiation

Author: R.D. Young, Dept. of Physics, Ill. State Univ

Version: 2/1/2000 Evaluation: Stage B0

Length: 2 hr; 8 pages

# Input Skills:

1. Vocabulary: linear damping force (MISN-0-29).

- 2. State Maxwell's equations (MISN-0-513).
- 3. Determine the Poynting vector for an electromagnetic field and calculate the flow of electromagnetic power (MISN-0-513).
- 4. Express the gradient, divergence, and curl operators in spherical polar coordinates (MISN-0-503).

# Output Skills (Knowledge):

- K1. Vocabulary: inhomogeneous wave equation, retarded time, retarded scalar potential, retarded vector potential, gauge transformation, Lorentz condition, Lorentz gauge, radiation resisitance.
- K2. Derive the radiation fields and the average radiated power of an oscillating electric or magnetic dipole.
- K3. Derive the average power radiated by an electron in the field of an electromagnetic wave.

# Output Skills (Rule Application):

R1. Calculate the average radiated power and the radiation resistance of a given electric or magnetic dipole.

# Output Skills (Problem Solving):

S1. Determine the relative efficiency of electric and magnetic dipole radiation.

# External Resources (Required):

1. J. Reitz, F. Milford and R. Christy, Foundations of Electromagnetic Theory, 4th Edition, Addison-Wesley (1993).

# THIS IS A DEVELOPMENTAL-STAGE PUBLICATION OF PROJECT PHYSNET

The goal of our project is to assist a network of educators and scientists in transferring physics from one person to another. We support manuscript processing and distribution, along with communication and information systems. We also work with employers to identify basic scientific skills as well as physics topics that are needed in science and technology. A number of our publications are aimed at assisting users in acquiring such skills.

Our publications are designed: (i) to be updated quickly in response to field tests and new scientific developments; (ii) to be used in both classroom and professional settings; (iii) to show the prerequisite dependencies existing among the various chunks of physics knowledge and skill, as a guide both to mental organization and to use of the materials; and (iv) to be adapted quickly to specific user needs ranging from single-skill instruction to complete custom textbooks.

New authors, reviewers and field testers are welcome.

## PROJECT STAFF

Andrew Schnepp Webmaster
Eugene Kales Graphics
Peter Signell Project Director

## ADVISORY COMMITTEE

D. Alan Bromley Yale University

E. Leonard Jossem The Ohio State University A. A. Strassenburg S. U. N. Y., Stony Brook

Views expressed in a module are those of the module author(s) and are not necessarily those of other project participants.

© 2001, Peter Signell for Project PHYSNET, Physics-Astronomy Bldg., Mich. State Univ., E. Lansing, MI 48824; (517) 355-3784. For our liberal use policies see:

http://www.physnet.org/home/modules/license.html.

3 4

# **ELECTROMAGNETIC RADIATION**

# by R. Young

# 1. Introduction

In this Unit, Maxwell's equations are applied to electromagnetic radiation from prescribed charge-current distributions. Radiation problems involve solutions to the inhomogeneous wave equation with (specified) sources. These solutions must represent outgoing waves and fall off as 1/r for large distances. The charge distributions treated involve an oscillating electric dipole, a half-wave antenna, and an oscillating magnetic dipole. In addition, the power radiated by a group of slowly moving charges and an accelerated charge will be treated.

# 2. Procedures

- 1. Read Sec. 20-1, 20-2 and 20-3 of the text
- 2. Solve these problems:

$\mathbf{Prob}$	Type
20-2	Power density, total power, and radiation resistance of an
	oscillating electric dipole
20-3	Radiation fields and total power of an oscillating magnetic
	dipole
20-4	

3. Show that the total power radiated by a electron that is free to move in an electric field of the form

$$E = E_0 \cos \omega (t - x/c)$$

is

$$P = \frac{1}{12\pi\epsilon_0} \frac{e^4 E_0^2}{m_e^2 c^3} \,.$$

# Acknowledgments

The author would like to thank Illinois State University for support in the construction of this lesson. Preparation of this module was supported

in part by the National Science Foundation, Division of Science Education Development and Research, through Grant #SED 74-20088 to Michigan State University.

5 6