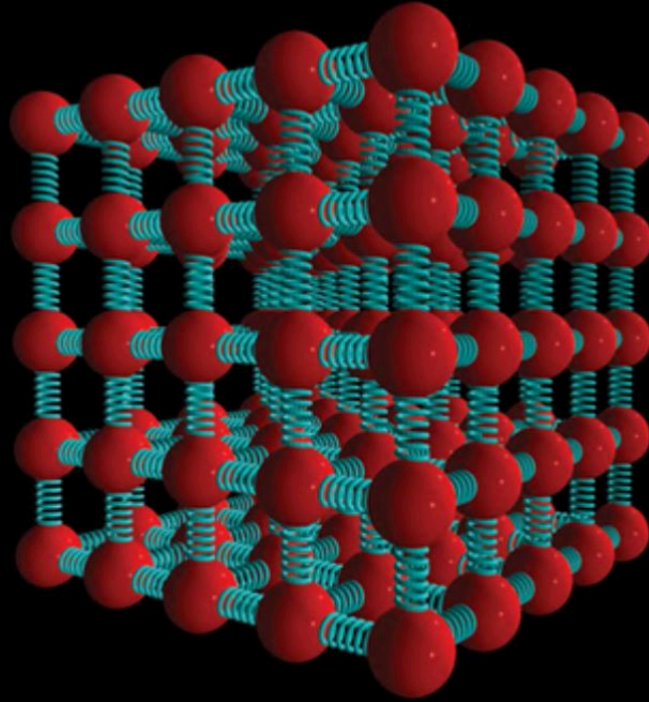
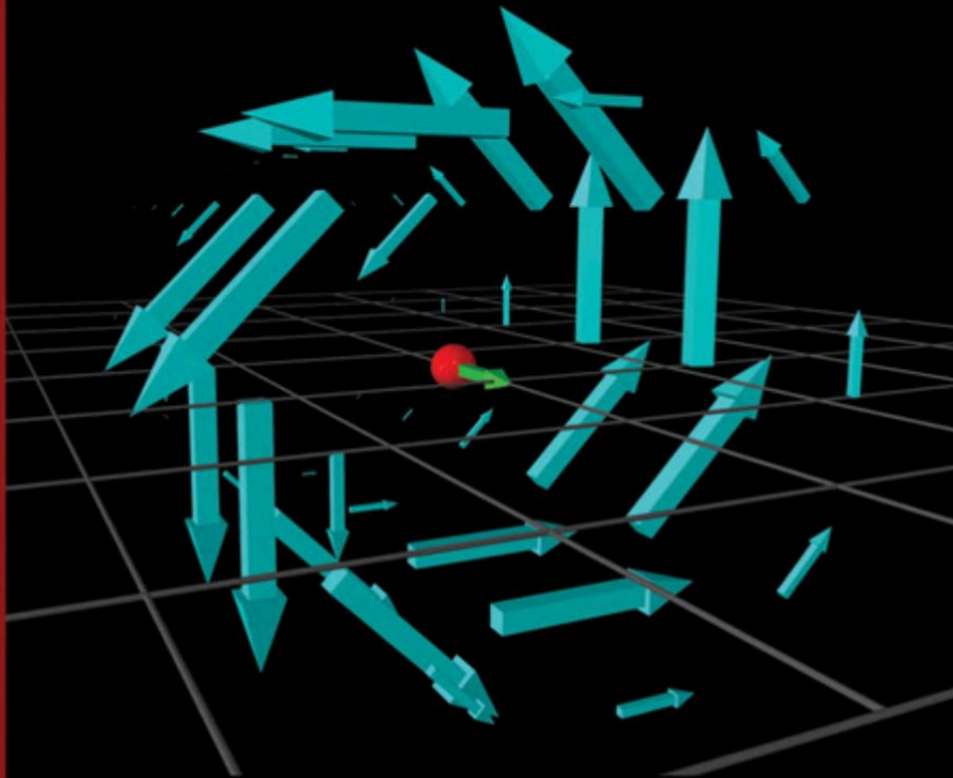


CHABAY • SHERWOOD



MATTER & INTERACTIONS
3rd EDITION



EXECUTIVE EDITOR *Stuart Johnson*
ASSISTANT EDITOR *Aly Rentrop*
ASSOCIATE MARKETING DIRECTOR *Christine Kushner*
SENIOR PRODUCTION EDITOR *Elizabeth Swain*
ART DIRECTOR *Jeof Vita*
TEXT DESIGN *Laura Ierardi*
SENIOR MEDIA EDITOR *Thomas Kulesa*
SENIOR ILLUSTRATION EDITORS *Sigmund Malinowski and Anna Melhorn*
COVER IMAGE *Ruth Chabay*

Cover Description

Volume 1: Ball-and-spring model of a solid Volume 2: Magnetic field of a moving charge

This book was set in 10/12 Times Ten Roman in LaTeX by Aptara[®], Inc. and printed and bound by Courier Kendallville. The cover was printed by Courier Kendallville.

This book is printed on acid-free paper.

Copyright © 2011, 2007, 2002 John Wiley & Sons, Inc. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, website www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030-5774, (201)748-6011, fax (201)748-6008, website <http://www.wiley.com/go/permissions>.

Evaluation copies are provided to qualified academics and professionals for review purposes only, for use in their courses during the next academic year. These copies are licensed and may not be sold or transferred to a third party. Upon completion of the review period, please return the evaluation copy to Wiley. Return instructions and a free of charge return shipping label are available at www.wiley.com/go/returnlabel. Outside of the United States, please contact your local representative.

Library of Congress Cataloging-in-Publication Data

Chabay, Ruth W.
Matter & interactions / Ruth W. Chabay, Bruce A. Sherwood.—3rd ed.
p. cm.
Includes index.
Volume 1 ISBN 978-0-470-50345-4 (pbk.)
Volume 2 ISBN 978-0-470-50346-1 (pbk.)
Complete ISBN 978-0-470-50347-8 (cloth)
1. Physics—Textbooks. 2. Mechanics—Textbooks. I. Sherwood, Bruce A. II. Title. III.
Title: Matter and interactions.

QC23.2.C43 2011
530—dc22

2009034010

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

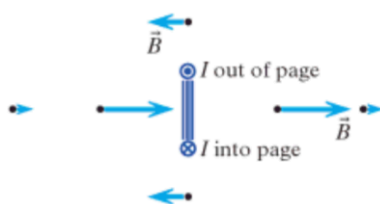


Figure 18.32 The magnetic field above and below the coil points in the opposite direction to the field along the axis.

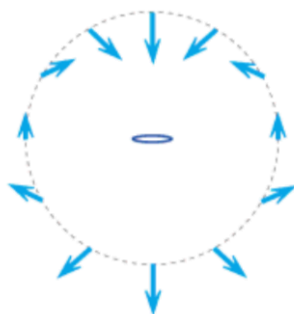


Figure 18.33 The magnetic field of a current loop (which lies in the xz plane, viewed edge-on), at locations outside the loop, in a plane containing the axis of the loop.

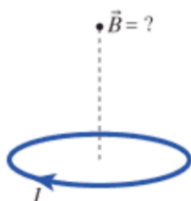


Figure 18.34 Curl the fingers of your right hand in the direction of the conventional current, and your thumb will point in the direction of the magnetic field.

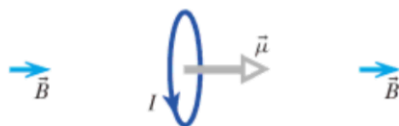


Figure 18.35 The magnetic dipole moment $\vec{\mu}$ is considered to be a vector pointing in the direction of the magnetic field along the axis.

Far above the coil in Figure 18.31, the closer upper part of the coil contributes a larger magnetic field to the left than does the slightly farther away lower part of the coil to the right. A detailed calculation shows that this is also true a short distance above the coil (Figure 18.32). Compare the pattern of magnetic field with the pattern of *electric* field around an electric dipole.

Magnetic Field at Other Locations Outside the Loop

The magnetic field at other locations outside the loop is more difficult to calculate analytically, but the magnetic field has a characteristic dipole pattern as shown in Figure 18.33, which is the result of a computer calculation that added up all the contributions of many short sections of the loop.

A Special Right-Hand Rule for Current Loops

There is another “right-hand rule” that is often used to get the direction of the magnetic field along the axis of a loop. Let the fingers of your right hand curl around in the direction of the conventional current, and your thumb will point in the direction of the magnetic field at any location on the axis.

QUESTION Try using this right-hand rule to determine the direction of the magnetic field at the indicated observation location in Figure 18.34.

You should find that the magnetic field points down. This right-hand rule should of course give the same result as applying the more general right-hand rule to the cross product $\Delta\vec{l} \times \hat{r}$ and adding up the contributions of the various parts of the loop, as called for by the Biot–Savart law.

QUESTION On the diagram, consider $\Delta\vec{l} \times \hat{r}$ for two short pieces of the loop, on opposite sides of the loop. Show that the two pieces together contribute a magnetic field in the downward direction above the loop.

18.9 MAGNETIC DIPOLE MOMENT

Recall the formula for the electric field along the axis of an electric dipole, at a distance r far from the dipole:

$$E_{\text{axis}} \approx \frac{1}{4\pi\epsilon_0} \frac{2p}{r^3}$$

where the “electric dipole moment” $p = qs$. Similarly, in the formula for the magnetic field along the axis of a current-carrying coil at a distance r far from the coil, we can write this:

$$B_{\text{axis}} \approx \frac{\mu_0}{4\pi} \frac{2\mu}{r^3}$$

where the “magnetic dipole moment” $\mu = IA$. (If there are N loops, $\mu = NIA$.) Here A is the area of the loop (πR^2 for circular loops). This formula for magnetic field is approximately valid even if the loop is not circular. The magnetic dipole moment $\vec{\mu}$ is considered to be a vector pointing in the direction of the magnetic field along the axis (Figure 18.35). This means that the direction of the magnetic dipole moment can be obtained by curling the fingers of your right hand in the direction of the conventional current, and your thumb points in the direction of the magnetic dipole moment.