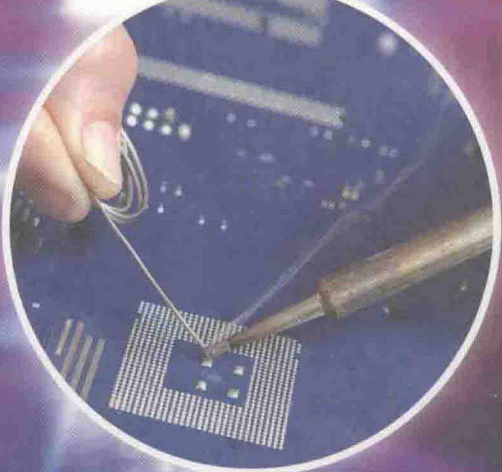
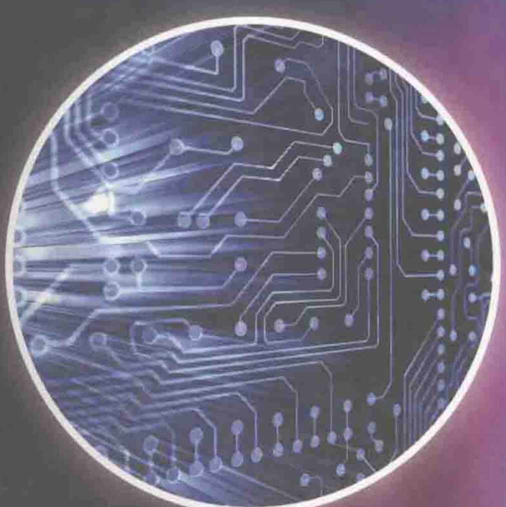
THIRD EDITION



ELECTRONICS

A FIRST COURSE



OWEN BISHOP

Newnes

Electronics
A First Course

Third Edition

Owen Bishop

ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD • PARIS
SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Newnes is an imprint of Elsevier

Newnes

Newnes is an imprint of Elsevier
The Boulevard, Langford Lane, Oxford OX5 1GB, UK
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA

First edition 2002
Second edition 2006
Reprinted 2006
Third edition 2011

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record of this book is available from the Library of Congress

ISBN: 978-1-85617-695-8

For information on all Newnes publications visit our website at www.newnespress.com

Printed and bound in Italy

11 12 13 10 9 8 7 6 5

Electronics
A First Course

Introduction

This is a complete introductory textbook intended for courses leading to GCSE Electronics. It also caters for the Electronics sections of GCSE Design and Technology (Electronic Products). It assumes no previous knowledge of electronics or of the electronic aspects of physics.

Most of the text is divided into numerous short Topics. The topics are dealt with thoroughly, with simple explanations and plenty of examples and illustrations. This presentation has two advantages. It allows students to confine their attention to the particular topics found in a given specification. It also presents the student with self-contained, easily assimilable and readily testable segments of knowledge.

The book is student-centred and it features:

- Frequent 'Self Test' questions to allow students to assess their progress.
- Sets of questions at numerous key stages in the book, linking together the material of consecutive Topics. Answers to these and the Self Test questions are given at the end of the book, if they are numerical or of few words.
- An abundance of practical examples, with numerous circuit diagrams. Detailed instructions for simple constructional techniques, and for test procedures appear in the 'In the Lab' sections.
- An underlying emphasis on electronic systems.
- 'Design time' pages provide a wealth of practicable suggestions for circuits and projects that students can design for themselves. These are intended to help students to prepare coursework projects for the examination, as well as to promote understanding of electronics theory.
- The book is copiously illustrated with halftone and line drawings, the circuit symbols following the guide set out in the AQA GCSE Electronics specification. There are numerous photographs, including close-ups of electronics components, and illustrations of constructional techniques.

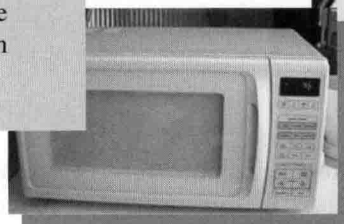
While updating the material for this edition we have taken into account the increased emphasis on electronic systems in the latest GCSE specifications. We have also tried to match the content of the book to the basic requirements for a number of units of the EDEXCEL level 2 BTEC First examinations in Electronics.

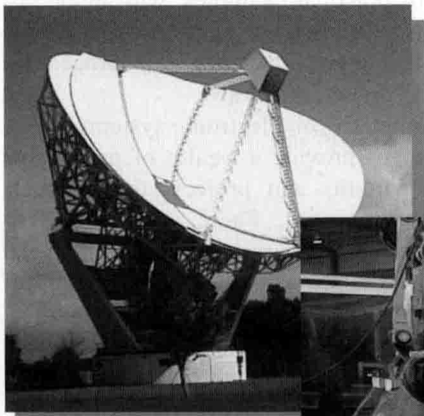
WHAT IS ELECTRONICS?

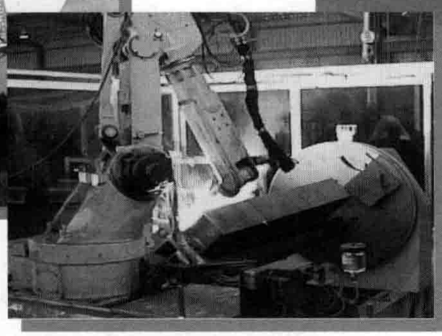
Electronics is about electrons.

It is about the ways we use electrons to do useful and interesting things.

The photos on this page show some of the things that we can do with electrons. Can you work out what these things are?







Electronics makes a big difference to all our lives. Without electronics, our lives would be less comfortable, less safe, less interesting and less fun. Or do you disagree? Talk about it with other students.

HOW TO USE THIS BOOK

Most of the book is set out as brief Topics. When you open the book at one of these Topics, the pages tell you all you need to know about one electronics topic. As well as the text and pictures, there may be:

- **Things to do** that help you to learn more.
- **Design tips** to help you design and build your electronics project.
- **Self tests** to find out how you are getting on. Answers are at the back of the book.

Most students will need to work on most of the spreads. These cover all the essential topics for Electronics exams at Level 2. Your teacher will tell you which spreads, if any, you can leave out.

In the Lab and **Design Time** pages provide you with advice and ideas for your project.

After every few spreads there is a batch of questions. The answers to these are on our website: http://www.elsevierdirect.com/companions/9781856176958.

In addition, there are several features on the website to help you study electronics more effectively. These include animated diagrams of electronic circuits in action. The interactive multiple-choice questions on the website are a novel and effective way for you to test your understanding of the subject.

Also after each group of spreads are some pages that give you more details or cover extra topics. These are mostly for students taking the Higher Tier papers in the exam. They also cover topics that are required by only one or two of the exam boards. Ask your teacher which topics to study.

Contents

Part 1

Electricity

Electrons

Put some small pieces of kitchen foil on the workbench. You can use small pieces of cork, instead. Rub a plastic pen with a dry woollen cloth. Rub hard for ten or twenty seconds. Hold the pen a few millimetres above the pieces of foil. They jump up and stick to the pen. Some of them may jump up and down again several times.

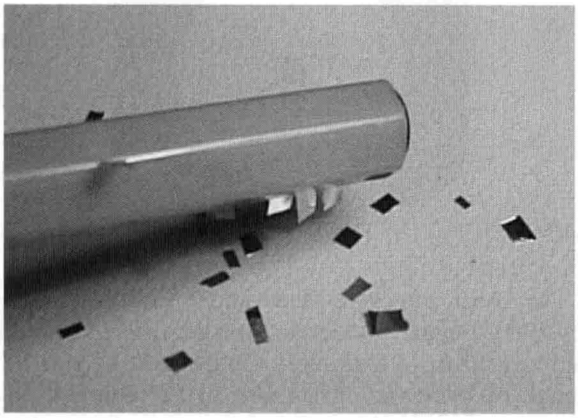


FIGURE 1.1

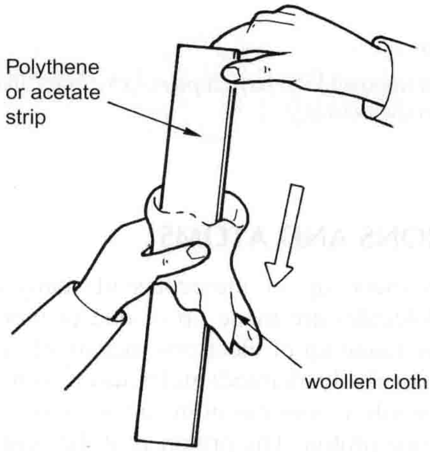


FIGURE 1.2

The reason that the pieces jump is that they are attracted by electrons on the pen. Rubbing the cloth on the pen has made electrons from the cloth transfer to the pen. We say that the pen is **charged** with electrons. It has an **electric charge**.

Some other things can be charged by rubbing. Rub a balloon with a cloth (or against your clothes). Then place it in contact with the wall of the room. It does not fall down to the floor but stays where you put it, on the wall. The electric charge has produced an **electric force** that holds the balloon against the wall.

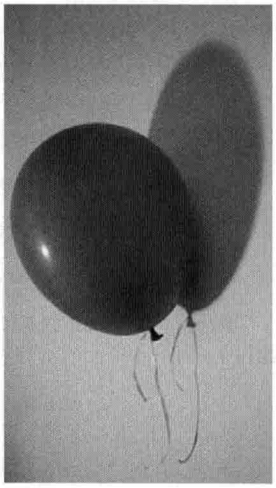


FIGURE 1.3

Things to do

You need two strips of polythene, about 30 cm by 2 cm, and a soft dry cloth. Put the strips on the workbench and rub them briskly with the cloth. Pick up the strips by one end, one in each hand. Hold them about 50 cm apart. Then slowly move them together.

Repeat this, using one strip of polythene and one strip of acetate sheet. What do the strips do now?

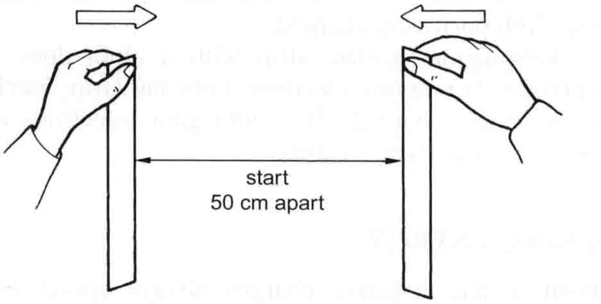


FIGURE 1.4

Electronics: A First Course.

> **Self Test**
> What do you expect will happen if you try to bring two charged acetate strips together?

KINDS OF CHARGE

You have found that:

- Two charged polythene strips **repel** each other. They try to stay apart.
- A polythene strip and an acetate strip **attract** each other. They try to come together.

It seems that the charge on acetate is different from that on polythene, so:

There are two kinds of charge

Two charged polythene strips repel each other, so:

Like charges repel

Two differently charged strips attract each other, so:

Unlike charges attract

> **Self Test**
> Pieces of foil jump up to a charged plastic pen. Then some of them jump down again. Why does this happen?

POSITIVE AND NEGATIVE CHARGE

The two kinds of charge are called **positive charge** and **negative charge**. These names do not mean that positive charge has something that negative charge does not have. They just mean that the charges are of opposite kinds.

Rubbing a polythene strip with a cloth transfers some of the electrons from the atoms in the cloth on to the strip. Electrons have negative charge, so the strip becomes negatively charged. Also, the atoms of the cloth have now lost some electrons. This makes the cloth positively charged.

Rubbing an acetate strip with a cloth does the opposite. It *removes* electrons from the strip, leaving it positively charged. The cloth gains electrons and becomes negatively charged.

USING ENERGY

Positive and negative charges always attract each other. They try to come together. When you rub the cloth on the plastic, you separate the negative charge from the positive. It takes energy to pull them apart when they are trying to come together. This energy comes from the muscles of your arm.

ELECTRONS

Electrons are too small to see, even with a powerful microscope.

Electrons are too light to weigh. You need 1 000 000 000 000 000 000 000 000 000 000 electrons to weigh 1 kg (an amazing fact that you do not need to remember).

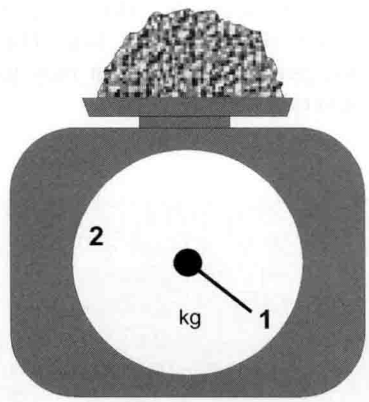


FIGURE 1.5

The most important fact about electrons is that they carry **negative electric charge**. The charge on a single electron is extremely small. But, if you have enough of them (as on the pen or the charged polythene), you can show the force that their charge causes. There are lots more things that we can do with electrons, as you will find out as you work through the book.

> **Self Test**
> Why is it impossible to have a *pile* of electrons, like that shown in the drawing?

ELECTRONS AND ATOMS

Matter is made up of molecules of many different kinds. Molecules are made up of one or more atoms. Atoms are made up of electrons (negatively charged), protons (positively charged) and neutrons (uncharged).

The simplest possible atom consists of one electron and one proton. The proton is at the centre of the atom and the electron is circling around it, in orbit.

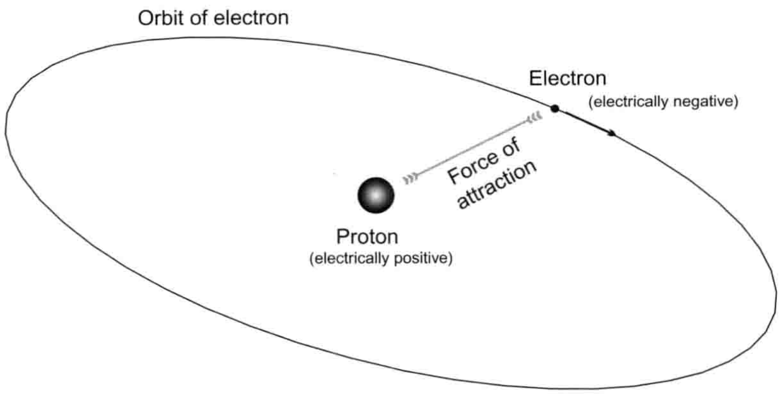


FIGURE 1.6

With one unit of negative charge on the electron and one unit of opposite but equal charge on the proton, the atom as a whole is uncharged.

The electron is circling at high speed around the proton, like a planet orbiting the Sun. There must be a force to keep it in orbit. In the case of a planet the force is gravity, the attraction between the masses of the Sun and the planet. In the case of the electron the force is the electrical attraction between oppositely charged bodies. The experiments on pages 3–4 demonstrated this.

OTHER KINDS OF ATOM

There are more than a hundred different elements in nature, including hydrogen, helium, copper, zinc, iron, mercury and oxygen, to name only a few.

Each element has its own distinctive structure, the atoms being made up of fixed numbers of electrons and protons.

In spite of these differences, all elements have the same basic plan. There is a central part, called the nucleus, where most of the mass of the atom is concentrated. The nucleus is surrounded by a cloud of circling electrons.

Atoms other than hydrogen have more than one proton and also some neutrons in the nucleus.

The protons in the nucleus give the nucleus a positive charge — one unit of charge for each proton. The number of electrons in the cloud equals the number of protons, so the cloud as a whole has an equal but negative charge which balances the charge on the nucleus.

The electrons of an atom are on the outside. They can be removed by friction, heating and electric fields. This is how we obtain the supply of electrons to use in the electronic circuits and devices described in this book.

OTHER PARTICLES

Some readers may have heard of quarks and other sub-atomic particles. Detailed studies by atomic scientists have discovered that atoms are actually made up of several more sorts of particle. In electronics, however, the only particle we need to know about is the electron.

Electric Current

Some substances let electric charge flow through them. These substances are called **conductors**.

One of the best-known conductors is copper. It conducts so well because the electrons of copper atoms are able to escape easily from the atoms.

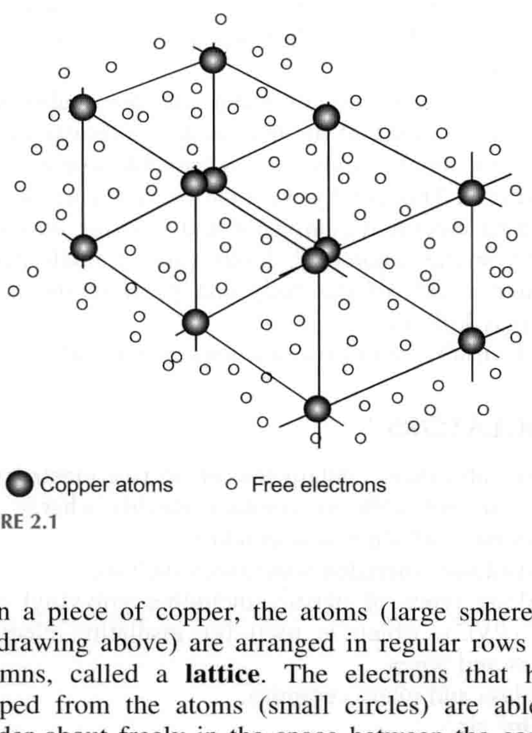


FIGURE 2.1

In a piece of copper, the atoms (large spheres in the drawing above) are arranged in regular rows and columns, called a **lattice**. The electrons that have escaped from the atoms (small circles) are able to wander about freely in the space between the copper atoms.

If we connect a battery to each end of a strip of copper, its negative terminal supplies electrons to the copper. Its positive terminal removes electrons from the other end. They are attracted by the positive (opposite) charge.

Things to do

Test different substances to find out if they are conductors or insulators (non-conductors).

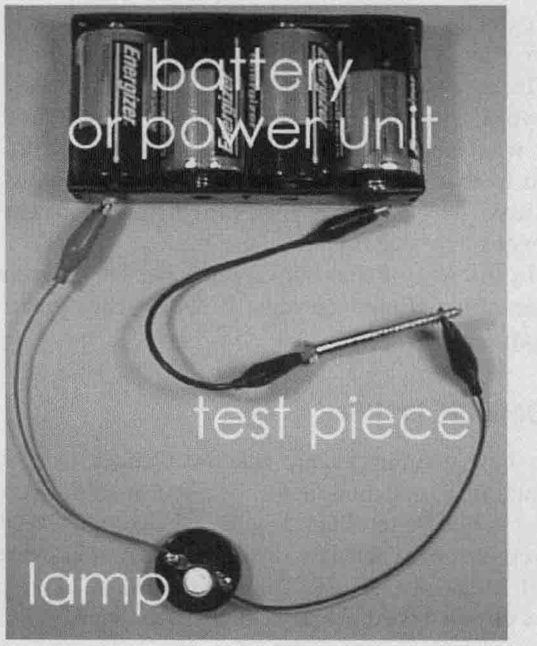


FIGURE 2.2

Try this with different materials, such as: an iron nail or screw (as shown), a piece of brick, a copper strip or wire, a plastic rod, a strip of aluminium kitchen foil, a piece of wood, a 'silver' coin, the 'lead' of a pencil (not really lead, but carbon), a piece of stone, and other materials.

The lamp shines when the material is a conductor. Make lists of conductors and non-conductors.

Electronics: A First Course.

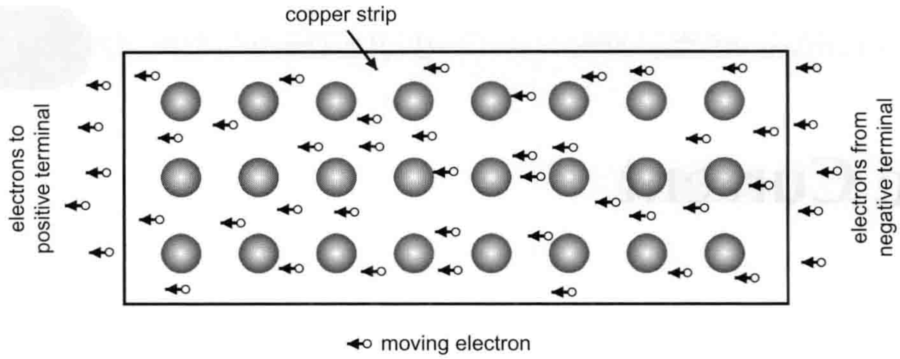


FIGURE 2.3

The flow of electrons along the copper strip is called an **electric current**. The flow is from negative to positive.

DIRECTION OF FLOW

As explained above, an electric current is a flow of negative charge (electrons) from negative to positive.

In electronics, we usually think of the current as flowing from positive to negative. Although this is not what actually happens, most people like to think of it in that way. This idea of a current flowing from positive to negative is known as **conventional current**.

In the rest of this book, when we say 'current' we mean conventional current, flowing from positive to negative.

CONDUCTORS

The best conductors are metals. Copper is the most commonly used conductor because it conducts electric charge better than any metal, except silver. But silver is too expensive to be used. Copper wires are used in almost all electronic equipment. The tracks on a circuit board are also made of copper.

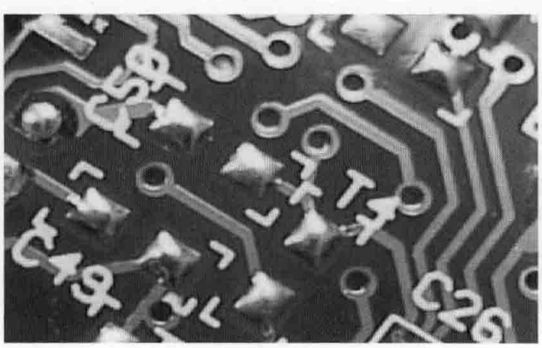


FIGURE 2.4

The next best conductor is aluminium. This is often used in power lines, because of its lightness and cheapness. It is not as strong as copper, so a few strands of steel wire are included when making the cable.

Carbon is a non-metal but it has important uses as a conductor. It does not conduct charge as well as the metals do. Rods of carbon are used for making certain kinds of electric cell. Carbon is also used in making resistors (p. 43).

Solutions of salts in water are reasonably good conductors. Much of the human body consists of such solutions, so the body is a reasonable conductor of electricity. This is why we must be very careful when handling electrical equipment and working with electricity in the laboratory. Even quite a small current through a part of the body can paralyse the nerves and may kill you.

Electricity can also cause unpleasant burns.

INSULATORS

These substances contain few or no free electrons, so they are not able to conduct electric charge. We sometimes call them non-conductors.

Insulators included substances such as:

Many types of plastic, including polyvinyl chloride (PVC), which is used for insulating electrical cables and wires.

Glass and many ceramics.

Dry air.

Paper.

Self test

List these substances in order, from the best conductor to the worst:

aluminium, rubber, copper, carbon, gold, silver