NONRESIDENT
TRAINING
COURSE

SEPTEMBER 1998

U.S. Navy Electricity & Electronics Training Program

Modules 1-24

NAVEDTRA 14173

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Navy Electricity and Electronics Training Series

Module 1—Introduction to Matter, Energy, and Direct Current

NAVEDTRA 14173

Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: To introduce the student to the subject of Matter, Energy, and Direct Current who needs such a background in accomplishing daily work and/or in preparing for further study.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards,* NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

TABLE OF CONTENTS

NAVY ELECTRICITY AND ELECTRONICS TRAINING SERIES

The Navy Electricity and Electronics Training Series (NEETS) was developed for use by personnel in many electrical- and electronic-related Navy ratings. Written by, and with the advice of, senior technicians in these ratings, this series provides beginners with fundamental electrical and electronic concepts through self-study. The presentation of this series is not oriented to any specific rating structure, but is divided into modules containing related information organized into traditional paths of instruction.

The series is designed to give small amounts of information that can be easily digested before advancing further into the more complex material. For a student just becoming acquainted with electricity or electronics, it is highly recommended that the modules be studied in their suggested sequence. While there is a listing of NEETS by module title, the following brief descriptions give a quick overview of how the individual modules flow together.

Module 1, *Introduction to Matter, Energy, and Direct Current*, introduces the course with a short history of electricity and electronics and proceeds into the characteristics of matter, energy, and direct current (dc). It also describes some of the general safety precautions and first-aid procedures that should be common knowledge for a person working in the field of electricity. Related safety hints are located throughout the rest of the series, as well.

Module 2, *Introduction to Alternating Current and Transformers,* is an introduction to alternating current (ac) and transformers, including basic ac theory and fundamentals of electromagnetism, inductance, capacitance, impedance, and transformers.

Module 3, *Introduction to Circuit Protection, Control, and Measurement,* encompasses circuit breakers, fuses, and current limiters used in circuit protection, as well as the theory and use of meters as electrical measuring devices.

Module 4, *Introduction to Electrical Conductors, Wiring Techniques, and Schematic Reading,* presents conductor usage, insulation used as wire covering, splicing, termination of wiring, soldering, and reading electrical wiring diagrams.

Module 5, *Introduction to Generators and Motors,* is an introduction to generators and motors, and covers the uses of ac and dc generators and motors in the conversion of electrical and mechanical energies.

Module 6, *Introduction to Electronic Emission, Tubes, and Power Supplies,* ties the first five modules together in an introduction to vacuum tubes and vacuum-tube power supplies.

Module 7, *Introduction to Solid-State Devices and Power Supplies,* is similar to module 6, but it is in reference to solid-state devices.

Module 8, *Introduction to Amplifiers,* covers amplifiers.

Module 9, *Introduction to Wave-Generation and Wave-Shaping Circuits,* discusses wave generation and wave-shaping circuits.

Module 10, *Introduction to Wave Propagation, Transmission Lines, and Antennas,* presents the characteristics of wave propagation, transmission lines, and antennas.

Module 11, *Microwave Principles,* explains microwave oscillators, amplifiers, and waveguides.

Module 12, *Modulation Principles,* discusses the principles of modulation.

Module 13, *Introduction to Number Systems and Logic Circuits,* presents the fundamental concepts of number systems, Boolean algebra, and logic circuits, all of which pertain to digital computers.

Module 14, *Introduction to Microelectronics,* covers microelectronics technology and miniature and microminiature circuit repair.

Module 15, *Principles of Synchros, Servos, and Gyros,* provides the basic principles, operations, functions, and applications of synchro, servo, and gyro mechanisms.

Module 16, *Introduction to Test Equipment,* is an introduction to some of the more commonly used test equipments and their applications.

Module 17, *Radio-Frequency Communications Principles,* presents the fundamentals of a radio-frequency communications system.

Module 18, *Radar Principles,* covers the fundamentals of a radar system.

Module 19, *The Technician's Handbook,* is a handy reference of commonly used general information, such as electrical and electronic formulas, color coding, and naval supply system data.

Module 20, *Master Glossary,* is the glossary of terms for the series.

Module 21, *Test Methods and Practices,* describes basic test methods and practices.

Module 22, *Introduction to Digital Computers,* is an introduction to digital computers.

Module 23, *Magnetic Recording,* is an introduction to the use and maintenance of magnetic recorders and the concepts of recording on magnetic tape and disks.

Module 24, *Introduction to Fiber Optics,* is an introduction to fiber optics.

CHAPTER 1

MATTER, ENERGY, AND ELECTRICITY

LEARNING OBJECTIVES

Learning objectives are stated at the beginning of each chapter. These learning objectives serve as a preview of the information you are expected to learn in the chapter. The comprehensive check questions are based on the objectives. By successfully completing the NRTC, you indicate that you have met the objectives and have learned the information. The learning objectives are listed below.

Upon completing this chapter, you will be able to:

1. State the meanings of and the relationship between matter, element, nucleus, compound, molecule, mixture, atom, electron, proton, neutron, energy, valence, valence shell, and ion.
2. State the meanings of and the relationship between kinetic energy, potential energy, photons, electron orbits, energy levels, and shells and subshells.
3. State, in terms of valence, the differences between a conductor, an insulator, and a semiconductor, and list some materials which make the best conductors and insulators.
4. State the definition of static electricity and explain how static electricity is generated.
5. State the meanings of retentivity, reluctance, permeability, ferromagnetism, natural magnet, and artificial magnet as used to describe magnetic materials.
6. State the Weber and domain theories of magnetism and list six characteristics of magnetic lines of force (magnetic flux), including their relation to magnetic induction, shielding, shape, and storage.
7. State, using the water analogy, how a difference of potential (a voltage or an electromotive force) can exist. Convert volts to microvolts, to millivolts, and to kilovolts.
8. List six methods for producing a voltage (emf) and state the operating principles of and the uses for each method.
9. State the meanings of electron current, random drift, directed drift, and ampere, and indicate the direction that an electric current flows.
10. State the relationship of current to voltage and convert amperes to milliamperes and microamperes.
11. State the definitions of and the terms and symbols for resistance and conductance, and how the temperature, contents, length and cross-sectional area of a conductor affect its resistance and conductance values.
12. List the physical and operating characteristics of and the symbols, ratings, and uses for various types of resistors; use the color code to identify resistor values.

INTRODUCTION

The origin of the modern technical and electronic Navy stretches back to the beginning of naval history, when the first navies were no more than small fleets of wooden ships, using wind-filled sails and manned oars. The need for technicians then was restricted to a navigator and semiskilled seamen who could handle the sails.

As time passed, larger ships that carried more sail were built. These ships, encouraging exploration and commerce, helped to establish world trade routes. Soon strong navies were needed to guard these sea lanes. Countries established their own navies to protect their citizens, commercial ships, and shipping lanes against pirates and warring nations. With the addition of mounted armament, gunners joined the ship's company of skilled or semiskilled technicians.

The advent of the steam engine signaled the rise of an energy source more practical than either wind and sails or manpower. With this technological advancement, the need for competent operators and technicians increased.

However, the big call for operators and technicians in the U.S. Navy came in the early part of the 20th century, when power sources, means of communication, modes of detection, and armaments moved with amazing rapidity toward involved technical development. Electric motors and generators by then had become the most widely used sources of power. Telephone systems were well established on board ship, and radio was being used more and more to relay messages from ship to ship and from ship to shore. Listening devices were employed to detect submarines. Complex optical systems were used to aim large naval rifles. Mines and torpedoes became highly developed, effective weapons, and airplanes joined the Navy team.

During the years after World War I, the Navy became more electricity and electronic minded. It was recognized that a better system of communications was needed aboard each ship, and between the ships, planes, submarines, and shore installations; and that weaponry advances were needed to keep pace with worldwide developments in that field. This growing technology carried with it the awareness that an equally skilled force of technicians was needed for maintenance and service duties.

World War II proved that all of the expense of providing equipment for the fleet and of training personnel to handle that equipment paid great dividends. The U. S. Navy had the modern equipment and highly trained personnel needed to defeat the powerful fleets of the enemy.

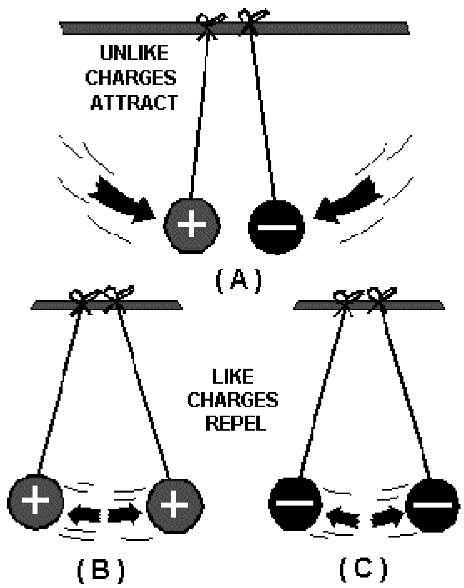
Today there is scarcely anyone on board a Navy ship who does not use electrical or electronic equipment. This equipment is needed in systems of electric lighting and power, intercommunications, radio, radar, sonar, loran, remote metering, weapon aiming, and certain types of mines and torpedoes. The Navy needs trained operators and technicians in this challenging field of electronics and electricity. It is to achieve this end that this module, and others like it, are published.

MATTER, ENERGY, AND ELECTRICITY

If there are roots to western science, they no doubt lie under the rubble that was once ancient Greece. With the exception of the Greeks, ancient people had little interest in the structure of materials. They accepted a solid as being just that a continuous, uninterrupted substance. One Greek school of thought believed that if a piece of matter, such as copper, were subdivided, it could be done indefinitely and still only that material would be found. Others reasoned that there must be a limit to the number of subdivisions that could be made and have the material still retain its original characteristics. They held fast to the idea that there must be a basic particle upon which all substances are built. Recent experiments have revealed that there are, indeed, several basic particles, or building blocks within all substances.

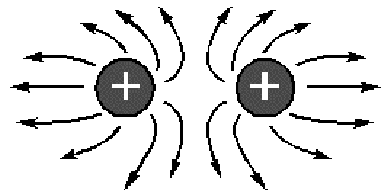
CONDUCTORS, SEMICONDUCTORS, AND INSULATORS are categorized as such by the number of valence electrons in their atoms. The conductor normally has 3 or less valence electrons and offers little opposition to the flow of electrons (electric current). The insulator contains 5 or more valence electrons and offers high opposition to electron flow. The semiconductor usually has four valence electrons of conductivity and is in the midrange. The best conductors in order of conductance are silver, copper, gold, and aluminum.

CHARGED BODIES affect each other as follows: When two bodies having unequal charges are brought close to each other, they will tend to attract each other in an attempt to equalize their respective charges. When two bodies, both having either positive or negative charges, are brought close together, they tend to repel each other as no equalization can occur. When the charge on one body is high enough with respect to the charge on an adjacent body, an equalizing current will flow between the bodies regardless of the conductivity of the material containing the bodies.



A NEUTRAL BODY may be attracted to either a positively or negatively charged body due to the relative difference in their respective charges.

CHARGED BODIES will attract or repel each other with a force that is directly proportional to the product of their individual charges and inversely proportional to the square of the distance between the bodies.



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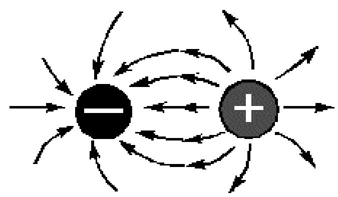

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ELECTROSTATIC LINES of force are a graphic representation of the field around a charged body. These lines are imaginary. Lines from a positively charged body are indicated as flowing out from the body, while lines from a negatively charged body are indicated as flowing into the body.

MAGNETISM is that property of a material which enables it to attract pieces of iron. A material with this property is called a magnet. Any material that is attracted to a magnet can be made into a magnet itself.

FERROMAGNETIC MATERIALS are materials that are easy to magnetize; e.g., iron, steel, and cobalt.

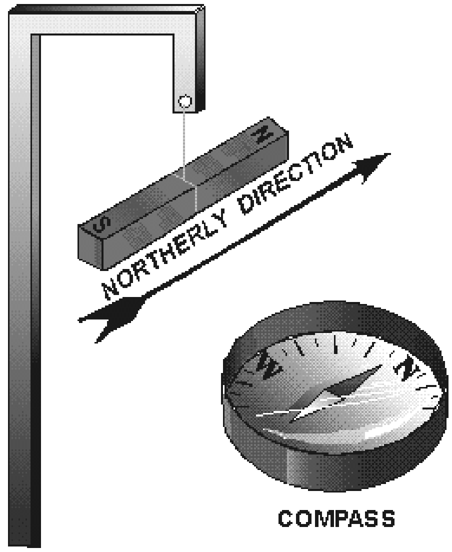
NATURAL MAGNETS, called magnetite, lodestones, or leading stones, were the first magnets to be studied. Most magnets in practical use are artificial or man-made magnets, and are made either by electrical means or by stroking a magnetic material with a magnet.

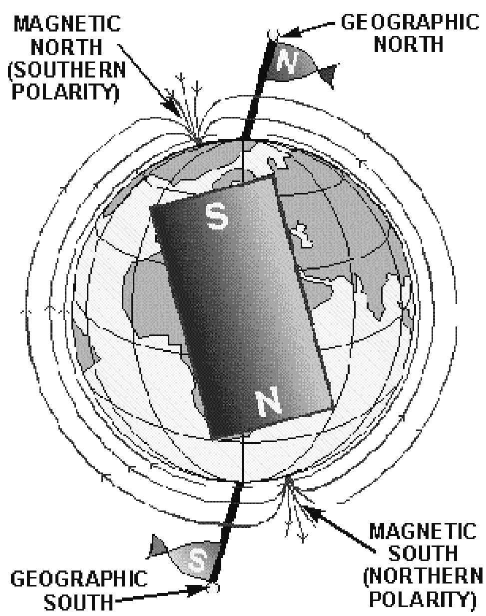
RELUCTANCE is defined as the opposition of a material to being magnetized.

PERMEABILITY is defined as the ease with which a material accepts magnetism. A material which is easy to magnetize does not hold its magnetism very long, and vice versa.

RETENTIVITY is defined as the ability of a material to retain magnetism.

A MAGNETIC POLE is located at each end of a magnet. The majority of the magnetic force is concentrated at these poles and is approximately equal at both poles.

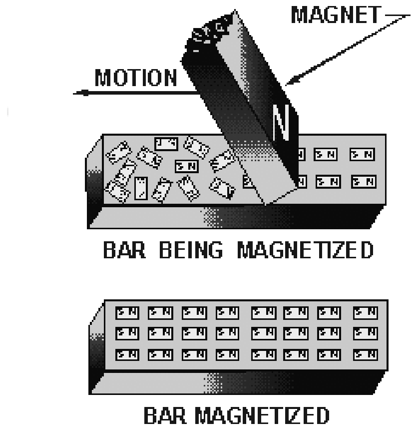




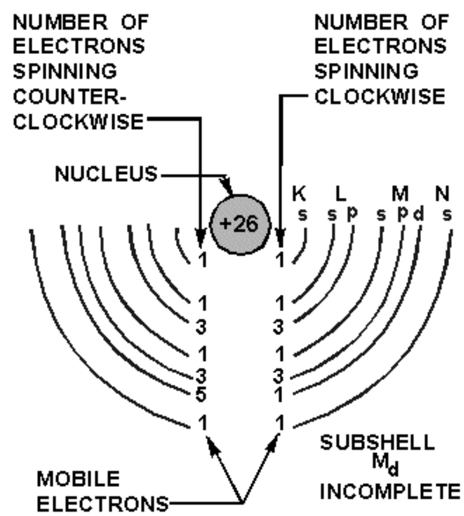
THE NORTH POLE, or north seeking pole, of a magnet freely suspended on a string always points toward the north geographical pole.

THE LIKE POLES of magnets repel each other, while the unlike poles attract each other.

WEBER'S THEORY OF MAGNETISM assumes that all magnetic material is made up of magnetic molecules which, if lined up in north to south pole order, will be a magnet. If not lined up, the magnetic fields about the molecules will neutralize each other and no magnetic effect will be noted.



THE DOMAIN THEORY OF MAGNETISM states that if the electrons of the atoms in a material spin more in one direction than in the other, the material will become magnetized.



A MAGNETIC FIELD is said to exist in the space surrounding a magnet.