Macmillan Career English

Engineering

Electrical Engineering

Richard A. Meyers

World Publishing Corporation

Engineering
Electrical Engineering

Richard A. Meyers

New York Institute of Technology

World Publishing Corporation

MACMILLAN PUBLISHING COMPANY
New York

COLLIER MACMILLAN INTERNATIONAL
New York

COLLIER MACMILLAN PUBLISHERS
London

Photograph Credits: Argonne National Laboratory; © Paul N. Bozek; Courtesy of General Electric Co.; Courtesy of IBM; Jeroboam, Inc.: © Ed Buryn, © Frank D Smith, Magnum Photos, Inc.: © Erich Hartman, © Richard Kalvar, © Alex Webb, Monkmeyer Press Photo Service: © Sybil Shelton; © W. S. Nawrocki; Photo Researchers, Inc.: © Peter G. Aitken, © Kent & Donna Dannen, © C. Falco, © Georg Gerster, © Russ Kinne; Kay Reese & Associates: © Ray Ellis; Courtesy RCA, Science Service; Smithsonian Institution; Stock, Boston © Barbara Alper, © J Berndt, © Daniel Brody, © David Aronson, © W.B Finch, © Ellis Herwig, © David A. Krathwohl, © Peter Southwick; Courtesy of Western Electric, Mount Wilson & Palomar Observatories. Cover Photo: © Ellis Herwig, Stock, Boston

Cover Design Rudy Michaels

Cover Photo © Richard Wood from Taurus Photos

Reprint authorized by Macmillan Publishers Ltd
Reprinted by World Publishing Corporation, Beijing, 1989
for sale in The People's Republic of China (excluding Hong Kong, Macao and Taiwan Province of China)

ISBN 0-02-973690-0
ISBN 7-5062-0432-0

Preface

This book is one of Macmillan's *Career English* series. *Career English* is intended for students who have some proficiency in English as well as a working knowledge of their own professional fields. The books are designed to teach the special terminology students need in order to communicate in English within their career areas.

Students will find the *Career English* books clear, lively, practical, and easy to use. Each chapter covers one specific topic and begins with a dialogue between an expert in the field and a student or a trainee. In the course of the dialogue, the key terms pertaining to the chapter topic are introduced in a realistic context. The dialogue is followed by a terminology practice in which each key term is defined and used in three sample sentences. At the end of each chapter, students will find a simple check-up exercise to determine whether or not they have mastered the terms introduced in the dialogue. An answer key to the check-ups is provided for self-correction. A glossary at the end of each book lists all the terms in the text with the numbers of the chapters in which they appear. In addition a cassette recording of the dialogues is available for each book. Use of the cassette is optional but highly recommended.

The books in the *Career English* series are designed to be equally useful for students studying in a classroom or independently.

To the student: If you are studying independently, the following suggestions will help you to use this book to its best advantage:

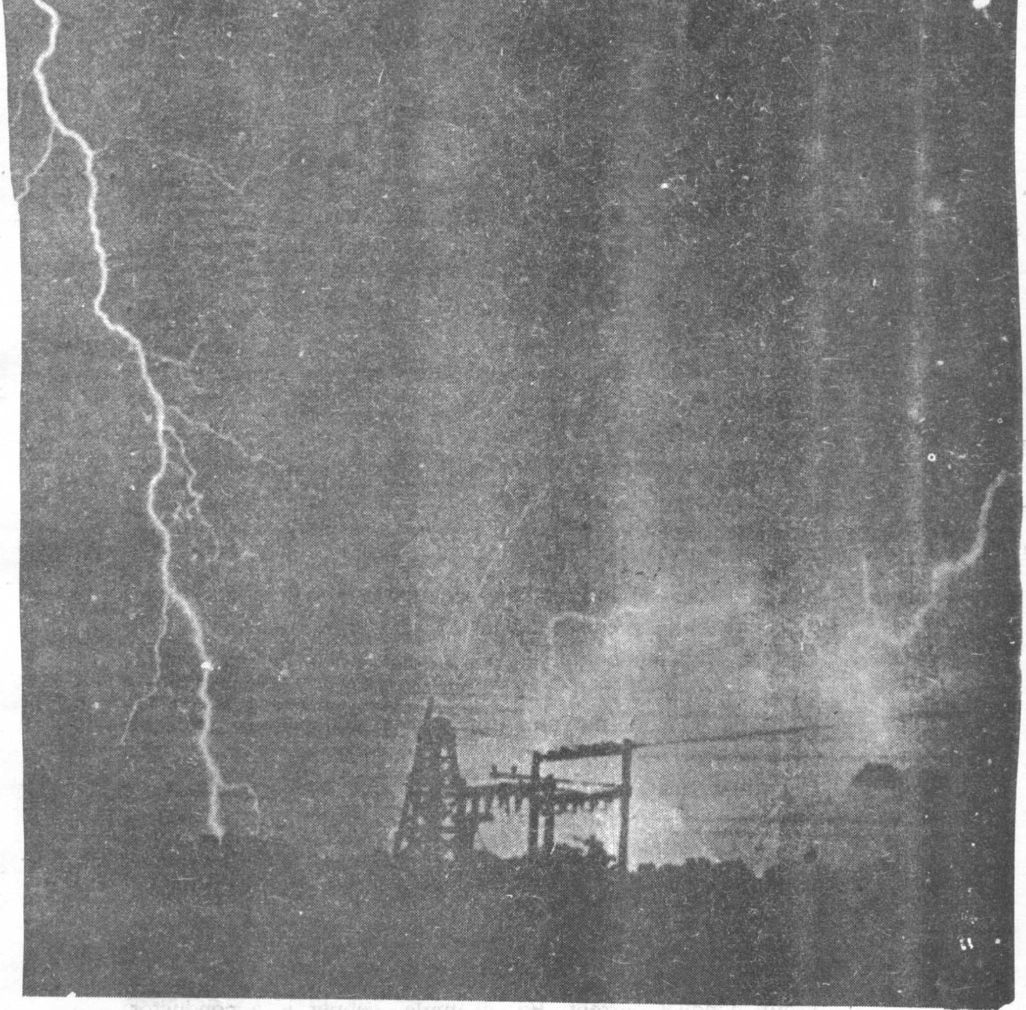
1. Read the dialogue from beginning to end.
2. Read the terminology practice.
3. If you have the tape, listen to it. Listen for the words in the terminology practice, paying special attention to pronunciation and intonation.
4. Reread the dialogue aloud. (If you have the tape, play it again to check your pronunciation.)
5. Do the end-of-chapter check-up to be sure you have mastered the terms introduced in the chapter. Check your answers with the answer key at the back of the book. If you have made an error in the check-up, use the terminology practice to look up the words you have not mastered. Find the terms in the dialogue, and reread the dialogue. Correct your errors.
6. Now you are ready to go on to the next chapter.

To the teacher: The following suggestions will help you to use this book to its best advantage in your classroom:

1. Ask students to read the dialogue silently.
2. Have them read the terminology practice to themselves.
3. If you have the tape, play it for the class. Suggest that students follow along in their books, listening carefully for the words in the terminology practice and paying careful attention to pronunciation and intonation.
4. Read each word in the terminology practice aloud, asking students to repeat after you. Check for pronunciation. Have students take turns reading the sample sentences aloud.
5. Ask two students to read the dialogue aloud, taking the parts of the characters in the dialogue. (You may wish to have several pairs of students read each dialogue.) As the dialogue is being read, help the students with their pronunciation and intonation.
6. Ask students to do the end-of-chapter check-up to be sure they have mastered the vocabulary introduced in the chapter. If students have their own books, they may write their answers directly in the book. If the books will be used by others, ask students to write their answers on separate paper.
7. Students can check their answers with the answer key at the back of the book. If they have made any errors, suggest they look up the terms in the terminology practice, reread the definitions and sample sentences, and reread the dialogue. Then have them correct their check-ups.

CONTENTS

Lesson		page
1	Fundamentals of Electricity	1
2	Circuit Elements	10
3	The MKS System of Units	14
4	More About Units	18
5	Electrical Measurements	21
6	Electromagnetic Radiation	26
7	Antennas	30
8	Transmission Lines	36
9	Digital Communications	42
10	Analog Communications	48
11	Amplifiers	54
12	Semiconductors	58
13	Transistors	64
14	Logic Circuits	70
15	Optical Communications	76
	Key to Check-Ups	82
	Glossary	84



LESSON

1 Fundamentals of Electricity

A. Dialogue

Student: How would you define electricity?

Engineer: That's a difficult question. I'd describe it as the behavior of charged particles in motion.

Student: So an electric current is the flow of charged particles?

Engineer: That's right. Electric current can be ac or dc.

Student: I know that these terms are abbreviations for alternating current and direct current. But what do they mean?

Engineer: In direct current the flow of charges, usually electrons, moves in one direction at a steady rate. In alternating current the charges flow first in one direction and then in the other, repeating this cycle with a definite frequency.

Student: I've often heard people use the term sine wave when discussing ac. What is a sine wave?

Engineer: It's one type of waveform. Here, I'll draw you a picture. This waveform graphically represents the time-varying behavior of a sinusoidal current.

Student: I infer from your drawing that it keeps repeating itself over long periods of time. Is that correct?

Engineer: Yes. Each repetition is called a cycle, and the amount of time taken for a wave to undergo one cycle is its period.

Student: It would seem to me that the shorter the period of the wave, the more cycles per second it would have.

Engineer: Correct. The number of cycles per second is the wave's frequency measured in hertz (Hz).

Student: I assume we can start measuring the current at any given instant in time and still be able to determine the period.

Engineer: Correct. In fact, any given instant in time for a cyclical waveform has an associated stage of wave development known as the phase of the wave.

Student: I think I understand that. Now can you tell me what conductors are?

Engineer: Conductors are substances that can easily carry an electric current. Insulators, on the other hand, are substances that do not easily conduct current. For example, copper is a conductor, and glass is an insulator. A conductor forms a definite path, called a circuit, through which charges flow, and an insulator confines electricity to the circuit.

Student: What causes current to flow?

Engineer: Voltage, or EMF, which stands for electromotive force. There are many different devices used to create an EMF.

Student: Would batteries and generators be examples?

Engineer: Exactly.

Student: If voltage causes current, then more voltage applied should cause more current to flow. Can we calculate current flow if we can measure the voltage applied?

Engineer: Yes. In fact, the ratio of voltage to current remains constant for most materials. This ratio is known as the material's resistance. Resistance is the electrical property of matter which measures its ability to oppose the flow of an electric current. Look at this diagram.

Student: What do the plus and minus signs indicate?

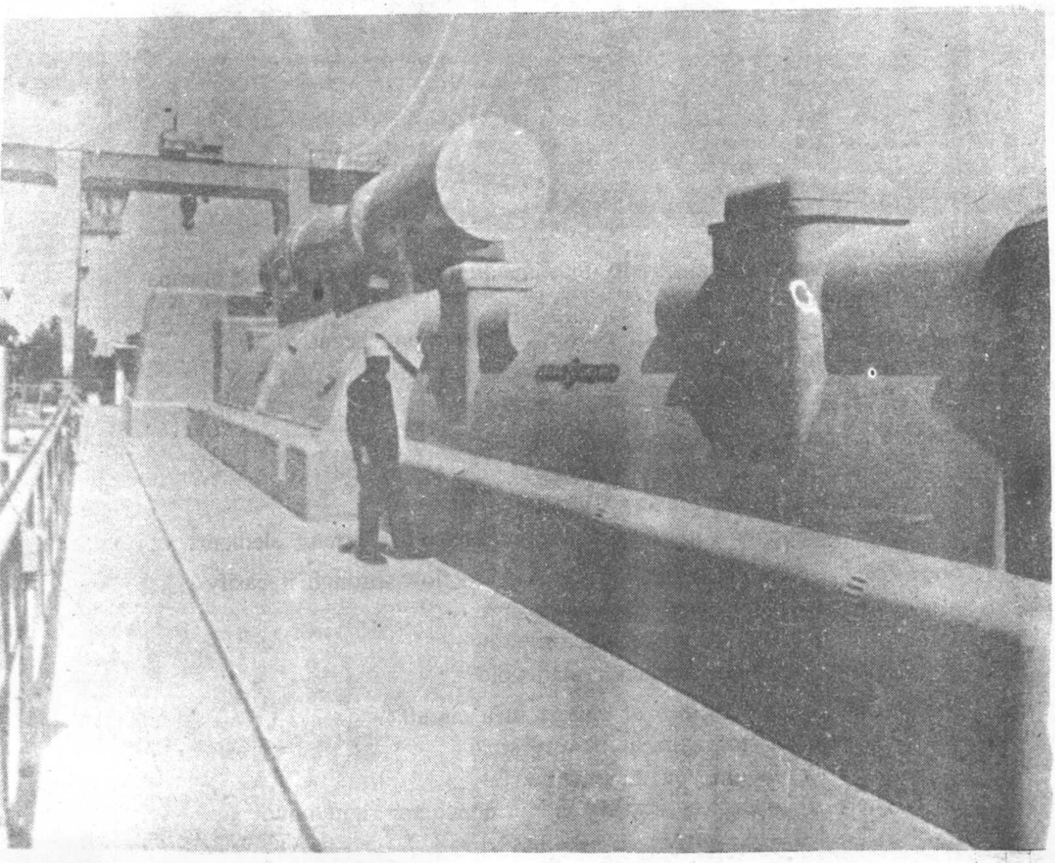
Engineer: They indicate voltage drop. Note also that resistance exists between two terminals.

Student: The terminals are represented by a and b in the diagram. What are the other electrical properties of matter?

Engineer: All materials have the properties of capacitance and inductance. Capacitance is the ability of a material to store charges. It is defined as the ratio of voltage across the material to the amount of charges stored. Inductance is the ability of a material to store energy in a magnetic field. Magnetic lines of force are caused by a flow of charges through the material. In other words, it is the ability of a material to act as a magnet when current flows through it. Inductance is defined as the ratio of the concentration of magnetic lines of force surrounding the material to the amount of current flowing through it.

Student: Could we say that capacitance refers to the effect of static charges stored by a material, while inductance refers to the effect of charges moving through a material?

Engineer: That's absolutely correct.



B. Terminology Practice

alternating current (ac): a flow of current that moves first in one direction, then in another, repeating this cycle with a definite frequency

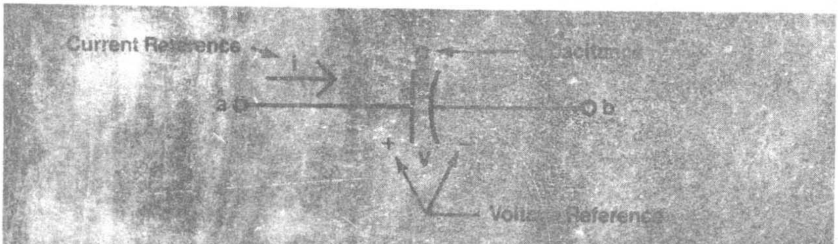
Ac voltages come from wall outlets.
There is an ac voltage across the terminals.
Does this meter read ac values?

battery: a device that supplies a constant voltage by converting chemical energy into electrical energy

This car battery should be recharged.
I need another nine-volt battery.
Do you have any flashlight batteries?

capacitance: the ability of a substance to store charges

The capacitance is too small for this circuit.
To increase the capacitance, make the area of the plates larger.
Is there any source of stray capacitance in this circuit?



Schematic representation of capacitance.

charge: a quantity of electricity that is stored by a substance and is capable of producing a force

There are two kinds of charges. positive and negative.
A positive charge will attract negative charges.
The charge on an electron is negative.

circuit: a specific conducting path for charges in motion

Charges move through a circuit.
A battery supplies energy to the circuit.
The components of electric circuits are called circuit elements.

conductor: a material that allows current to flow through it easily

All metals are good conductors.
Glass is a very poor conductor.
Is there a better conductor than gold?

current: the rate of motion of charge in a circuit

In large resistors current is very small.
What current do you measure?
There is no current flowing in the conductor right now.

cycle: one periodic repetition of a wave
The cycle for a 60 Hz waveform lasts 1/60 second.
How many cycles are visible on the screen?
All periodic waveforms go through cycles.

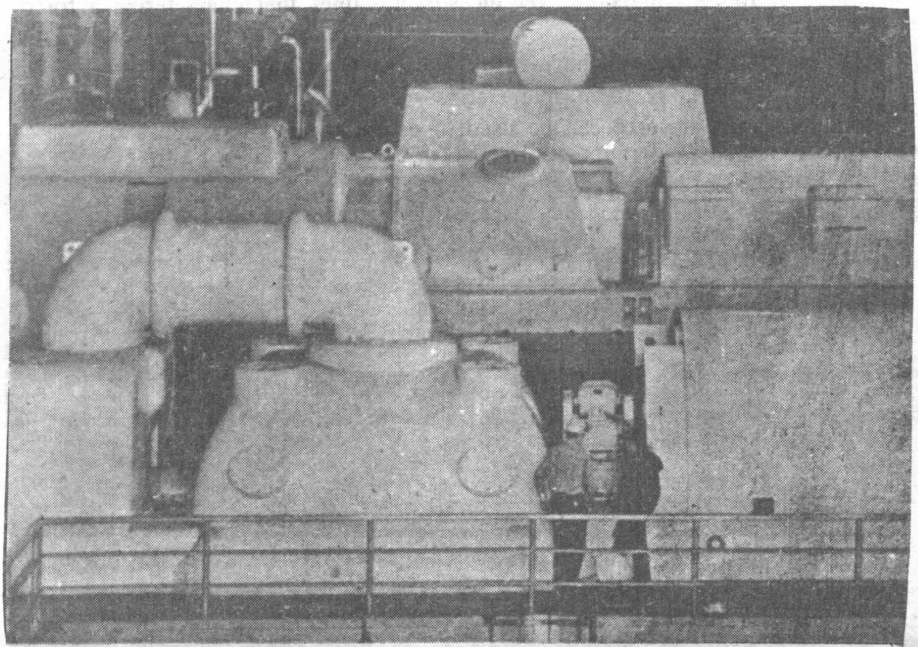
direct current (dc): a flow of charges that moves in one direction only, for a particular period of time
Batteries provide dc voltages.
The dc value of the current is 50 milliamperes.
Will this device display dc values for voltage and current?

electromotive force (EMF): see voltage

electron: a small, negatively charged, fundamental atomic particle
Most electric currents are caused by a flow of electrons.
Even with a very small current, millions of electrons are in motion.
Is the charge in this device caused by electrons?

frequency: the number of times per second a periodic waveform repeats itself
The frequency of current in European power systems is 50 Hz.
What is the frequency of the square wave?
Some frequencies are too high for humans to hear.

generator: a device supplying ac voltage
This generator can deliver 20 volts at either 50 or 60 Hz.
We need more gasoline for the generator.
How long can the generator run without refueling?

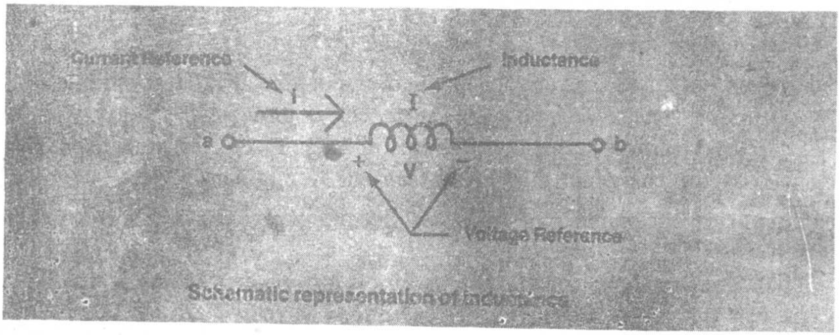


hertz (Hz): a unit of frequency defined as one cycle per second

One hertz is a very low frequency.
The human ear hears sound in the 20 Hz to 10,000 Hz range.
A wave's frequency is measured in hertz.

inductance: the ability of a material to act as a magnet when current flows through it

We will have to retune the circuit to eliminate the stray inductance.
Is inductance the opposite of capacitance?
A good electromagnet is characterized by a high inductance.



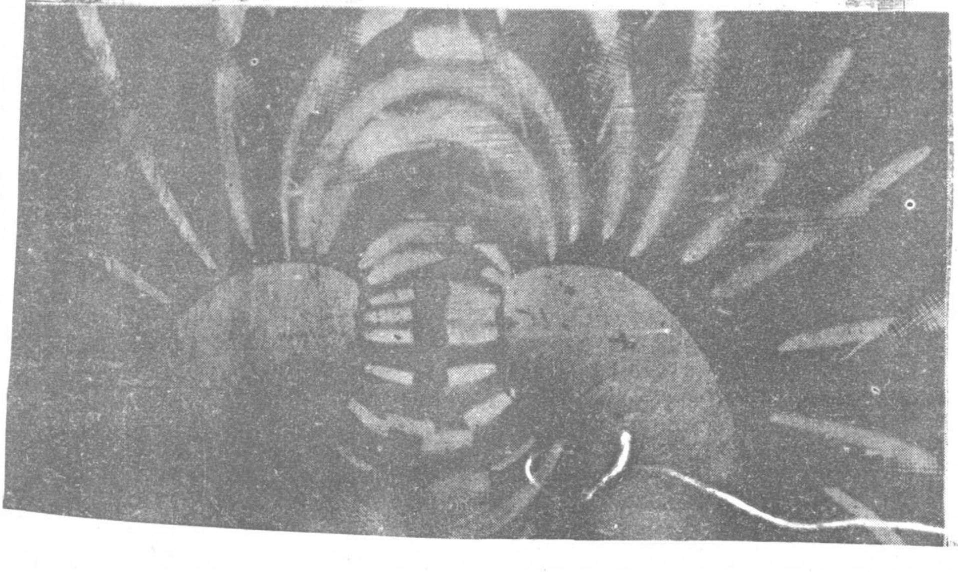
Schematic representation of inductance

insulator: a substance or object that is a poor conductor of electric current

Watch that insulator! It's very hot!
Porcelain is a good insulator for commercial uses.
Is this insulator large enough?

lines of force: invisible, yet measurable, lines that characterize a force field

Strong magnets have many lines of force about them.
Do lines of force characterize substances other than magnets?
Lines of force can be used to define an electric field.



magnet: a body having the property of attracting iron and producing a magnetic field external to itself

Our planet, with its lines of force, is a magnet.

A compass needle is also a magnet.

What is the difference between a bar magnet and a horseshoe magnet?

magnetic field: the portion of space near a magnetic body in which the forces due to the body can be detected

Iron filings outline the magnetic field of any permanent magnet.

Current flowing in a wire generates a magnetic field about the wire.

Does the planet Jupiter have a magnetic field that can be measured?

period: the time taken for a periodic waveform to repeat itself

The period of the sawtooth wave is one hundredth of a second.

The period of a waveform is the reciprocal of its frequency.

What is the period of a 50 Hz waveform?

phase: the time-dependent stage of development of a periodic wave

These two currents are 100° out of phase.

What phase differences do you measure in the rest of the circuit?

We found no phase difference between the two points.

ratio: a third quantity formed by dividing one quantity by another

Electrical properties are often defined as ratios.

The ratio of charge to voltage defines a substance's capacitance.

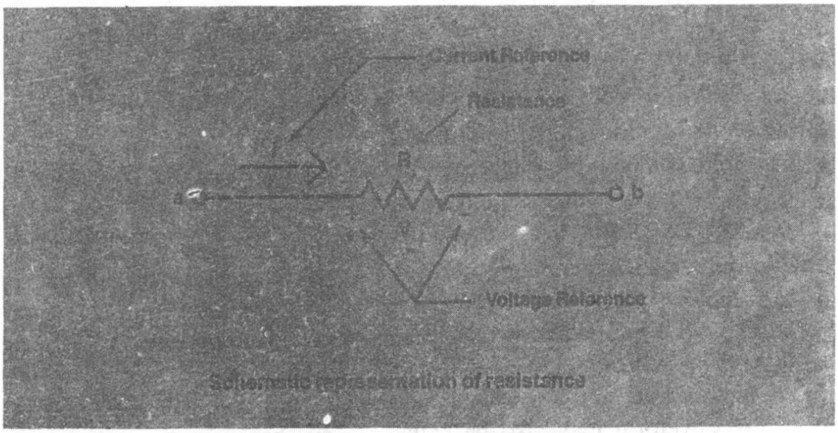
What kind of a ratio defines inductance?

resistance: a property of a substance that measures its ability to oppose the flow of an electric current

The resistance of the component is 100 ohms.

An electric charge gives up energy when passing through a resistance.

What did you measure the resistance to be?



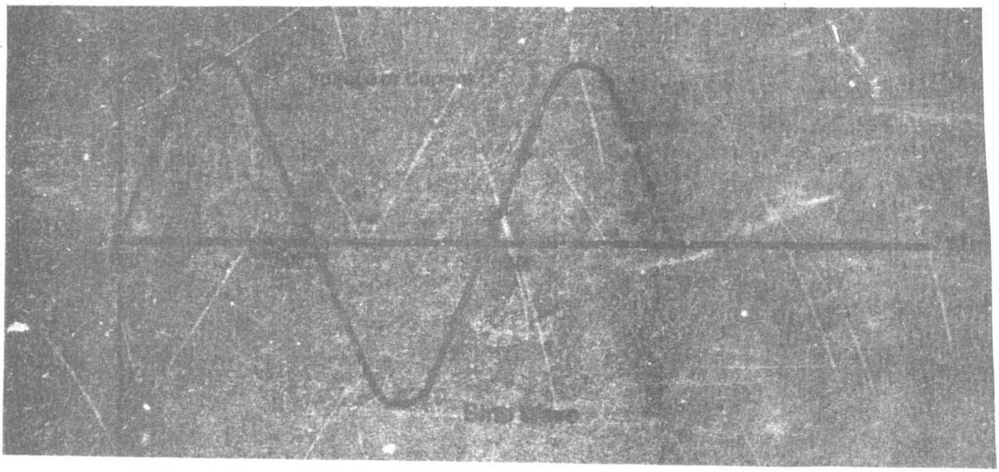
Schematic representation of resistance

sine wave: a common waveform

Sine waves occur throughout nature.

What is the frequency of this sine wave?

Tuning forks vibrate as sine waves.



sinusoidal: describing a sine wave

Sinusoidal waves occur very frequently in nature.

Why are sinusoidal waves used on power lines?

Sinusoidal waveforms are very easy to generate at power stations.

static: not in motion

A Leyden jar stores static charges.

Don't build up too much of a static charge.

Why is capacitance defined as a property of static electricity?

terminal: a point in a device at which an electric connection may be made to other elements or devices

In the diagram, the terminals are represented by a and b.

Do some devices have more than two terminals?

Please connect a wire to each terminal.

voltage: the ability to produce an electric current

High voltages are dangerous to human life.

As voltage increases, current increases.

Will you lower the voltage, please?

waveform: the shape or appearance of a wave as it changes in time or space

All waveforms that repeat themselves are comprised of different sine waves.

Is that how a rectangular waveform should appear?

A waveform may also be called a waveshape.

C. Check-Up

Fill in the blanks with the proper terms from the list.

capacitance	insulator
current	resistance
electron	static
inductance	voltage

1. ______ charges do not move.
2. An ______ has a very small unit of charge.
3. An ______ does not conduct an electric current easily.
4. ______ is the ability of a substance to become a magnet when an electric current flows through it.
5. ______ causes current to flow.
6. ______ is the ability of a material to store charges.
7. ______ refers to a directed flow of charges.
8. ______ is a substance's ability to oppose the flow of current.

LESSON

2 Circuit Elements

A. Dialogue

Engineer: Let's begin by talking about three types of circuit elements: resistors, capacitors, and inductors.

Student: Are resistors those circuit elements which have very high resistance values?

Engineer: Not necessarily. A resistor is a kind of circuit element whose resistance is known within certain tolerance limits. They are used in circuits to realize required resistance values.

Student: But they do have capacitance and inductance values? You said that all substances have these properties.

Engineer: Yes, they do have low levels of stray capacitance and inductance, but these are usually negligible in practical applications.

Student: What are capacitors and inductors?

Engineer: A capacitor is a circuit element made up of two metal plates separated by a non-conducting material. An inductor is a circuit element made of a coil of wire. However, for circuit applications their current-voltage relationships are more important.

Student: Oh. Do capacitors and inductors behave like resistors?

Engineer: In a way. Both capacitors and inductors display a resistance-like quality called reactance. However, reactance is frequency-dependent. For dc a capacitor has infinite reactance while an inductor has zero reactance.

Student: Would you please define reactance?

Engineer: It is the ratio of ac voltage to ac current.

Student: This sounds exactly like resistance to me.

Engineer: Yes, but it is frequency-dependent. Resistance is frequency-independent. At very high frequencies a capacitor has extremely low reactance, and an inductor has extremely high reactance.

Student: So they display opposite current-voltage relationships with respect to frequency variations. In dc a capacitor will have a voltage across it but no current through it, while an inductor has no voltage across it but a current flowing through it.

Engineer: That's right.

Student: What are the specific current-voltage relationships?

Engineer: The capacitance of a circuit element is defined as the ratio of current flowing through it to the time derivative of the voltage across it. Inductance is defined as the ratio of the voltage across the inductor to the time derivative of the current flowing through it.

Student: Time derivatives. Now I see why reactance changes as frequency changes. Do these elements have any dc applications?

Engineer: Very large capacitors store very large charges and are used in a number of different applications. Very large inductors are often used as extremely powerful electromagnets.

Student: Both capacitors and inductors store electrical energy. Are there any circuit elements which supply other types of energy?

Engineer: Of course. We have devices such as batteries which convert chemical energy into dc voltage. Commercial power generators supply ac voltages by converting mechanical and nuclear energy into electrical energy.

Student: Resistors don't store or supply energy; so I guess they must dissipate it.

Engineer: That's right. The energy dissipated by a resistor gets spent by being heated.