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МЕТОДИЧНІ ВКАЗІВКИ

**до практичних занять з англійської мови
для студентів І курсу
спеціальності 141 «Електроенергетика, електротехніка та електромеханіка» денної форми навчання**

«Basics of electric engineering»

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UNIT 1. ELECTRONS AND ELECTRICITY

Text A

Before reading the text

Task 1. Guess the meaning of these words.
electron, atom, element, molecule, proton, neutron, negative, positive, neutral, opposite.

Task 2. Match the names of these elements.

1. copper	a) свинець
2. hydrogen	b) вуглець
3. carbon	c) кисень
4. gold	d) мідь
5. oxygen	e) гелій
6. helium	f) водень
7. lead	g) золото

Task 3. Match these words with their definitions.

1. substance	a) the number of protons in the element
2. atom	b) protons and neutrons clumped together in the center
3. molecule	c) substance that gives up or accepts an electron
4. element	d) total number of protons and neutrons in elements
5. compound substance	e) substance that resists to releasing or accepting electrons
6. nucleus	f) substance made up of just one type of atom
7. atomic number	g) the smallest unit of matter recognizable as a compound of atoms
	h) made up of protons,

8. atomic weight — neutrons and electrons
9. conductor — i) made up of tiny particles called atoms
10. insulator — j) two or more elements combined into a complex substance

Task 4. Find the words that have opposite meaning to:

1. attract	a) release
2. internal	b) outermost
3. accept	c) repel
4. innermost	d) external
5. inside	e) decrease
6. increase	f) outside
7. surplus	g) shortage

Task 5. Find the meaning of these adverbs in the list given below.

1. considerably
2. roughly
3. additionally
4. equally
5. arbitrarily
6. similarly
7. conversely
8. ordinarily
9. instantaneously
10. separately
11. approximately

довільно, навпаки, окремо, приблизно, звичайно, додатково, значно, миттєво, однаково, подібно

Task 6. Match these symbols with mathematical operations.

1. +	a) multiply
2. -	b) equals
3. ×	c) add
4. :	d) subtract
5. =	e) divide

Task 7. Find synonym to each word or expression.

1. substance	a) revolve

2. circle	b) wattage
3. remove	c) to be referred to as …
4. power	d) matter
5. to be called	e) delete

Task 8. Try to answer these questions.

1. What do you know about an atom and its structure?
2. Has the atom electrical charge?
3. Can an electric current pass through all substances?

Task 9. Read the text, translate it and check your answers.

Atoms and their structure. To understand electricity and electronics, you need at least a basic grasp of the theoretical structure of atoms. All substances are made up of tiny particles called *atoms*. There are approximately 100 different kinds of atoms (92 occur in nature; others are *synthetic* or created by human beings). A substance that is made up entirely of just one type of atom is called an *element*. Copper, hydrogen, carbon, gold, and oxygen are a few familiar elements.

Two or more elements can be chemically combined into a more complex *compound* substance. For example, water is made up of hydrogen and oxygen atoms. The smallest unit of matter that is recognizable as a compound, rather than as its component elements, is a *molecule*. If you broke a single molecule of water into smaller particles, you'd have two hydrogen atoms and one oxygen atom. Billions of different substances can be formed by various combinations of the basic elements, just as the 26 letters of the alphabet can be arranged into millions of different words.

Although an atom is the smallest particle recognizable as a specific element, atoms themselves are made up of smaller particles. Atoms are made up of particles called *protons*, *neutrons*, and *electrons*. Recent discoveries have indicated the presence of a large number of additional subatomic particles, but you can probably ignore them. The three kinds of subatomic particles are all roughly of equal size, but protons and neutrons are considerably more massive than electrons.

If 250 million hydrogen atoms were laid end to end, they'd span only about one inch. It would take 100,000 electrons (or protons or neutrons) laid side by side to span the width of a single hydrogen atom. Atoms don't contain anywhere nearly that many particles. The hydrogen atom typically consists of only a single proton and a single electron. Most of the space of an atom is empty. The protons and neutrons are clumped together in the center, forming a structure called the *nucleus*. The electrons revolve around the nucleus. The basic structure of a typical atom (carbon) is usually drawn as shown in Fig. 1.1

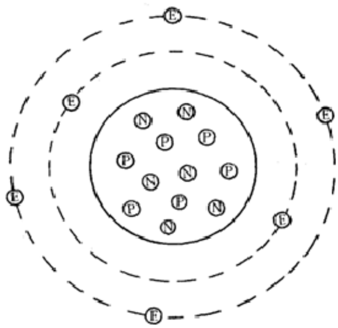

Figure 1.1– Structure of an atom

You'll notice that this arrangement is roughly similar to the solar system. The electrons revolve around the nucleus like the various planets revolve around the sun. It is important to realize that a lead proton is exactly the same as, say, a gold proton. What differentiates the elements is simply the number of these particles contained within the atom.

Electrical charge. When an electron is isolated from an atom, it exhibits a tiny *electric charge.* The basic unit for measuring electric charge is the *coulomb.* The combined charge of 6,250,000,000,000,000,000 (6.25 x 10^{18}) electrons equals a charge of one coulomb.

There are actually two types of electrical charges. The type exhibited by an electron is arbitrarily called a *negative charge.* A proton has the same amount of electrical charge as an electron, but it is the opposite type. It is referred to as a *positive charge.*

Two similarly charged particles (that is, two electrons or two protons) tend to repel each other. Two oppositely charged particles (an electron and a proton) tend to attract each other. This attraction is one of the factors that keeps the electrons in orbit around the oppositely charged protons in the nucleus.

Ordinarily, an atom has an equal number of electrons and protons; therefore, the atom as a whole has no electrical charge. That is, it is electrically *neutral.* But in most cases, an extra electron can be added to an atom, giving the atom (as a unit) a negative charge. Conversely, an electron can be deleted, leaving the atom as a unit with a positive electrical charge.

Neutrons, which are contained within the nucleus along with the protons, have no electrical charge. As their name implies, they are neutral.

Isotopes. The number of particles in an atom determines what kind of atom it is. For instance, an ordinary hydrogen atom (hydrogen is the simplest element) consists of a single proton, a single electron, and no neutrons. Sometimes, however, a hydrogen nucleus does contain one or even two neutrons (heavy hydrogen). In this case, it is still a hydrogen atom, but it has a few different properties. This kind of atomic variation is called an *isotope.*

Atomic number and atomic weight. Elements are often identified by their *atomic number*, which is simply the number of protons they contain. Each element has a unique atomic number. For example, hydrogen has an atomic number of one. The atomic number for helium is 2, carbon is 6 and lead is 82. *Atomic weight*, on the other hand, is the total number of both the protons and the neutrons.

Electron rings. Look again at the diagram of the atom in Fig.1.1. Notice that the electrons circle the atom in a number of fixed, concentric rings. These rings have a definite pattern in the maximum number of electrons each ring can contain.

The first ring, the one closest to the nucleus, can only hold one or two electrons. If the atom has three electrons, two are in this innermost ring; the third is in the second ring, farther out. This second ring can hold up to eight electrons. The third ring can hold 18, the fourth 32, the fifth 50, and the sixth can hold 72 electrons. No known atom has more than six rings. Usually the inner rings are completely filled before the outer rings are started, but there are exceptions.

Obviously, the easiest electrons to remove, giving the atom a positive charge, are those in the outermost ring. They are the easiest to strike with an external force, and they are the farthest from the attraction of the positively charged protons that try to hold the electrons in place.

Conductors and insulators. Certain substances give up an electron (or accept an extra electron) more readily than others. Such substances (typically metals) are called *conductors*, because they can conduct electricity. That is, they allow an electric current to pass through them.

A substance that has strong internal attraction and is thus resistant to releasing or accepting electrons is an *insulator*. Electric current can pass through an insulator, but it takes a far greater amount of force than for a conductor.

Any atom can be made to give up an electron. Conductors are simply those substances that give up electrons without a great deal of external force.

Vocabulary

electricity – електрика
structure – структура
particle – частка
synthetic – штучний
subatomic – внутрішньоатомний
space – простір
isolate – ізолювати
charge – заряд
measure – вимірювати
coulomb – кулон
equal – однаковий, рівний, дорівнювати
amount – кількість, величина, ступінь, міра
extra – додатковий
pattern – модель, зразок, малюнок

Task 10. Answer these questions about the text.

1. What differentiates the elements?
2. What does an electron exhibit when it is isolated from an atom?
3. What is the basic unit for measuring electric charge?
4. What types of electrical charges are there?
5. What does the number of particles in an atom determine?
6. How are elements identified?
7. How do the electrons circle the atom?

Task 11. Decide whether the following statements are true or false. If you think a statement is false, change it to make true.

1. Protons and neutrons are considerably more massive than electrons.

2. The electrons revolve around the protons.
3. A proton and an electron have different amount of electrical charge.
4. Two similarly charged particles tend to attract each other and two oppositely charged particles tend to repel each other.
5. The atom is electrically neutral.
6. Electric current cannot pass through an insulator.

Task 12. Translate the sentences. Look carefully at the meaning of the words <u>one</u>, <u>those</u> and <u>does</u> in the following sentences.

1. The first ring, the one closest to the nucleus, can only hold one or two electrons.
2. The easiest electrons to remove, giving the atom a positive charge, are those in the outermost ring.
3. An ordinary hydrogen atom consists of a single proton, a single electron, and no neutrons. Sometimes, however, a hydrogen nucleus does contain one or even two neutrons.

Text B

Before reading the text

Task 1. Match the units of measurement with these electrical quantities.

1. current	a) ohm
2. voltage	b) watt
3. power	c) volt
4. resistance	d) ampere
5. capacitance	e) henry
6. inductance	f) farad

Task 2. Choose the correct word to complete each sentence.

1. resist, resistor, resistance, resistivity
   a) Electrical circuits always have some … .
   b) A … is designed to oppose the current flow.
   c) There is no substance that perfectly doesn’t … current flow.

2. measure, measuring, measurement, measurable
   a) There are instruments that are employed to … electrical quantities.
   b) D'Arsonval movement has been around since the earliest days of electricity, but it is still used in some … devices today.
   c) The … of larger voltages requires special devices.

3. insulate, insulation, insulator, insulating
   a) Most gases are good electrical … .
   b) Excellent … materials can be used in capacitors.
   c) Sometimes an … gets perforated by a spark.

Task 3. Try to answer the following questions.

1. What is an electric current?
2. What can you tell about voltage?
3. Do you know what power is?

Task 4. Read the text, translate it and check your answers.

Electrical current. When an electron is knocked free from an atom, it drifts through space until it collides with a second atom that accepts it and throws off one of its own original electrons. This electron then strikes a third atom, and so forth. Each individual electron doesn't travel very far, but the energy of electron movement can be transmitted along the length of the conductor.

A simplified model of this kind of process is shown in Fig. 1.2. A cardboard tube is filled with three ping pong balls. When an extra ball, X, is pushed into the tube, it displaces ball 1, which displaces ball 2, which shoves ball 3 out of the far end of the tube. It all takes place almost instantaneously - when X is pushed in, 3 is shoved out. Each ball moved very little, and fairly slowly, but the energy was quickly transmitted through the tube.

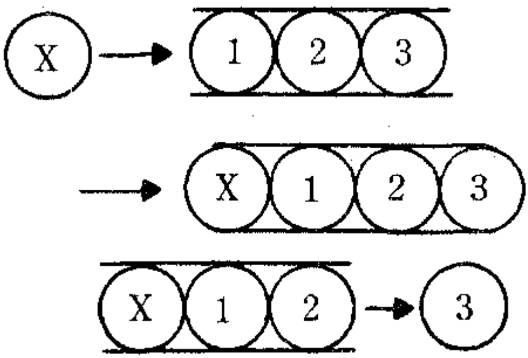

Figure 1.2– Model of current flow

When this process takes place with electrons in a conductor, it is called *electricity,* or *electron current.*

Another way to put it would be to consider current the effective flow of electrons (usually simplified as *electron flow).* If a coulomb (6.25 x 10^{18} electrons) flows past a given point within one second, the current equals 1 *ampere (A).*

The ampere is the basic unit of measurement for electric current, but in many practical cases, it is too large a unit to be convenient. In these instances, it is simpler to use the *milliampere*(mA), which equals one thousandth of an ampere, or *microampere* (µA), which equals one millionth of an ampere (one thousandth of a milliampere). For example, 50mA equals 0.05A, or 50,000µA. Generally you can use whichever unit gives you the most manageable figures.

The word *ampere* is sometimes abbreviated as *amp,* or simply the letter *A* as indicated above. Similarly, milliampere can be written as *milliamp* or *mA.* Microampere is usually abbreviated as µ*A.*

In electrical equations, current is usually represented by the letter I. The value of I is generally assumed to be in amperes unless otherwise stated.

Voltage. Because current specifies the number of electrons moving past a given point within a given time period, it can be considered the speed of the electron flow.

If you visualize electron flow as a toy car, you can draw a clear analogy to the basic elements of electricity. If you set the toy car on a perfectly flat table top, the speed (current) is zero - there is nothing to make it go. But if you tilt up one end of the table, the car starts to roll down the hill. The steeper the slope, the faster it goes.

What is making the car move is the difference between the highest point and the lowest point of the slope. In electricity the "highest point" is a point with a surplus of electrons (negative charge), and the "lowest point" is an electron shortage (positive charge). Because like charges repel and opposite charges attract, a stream of electrons flows from the most negative point to the most positive point.

Remember, each individual electron doesn't move very far, but the disturbance travels through the entire *circuit.* A circuit is a complete path for current flow. If the path is broken at any point, no current flows.

How strongly the current flows depend on the difference in charge between the most negative point and the most positive point of the circuit. This *difference of electrical potential* is also called *voltage* or *electromotive force.*

Voltage is measured in units called *volts* (V). One volt pushes 1 A of current through one *ohm (Ω)* of *resistance.* Resistance is discussed in the next UNIT.

If the volt is too large a unit, you can measure voltage in *millivolts* (mV). One volt equals 1000mV. If the volt is too small a unit, use the *kilovolt* (kV) as the unit of measurement. One kV equals 1000V. For example, 25V equals 25,000mV, or 0.025kV. Similarly, 2300V equals 2.3kV or 2,300,000mV.

In electrical equations, voltage is usually represented by the letter *E*. *E* is given in volts unless otherwise stated.

Power. If you want to determine how much work the circuit is doing, you need to consider both the voltage and the current. The total energy consumed is called power and is measured in watts (W). One watt of power is consumed when 1 V pushes 1 A through a circuit.

The relationship between power, voltage, and current is stated in the following formula:

$$P = EI \qquad \textbf{(1.1)}$$

P is power, *E* is voltage, and *I* is current. So power in watts equals voltage in volts times current in amperes.

This formula can be rearranged if you know the wattage (power) and the voltage and need to find the current. In this case:

$$I = P/E \tag{1.2}$$

The meaning of the variables is the same as in Equation 1-1.

The final possibility is if you know the wattage and the current, but not the voltage. Here you can write the equation as:

$$E= P/I \tag{1.3}$$

Again, the variables are the same as above. P is usually given in units of watts. You can use kilowatts (kW) or milliwatts (mW) if they are more convenient. The conversion is the same as with volts to kilovolts or to millivolts.

Vocabulary

energy – енергія
transmit – передавати
displace – переміщати, витісняти
flow – потік, протікати
equation – рівняння
slope – нахил
disturbance – збудження, порушення, пошкодження
travel – переміщатись, розповсюджуватись
circuit – коло, ланцюг
path – шлях, коло, частина кола
potential – потенціал
electromotive force – електрорушійна сила
consider – брати до уваги, враховувати
total – загальний, повний
consume – споживати
relationship – співвідношення, відношення, залежність
formula – формула
conversion – перетворення

Task 5. Work in pairs. Ask your partner to answer these questions.

1. What is a difference of potential?
2. Can the difference of potential be called electromotive force?

Task 6. Underline the words expressing the comparison. Decide the forms of comparison.

1. The steeper the slope, the faster object goes.
2. In the electricity the “highest point” is a point with a surplus of electrons (negative charge), and the “lowest point” is an electron shortage (positive charge).
3. Because like charges repel and opposite charges attract, a stream of electrons flows from the most negative point to the most positive point.

TEST (UNIT 1. Electrons and electricity)

Choose the correct answer

1. Which of the following is not a basic part of an atom?

A. Coulomb
B. Electron
C. Proton
D. Neutron

2. What flows through a conductor to create an electrical current?

A. Protons
B. Isotopes
C. Molecules
D. Electrons

3. If a coulomb flows past a given point within one second, the current equals

A. 0.05A
B. 50mA
C. 50000mA
D. 1A

4. What is the basic unit for measuring current flow?
A. Volt
B. Atomic weight
C. Ampere
D. Coulomb

5. Which of the following is not a unit for measuring voltage?
A. Volt
B. Millivolt
C. Isotope
D. Kilovolt

6. What is the basic unit for measuring electrical power?
A. Watt
B. Volt
C. Ampere
D. Electrolyte

7. How is the total energy consumed when the current flows through the circuit called?
A. Watt
B. Power
C. Voltage
D. Equation

8. One watt of power is consumed when
A. Like charges repel
B. Electron strikes an atom
C. 1V pushes 1A though the circuit
D. Electron is knocked free from an atom

9. If the voltage applied to a circuit is 15V, and the current flow is 2A, what is the wattage (power) consumed by the circuit?
A. 17W
B. 30W
C. 7.5W
D. 0.133W

10. If 12V are applied to a circuit that consumes 78W, what is the current flow through the circuit?

A. 936A
B. 0.15A
C. 9.36A
D. 6.5A

UNIT 2. RESISTANCE AND OHM'S LAW

Text A

Before reading the text

Task 1. Find the appropriate meaning to these phrases.

1. integrated circuit	a) дротовий резистор
2. fixed resistor	b) резистор змінного опору, змінний реостат
3. wirewound resistor	c) композиційний резистор
	d) металоплівковий резистор
4. composition or carbon resistor	e) інтегральна схема
5. metal-film resistor	f) резистор постійного опору, постійний опір
6. variable resistor	g) графічне зображення
7. resistance wire	h) реостатний дріт, дріт високого опору
8. schematic symbol	

Task 2. Try to answer these questions.

1. What can you compare a resistance with?
2. Is a resistance useful property or it has an adverse effect in the circuit?

Task 3. Read the text, translate it and check your answers.

A resistance is an electrical equivalent to friction and is represented by the letter *R.* Resistance impedes, or works against the flow of current. You might think that resistance is something that should always be avoided as much as possible, but it's actually quite a useful factor in practical circuits.

Remember that the higher the current drawn from a battery or cell, the faster the battery or cell will be discharged. Resistance limits the amount of current drawn. It can also, as you'll see, reduce the voltage in certain portions of a circuit.

Ohm's law. The basic unit of resistance is the *ohm,* which is sometimes written as Ω (the Greek letter omega). One volt can push 1 A of current through 1 Ω of resistance. The relationship between these three factors is perhaps the most important concept in electronics and electricity. This relationship is defined by a principle called *Ohm's law.* According to this law, voltage equals current times resistance, or:

$$E = IR \tag{2.1}$$

E is the voltage in volts, *I* is the current in amperes, and *R* is the resistance in ohms. *E* will also be in volts if the current is in milliamperes and the resistance in kilohms (kΩ) (see below)

With a little simple algebraic manipulation, you can rearrange the equation to solve for current if voltage and resistance are known:

$$I = E/R \tag{2.2}$$

Or, solving for resistance with known voltage and current:

$$R = E/I \tag{2.3}$$

You learned that power in watts equals voltage times current ($P = EI$). You can combine this equation with Ohm's law to find power consumed when only the resistance and the current are known:

$$P = EI$$

and

$$E = IR$$

$$\text{so } P = (IR)I$$

$$\text{or } P = I^2R \tag{2.4}$$

Similarly, if you know the resistance and the voltage:

$$P = EI$$

and

$$I = E/R$$

$$\text{so } P = E\,(E/R)$$

$$\text{or } P = E^2/R \tag{2.5}$$

These equations are quite versatile, and they are absolutely essential to your understanding of electronics.

In most practical circuits the ohm is a too small unit, so the *kilohm* (kΩ -1000 ohms) and the *megohm* (MΩ - 1,000,000) are often used.

Resistors. A *resistor*is an electric component that is designed to introduce a specific amount of resistance into a circuit. Resistors are probably the most commonly used class of components in electrical engineering. Different size resistors can handle different amounts of power, or wattage. The action of a resistor causes it to heat up. That is, it converts electrical energy into *thermal energy* (heat). If a resistor gets too hot, it can change its resistance value or it can become damaged. To prevent this problem, always use a resistor that will *dissipate* (or handle) the required amount of power. If in doubt, use a larger resistor. A 2W resistor, for example, will work fine in a 1/2W circuit.

Unfortunately, large wattage resistors tend to be more expensive and take up quite a bit of space. So generally, use the smallest resistor that will comfortably handle the required wattage. For most electronic circuits, 1/4W resistors are more than sufficient. In circuits built around *integrated circuits*, you would normally use 1/4W resistors.

Types of fixed resistors. If only a few ohms of resistance are needed in a circuit, the resistor can simply be a piece of *nichrome* (nickel-chromium) wire of suitable width and length. Nichrome wire has a much greater resistance than standard copper wire (all conductors have some resistance) so small *wirewound resistors* can be made without the length being unreasonable. This nichrome wire (sometimes called resistance wire) is usually wound around a ceramic core and covered with some insulating material.

Usually the resistances needed in practical electronic circuits are too large for reasonable wirewound resistors, so *composition resistors* are more commonly used. These resistors are usually made of a thin coating of carbon on a ceramic tube. Carbon is only a fairly poor conductor, so a fairly large resistance can be achieved in a relatively small space.

The upper limit for such a *carbon resistor* is generally around 10MΩ. Of course, the resistor itself is covered with an insulating body. The color coding bands are painted on the outside of the insulation.

Another common type of resistor uses a thin metallic film instead of carbon. *Metal-film resistors* can usually be made to more precise values than carbon composition resistors. Metal-film resistors are also less sensitive to temperature fluctuations (carbon resistors can sometimes change value at temperature extremes) and produce less *internal noise* (random and undesirable voltages and power fluctuations).

All of these devices are called fixed *resistors* because, unless they are in some way damaged, their value is more or less constant (all resistors change value somewhat in response to temperature fluctuations). The schematic symbol for a fixed resistor is shown in Fig. 2.1.

Figure 2.1 - Schematic symbol for a fixed resistor

Variable resistors. It is often necessary to be able to alter the amount of resistance in a circuit. In these cases a *variable resistor* is used. Variable resistors are usually called *rheostats* or *potentiometers* (often shortened to *pots)*. These terms are more or less interchangeable, but generally the word *rheostat* is used to identify a device that is suitable for heavy-duty ac (alternating-current) circuits and potentiometers are generally used in circuits having relatively low power.

Also, potentiometers usually have three terminals. The two outside terminals act like a simple fixed resistance - the resistance between these two terminals does not change. The center terminal, however, is attached to a *slider*, which is controlled by a knob. You can move the slider along the resistance element, which is either wound wire, or a strip of carbon. Depending on the position of the slider, the resistance between it and either of the outside terminals will vary. See Fig. 2.2. Notice that the total of resistance *AB* plus resistance *BC* always equals the constant resistance *AC.* As resistance *AB* increases, resistance *BC* decreases, and vice versa.

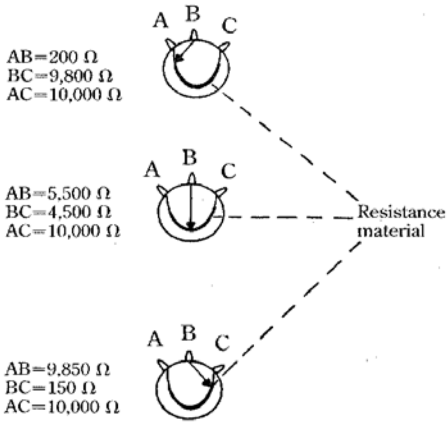

Figure 2.2– Resistance of a potentiometer varies as the slider is moved through its range

A variation on the standard potentiometer is the *slide pot.* It works in exactly the same way as a regular potentiometer, except the slider moves in a straight line rather than in circular motion. The only advantage of using a slide pot is that in certain applications, it is easier to see where the slider is positioned.

The schematic symbol for a potentiometer is shown in Fig. 2.3. The symbol is the same whether it is for a slide pot or standard round pot.

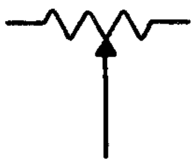

Figure 2.3– Schematic symbol for a three-terminal variable resistor

A rheostat, on the other hand, is often a two-terminal device. That is, there is one fixed terminal and the movable terminal (slider). The second fixed terminal is simply left off. Fig.2.4 shows the most common schematic symbol for a two terminal variable resistor. Alternatively, the standard symbol for a potentiometer can be used with one of the outer (fixed) terminals left disconnected.

Figure 2.4– Schematic symbol for a two-terminal variable resistor

Potentiometers and rheostats are generally panel controls. To use a potentiometer or rheostat, you rotate a knob (which is connected to the shaft of the variable resistor) that in some way alters the operation of the circuit.

Vocabulary

friction – тертя
battery – батарея
cell – елемент
discharge – розряджатися
resistor – опір, резистор
thermal – тепловий
damage – пошкодитися, псуватися
dissipate – розсіювати (ся)
wire – дріт, провід, провідник
nichrome – ніхром
rheostat – реостат
potentiometer – потенціометр
device – прилад, пристрій
heavy-duty – важкий режим
terminal – вивід, зажим, клема
slider – повзун
slidepot – повзунковий потенціометр
rotate – обертати (ся)
knob – ручка, кнопка
shaft – вал
operation – робота
alternating current (a.c.) – змінний струм
reduce – зменшувати

Task 4. Answer these questions about the text.

1. What is the basic unit of resistance?
2. How is the relationship between voltage, current and resistance defined by Ohm's law?
3. What is a resistor designed for?
4. What does a resistor convert?
5. When can a resistor be damaged?
6. What types of fixed resistors are commonly used?
7. When is a variable resistor used?
8. How are variable resistors usually called?

Task 5. Work in pairs. Make up the problems of your own similar to those given in the models 1-5. Ask your partner to solve these problems using the relationships of Ohm's Law and comment on them.

Model 1. Suppose that generator produces 10V and potentiometer is set to a value of 10 Ω . What is the current?
This is solved by the relationship I = E/R. Plug in the values for E and R, they are both 10. Then I =10/10 =1.0 A

Model 2. Assume that potentiometer is set to 100 Ω and the measured current is 10 mA. What is the voltage?
Use the relationship E = IR. First, convert the current to amperes: 10mA=0,01A. Then multiply: E=0,01x100=1.0V

Model 3. What is the value of the resistance if the current is 18mA and the voltage is 229 mV?
First, convert these values to amperes and volts. This gives I=0,018A and E=0,229V. Then plug into the equation: R=E/I=0,229/0,018=13Ω.

Model 4. Suppose that the voltmeter reads 12V and the ammeter shows 50mA. What is the power dissipated by the potentiometer?
Use the formula P=EI. First, convert the current to amperes, getting I=0,050A. Then multiply by 12V, getting P = PI = 12 x 0,050 = 0,60W.

Model 5. If the resistance in the circuit is 999 Ω and the voltage source delivers 3V, what is power dissipated by the potentiometer?
Use the formula $P = E^2/R = 3 \times 3/999 = 9/999 = 0{,}009W = =9\ mW$

Text B
Combinations of resistors

Task 1. Before reading the text try to answer the following questions.

1. What combinations of components in the circuits do you know?
2. What is the difference between series and parallel connection?

Task 2. Read the text, translate it and check your answers.

Practically electrical and electronic circuits consist of just a single resistance, so you need a way of determining the total value of multiple resistances in various combinations.

Series Resistances. Figure 2.5 shows a simple circuit with two resistors in series. Assume the battery generates three V. The value of R_1 is 100Ω, and R_2 is 200Ω. How do you find the current? Because the total current has to flow through both resistors, it must have the same value for each resistor. The current has to flow through 100Ω; then it has to flow through an additional 200Ω more. As you might have guessed, this resistance appears to the current as a single 300Ω resistor. Resistances in series add. Stated algebraically, the formula for resistance in series is:

$$R_T = R_1 + R_2 \ldots + R_n \qquad \textbf{(2.6)}$$

where R_T is the total resistance. The letter n represents the total number of resistances in the circuit.

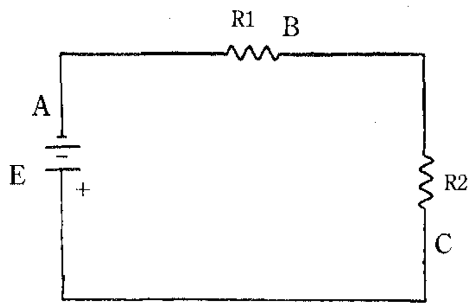

Figure 2.5 – A simple series resistance circuit

In the example, you have just two resistances. $R_T = R_1 + R_2 = 100 + 200 = 300\Omega$. Now that you know the total effective resistance in the circuit, you can use Ohm's law to find the current. You know that $I = E/R$ (current equals voltage divided by resistance), so the current in this circuit equals 3V/300Ω, or 0.01A (10mA).

Now, what is the voltage dropped by each resistor? Because $E = IR$ (voltage equals current times resistance), the voltage through R_l must equal 0.01 A x 100Ω, or 1V. Similarly, the voltage through R_2 equals 0.01A x200Ω, or 2V. Notice that adding the voltages dropped across each of the resistors will give you the original source voltage. You can say that all of the voltage is used up by the resistances, which is true of all circuits. As the current passes through each resistor, the resistance causes the voltage to drop. At point A you have the full source voltage, or 3V. At point B, R_l has dropped 1V, so there is 3 - 1, or 2V. R_2 drops 2V, and so at point C the voltage is 0. The source voltage is used up.

Finally, you can calculate the total power consumed by the circuit. You'll recall that the formula is $P = EI$ (power or wattage equals voltage times current). In the example, you have 3V x 0.01A, or 0.03W (30 milliwatts-mW).

Try another example, and use a slightly different method of solving it. You'll still be using the circuit shown in Fig. 2.5, but this time the battery generates 12V, R_l is 1000 Ω, and R_2 is 150Ω. The total resistance in the circuit is 1000 + 150, or 1150Ω. Because you know that the total power consumed by a circuit can be calculated with the formula $P = E^2/R$, you can insert the known values. $P = 12^2/1150 = 144/1150 =$ approximately 0.125W (125 mW).

Solving for current you can rearrange $P = EI$ to $I= P/E$, or 0.125/12 equals just over 0.01 A (about 10 mA). The voltage drop across R_l is found by Ohm's law. $E = IR = 0.01A \times 1000\Omega = 10V$. The voltage drop across R_2 equals 0.01A x 150Ω, or about 1.5V. You'll notice that the calculated voltage drop is 10V + 1.5V, or 11.5 V, rather than the source voltage of 12V. What happened to that extra half volt? Actually, nothing. You lost it in the calculations because of rounding off. The wattage consumed is actually 0.1252174W, but rounding this figure off to 0.125W made the rest of the calculations simpler. There is nothing wrong with rounding off the results of these equations, and usually the calculated values will be close enough. But when a discrepancy does show up, you might find it necessary to go back and work with the exact values.

Parallel resistances. Now, what if you have a circuit like the one shown in Fig. 2.6? In this case, the electron flow drawn from the battery (the current) is split up between the two resistors. There are two *parallel* paths for the current to follow. Some of it will flow through R_1, and some will flow through R_2.

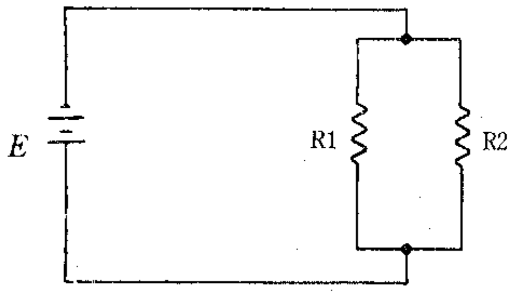

Figure 2.6– A simple parallel resistance circuit

Naturally, more current will flow through the path with less resistance. If both resistors are of equal value, equal currents will flow through them. As far as the voltage is concerned, a parallel circuit looks like two separate circuits, as in Fig. 2.7. The full source voltage is dropped across each resistor.

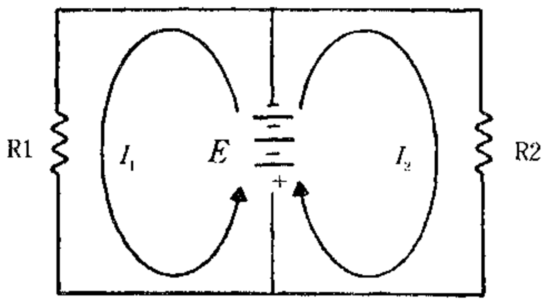

Figure 2.7– Parallel resistance as it appears to the voltage source

Suppose the circuit is powered by a 6V battery. R_x is 1000Ω and R_2 is 3000Ω. You already know that the full source voltage (6V) will be dropped across each resistor, so you can use Ohm's law and solve for the currents separately. For R_l, $I = E/R$ = 6V/1000Ω= 0.006A (6 mA). The current through R_2 is 6V/3000Ω, or 0.002A (2mA). R_l draws 6 mA from the battery, and R_2 draws an additional 2 mA, so the total current drawn by the parallel circuit is 8 mA.

Solving for the equivalent resistance of the entire circuit, you can use the formula $R = E/I = 6$V/0.008 A = 750Ω. Notice that this total equivalent resistance is less than the value of the smallest resistor. This relationship is always true in a parallel circuit. If the two resistors are equal, the equivalent resistance will be exactly one half their individual values.

Another formula for determining the equivalent resistance of n resistors in a parallel circuit is:

$$1/R_1 + 1/R_2 \ldots + 1/R_n = 1/R_T \qquad \textbf{(2.7)}$$

R_T is the total effective resistance of the parallel circuit. Using the example above, you find 1/1000 + 1/3000 = 0.001 + 0.00033333 = 0.00133333. Taking the reciprocal (1/0.00133333), you get 750Ω. You get the same answer, no matter which method you use.

The power consumed by the circuit is solved in the usual way. That is, $P = EI$. In this circuit, 6V x0.008A = 0.048W. This value can be rounded off to about 50mW.

As you can tell from Equation 2.7, any number of resistances can be combined in parallel. For example, imagine a circuit with four resistors in parallel. Their values are 1000Ω, 2200Ω, 6800Ω and 10.000Ω. So you have 1/1000 + 1/2200 + 1/6800 + 1/10,000 = 0.001 + 0.0004545 + 0.0001471 + 0.0001 = 0.0017016. Taking the reciprocal to find the total effective resistance, you get just under 590Ω. Notice that this equivalent value is lower than the individual value of any of the separate resistors.

Series-parallel combinations. In actual practice, you'll rarely come across a circuit with just series resistances or just parallel resistances. Usually you'll find a combination of the two forms. Take a look at Fig. 2.8. Here you have a circuit with four resistors both in series and in parallel. It might look complicated to solve for such a combination circuit, but it's easy enough if you go one step at a time.

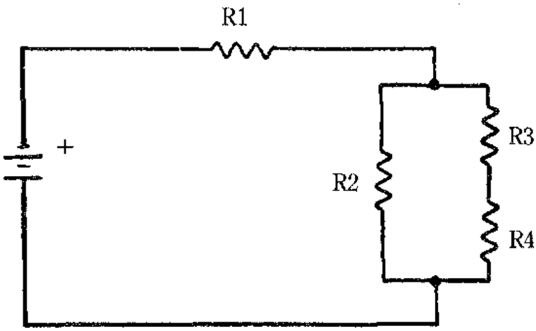

Figure 2.8– A series-parallel resistances circuit

Assume the source voltage is 15V. R_1 equals 1500Ω, R_2 equals 2200Ω, R_3 equals 470Ω, and R_4 equals 1000Ω. First you should find the equivalent resistance of the R_3 – R_4 combination. Because these two resistances are in series, their values simply add. That is, 470 + 1000Ω = 1,470. For simplicity, you can consider this combination as a single resistor, R_A. See Fig. 2.9.

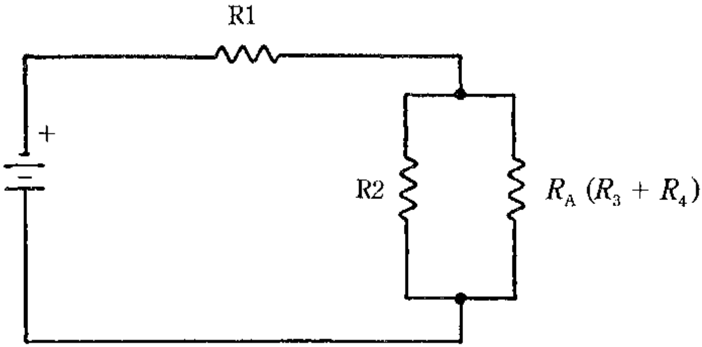

Figure 2.9 – Simplification of Fig. 2.8

Now solve for the R_2 - R_A parallel combination. 1/2200 + 1/1470 = 0.0004545 + 0.0006803 = 0.0011348. So the equivalent resistance is just over 880Ω. Call this value R_B. See Fig. 2.10.

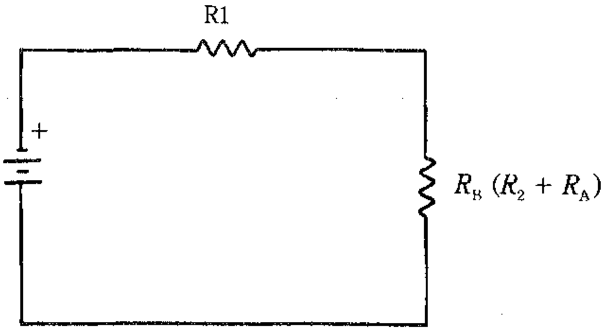

Figure 2.10– Further simplification of Fig. 2.8

Now, you just have R_1in series with R_B. $R_1 + R_B = 1500 + 880 = 2380\Omega$, which is the total equivalent resistance for the entire circuit. Solving for the total circuit current, you find that because $I = E/R$, the current equals 15 V/2380Ω, or about 0.0063A (6.3mA). The full current flows through R_l, because there is no other path for it to take to bypass this resistor. You can solve for the voltage drop across R_l. $E = IR$ = 0.0063A x 1500Ω = 9.45V.

Looking at the R_B combination as a single resistor, you find the total voltage drop is about 0.0063 x 880, or 5.55V (9.45V across R_l, and 5.55V across R_B equals the source voltage -15V). Because R_B consists of R_2 and R_A in parallel, you know the voltage dropped across each of these resistances is equal. Specifically, 5.55V. The current through R_2 equals 5.55V/2200Ω or approximately 0.0025A (2.5mA). The current through the R_A combination is 5.55V/1470Ω, or about 0,0038A (3.8mA). R_A is actually R_3 and R_4 in series. Because these two resistors are in series, they pass the same current- 3.8mA. The voltage drop through R_3 is 0.0038A x 470Ω, or 1.77V. Across R_4 it is 0.0038A x 1000Ω, or 3.78V. Notice that 3.78V + 1.77V equals 5.55V.

Further, the current through R_2 (2.5mA) plus the current through R_A (3.8mA) equals 6.3mA - the same value you got for the entire circuit. You can see how all these equations are interconnected.

Finally, the power through the entire circuit is 15V times 0.0063A, or 0.0945W. You can round this value off to about 95mW.

Vocabulary

in series – послідовно
in parallel – паралельно
generate – генерувати
effective resistance – ефективний опір
source – джерело живлення
source voltage – напруга живлення
drop – падати, знижуватись
voltage drop – падіння напруги
calculate – обчислювати
solve – розв’язувати
round off – округляти
discrepancy – розходження
exact – точний
split up – розділятися, розщеплюватися
power – живити (ся)
bypass – обходити
equivalent resistance – еквівалентний опір
reciprocal – обернений, обернене число

Task 3. Work in pairs. Ask your partner to draw the circuit in which resistors are connected:

- in series;
- in parallel;
- in series-parallel configuration.

Comment on each configuration.

Task 4. Make up the problems of your own for all types of connections similar to those given above in the text. Solve and comment on them.

TEST (UNIT 2. Resistance and Ohm’s Law)

Choose the correct answer

1. **What does a resistance do in the circuit?**

A. Helps to draw the current out of the battery
B. Impedes the flow of current

C. Avoids to reduce the voltage
D. Rearrange the circuit
E. None of the above

2. Which of the following is not a valid expression of Ohm's law?
A. $R = E/I$
B. $E = IR$
C. $I = E/R$
D. $R = E^2/I$
E. None of the above

3. Which of the materials is sometimes called a resistance wire?
A. Ceramics
B. Carbon
C. Copper
D. Nichrom
E. None of the above

4. Which of the following is not a variable resistor?
A. Pot
B. Rheostat
C. Slider
D. Potentiometer
E. None of the above

5. If a 3300Ω resistor and a 22000Ω resistor are connected in series, what is the total resistance?
A. 18,700Ω
B. 2870Ω
C. 25,300Ω
D. 5500Ω
E. None of the above

6. If three resistors, each with a value of 560Ω, are connected in parallel, what is the total resistance of the combination?
A.187Ω
B.1867Ω
C. 560Ω

D.1680Ω
E. None of the above

7. Assume 15V is applied to a simple series circuit consisting of a 2200Ω resistor and a 4700 ohm resistor. What is the value of the current flowing through this circuit?
A. 0.010A
B. 0.0022A
C. 22A
D. 0.460A
E. None of the above

8. **A 33 kΩ resistor is connected in series with a parallel combination made up of a 56 kΩ resistor and a 6.8 kΩ resistor. What is the total combined resistance of these three resistors?**
A. 95,800Ω
B. 49,069Ω
C. 39,067Ω
D. 63,769Ω
E. None of the above

9. When resistors are connected in series, what happens?
A. Nothing
B. The effective resistance is decreased
C. The effective resistance is increased
D. The tolerance is decreased
E. None of the above

10. When resistors are connected in parallel, what happens?
A. Nothing
B. The effective resistance is decreased
C. The effective resistance is increased
D. The tolerance is decreased
E. None of the above

UNIT 3. KIRCHHOFF'S LAWS

Text A

Before reading the text

Task 1. Match each word and expression in the list on the left with the appropriate meaning on the right.

1. algebraic sum	a) замкнута частина кола
2. cancel out	b) замкнутий контур
3. loop	c) вузол
4. closed path	d) алгебраїчна сума
5. closed loop	e) зрівнювати (ся)
6. node	f) контур
7. count	g) довільний
8. arbitrary	h) рахувати
9. sign convention	i) джерело напруги
10. voltage source	j) правило знаків

Task 2. Try to answer the following questions.

1. What properties of electrical circuit Kirchhoff's laws are related to?
2. When are these laws usually used?

Task 3. Read the text, translate it and check your answers.

Kirchhoff's laws are a handy set of tools for analyzing what's going on within an electrical circuit. You have a choice of whether to use Kirchhoff's voltage law or Kirchhoff's current law. They are just two different paths to the same ends. Ultimately, they give the same results.

Kirchhoff's laws are especially useful in analyzing circuits that cannot be broken down into simple series, parallel, or series-parallel combinations of resistances. Such a circuit is shown in Fig.3.1.

Kirchhoff's voltage law. According to Kirchhoff's voltage law, "the algebraic sum of the voltage sources in any loop is equal to the algebraic sum of the voltage drops around the loop." If you don't understand this statement, don't worry about it. In somewhat simpler terms, it means - the total amount of voltage put into the loop must be exactly cancelled out to the voltage used up (dropped) within the loop. This idea will become clearer as you go on. To understand Kirchhoff's voltage law, you first need to know what is meant by a *loop.*

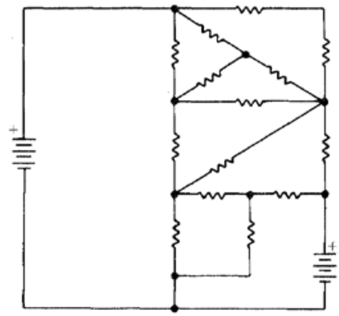

Figure 3.1– Some circuits cannot be broken down into simple series-parallel combinations

Loops. In the Kirchhoff system, a loop is any closed conducting path within the circuit. Loops can be made up of any combination of conductors, resistances, reactances, or voltage sources (but not current sources). For now all you really need to know that a reactance is essentially an ac resistance.

A fairly simple circuit is shown in Fig. 3.2. This circuit is broken up into its component loops in Fig. 3.3. Notice that the loops are redundant. Although the circuit is made up of three loops, any two of the loops include all of the circuit elements. The third loop is not needed. More complex circuits will break down into more than three loops, of course, but the principle is the same.

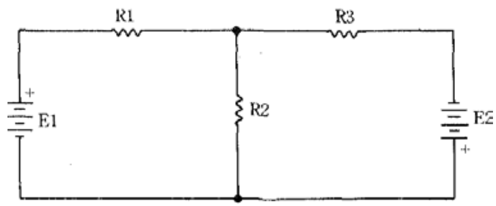

Figure 3.2– This circuit will be used to demonstrate Kirchhoff's laws

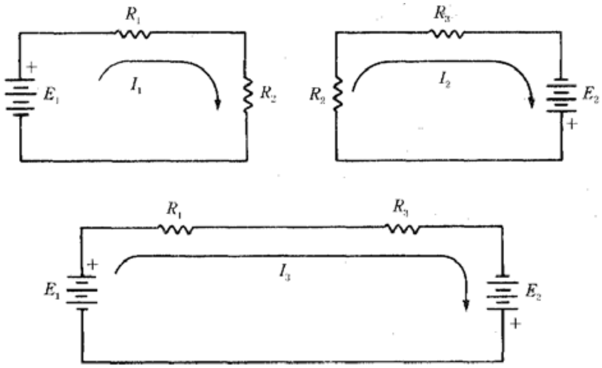

Figure 3.3– The circuit of Fig. 3.2 shown in component loops

In working with Kirchhoff's voltage law, you will use the minimum number of loops that will include all of the circuit elements. To use any more loops would merely be redundant and make unnecessary extra work for you.

Loop Currents. The next expression you need to understand is *loop current.* The definition is pretty obvious. A loop current is simply the current assumed to flow through a given loop. The loop currents are indicated in Fig.3.3.

It is important to realize that loop currents are a theoretical concept. They exist only mathematically. If you actually measured the current at a given point in the circuit, you might or might not get a value close to the assumed loop current. There is a perfectly good reason for this. The tested point can be (and probably is) part of more than one loop. There might well be multiple loop currents flowing through that circuit point. For example, in Fig. 3.3, loop currents I_1 and I_2 both flow through resistance element R_2

For purposes of Kirchhoff circuit analysis, you simply artificially separate these simultaneous currents into independent loop currents. This concept is somewhat confusing, so it might be worthwhile to go back and reread the brief discussion on loop currents before going any further.

Sign conventions. Kirchhoff's voltage law deals with *algebraic sums.* Using algebraic sums, you will be dealing with positive (plus) and negative (minus) quantities. Various values will be added or subtracted, depending on what *algebraic sign* they have. Obviously you need a set of conventions or rules to determine whether a given value should be given a plus or minus sign. The procedure for determining the proper signs is: pick a direction, either clockwise or counterclockwise. It doesn't really matter which one you pick, as long as your choice remains consistent throughout the analysis. A negative sign simply indicates that the current is moving in the opposite direction from the one you selected.

All of the loop currents must be assumed to flow in the same direction (all clockwise, or all counterclockwise). It is important to remember that the use of a plus or minus sign here does not refer to ordinary electrical polarity. It is just a mathematical convention for your convenience in analyzing the circuit.

If a current flows through a resistor in the same direction as the loop current for that loop, the voltage drop across the resistance is positive. Of course, if the current flowing through the resistor is in the opposite direction, you will consider the voltage drop across the resistance to be negative.

There are two kinds of current flowing through the loop. There is the loop current for the loop presently under consideration, and there are loop currents from other loops in the circuit. As a rule of thumb, voltage drops caused by the present loop current will almost always be positive. Voltage drops due to currents from other loops can be either positive or negative.

Loops can contain voltage sources. If a loop current passes through a voltage source from the negative terminal to the positive terminal, that current has a positive value. If it flows in the opposite direction (from the voltage source positive terminal to the negative terminal), that current is negative. By following these rules, you can determine the proper sign for any current or voltage drop in a loop.

Kirchhoff's voltage law in action. You might be scratching your head at this point. You might be starting to believe this is all beyond you, but don't worry. Kirchhoff's voltage law is a little difficult to explain abstractly, but once you go step by step through a practical example, you should have a better grasp of the concepts described.

You will analyze the simple circuit shown in Fig. 3.2. Of course, you can't do that without knowing the voltages and resistance values in the circuit. You will assume the following values:

E_1 12V
E_2 6V
R_1 100Ω

R_2 47Ω
R_3 220Ω

In analyzing the circuit, you can use either two of the loops shown in Fig. 3.3. Use loop A and loop B. These loops are shown in Fig. 3.4. The loop currents are assumed to flow in a clockwise direction. Loop A consists of E_l, R_l, and R_2. The loop current for loop A is labeled I_1. Loop B consists of E_2, R_2, and R_3.

The loop current for loop B is labeled I_2. Notice that resistance R_2 is part of both loops. Therefore, both the I_1 and I_2 currents flow through this component.

Kirchhoff's voltage law states that the algebraic sum of all voltage sources in the loop equals the algebraic sum of all voltage drops in the circuit. In other words, the total amount of voltage put into the loop must be exactly cancelled out to the voltage used up (dropped) within the loop.

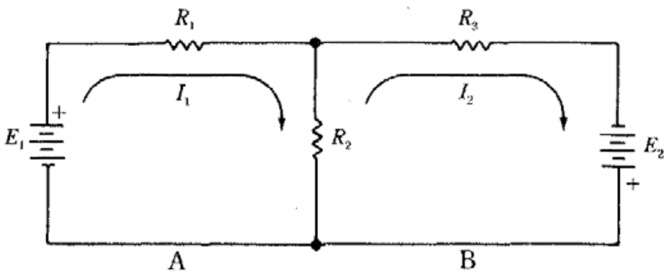

Figure 3.4– Use loop A and loop B from the circuit of Fig. 3.2

Once again, you have a slight imbalance due to cumulative rounding errors, but the total voltage sources in the loop again is approximately equal to the total voltage drops in the loop. If you recalculate all the values exactly (without any rounding off), you will find that Kirchhoff's voltage law accurately predicts what is happening here. The results of the analysis of this circuit using Kirchhoff's voltage law are shown in Fig. 3.5.

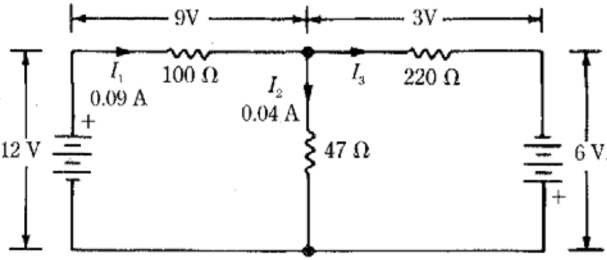

Figure 3.5– The results of Kirchhoff's voltage law analysis of Fig. 3.2

For simplicity in the discussion to this point, you have rounded off the calculated values as much as possible. Inevitably this comes at a cost in accuracy of results. It is okay for quick-and-dirty calculations. For more precision work, you probably won't want to round off quite this much. Rounding errors are often (but not always) somewhat cumulative.

Task 4. Work in pairs. Make up the problems of your own similar to that given in the model. Ask your partner to solve and comment on it.

Model. Suppose the circuit includes four resistors in series having values of 50Ω, 60Ω, 70Ω and 80Ω and that the current through each of them is 500mA. What is the battery voltage, E?

Find the voltages E_1, E_2, E_3 and E_4 across each of the resistors. This can be done using Ohm's Law. For E_1 say with the 50Ω resistor, calculate E_1 = 0,500 x 50 = 25V. In the same way calculate E_2 = 30V, E_3 = 35V and E_4 = 40V. The supply voltage is the sum $E_1+E_2+E_3+E_4$ = 25+30+35+40 = 130V. Kirchhoff's Voltage Law tells us that the polarities of the voltages across the resistors are in the opposite direction from that of the battery. Therefore, $E_1+E_2+E_3+E_4 = 0$.

Text B

Task 1. Before reading the text try to answer this question.

1. What can you compare Kirchhoff's Current Law with? (instead of current use something else)

Task 2. Read the text, translate it and check your answer.

Kirchhoff's current law. There is an alternate to Kirchhoff's voltage law, and it is Kirchhoff's current law. This second Kirchhoff's law permits you to deal with actual currents rather than the mathematical fictions (loop currents) of Kirchhoff's voltage law.

According to Kirchhoff's current law, "the amount of current flowing into a node always exactly equals the current flowing out of that node." That idea certainly makes sense when you think about it. What you put into a node is what you get out of it. In more mathematical terms, the algebraic sum of all currents flowing through a node is zero. Obviously, before you go any further, you should understand just what you mean by the term *node.*

Nodes. A node is simply the connection point between two or more conductors.The simple example circuit is shown in Fig. 3.6, with the nodes indicated. This particular circuit has just two nodes (A and B).

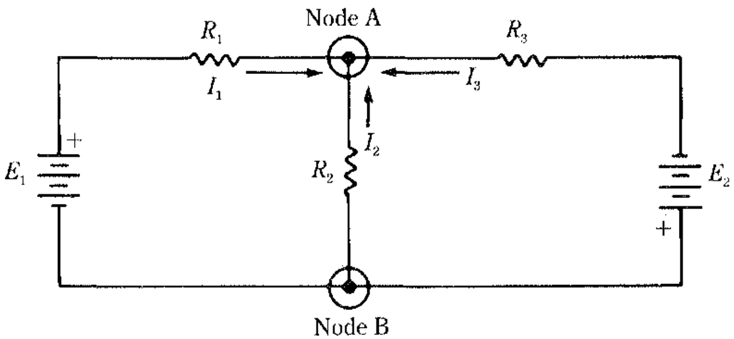

Figure 3.6 - The circuit of Fig. 3.2 with the current nodes indicated

Current flowing into any node is always assumed to be positive. Current flowing out of the node is assumed to be negative. For voltage drops across any resistance elements, the terminal where the current enters is assumed to be at a higher potential (more positive) than the terminal where the current exits. This concept is illustrated in Fig. 3.7.

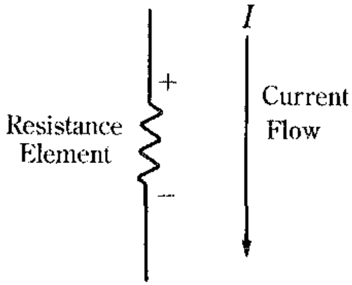

Figure 3.7– The terminal of a resistance element where the current enters is assumed to be more positive than the terminal where the current exits

When using Kirchhoff's current law, the first step is to count the number of nodes in the circuit to be analyzed. If the circuit has N nodes, you will need to examine N-l nodes to completely analyze the circuit. The required number of node equations is always one less than the total number of nodes in the circuit.

Kirchhoff's current law in action. In the sample circuit of Fig. 3.6, you have two nodes, so you only need to look at one to analyze the circuit. Use node A. You could just as easily use node B. The choice of which one to leave out is purely arbitrary.

There are three current paths into node A. These are marked in Fig.3.6 as follows:

$$I_1, I_2, I_3$$

According to Kirchhoff's current law, the algebraic sum of these three currents must be equal to zero. That is:

$$I_1+I_2+I_3 = 0$$

Note that at this point you don't know which of these currents are positive and which are negative. This basic equation can't do you much good until you relate the currents to the voltages and resistances within the circuit.

Current I_1 flows through resistor R_1. Thanks to Ohm's law ($I= E/R$), you know that current I_1 must be equal to the voltage drop across R_1 divided by the value of the resistance.

The voltage drop across R_l must be equal to the voltage going into the resistance element at the positive terminal (which is E_l, in this case) minus the voltage at the negative terminal of the resistance element. You will call the voltage at the negative terminal E_a. The current direction of I_2 tells you that node A is less positive (more negative) than node B, so voltage E_a takes on a negative sign.

$$I_1=(E_1-(-E_a))/ R_1$$

The two negative signs in front of E_a cancel each other out, which leaves you with:

$$I_1=(E_1+E_a)/ R_1$$

Current I_2 is defined by the voltage drop across R_2, which is simply equal to E_a, so:

$$I_2 = E_a / R_2$$

Yes, it works. Kirchhoff s Current Law gave an accurate prediction of how the currents in the circuit interact at the examined node.

Other circuits will end up with slightly different equations. Naturally, the more nodes there are in the circuit, the more equations you will have to work with.

Task 3. Work in pairs. Make up the problems of your own similar to that given in the model. Ask your partner to solve and comment on it.

Model 1. Suppose all three resistors have values of 100Ω and that I_1= 2,0A and I_2= 1,0A. What is the battery voltage?
First, find the current I drawn from the battery: I =I_1+I_2 =2,0 + 1,0 = 3,0A. Next, find the resistance of the entire circuit. The two 100Ω resistances in series give a value of 200 Ω, and this is in parallel with 100 Ω. You can do the calculations and find that the total resistance, R, connected across the battery is 66,67Ω. Then E = IR = 3,0 x 66,67 = 200V

TEST (UNIT 3. Kirchhoff's Laws)

Choose the correct answer

1. Which of the following is not one of Kirchhoff's laws?
A. Kirchhoff's voltage law
B. Kirchhoff's resistance law
C. Kirchhoff's current law
D. None of the above

2. For Kirchhoff's voltage law, circuits are divided into which of the following?
A. Nodes
B. Ohms
C. Series-parallel circuits
D. Loops

3. What is a node?
A. A mathematical fiction
B. A terminal point for a loop current
C. A connection point between two or more conductors
D. None of the above

4. Which of the following correctly describes Kirchhoff's voltage law?
A. The algebraic sum of all the voltage sources in a loop equals the algebraic sum of all voltage drops in that loop.
B. The algebraic sum of all the currents entering a node equals the algebraic sum of all currents exiting that node.
C. A voltage drop equals the current multiplied by the resistance.
D. The algebraic sum of all loop currents equals the algebraic sum of all voltage drops in that loop.

5. Which of the following cannot be included in a loop for Kirchhoff's voltage law?
A. Resistances
B. Current sources
C. Voltage sources
D. Reactances

6. How many nodes are needed to completely analyze a circuit according to Kirchhoff's current law?

A. One
B. Two
C. All nodes in the circuit
D. One less than the total number of nodes in the circuit.

7. Loop currents should be assumed to flow in which direction?

A. Clockwise
B. Counterclockwise
C. Either A or B can be arbitrarily selected
D. None of the above

8. According to Kirchhoff's current law, what is the algebraic sum of all currents entering and exiting a node?

A. A positive value
B. A negative value
C. The algebraic sum of all loop currents
D. Zero

9. If a resistance element is part of two loops, how many voltage drops must be calculated for that component?

A. None
B. One
C. Two
D. Three

10. In Kirchhoff's current law, which terminal of a resistance element is assumed to be at a higher potential (more positive) than the other?

A. The terminal where the current enters the resistance element
B. The terminal where the current exits the resistance element
C. The terminal closest to the node being analyzed
D. Either A or B can be arbitrarily selected

UNIT 4. ALTERNATING CURRENT

Text A

Before reading the text

Task 1. Find the words and expressions that have opposite meaning to:

1. direct current
2. heavy-wattage
3. to be in phase
4. charge

a) discharge
b) to be out- of-phase
c) alternating current
d) low-power

Task 2. Try to answer the following questions.

1. What forms of electricity do you know?
2. What is the difference between them?

Task 3. Read the text, translate it and check your answers.

So far you have been working with circuits where the current flows in only one direction. This form of electricity is called *direct current,* or *dc.* Many other circuits, however, operate on a voltage and current that continuously varies in value, according to a repetitive, periodic pattern. Electricity in this form is called *alternating current,* or *ac*.

Varying voltage and current. The polarity of a voltage source determines the direction of current flow. The current will flow from the negative terminal of the voltage source to the positive terminal. If the polarity of the voltage source is reversed, the current will flow in the opposite direction.

Take a look at the circuit in Fig. 4.1. Here you have a circuit with two voltage sources, each a 3 V battery. As far as these batteries are connected with opposing polarities, if they were allowed to have an equal effect on the circuit, they would simply cancel each other out. No current would flow through the circuit, and the power consumed would be zero.

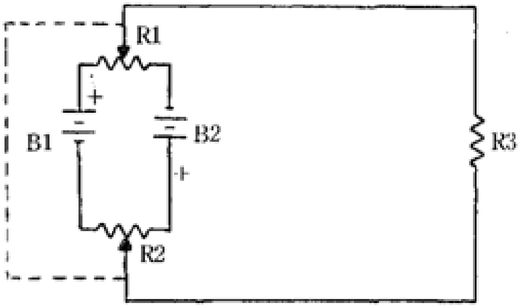

Figure 4.1– A circuit powered by a voltage with reversible polarity

The two potentiometers labeled Rl and R2 control thé relative effect of the two batteries in the main circuit. The dotted line between these two schematic symbols indicates that they are mechanically tied together. That is, one knob controls both potentiometers simultaneously. Such multiple components are said to be *ganged.* Potentiometers can be dual, triple, or even quadruple ganged. Dual ganged pots are not uncommon, but larger combinations tend to be fairly rare.

For convenience in this discussion, refer to Rl and R2 as if they were a single potentiometer, because they always work in unison. If the potentiometer slider is in the exact center of its path of rotation, equal resistances will be seen by each of the source voltages. So both batteries will present an equal, but opposite voltage to the main circuit. This results in the voltages canceling each other out, and no current flows through the circuit.

If, however, the slider is moved all the way towards battery 1, that battery will see a minimum resistance, and battery 2 will see a maximum resistance. In other words, most of battery 2 voltage is dropped across the resistance of the potentiometer. But most of the voltage from battery 1 makes its way through to the external circuit. Therefore, as far as the load circuit is concerned, battery 2 doesn't exist. Battery 1 provides the power to operate the circuit.

At the other extreme of slider path, the situation is reversed—battery 2 is dominant, and battery 1 is ignored. At intermediate positions of the slider, the two voltages will interact in a subtractive manner. The battery closest to the slider will have the greater effect, but the other battery will cancel out some of the voltage.

For example, if the potentiometer is set so that 2.5V is passed from battery 1, but battery 2 is allowed to put out only 0.5V, the load circuit will see a voltage source of 2V (battery 1 - battery 2). This voltage will have the same polarity as the larger of the opposing voltages. In this case, battery 1 determines the polarity.

If you draw a graph of the effective voltage seen by the circuit, as the potentiometer slider is rotated through its entire range, it would look like Fig.4.2.

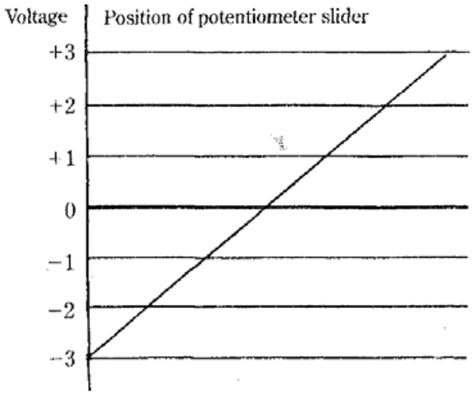

Figure 4.2– The voltage through the circuit of Fig. 4.1 as the potentiometer is moved through its entire range

Now, suppose you start with the slider in its center position, and then smoothly rotate the knob back and forth. A graph of the effective voltage under these circumstances would resemble the one in Fig. 4.3.

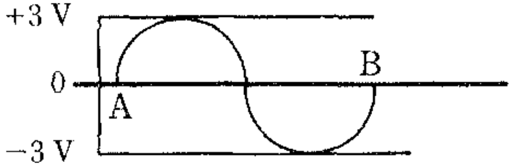

Figure 4.3– A sine wave

Notice that there is a repeating pattern in this graph. If you happen to be familiar with trigonometry, you might recognize this graph as a series of representations of the function called the *sine* of an angle. For this reason, this *wave shape* is called a *sinusoidal,* or *sine wave.* Each complete pattern, without repetition (as from point A to point B in Fig. 4.3) is called a *cycle,* or a *wave.*

If you try a few Ohm's law equations, you'll find that the current drawn by the circuit varies in step with the fluctuations of the applied voltage. When the voltage goes up, the current goes up, and vice versa. The current is said to be *in phase* with the voltage. A purely resistive circuit does not alter the phase relationship. When the voltage and current in a circuit fluctuate in this manner, you have an *alternating current.*

Ac voltage sources. Fig. 4.4 shows the schematic symbol for any ac voltage source that generates a sine wave (other wave shapes are discussed in other UNITs). Notice that because the current is constantly reversing itself, there is no fixed polarity for such a voltage source.

Figure 4.4– Schematic symbol for an ac (alternating current) voltage source (sine wave)

An ac source changes its polarity many times each second. By counting the number of complete cycles in a second, you get the *frequency* of the wave. Frequency is measured in *cycles per second* (cps). Another name for a cycle per second is *hertz* (Hz), named after a pioneer in the field of electricity. One thousand hertz is a *kilo-hertz* (kHz), or a *kilocycles per second* (kcps). Similarly, a million cps is one *megahertz* (MHz), or *megacycle.*

Typically, ac power sources operate at a fairly low frequency. In the United States, house current alternates at a 60Hz rate. Other countries use a 50Hz standard. It might seem that using ac would just complicate matters, but actually, the reverse is true. For low-power applications, it is easier to make dc devices (that is, batteries) than ac devices. In heavy-wattage installations, ac is much more practical to generate. It is also easier to transmit ac over long lines. Ease of transmission is why the electric power companies operate on ac.

The most readily available source of ac for powering electric circuits is the house current provided by the electric company through ordinary wall sockets. The wall socket is a power source of about 110 to 120V ac (the level fluctuates somewhat) with a nominal frequency of 60Hz. This frequency also fluctuates slightly, but the average is usually very close to 60Hz.

Many electric circuits are designed to operate directly from an ac wall socket. In some circuits, power is first passed through a *transformer* to change the voltage or through a power supply to convert the ac to a dc voltage.

Phase. The current from an ac voltage source is ordinarily in step with the voltage. That is, when the voltage increases, so does the current, and when the voltage decreases, the current also decreases. The voltage and the current are *in phase*. Their cycles start at the same instant. But some components can throw the voltage and current *out-of-phase*. That is, one is delayed so that the two are no longer in step with each other.

Multiple ac sources. Remember that when you have two or more dc voltages in series (such as cells in a battery), you can find the total voltage simply by adding the component voltages from each individual source. Or, if you have two voltages of opposite polarity, you can simply subtract the smaller from the larger to find the total effective voltage in the circuit. With ac sources, however, the situation is much more complex. If the two voltage sources in a circuit like in Fig. 4.5 are in phase with each other, there

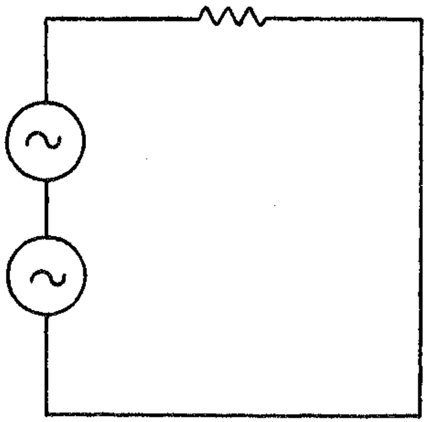

Figure 4.5– Two ac sources in series

is no problem, you can simply add the voltages, just as with dc. Or, if the voltage sources are 180 degrees out of phase with each other (one full cycle equals 360 degrees - see Fig. 4.6), you can just subtract the smaller from the larger voltage.

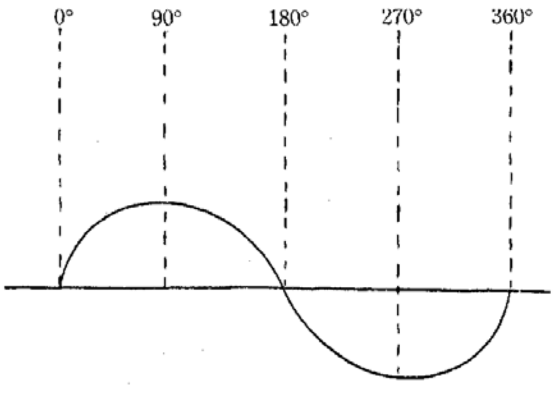

Figure 4.6– The degrees of a cycle

Of course, if two equal ac voltages are 180 degrees out of phase with each other, they will cancel each other out, leaving a net voltage of zero.

To calculate any other phase relationship requires fairly complicated mathematics. For example, consider the graphs in Fig.4.7. The voltage in graph B is 60 degrees out of phase with the voltage in graph A. Mathematically calculating the effective voltage of A and B would require numerous equations.

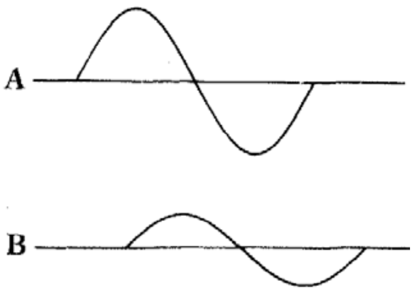

Figure 4.7– Out-of-phase ac voltages

Vocabulary

reverse – змінювати напрямок на протилежний
polarity – полярність
effect – дія, вплив
gang – механічно з’єднувати,
ganged – спарений (має спільне управління)
extreme – крайня точка
load – навантаження
operate – приводити в дію
dominant – домінуючий
intermediate – проміжний
interact – взаємодіяти
range – діапазон
sine – синус
angle – кут
representation – зображення
wave – хвиля
sinusoidal (sine) wave – синусоїдальна, гармонічна хвиля

cycle – період
fluctuate – коливатися, відхилятися
phase – фаза
frequency – частота
per – в, на, за
socket – розетка
transformer – трансформатор
convert – перетворювати
delay – затримка, затримувати, запізнюватись

Task 4. Work in pairs. Give your own examples of using dc and ac current and ask your partner to do the same.

TEST (UNIT 4. Alternating current)

Choose the correct answer. In one case there are two possibilities.

1. **What determines the direction of current flow?**

A. Electrons
B. Molecules
C. Resistance
D. Polarity of voltage source
E. None of the above

2. **If the polarity of the voltage source is reversed, what happens?**

A. Current flow will not change its direction
B. Current will flow in opposite direction
C. Current will vary in value
D. Negative terminal and positive one will cancel out each other
E. None of the above

3. **What equations are used to find that the current drawn by the circuit varies in step with the fluctuations of the applied voltage?**

A. Kirchhoff’s voltage law equations

B. Ohm’s law equations
C. Kirchhoff’scurrent law equations
D. Kirchhoff’s resistance law equations
E. None of the above

4. **Which of the following is not a unit for measuring ac frequencies?**
A. Cycles per second
B. Waves per second
C. Hertz
D. Kilocycles per second
E. Megahertz

5. **Why do the electric power companies operate on ac?**
A. It is difficult to make dc devices
B. It is more practical to generate
C. It is easier to transmit over long lines
D. It is used for law power applications
E. None of the above

6. **What frequency do ac power sources usually operate?**
A. 60Hz
B. 110Hz
C. 120Hz
D. 220Hz
E. None of the above

7. **Which of the following is true for the statement “the voltage and the current are in phase”?**
A. One of them is delayed
B. When voltage increases current decreases
C. When voltage decreases current increases
D. Their cycles start at the same instant
E. None of the above

8. If you have two ac voltages of opposite polarity how can you find the total effective voltage in the circuit?

A. To add voltages from each individual source
B. To make the same polarity
C. To subtract the smaller from the larger
D. To start their cycles at different instants
E. None of the above

9. How many degrees are there in one complete wave cycle?

A. 180 degrees
B. 90 degrees
C. 360 degrees
D. 720 degrees
E. None of the above

10. If two equal ac voltages are 180 degrees out of phase with each other, what happens?

A. Nothing
B. Voltages are added
C. Voltages are subtracted
D. Voltages will cancel each other out
E. None of the above

UNIT 5. CAPACITANCE

Text A

Task 1. Before reading the text try to answer the following questions.

1. What are the main components of electrical circuit?
2. Do you know the function of a capacitor in the circuit?

Task 2. Read the text, translate it and check your answers.

It has been mentioned that the most commonly used component in electric circuits is the resistor. Probably the second most commonly used component is the *capacitor.*

What is capacitance? If two metal plates are separated by an insulator (or *dielectric),* and a dc voltage is applied between the plates, current will not be able to cross the dielectric. But a surplus of electrons will be built up on the plate connected to the negative terminal of the voltage source, and there will be a shortage of electrons on the plate connected to the positive terminal. The voltage source will try to force electrons into one plate (negative terminal) and draw them out of the other (positive terminal).

At some definite point, these plates will be completely saturated. No further electrons can be forced into the negative plate, and no more electrons can be drawn from the positive plate. At this point, the plates have an electrical potential equal to that of the voltage source. In fact, the plates now act like a second voltage source in parallel with the first, and with the opposite polarity. Naturally, because these opposing voltages are equal, they cancel each other out and no current can flow between the voltage source and the plates in either direction. The plates are said to be *charged.*

Now if the voltage source is removed from the circuit, the plates will stay charged, because there is no place for the electrons on the negative plate to go. Similarly, there is no place for the positive plate to draw electrons from. The voltage is stored by the plates.

Replacing the missing voltage source with a resistor, provides a current path for the excess electrons stored on the negative plate to flow to the positively charged plates. This flow will continue until both plates are returned to an electrically neutral state. This process is called *discharging* the plates.

Such a device (two conductive plates/separated by insulator) is called a *capacitor.* A capacitor is used to store electrical energy. At one time, capacitors were known as *condensers,* but this term is somewhat misleading and has fallen into disuse. You might run across it once in a while. Just remember, it is simply another name for a capacitor.

A capacitor cannot hold a charge indefinitely. Even air can conduct some current, so the charge will slowly seep off into the air. This action is a form of *leakage.* There will also be some leakage through the insulating dielectric. Of course, if all other factors are equal, the lower the internal leakage, the better the capacitor.

Now, consider what happens in a capacitor when an alternating current is applied to it. During the first part of the cycle, as the source voltage increases from zero, it will charge the plates of the capacitor in a manner similar to the dc circuit described above. The polarity of the charged capacitor opposes that of the source voltage.

The capacitor might or might not be completely charged by the time the applied voltage passes its peak and starts to decrease again (depending on the size of the plates, how much voltage is applied, and the frequency of the ac signal). In either case, as the applied voltage decreases, a point will be reached when it is less than the charge stored in the capacitor. This situation will allow the capacitor to start discharging through the ac voltage source.

The capacitor might or might not be completely discharged when the ac voltage reverses polarity, but because the source polarity is the same as the capacitor polarity, the voltages add, quickly discharging the capacitor the rest of the way, then charging it with the opposite polarity from the original charge. When the ac source voltage reverses direction, the capacitor is discharged again, and the entire process is repeated with the next cycle of the ac waveform.

If you constructed the circuit illustrated in Fig. 5.1 with a dc voltage source, the lamp would not light, because the dc current cannot flow through the circuit - it is blocked by the dielectric. The capacitor acts like an open circuit as far as direct current is concerned.

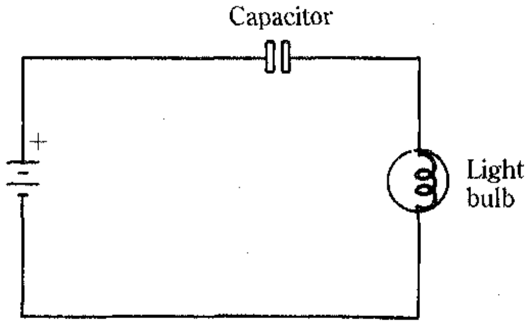

Figure 5.1– Circuit to test current flow through a capacitor

If, however, the same circuit were built with an ac voltage source, the lamp will light (see Fig. 5.2). The light indicates that alternating current is flowing through the circuit. Of course, virtually no current (except the tiny leakage current) will flow across the dielectric itself. Remember, any given electron doesn't travel very far in an electric circuit. It merely moves far enough to disturb its neighbor. The process of charging, discharging, and recharging a capacitor from an ac voltage source, gives the same effect as if the current was actually flowing through the capacitor itself. Moreover, if you decrease the frequency of the ac source, the lamp will dim. Increasing the frequency will cause the lamp to burn brighter. A capacitor lets more current flow as the frequency of the source voltage is increased.

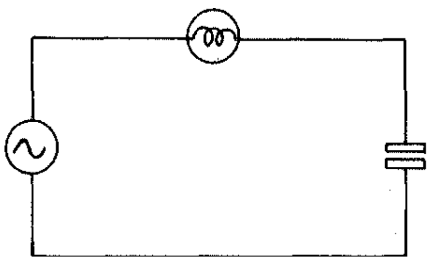

Figure 5.2– AC capacitor circuit

If you measured the dc resistance of a discharged capacitor, the meter needle would show a sharp kick down to a moderately low resistance as the capacitor is being charged. Then it will settle down to a very high resistance value. In an ideal capacitor you would have an infinite resistance; that is, you would have a completely open circuit. However, you've already learned that ac can flow through a circuit with a capacitor. The apparent resistance of a capacitor in an ac circuit is less than its dc resistance. This apparent ac resistance is called *capacitive reactance.* Its value decreases as the applied frequency increases. A capacitive reactance slows down voltage more than it does current, so the voltage lags the current by 90 degrees (assuming a purely capacitive circuit).

Before you can understand the formula for determining capacitive reactance, you need to know how capacitance is determined. The basic unit of capacitance is *the farad.* If one ampere of current flows when the applied voltage changes at a rate of one volt per second, you have one farad of capacitance (1F). In actual circuits, the farad is far too large a value. Instead, you generally use the *microfarad* (μF), which is one millionth of a farad and the picofarad (pF) which is one millionth of a microfarad. The abbreviation μF is generally preferred today.

Filters. A *filter* is a circuit that allows some frequencies to pass through it but blocks other frequencies. A capacitor is automatically a sort of filter by definition, because it allows higher frequencies to pass through it easily, but it blocks a dc signal (that is, a signal of 0 Hz). A filter that passes high frequencies, but blocks low frequencies is called a highpass filter, while a filter that passes low frequencies, but blocks high frequencies is called a lowpass filter.

Vocabulary

capacitor – конденсатор
dielectric – діелектрик
apply – прикладати, подавати, застосовувати
saturate – насичувати (ся)
store – накопичувати (ся)
leakage – розсіювання, втрата
apparent – явний, уявний
apparent resistance – уявний опір
capacitive reactance – ємнісний опір
lag – затримуватись, відставати
filter– фільтр
highpass filter – фільтр верхніх частот
lowpass filter – фільтр нижніх частот.

Task 3. Answer these questions about the text.

1. What is a capacitor?
2. What is it used for?
3. What does a leakage mean?
4. Does a quality of the capacitor depend on the leakage?

Task 4. Work in pairs. Ask your partner and let him answer the following questions.

1. What is a filter?
2. What kinds of filters are there in electrical circuits?

Text B

Combinations of capacitors

Before reading the text

Task 1. Match each word and phrase with the appropriate meaning.

1. effective capacitance	a) коло високої частоти
2. stray capacitance	b) загальний вивід на землю
3. high frequency circuit	c) ефективна ємність
4. shield	d) заземлення
5. earth ground	e) захищати, екранувати
6. common ground	f) паразитна ємність

Task 2. Try to answer what happens when there is more than one capacitor in the circuit.

Task 3. Read the text, translate it and check your answer.

Now, examine what happens when you have more than one capacitor in a circuit.

Capacitors in parallel. A circuit with two capacitors in parallel, as shown in Fig. 5.3, can be drawn more pictorially, as in Fig. 5.4. Because plates A and B are tied together, they are at the same electrical potential, you can think of them as a single plate. Similarly, plates C and D are electrically combined into an apparent single plate.

Remember that the larger the surface area of the plates in a capacitor, the higher the capacitance will be. Obviously, combination plate A-B is going to be larger than either plate A or plate B separately. The same is true of combination plate C-D. So the total effective capacitance of multiple capacitors in parallel always increases. The total capacitance is larger than any of the separate, component capacitances.

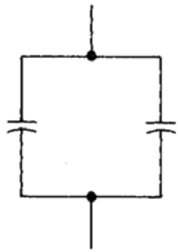

Figure 5.3– Capacitors in parallel

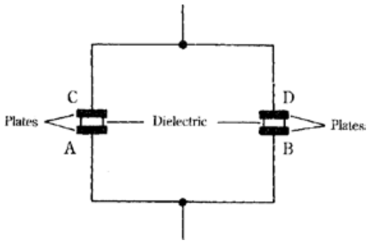

Figure 5.4– Pictorial diagram of parallel capacitors

In fact, you can simply add the capacitances of capacitors in parallel. That is, for n capacitors in parallel:

$$C_T = C_1 + C_2 + \dots C_n \qquad (5.1)$$

Notice that this formula is the same as the formula for finding the total resistance of multiple resistors in series.

Capacitors in series. Similarly, capacitors connected in series, as in Fig. 5.5, work against each other, reducing the total effective capacitance of the circuit. The formula for capacitors in series mirrors the formula for multiple resistors in parallel:

$$1/C_T = 1/C_1 + 1/C_2 + \ldots 1/C_n \quad (5.2)$$

Figure 5.5– Capacitors in series

Therefore, two 0.1µF capacitors in series would act like a single 0.05µF capacitor. If the same capacitors were connected in parallel they would equal 0.2µF. Of course, both series and parallel combinations of capacitances can be included within a single circuit, just as with resistances.

For example, consider the string of capacitors in Fig. 5.6. Assume C_1 is 0.1µF, C_2 is 0.033µF, C_3 is 0.0015µF, and C_4 is 0.22µF. First solve for the series combination of C_1 and C_2. $1/C_T = 1/C_1 + 1/C_2 = 1/0.1 + 1/0.033 = 10 + 30.30303 =$ about 40. Taking the reciprocal, you find the series combination of C_1 and C_2 is approximately 0.025µF. This capacitance is in parallel with C_3, so $C_T = 0.025 + 0.0015 = 0.0265$.

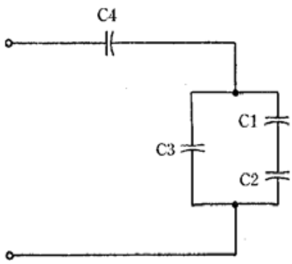

Figure 5.6– A series-parallel capacitor circuit

This effective capacitance is in series with C_4, so the effective capacitance for the entire circuit equals $1/0.0265 + 1/0.22 = 37.7 + 4.5 = 42.2$. Taking the reciprocal, you conclude that the total effective capacitance is just under 0.024µF.

Now, find the total effective capacitance for the circuit if C_1=15µF, C_2 = 0.47µF, C_3 = 3.3µF, and C_4 = 2.2µF.

Stray capacitances. Because a capacitor is simply two conducting surfaces, separated by an insulator, small, unintentional capacitances can be formed by adjacent wires, or component leads. Generally, these *stray capacitances* are far too small to be of any real significance, but in some very high frequency circuits (such as radio circuits) they can be very troublesome. These undesirable capacitances can allow signals to pass into portions of the circuit where they could hinder proper operation.

To prevent such stray capacitances in high frequency circuits, leads should be as short as possible reducing the effective plate area. Leads should also be *shielded* (that is, enclosed in a conductor that is connected to ground - either earth ground or common ground) if more than just a few inches long.

Task 4. Work in pairs. Ask your partner to tell about stray capacitance and how it can be prevented.

Task 5. Solve the problems.

Problem 1. Suppose two capacitors, with values of C_1= 0,10µF and C_2 = 0,050µF, are connected in series. What is the net capacitance?

Problem 2. Suppose two capacitors, with values of 0,0010µF and 100pF, are connected in series. What is the total capacitance?

Problem 3. Suppose three capacitors are in parallel, having values of C_1= 0,100µF, C_2 = 0,0100µF and C_3 = 0,001000µF. What is the total capacitance?

TEST (UNIT 5. Capacitance)

Choose the correct answer

1. What is a dielectric?

A. A conductive plate in a capacitor
B. A measurement of capacitance
C. A charged particle
D. An insulator between two metal plates in a capacitor
E. None of the above

2. Which of the following describes the action of a capacitor?

A. Opposes changes in current flow
B. Converts ac into dc
C. Creates a dc resistance
D. Stores electrical energy
E. None of the above

3. What component of the circuit provides a current path for discharging the plates of a capacitor?
A. Voltage source
B. Loop
C. Node
D. Resistor
E. Terminal

4. When an alternating current is applied to a capacitor, what happens?
A. Capacitor charges indefinitely
B. Capacitor starts charging to a point when the applied voltage is less than the charge stored in the capacitor
C. Capacitor starts charging to a point when the applied voltage is more than the charge stored in the capacitor
D. Capacitor cannot hold a charge
E. None of the above

5. What is a capacitive reactance?
A. A lamp
B. A circuit
C. DC resistance
D. Apparent ac resistance
E. None of the above

6. Which of the following is not a unit for measuring capacitance?
A. Megohm
B. Farad
C. Microfarad
D. Picofarad
E. None of the above

7. What type of signal experiences the greatest resistance through a capacitor?

A. Low-frequency signals
B. AC signals
C. High-frequency signals
D. Out-of-phase signals
E. None of the above

8. Which of the following is a stray capacitance?

A. Highpass filter
B. Lowpass filter
C. Unintentional capacitance formed by adjacent wires
D. Shielded leads
E. None of the above

9. If two 0.25μF capacitors are connected in series, what will be the total effective capacitance?

A. 0.50μF
B. 0.0625μF
C. 0.125μF
D. 2.5μF
E. None of the above

10. If two 0.25μF capacitors are connected in parallel, what will be the total effective capacitance?

A. 0.50μF
B. 0.0625μF
C. 0.125μF
D. 2.5μF
E. None of the above

UNIT 6. MAGNETISM AND ELECTRICITY

Text A

Before reading the text

Task 1. Match each word and phrase with the appropriate meaning.

1. magnet	a) полюс
2. lodestone	b) магнітний опір
3. pole	c) потік
4. magnetic lines of force	d) магнітне поле
5. flux	e) магніт
6. magnetic field	f) магнітні силові лінії
7. magnetomotive force	g) електрорушійна сила
8. electromotive force	h) магніторушійна сила
9. reluctance	i) магнетит

Task 2. Try to answer the following questions.

1. Can you give any examples of the phenomena of magnetism?
2. Where can this property of materials be used?
3. Is there any relationship between magnetism and electricity?

Task 3. Read the text, translate it and check your answers.

What is a magnet? Very closely related to the concept of electricity is the concept of magnetism. Let's study how these two phenomena interact. Magnetism has been known to humans for well over 2000 years. The ancient Greeks discovered a peculiar lead-colored stone that had the mysterious ability to attract small particles of iron ore. Some time later, the Chinese found a practical use for this seemingly magical stone. They learned that if a piece of this stone is suspended on a string or floated on a liquid it always tries to point in one specific direction (north). Because they used this device to lead them through the desert, the stone came to be called *lodestone* (that is, the leading stone).

You know now that the lodestone is a natural *magnet.* Although in some ways, magnetism is still rather mysterious, much is now known about its properties. Magic is not involved. You can make magnets out of certain other materials, even though they aren't naturally magnetized. Lodestone is a fairly weak magnet, but stronger magnets can be made of iron, nickel, cobalt, or steel.

The two opposite ends of a magnet are called the *poles.* See Fig. 6.1. One pole will tend to point towards the earth's north pole if the magnet is floated or freely suspended. This north-seeking pole is called the *north pole* of the magnet. The other pole is referred to as the *south pole.*

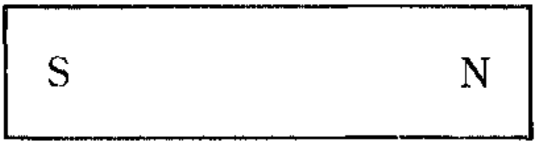

Figure 6.1– Poles of a magnet

Remember that in an electrical circuit, like charges repel and opposite charges attract. The same effect occurs with magnetic poles. If two magnets are brought together, north pole to north pole, they will try to repel each other. If, however, one of the magnets is turned around so that the north pole of one magnet is facing the south pole of the other, the magnets will exhibit a strong attraction towards each other.

If you place a bar-shaped magnet under a sheet of paper, sprinkle some iron filings on top of the paper, and shake the paper gently, the filings will tend to arrange themselves into a pattern like the one shown in Fig 6.2.

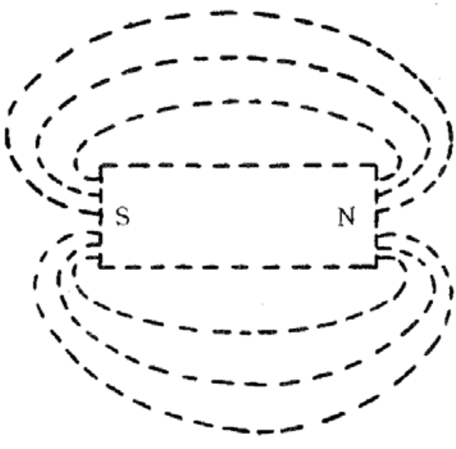

Figure 6.2– Magnetic lines of force

Notice that the iron filings arrange themselves in a set of parallel lines arcing from one pole to the other. These lines never cross or unite. They are an indication of the *magnetic lines of force,* or *flux.* The area they cover is the *magnetic field.*

The flux flows from the north pole to the south pole of the magnet, just as electrical current flows from the negative terminal to the positive terminal of a voltage source. The flux is produced by a force called *magnetomotive force.* Magnetomotive force is somewhat analogous to electrical voltage (which is also sometimes called *electromotive force).*

Just as certain substances conduct electrical current better than others, certain substances allow magnetic lines of flux to pass through them more readily than other substances. In other words, some materials present a greater resistance to the flux. The magnetic equivalent of resistance is called *reluctance.*

The similarities between magnetism and electricity are so strong that Ohm's law applies to magnets too. In magnetic circuits, flux equals magnetomotive force divided by reluctance. This relationship directly reflects the electrical formula, current equals voltage divided by resistance ($I = E/R$).

Task 4. Work in pairs. Ask your partner and let him answer these questions.

1. What is a magnetic field?
2. What is a magnetomotive force?
3. What relationship reflects the similarities between magnetism and electricity?

Text B

Task 1. Before reading the text try to answer these questions.

1. How can a magnetic field be produced?
2. Do you know such a device as electromagnet? What does it consist of? Where is it often used?
3. What is a common way of producing electricity with the help of a magnet?

Task 2. Read the text, translate it and check your answers.

Producing magnetism with electricity. When an electric current passes through a conductor, such as a piece of copper wire, a weak magnetic field is produced. The magnetic lines of force encircle the wire at right angles to the current flow, and are evenly spaced along the length of the conductor. See Fig.6.3. The strength of the magnetic field decreases at greater distances from the conductor. The size and overall strength of the magnetic field is dependent on the amount of power flowing through the electrical circuit, but it is always fairly weak. The magnetic force surrounding the conductor can, however, be dramatically increased by winding the wire into a coil, so the lines of force can interact and reinforce each other.

An even greater magnetomotive force can be generated if the coil is wound around a piece of low reluctance material, such as soft iron. Because the magnetomotive force vanishes as soon as the current stops flowing in the wire, you have a magnet that can be turned on and off. The strength of the magnet is also electrically controllable. Such a device is called an *electromagnet.*

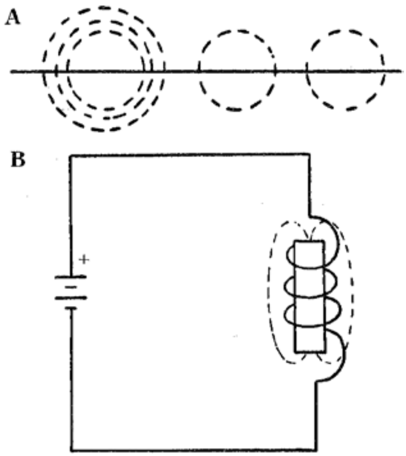

Figure 6.3– The magnetic field surrounding an electric conductor

Producing electricity with magnetism. Because you can produce magnetism with an electrical current, it shouldn't be surprising that you can also produce electricity with a magnet. Look at Fig. 6.4. It is basically the same as Fig. 6.3, but there is no electrical voltage source, and the material in the center of the coil (the *core)* is a permanent magnet.

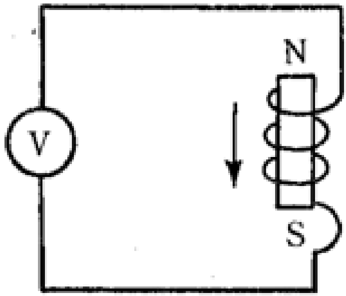

Figure 6.4– Producing electricity with a magnet

If you move the magnet up through the coil of wire, an electric current will start to flow through the wire. The strength of this induced current depends on a number of factors. These include the intensity of the magnetic field, how many lines of force are cut by the conductor, the number of conductors (each turn of the coil acts like a separate conductor in this case) cutting across the lines of force, the angle at which the lines are cut, and the speed of the relative motion between the magnet and the conductor.

This current will continue to flow until either the magnet is too far away for any of its lines of force to cut across the conductor, or the magnet stops moving.

If the magnet and the coil are stationary with respect to each other, no current is induced. Then, if you push the magnet back down through the coil (the direction of the movement is reversed) current will also flow, but it has the opposite polarity. That is, it flows in the other direction. The exact same effect can be achieved if the magnet is stationary and the conductor is moved. It is the relative motion between the components that is important.

All this might not seem terribly useful, because you have to keep moving the magnet or the coil back and forth to produce a continuing current. The current will keep reversing polarity each time the direction of movement is changed, but this method is actually a very efficient way of producing electricity.

This concept is used by power companies to produce their high-wattage ac power. Any of a number of mechanical means can be used to rotate a conductor between a magnetic north pole and south pole (see Fig.6.5). It is usually more practical to rotate the conductor rather than the magnet. Because the conductor is rotating between the magnetic poles, the direction of its relative movement between the poles appears to alternate, so the induced current, as mentioned above, is an alternating current. Very large amounts of electrical power can be produced in this manner.

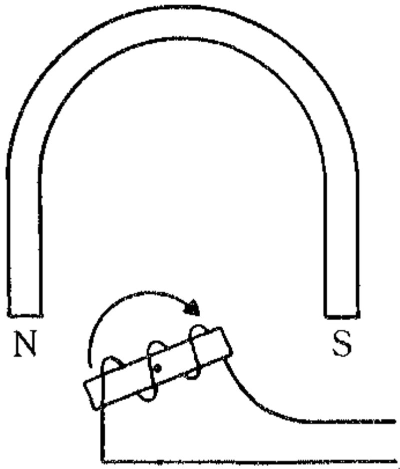

Figure 6.5– Producing ac electricity with a magnet

Vocabulary

strength – сила, напруженість
magnetic strength – магнітна індукція
intensity – напруженість інтенсивність
induce – індукувати, збуджувати
coil – катушка, обмотка
core – сердечник

Task 3. Work in pairs. Ask your partner and let him answer these questions.

1. Is current induced if the magnet and the coil are stationary with respect to each other?
2. What does the strength of induced current depend on?
3. What is the efficient way of producing electricity?
4. What is more practical to rotate the conductor or the magnet in order to produce high-wattage ac current?

TEST (UNIT 6. Magnetism and electricity)

Choose the correct answer

1. Which of the following cannot be used to make a magnet?

A. Lodestone
B. Cobalt
C. Carbon
D. Iron
E. Nickel

2. How are the ends of a magnet called?

A. Poles
B. Lodestones
C. Ions
D. Armatures
E. None of the above

3. What is another name for magnetic lines of force?

A. Armature
B. Flux
C. Magnetic pole
D. Lodestone
E. None of the above

4. If like poles of two magnets are brought near each other, what will happen?

A. They will attract each other
B. They will be damaged
C. They will repel each other
D. An electrical current will be generated
E. None of the above

5. What is the magnetic equivalent to electrical voltage?
A. Flux
B. Magnetomotive force
C. Reluctance
D. Magnetic field
E. None of the above

6. What is the magnetic equivalent of electrical current?
A. Flux
B. Magnetomotive force
C. Reluctance
D. Magnetic field
E. None of the above

7. What is the magnetic equivalent to electrical resistance?
A. Flux
B. Magnetomotive force
C. Reluctance
D. Magnetic field
E. None of the above

8. Which of the following doesn't influence the size and overall strength of the magnetic field produced around the conductor carrying an electric current?
A. Distance of the magnetic field from the conductor
B. Amount of power flowing through the conductor
C. Winding the wire into a coil
D. Winding a coil around a piece of law reluctance material
E. None of the above

9. How can an electrical current be induced with a coil and a magnet?

A. Placing the coil at right angles to the magnetic field
B. Placing the coil parallel to the magnetic field
C. Holding both the magnet and the coil perfectly stationary
D. Moving either the magnet or the coil
E. None of the above, it can't be done.

10. Rotating an armature in a magnetic field produces what type of electricity?

A. Static
B. AC
C. DC
D. Pulsating dc
E. None of the above

UNIT 7. INDUCTANCE

Text A

Before reading the text

Task 1. Match these words and phrases with their definitions.

1.	induced current	a)	opposition to high ac frequencies
2.	inductor	b)	the property of electrical component to oppose any change in the current flow
3.	inductance	c)	the electrical component that oppose the flow of alternating current
4.	inductive reactance	d)	when the current flowing through the coil starts to change the magnetomotive force causes the magnetic lines of force to cut through some of the turns of the coil generating an electric current

Task 2. Try to answer the following questions.

1. What do you know about inductance, another important property of electrical circuits?
2. What is an induced current?

Task 3. Read the text, translate it and check your answers.

You have learned that winding a wire carrying an electric current into a coil will increase the electromagnetic effect. Another result of passing current through a coil of wire is a phenomenon called *inductance.* Inductance is another important factor in electric circuits.

What is inductance? Because an electric current flowing through a coil of wire can create a magnetic field, and a magnetic field moving relative to a coil of wire can create an electric current, what happens when the current flowing through a coil changes? As long as current flows through the coil at a steady, constant level, and in just one direction (dc), a nonmoving magnetic field is generated. As long as the magnetic field and the coil are stationary in relation to each other, the magnetic field will have no particular effect on the current flow through the coil. But if the current through the coil starts to drop, the magnetomotive force generated by the coil will also be decreased, causing the magnetic lines of force to move in closer. Some of these moving lines of force will cut through some of the turns of the coils, inducing an electric current in the coil. This *induced current* will flow in the same direction (same polarity) as the original current.

Of course, this induced current passing through the coil will produce a magnetic field of its own. A finite time is required for this back-and-forth effect to die down. Current through a coil cannot be stopped or reversed in polarity instantly. Inductance tends to oppose any change in the current flow.

In some ways inductance is the opposite of capacitance. Capacitance offers very little resistance to high frequencies, but opposes low frequencies, or dc (constant current). Inductance, on the other hand, passes dc with practically no resistance, but opposes higher ac frequencies (changing current). This opposition to high frequencies is called *inductive reactance.*

Inductance is measured in *henries* (H). One henry is the inductance in a circuit in which the current changes its rate of flow by one ampere per second and induces one volt in the coil. The henry is a too large unit for practical electronic circuits, so the millihenry (one thousandth of a henry – mH) is more commonly used.

Inductive reactance. The formula for inductive reactance is:

$$X_L = 2\pi FL \qquad \textbf{(7.1)}$$

where X_L is the inductive reactance in ohms, L is the inductance in henries (not millihenries), and F is the frequency in hertz. 2π, of course, is a constant, equaling approximately 6.28.

Suppose you have a circuit with 100mH of inductance (0.1 H). If the frequency of the source voltage is 60Hz, then the inductive reactance equals 6.28 x 60 x 0.1, or just under 38Ω. If the same circuit is used, but the applied frequency is increased to 500 Hz, the inductive reactance becomes 6.28 x 500 x 0.1, or 314 Ω.

Raising the ac frequency still further, to 2000Hz, brings the inductive reactance up to 6.28 x 2000 x 0.1, or 1256Ω.

If the frequency remains constant, but the inductance is increased, then the reactance will also be increased. For example, you've already found that 100mH in a 60Hz circuit results in an inductive reactance of about 38Ω. If you increase the inductance to 500mH (0.5H), and keep the frequency at 60Hz, the inductive reactance comes out to 6.28 x 60 x 0.5, or approximately 188Ω.

You'll notice the relationship between the frequency and the inductance to the inductive capacitance is just the opposite of that of the frequency and the capacitance to the capacitive reactance.

Determine the inductive reactance of a circuit consisting of 25mH (0.025H) of inductance at 50Hz, 300Hz, and 4000Hz. Then change the inductance to 300mH (0.3H) and solve for the same three frequencies.

Task 4. Answer these questions about the text.

1. What happens when the current flowing through a coil of wire changes?
2. Will the magnetic field have any effect on the current flow through the coil when the magnetic field and the coil are stationary in relation to each other?
3. What happens when the current through the coil starts to drop?
4. What direction the induced current will flow?

Task 5. Work in pairs. Ask your partner to answer the following questions.

1. Will the induced current passing through the coil produce a magnetic field of its own?
2. What does inductance tend to do?
3. What is inductive reactance?
4. What are the units for measuring induction?

Task 6. Decide whether the following statements are true or false. If you think a statement is false, change it to make true.

1. Capacitance doesn’t offer resistance to high frequencies and opposes law frequencies (dc).

2. Inductance passes dc with very little resistance and opposes higher ac frequencies.

Task 7. Work in pairs. Make up the problems of your own similar to those given in the text and ask your partner to solve and comment on them.

Text B

Task 1. Before reading the text try to describe what a coil is and tell what factors the inductance of a coil depends on.

Task 2. Read the text, translate it and check your answer.

Coils. In electronics, the component called a *coil* (or *inductor)* is just that - a coil of insulated wire wound around some core. This core might be made of powdered iron or some other magnetic material, or it might simply be air or a small cardboard tube.

The inductance of a coil is determined by a number of factors: the width of the core, the diameter of the wire, the number of turns of the wire around the core, and the spacing between the turns of the coil, to name just a few of the more important factors.

The material the core is made of is also important. A core with low magnetic reluctance can increase the strength of the magnetic field, thereby increasing the strength of the induced voltage. Fig. 7.1 shows the construction of a typical coil.

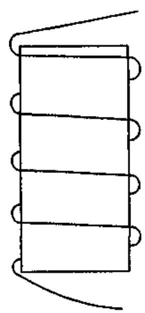

Figure 7.1– The basic construction of a coil

Some coils are adjustable. Usually the core is constructed so it can be moved slightly in and out of the center of the coil with a screw called a *slug*. This arrangement makes the core appear to be partially made of air and partially of (usually) powdered iron, thereby altering the reluctance of the core and thus the inductance of the coil.

Many coils have the wires visibly exposed (but insulated, of course). But some are sealed in metal cans to avoid interaction with other components. Without this *shielding*, the magnetic field could induce a voltage in other nearby components. Obviously inducing a voltage where it's not intended can be detrimental to circuit operation.

The wires in a coil must usually be insulated, because they are generally wound quite closely together. If separate turns of uninsulated wire shift position and touch, allowing current to pass between them, a *short circuit* exists, making the coil appear to have fewer turns, as far as the current is concerned. See Fig. 7.2.

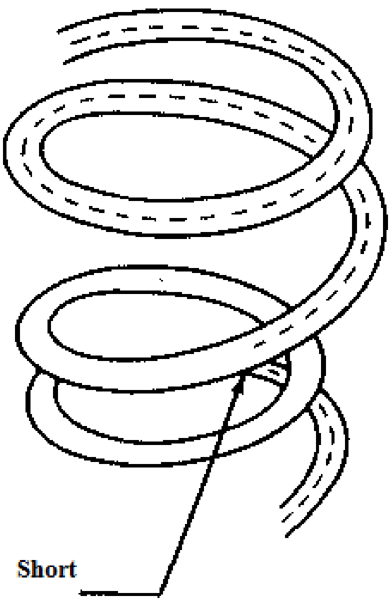

Figure 7.2– A shorted coil

Winding coils. A number of factors determine the inductance of a coil. These include the core material and diameter, the number of turns in the coil, and how closely they are spaced. For a single-layer coil (no overlapping windings) on a nonmagnetic core, the formula for determining inductance is as follows:

$$L = \frac{0{,}2d^2N^2}{3d + 9l}$$

where *L* is the inductance of the coil in millihenries (mH), *d* is the diameter of the coil winding in inches, l is the length of the coil winding in inches, and *N* is the number of turns in the coil.

For example, assume you have a coil on a 0.75inch diameter core, consisting of 150 closely wound turns of #32 enameled wire. The length of the coil is 1.2 inche. The inductance works out to:

$$L = \frac{0{,}2\ \mathrm{x}0{,}75^2\ \mathrm{x}150^2}{3\mathrm{x}\ 0.75 + 9\mathrm{x}\ 1.2} = \frac{0.2\mathrm{x}\ 0.5625\mathrm{x}\ 22500}{2.25 + 10.8} = \frac{2531.25}{13.05} = 193.96552 \approx 194mH$$

If the number of turns *(N)* is increased, and the diameter *(d)* is held constant, the inductance (L) will be increased. The amount of increase will depend on whether the length is increased by the added windings, or if it is held constant to the original value of 1, by squeezing the turns more tightly together.

The basic inductance formula can be algebraically rearranged to solve for the necessary number of turns (N):

$$N = \sqrt{\frac{L(3d + 9l)}{0{,}2d^2}}$$

Vocabulary

turn – виток
slug – підстроювальний сердечник
short circuit – коротке замикання

Task 3. Work in pairs. Make up the problems of your own similar to those given in the text. Ask your partner to solve and comment on them.

TEST (UNIT 7. Inductance)

Choose the correct answer

1. **Which of the following characterizes inductance?**
   A. Tends to oppose changes in voltage
   B. Tends to oppose changes in current
   C. Tends to oppose dc
   D. Opposes all frequencies equally
   E. None of the above

2. **The reactance of a 25mH coil at 5000Hz is which of the following?**
   A. 0.0013Ω
   B. 785.000Ω
   C. 785Ω
   D. 13Ω
   E. None of the above

3. **What is the reactance of a 25mH coil at 600Hz?**
   A. 785Ω
   B. 94Ω
   C. 0.011Ω
   D. 94.000Ω
   E. None of the above

4. **Which of the materials the core of the coil might not be made of?**
   A. Any magnetic material
   B. Powdered iron
   C. Air
   D. Cardboard
   E. None of the above

5. What is the effect of the material the core is made of?

A. A core with high magnetic reluctance increases the strength of the magnetic field

B. A core with high magnetic reluctance increases the strength of the induced voltage

C. A core with law magnetic reluctance increases the strength of the magnetic field and that of the induced voltage

D. A core with law magnetic reluctance decreases the strength of the magnetic field

E. None of the above

6. Which of the factors doesn’t determine the inductance of a coil?

A. A number of turns

B. The diameter of wire

C. The spacing between the turns

D. The width of the core

E. None of the above

7. What is a slug?

A. Screw

B. Winding

C. Insulation

D. Movable core

E. None of the above

8. Induction of voltage where it is not required can

A. Improve the operation of the circuit

B. Be useful to circuit operation

C. Be of no use to circuit operation

D. Be detrimental to circuit operation

E. Nothing

9. What is the inductance of a single-layer coil on a 0.8inch diameter nonmagnetic core with a length of 1.25inch, and 320 turns of wire?

A. 960mH
B. 3.8mH
C. 3.8H
D. 1200mH
E. None of the above

10. Assume you need a 150mH coil on a 0.75 inch diameter nonmagnetic core, 1 inch long. How many turns of wire will be required?

A. 15.000
B. 15
C. 122
D. 507
E. None of the above