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Introduction to Physics & Nanotechnology: part 2

Учебное пособие

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INTRODUCTION TO PHYSICS & NANOTECHNOLOGY: part 2: Учебное пособие по физике и нанотехнологиям для студентов неязыкового вуза /Сост. А.И. Матяшевская, Е.В. Тиден. — Саратов, 2016. — 64 с.

Предлагаемое учебное пособие представляет собой тексты по данной специальности с системой упражнений, направленных на развитие навыков устной и письменной речи. Аутентичный учебный материал позволяет решать учебно-методические проблемы на современном уровне.

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PREFACE

Настоящее пособие включает тексты по актуальной на сегодняшний день проблемам физики и нанотехнологий.

Пособие предназначено для студентов факультета нано- и биомедицинских технологий.

Целью данного пособия является формирование навыка чтения и перевода научной литературы, а также развитие устной речи.

Данное пособие помогает подготовить студентов к самостоятельной работе со специальной литературой, обучить устным формам общения по научной тематике на материале предложенных специальных текстов.

Пособие состоит из разделов, посвященных нанотехнологиям, механике, каждый из которых содержит тексты и упражнения. Раздел “Supplementary reading“ служит материалом для расширения словарного запаса и дальнейшего закрепления навыков работы с текстами по специальности.

Пособие предназначено как для аудиторных занятий, так и для внеаудиторной практики.

1. Electrons and Charges

Part 1

Exercise I .

Say what Russian words help to guess the meaning of the following words: electricity, electron, proton, negative, positive, atom, center, concentrate, form, result, ion

Exercise II.

Make sure you know the following words and word combinations.

negative charge (1), positive charge (1), atom (1), protons (1), electrons (1), lightning (3), friction (4), static electricity (5), insulators (5), nonconductors (5)

Moving Electrons and Charges

Electricity is related to charges, and both electrons and protons carry a charge. The amount of the charge is the same for each particle, but opposite in sign. Electrons carry a negative charge, while protons carry positive charge. The objects around us contain billions and billions of atoms, and each atom contains many protons and electrons. The protons are located in the center of the atom, concentrated in a small area called the nucleus. The electrons are in motion outside of the nucleus in orbitals. The protons are basically trapped inside the nucleus and can't escape the nucleus. As a result, it is moving electrons that are primarily responsible for electricity. (1)

There aren't a lot of places that you can see electricity. The most commonly-observed form of electricity is probably lightning. Lightning is a big spark that occurs when lots of electrons move from one place to another very quickly. There are three basic forms of lightning, cloud to cloud, cloud to surface, and surface to cloud. All are created when there is an unequal distribution of electrons. (2)

Separating Charges

Atoms start out with the same number of negative charges (electrons), and positive charges (protons). Under certain conditions, electrons can be removed from, or added to atoms. Removing electrons would leave the atom with more positives than negatives, and we call this a positive ion (An ion is a charged atom). Conversely, adding electrons to an atom would result in a negative ion. If you do this enough times, you can make an object positive or negative. (3)

Friction is one of the ways to separate charge. Have you ever had a science lab where you rub fur on glass rods, or try to make static cling? When you do that rubbing, you are actually rubbing electrons off one object and onto another. When you scuff your feet on the rug, especially in the winter, you can often charge yourself. Clothes tumbling in the dryer often cling together and crackle when you separate them. Lightning is produced, in part, because of air blowing over land. You can also use batteries to separate charge. (4)

Static Charges

Electrons can move more easily in some objects than in others. If you put a charge on things like glass, plastic, rubber, and wood, that charge stays where you put it. We say the charges are static, and we call this static electricity. Materials like glass and plastic are called insulators, or nonconductors. Static electricity can happen on a dry winter day when you walk across a carpet. You are actually building up loads of electrons on your skin. Charges don't "want" to stay separated, however. There is always a tendency for charges to return to their original locations, and all that is needed is a pathway for charges (electrons) to use. When you touch a metal doorknob, for example, electrons can jump and give you a shock. Static charges build up on clouds until they can hold no more. At that point, lightning can occur. The study of electricity where the charges are not moving is called electrostatics. (5)

Field Basics

Scientists understood why forces acted the way they did when objects touched. The idea that confused them was forces that acted at a distance without touching. Think of examples such as gravitational force, electric force, and magnetic force. To help them explain what was happening, they used the idea of "field". They imagined that there was an area around the object, and anything that entered would feel a force. We say, for example, that the Moon has a gravitational field around it, and if you get close to the Moon, it will pull you down to its surface. (6)

Electric Fields

An electric field describes the area near any electrically-charged object. It could also be called an electrostatic field. Any other charge that enters that area will feel a force, and the original object will also feel that force (Newton's Third Law). It's kind of like a spider sitting at the center of a web. A normal field is a vector, and is represented by arrows. The Earth's (or any planet's) gravitational field would be drawn as arrows pointing toward the ground. A field vector shows the direction of the effect on an object entering the field. Gravity acts downward. For an electric field, things are a little more complicated, since there are two kinds of charges, and some combinations attract while others repel. In order to be in agreement with each other, physicists decided that they would always use positive charges to determine the direction of the effect of a field. So, if the central charge was positive, and you put another positive charge near it, that second charge would be repelled outward. So the field vectors for a central positive charge point outward. If the central charge is negative, a positive charge placed nearby would be attracted toward the center charge, so the field vectors for a central negative charge point inward. (7)

Since fields are directly related to the forces they exert, their strength decreases with distance, and increases with the size of the charge producing the field. When you put charges near one another, their fields interact and change shape. Electric fields can also be created by magnetic fields. Magnetism and electricity are always connected. (8)

Magnetic Field Basics

Magnetic fields are different from electric fields. Although both types of fields are interconnected, they do different things. The idea of magnetic field lines and magnetic fields was first examined by Michael Faraday and later by James Clerk Maxwell. Both of these English scientists made great discoveries in the field of electromagnetism. Magnetic fields are areas where an object exhibits a magnetic influence. The fields affect neighboring objects along things called magnetic field lines. A magnetic object can attract or push away another magnetic object. You also need to remember that magnetic forces are NOT related to gravity. (9)

The amount of gravity is based on an object's mass, while magnetic strength is based on the material that the object is made of. If you place an object in a magnetic field, it will be affected, and the effect will happen along field lines. Many classroom experiments watch small pieces of iron line up around magnets along the field lines. Magnetic poles are the points where the magnetic field lines begin and end. Field lines converge or come together at the poles. You have probably heard of the poles of the Earth. Those poles are places where our planets field lines come together. We call those poles north and south because that's where they're located on Earth. All magnetic objects have field lines and poles. It can be as small as an atom or as large as a star. (10)

Exercise III.

Find paragraphs, dealing with the following:

escape, spark, conditions, cling, pathway, Moon, web, repel, magnetism, star

Exercise IV.

Answer the following questions:

1. How would life be different without electricity?

2. What is the direction of magnetic lines of force?

3. What do you call a material which is slightly repelled by magnetic field?

4. What do you call the ratio of intensity of magnetisation to the magnetisation force?

5. What is a pathway for the flow of electricity?

6. In a simple series circuit, why does the bulb light when you close the switch?

7. If there is a 1.5V battery and a bulb on a simple series circuit and the battery is changed to a 3V, what happens to the bulb?

8. What do the long straight lines represent in a circuit diagram?

9. When charge builds up on your body after rubbing your feet on the carpet, what happens?

10. When you rub a balloon on a wool sweater or your hair, an excess of what type of charge causes it to stick to the wall?

11. What can the electric current do in a parallel circuit?

12. In a parallel circuit, two light bulbs can share the full voltage of the battery. Does this make the bulbs bright or dim?

13. Why are parallel circuits found in most household electrical wiring?

14. What is differential amplifier?

15. Why AC systems are preferred over DC systems?

16. Explain the application and advantages of storage batteries.

Exercise V.

Fill in the gaps according to the text.

1. Protons carry**………..** charge.
2. ……….. carry a negative charge**.**

3. The protons are located in the center of the atom, concentrated in a small area called the…………...

4. The most commonly- observed form of electricity is probably**…………..**

5. ………is one of the ways to separate charge.

6. We say the charges are static, and we call this ………electricity.

7. Materials like glass and plastic are called…………, or nonconductors.

8. The study of electricity where the charges are not moving is called…………….

9. The Moon has a ………….field around it, and if you get close to the Moon, it will pull you down to its surface.

10. Magnetic ……….are the points where the magnetic field lines begin and end.

<u>Exercise VI</u> .

Make up sentences of your own with the following word combinations: start out with , under certain conditions, result in, at that point, get close to , pull somebody down to, to be in agreement with each other, point outward, point inward, decrease with distance

<u>Exercise VII</u>.

Determine whether the statements are true or false. Correct the false statements:

1. Both electrons and protons carry a charge.

2. The amount of the charge is different for each particle.

3. Electrons carry a positive charge.

4. Each atom contains many protons and electrons.

5. The protons are basically trapped inside the nucleus and can escape the nucleus.

6. There are a lot of places that you can see electricity.

7. Lightning is a big spark that occurs when lots of electrons move from one place to another very slowly.

8. There are two basic forms of lightning

9. Under certain conditions, electrons can be removed from, or added to atoms.

10. Removing electrons would leave the atom with more positives than negatives, and we call this a negative ion.

Exercise VIII .

Match the words to the definitions in the column on the right:

ion	staying in one place without moving, or not changing for a long time
electron	a form of energy that can be produced in several ways and that provides power to devices that create light, heat, etc.:
proton	the smallest unit of any chemical element, consisting of a positive nucleus surrounded by negative electrons
static	a flash of bright light in the sky that

	is produced by electricity moving between clouds or from clouds to the ground
electricity	the central part of an atom, usually made up of protons and neutrons
friction	an extremely small piece of matter with a negative electrical charge
atom	an atom or small group of atoms that has an electrical charge because it has added or lost one or more electrons
lightning	a type of elementary particle (a very small piece of matter) with a positive electrical charge that is found in the nucleus of all atoms
nucleus	the force that makes it difficult for one object to slide along the surface of another or to move through a liquid or gas

Exercise IX.

Summarize the article "Moving Electrons and Charges."

Part 2

Exercise I.

Identify the part of speech the words belong to.

negative, carry, positive, nucleus, motion, responsible, lightning, unequal, certain, science

Exercise II .

Form adjectives from the following words:

electricity (1), center (1), object (3), attract (7), physicist (7), strength (8), gravity (10), magnet (10), locate (10)

Exercise III.

Find synonyms to the following words. Translate them into Russian: power (1), interconnected (1), dot (1), include (1), movement (1), disappear (1), flash (2), fundamental (2), circumstances (3), unchanged (5)

Exercise IV .

Find antonyms to the following words. Translate them into Russian: positive (1), identical (1), edge (1), dispersed (1), inside (1), add (3), connect (3), dynamic (5), wet (5), last (5)

Exercise V .

Match the words to make word combinations:

static	distribution
field	influence
electric	force
negative	vector
gravitational	field
unequal	electricity
magnetic	charge

Exercise VI.

QUIZ:

1. A material through which heat or electricity do not flow easily

A. Circuit
B. Current
C. Insulator
D. Conductor

2.A material through which heat or electricity flows easily
A. Circuit
B. Current
C. Insulator
D. Conductor

3. A circuit in which each object is connected to the cell separately
A. Series circuit
B. Parallel circuit
C. Complete circuit

4. A circuit in which the objects are connected in a single path
A. Series circuit
B. Parallel circuit
C. Complete circuit

5. A temporary magnet created when current flows through wire wrapped in coils around an iron bar.
A. Permanent magnet
B. Electro magnet
C. Powerful magnet

6. A device that creates alternating current by spinning an electric coil between magnets

A. Circuit
B. Electric motor
C. Generator

7. A reusable switch that protects circuits from dangerously high currents
A. Circuit
B. Fuse
C. Circuit breaker

8. A device that melts to keep too much electricity from flowing through wires
A. Circuit
B. Fuse
C. Circuit breaker

9. A complete path through which electricity can flow
A. Current
B. Discharge
C. Circuit

10. A moving electrical charge is
A. Current electricity
B. Circuit
C. A magnetic field

11. A power source that transforms electrical energy into movement
A. Electric motor
B. Generator
C. Magnetism

12. A region of magnetic force around a magnet
A. Pole
B. Discharge

C. Magnetic field

13. The sudden movement of an electric charge from the object where it built up onto another nearby object
A. Pole
B. Generator
C. Circuit
D. Discharge

14. The buildup of an electric charge on a material
A. Discharge
B. Circuit
C. Static electricity
D. Current electricity

15. Lightning is an example of a …........................
16. The region of magnetic force around a magnet is called.....................
17. Most newer houses or electrical systems use a.................to protect circuits from dangerously high currents
18. A circuit with two light bulbs on the same circuit is known as a …....................... circuit

2. Semiconductors

Part 1

Exercise I .

Say what Russian words help to guess the meaning of the following words: material, agent, standard, control, fundamental, modern, unique, electronic, structure, energy

Exercise II.

Make sure you know the following words and word combinations.
Conductors (1), insulators (1), current flow (1) ,electron hole (1) , silicon dioxide (2), pure silicon (2), n-type semiconductor (3), p-type semiconductor (3), intrinsic semiconductors (6), extrinsic semiconductor (6)

Semiconductors

Semiconductors are materials with electrical conductivities that are intermediate between those of conductors and insulators. Semiconductors are useful for electronic purposes because they can carry an electric current by electron propagation or hole propagation, and because this current is generally uni-directional and the amount of current may be influenced by an external agent. Electron propagation is the same sort of current flow seen in a standard copper wire — heavily ionized atoms pass excess electrons down the wire from one atom to another in order to move from a more negatively ionized area to a less negatively ionized area. "Hole" propagation is a rather different proposition - in the case of a semiconductor experiencing hole propagation, the charge moves from a more positively ionized area to a less positively ionized area by the movement of the electron hole created by the absence of an electron in a nearly-full electron shell. (1)

While silicon dioxide or sand is an insulator, pure silicon is a semiconductor. (2)

The properties of semiconductors, e.g. the number of carriers (and therefore the prevalence of electron propagation or hole propagation), can be controlled by "doping" the semiconductor blocks with impurities. A semiconductor with more electrons than holes is called an n-type semiconductor, while a semiconductor with more holes than electrons is called a p-type semiconductor. (3)

Semiconductors are the fundamental materials in many modern electronic devices. Semiconductors exhibit a number of useful and unique properties related to their electronic structure. In solids the electrons tend to occupy various energy bands. The highest energy band occupied by electrons in their ground state is called the valence band. The lowest energy band occupied by excited electrons is called the conduction band. As the name implies, electrons in the conduction band are able to conduct electricity. The energy spacing between the valence band and the conduction band is called the band gap and corresponds to the energy necessary to excite an electron from the valence band into the conduction band. For some metals, such as magnesium, the valence and conduction bands overlap, corresponding to a negative band gap. In this situation, there are always some electrons in the conduction band and the material is highly conductive. Other metals, such as copper, have empty states in the valence band. In this case electrons in the valence band can conduct electricity by moving between the various states and again the material is highly conductive. For insulators the valence band is completely filled and the band gap is relatively large, preventing conduction. Semiconductors have an electronic structure similar to that of insulators, but with a relatively small band gap, generally less than 2 eV. Because the band gap is relatively small, electrons can be thermally excited into the conduction band, making semiconductors somewhat conductive at room temperature. (4)

Electrons in the conduction band are free to move through the material conducting electricity. In addition, when an electron is excited into the conduction band it leaves behind an empty state in the valence band, corresponding to a missing electron in one of the covalent bonds. Under the influence of an electric field, an adjacent valence electron may move into the missing electron position, effectively moving the location of the missing electron. Thus, like the electron, this missing electron or hole is also able to move through the material, conducting electricity. Holes are considered to have a charge of the same magnitude as an electron, but of opposite charge. Thus, in the presence of an electric field excited electrons and holes move in opposite directions. Electrons are somewhat more mobile than holes and are thus more efficient at conducting electricity. Because both electrons and holes are capable of carrying electricity, they are collectively called carriers. The concentration of carriers is strongly dependent on the temperature. Increasing the temperature leads to an increase in the number of carriers and a corresponding increase in conductivity. This contrasts sharply with most conductors, which tend to become less conductive at higher temperatures. (5)

Intrinsic semiconductors are those in which the electrical behavior depends on the electronic structure of the pure material. For the case of intrinsic semiconductors, all carriers are created by exciting electrons into the conduction band. Thus equal numbers of electrons and holes are created. An extrinsic semiconductor is a semiconductor that has been doped with various impurities to modify the number of holes and excited electrons. The purpose of n-type doping is to produce an abundance of carrier electrons in the material. The purpose of p-type doping is to create an abundance of holes. (6)

Exercise III.

Find paragraphs, dealing with the following:

intermediate, shell, sand, wire, mobile, magnesium, covalent, adjacent, magnitude, modify

Exercise IV.

Answer the following questions:

1. What is a semiconductor and what materials is it made of?

2. What characteristic clearly distinguishes semiconductors from metals and nonmetals?

3. In which column on the periodic table do the elemental semiconductors reside?

4. Why are semiconductors valuable in modern electronics?

5. When an electron jumps from the valence shell to the conduction band, it leaves a gap. What is this gap called?

6. Silicon atoms combine into an orderly pattern, what is it called?

7. Ionization within a P-N junction causes a layer on each side of the barrier, what is it called?

8. Intrinsic semiconductor material is characterized by a valence shell of how many electrons?

9. What is an energy gap?

10. What causes the depletion region?

11. Forward bias of a silicon P-N junction will produce a barrier voltage of approximately how many volts?

12. When is a P-N junction formed?

13. What is the most significant development in electronics since World War II?

14. What is the working principle of a transistor? What are the components of a typical transistor?

15. When and who discovered that more than one transistor could be constructed on a single piece of semiconductor material?

<u>Exercise V</u>.

Fill in the gaps according to the text.

1. …………..are materials with electrical conductivities that are intermediate between those of conductors and insulators.

2. Semiconductors are useful for electronic purposes because they can carry an electric current by electron propagation or hole propagation, and because this current is generally uni-directional and the amount of current may be influenced by an ………… agent.

3. While silicon dioxide or sand is an………., pure silicon is a semiconductor.

4. A semiconductor with more holes than electrons is called a ……….semiconductor.

5. The highest energy band occupied by electrons in their ground state is called the…………

6. The energy spacing between the valence band and the conduction band is called the ………..

7. Other metals, such as…………, have empty states in the valence band.

8. Holes are considered to have a charge of the same ………..as an electron, but of opposite charge.

9. Because both electrons and holes are capable of carrying electricity, they are collectively called………...

10. ……………....semiconductors are those in which the electrical behavior depends on the electronic structure of the pure material.

Exercise VI .

Make up sentences of your own with the following word combinations: highly conductive, at room temperature, be free to move through, under the influence of, in the presence of, be efficient at, be dependent on, tend to become, at higher temperatures, for the case of

Exercise VII.

Determine whether the statements are true or false. Correct the false statements:

1. "Hole" propagation is a rather different proposition - in the case of a semiconductor experiencing hole propagation, the charge moves from a less positively ionized area to a more positively ionized area by the movement of the electron hole created by the absence of an electron in a nearly-full electron shell.
2. A semiconductor with more electrons than holes is called an p-type semiconductor.
3. Semiconductors are the fundamental materials in many modern electronic devices.
4. The highest energy band occupied by excited electrons is called the conduction band.
5. Electrons in the conduction band are able to conduct electricity.
6. For some metals, such as magnesium, the valence and conduction bands overlap, corresponding to a positive band gap.
7. For insulators the valence band is completely filled and the band gap is relatively small, preventing conduction.
8. Electrons are somewhat less mobile than holes and are thus more efficient at conducting electricity.

9. Decreasing the temperature leads to a decrease in the number of carriers and a corresponding decrease in conductivity.

Exercise VIII .

Match the words to the definitions in the column on the right:

conduction band	a semiconductor with more holes than electrons
hole	a material or covering that electricity, heat, or sound cannot go through
valence band	a semiconductor with more electrons than holes
conductor	transmission of motion, light, sound, etc. in a particular direction or through a medium
unidirectional	a position from which an electron is absent, especially one regarded as a mobile carrier of positive charge in a semiconductor
n-type semiconductor	a substance that brings about a chemical or physical effect or causes a chemical reaction
insulator	moving or operating in a single direction
propagation	a substance that allows heat or electricity to go through it
p-type semiconductor	the highest energy band occupied by electrons in their ground state
agent	the lowest energy band occupied by excited electrons

Exercise IX.

Summarize the article “Semiconductors.”

Part 2

Exercise I.

Identify the part of speech the words belong to.

semiconductor, material, intermediate , conductor, insulator, electronic electric , electron, propagation, external

Exercise II .

Form verbs from the following words:

conductivity(1), movement(1), carrier(5), concentration(5), dependent(5)

Exercise III.

Find synonyms to the following words. Translate them into Russian:

in-between(1), affected(1), stream(1), cable(1), cover(1), solid(2), regulate(3),, transmit (4), gadget(4), special (4)

Exercise IV.

Find antonyms to the following words. Translate them into Russian:

unhitch (1), common(1), decrease (1), pessimism(1), minor(1), disappearance(1), crude (1), prophylactic(1), destroy(1), shorten(1)

Exercise V .

Match the words to make word combinations:

electric	shell

ionized	wire
external	current
electron	atoms
copper	silicon
silicon	agent
energy	gap
room	dioxide
pure	bands
band	temperature

Exercise VI

QUIZ:

1. To pull towards one another.

A. Circuit
B. Attract
C. Pole lightning
D. Detract

2.A build-up of electrical charge.
A. Static electricity
B. Insulator
C. Fuse
D. Short circuit

3. To push away.
A. Discharge
B. Open circuit
C. Closed circuit
D. Repel

4. An instrument that uses a freely moving magnetic needle to indicate direction.
A.Compass
B. Insulator
C. Static electricity
D. Fuse

5. A material through which electricity doesn't flow.
A.Insulator
B. Open circuit
C. Conductor
D. Closed circuit

6. A material in which electricity flows easily.
A. Insulator
B. Open circuit
C.Conductor
D.Closed circuit

7.When a build-up of electrical charge empties into something.
A.Short circuit
B.Discharge
C. Fuse
D. Series circuit

8. Either of two opposing forces or parts, such as the poles of a magnet.
A. Pole
B. Lodestone
C. Patent
D. Repel

9. A circuit in which each bulb is connected to the cell separately.
A. Closed circuit

B. Circuit
C. Parallel circuit
D. Series circuit

10. A flash of light caused by a discharge of static electricity.
A. Static electricity
B. Discharge
C. Lightning
D. Current

11. When too much current flows through a conductor.
A. Shutdown
B. Short circuit
C. Blown fuse
D. Insulator

12. A material in which electricity has difficulty flowing.
A. Resistor
B. Conductor
C. Insulator
D. Circuit

13. A circuit in which the current must flow through one bulb in order to flow through the other
A. Series circuit
B. Parallel circuit
C. Circuit breaker

14. A device that keeps too much electric current from flowing through wires.
A. Circuit breaker
B. Fuse
C. Block
D. Pole

3. Semiconductors and the Hall effect

Part 1

Exercise I .

Say what Russian words help to guess the meaning of the following words: personal, computer, mobile, composition, characteristic, type, mobility, electric, contact, diode

Exercise II

Make sure you know the following words and word combinations.
solid state electronics (2) , forward biased (2), reverse biased (2), basic diode (2), n-type dopant (2), impurity sites (3), conduction band (3), Coulomb force (4) , field probe (7), Teslameter (7)

Conduction Properties of Semiconductors using the Hall Effect

1. What it's about

Semiconductors devices are all around us, from personal computers and mobile phones to domestic and entertainment technology, medical equipment and space technology. The behaviour of semiconductors varies widely depending on the material composition which in turn affects the energy band structure of the material. Amongst other things, the basic characteristics of semiconductors depend on the type of charge carriers, so called n-type and p-type (electrons - negative carriers or holes - positive carriers) and the number density of the carriers that conduct the electric current. A further important basic characteristic is the mobility of the charge carriers, that is, how fast the charge carriers drift through the semiconductor per unit of electric field applied to it. (1)

One of the crucial keys to solid state electronics is the nature of the P-N junction. When p-type and n-type materials are placed in contact with each other, the junction behaves very differently than either type of material alone. Specifically, current will flow readily in one direction (forward biased) but not in the other (reverse biased), creating the basic diode. This non-reversing behavior arises from the nature of the charge transport process in the two types of materials. The open circles on the left side of the junction above represent "holes" or deficiencies of electrons in the lattice which can act like positive charge carriers. The solid circles on the right of the junction represent the available electrons from the n-type dopant. Near the junction, electrons diffuse across to combine with holes, creating a "depletion region". (2)

When a p-n junction is formed, some of the free electrons in the n-region diffuse across the junction and combine with holes to form negative ions. In so doing they leave behind positive ions at the donor impurity sites. In the p-type region there are holes from the acceptor impurities and in the n-type region there are extra electrons. When a p-n junction is formed, some of the electrons from the n-region which have reached the conduction band are free to diffuse across the junction and combine with holes. Filling a hole makes a negative ion and leaves behind a positive ion on the n-side. A space charge builds up, creating a depletion region which inhibits any further electron transfer unless it is helped by putting a forward bias on the junction. (3)

Equilibrium of junction. Coulomb force from ions prevents further migration across the p-n junction. The electrons which had migrated across from the N to the P region in the forming of the depletion layer have now reached equilibrium. Other electrons from the N region cannot migrate because they are repelled by the negative ions in the P region and attracted by the positive ions in the N region. Reverse bias: An applied voltage with the indicated polarity further impedes the flow of electrons across the junction. For conduction in the device, electrons from the N region must move to the junction and combine with holes in the P region. A reverse voltage drives the electrons away from the junction, preventing conduction. Forward bias: An applied voltage in the forward direction as indicated assists electrons in overcoming the coulomb barrier of the space charge in depletion region. Electrons will flow with very small resistance in the forward direction. (4)

2. Preparations - Calibration of the Magnetic Field Source

This experiment allows these important physical quantities of semiconductors to be discovered in a real semiconductor material. The semiconductor parameters can be determined from electrical measurements of a semiconductor when a magnetic field is applied to it. The physical effect used to determine the conduction properties is called the Hall Effect. Applying a magnetic field perpendicularly to a semiconducting material with current flowing through it leads to the generation of a voltage perpendicular to axes of both the current flow and the applied field. This voltage is termed the Hall voltage. The magnitude and polarity of the Hall voltage depend on the carriers within the material. The Hall voltage depends on the magnetic field and the current through the material. The linearity of the Hall voltage with magnetic field is used in magnetic field sensors (although the sensitivity to magnetic field is not as high as other types of field sensors). To undertake a quantitative experimental work a calibrated magnetic field source is needed. (5)

In order to determine, quantitatively, the properties of the semiconductor an electromagnet is provided as a magnetic field source – this needs to be calibrated; that is, the variation of the magnetic field as a function of current supplied to the electromagnet needs to be measured. A magnetic field probe is used to calibrate the electromagnet. An electromagnet is a device for generating large magnetic fields by passing current through coils of wire. The field produce by the current flow in the coils is enhanced by filling the coils with a ferromagnetic "core" material (usually iron) to increase the field obtained in the gap between poles of the electromagnet. The electromagnet is controlled by supplying current to the coils from the power supply provided, this should be connected already. (6)

Check the electromagnet current supply by switching on the power supply unit and adjusting the current up to a maximum of 1.5 amps and return the current to zero before switching off the supply. Before using the magnetic field probe for calibration, first check that the probe is set correctly at zero – make sure the field probe is well away from the electromagnet. If you are using a Teslameter probe with the analogue display, set the meter to read zero by carefully turning the 'zero' adjustment screw indicated on the front of the meter using a screwdriver until the output is zero. Next, to calibrate the electromagnet, position the field probe between the poles of the electromagnet using the clamp provided. The field sensitive part is near to the end of the probe wand. For accurate calibration the field probe must be in the correct orientation within the pole pieces. This can be achieved by supplying some fixed current to the electromagnet and then carefully rotating the probe around its axis. (7)

With the field probe in the correct position you can start to collect data to calibrate the electromagnet. First increase the current to a maximum of 1.5 amps and then reduce to zero. Increase the current in increments of your own choosing up to the maximum value and measure the magnetic field obtained at each increment. Then decrease the current incrementally to zero, measuring the magnetic field at each step. Take care with the errors if you change the range of the field probe meter while collecting a series of data points. (8)

Exercise III.

Find paragraphs, dealing with the following:

space, lattice, diffuse, depletion, parameter, axes, calibrated, sensors, ferromagnetic, rotate

Exercise IV.

Answer the following questions:

1. Which electronic devices are primarily made from semiconductors?

2. How does the conductivity in pure semiconductors vary with temperature?

3. What explains why semiconductors have different electrical properties from metals?

4. Which would have a smaller energy gap between the valence band and the conduction band, glass or silicon?

5. In a metallic conductor, are the valence shells filled, empty, or partially filled?

6. In a semiconductor, are the valence shells filled, empty, or partially filled?

7. Are electrons in the valence band of a semiconductor in the bonding or anti bonding state?

8. At what temperature are there no electrons in the conduction band of a semiconductor?

9. As the temperature increases, more or less electrons can be promoted to the conduction band?

10. What occurs when a conduction-band electron loses energy and falls back into a hole in the valence band?

11. PN-junction diodes and transistors are fabricated by implanting impurities. What is this process called?

12. What factor(s) do(es) the barrier potential of a pn junction depend on: type of semiconductive material or the amount of doping or the temperature?

13. Why does thermal runaway happen in a semiconductor?

14. In a trivalent-doped semiconductor material, what are the majority charge carriers?

15. How many electrons are present in the outer valence shell of a silicon atom?

16. Name the three terminals of a bipolar junction transistor.

Exercise V.

Fill in the gaps according to the text.

1. An …………is a device for generating large magnetic fields by passing current through coils of wire.
2. Near the junction, electrons diffuse across to combine with holes, creating a "…………..".
3. ……………..force from ions prevents further migration across the p-n junction.
4. The electrons which had migrated across from the N to the P region in the forming of the depletion layer have now reached ………
5. A …………drives the electrons away from the junction, preventing conduction.
6. The physical effect used to determine the conduction properties is called the…………

7. The ………….depends on the magnetic field and the current through the material.

8. The ……………of the Hall voltage with magnetic field is used in magnetic field sensors.

9. To undertake a quantitative experimental work a ………… magnetic field source is needed.

10. A magnetic field probe is used to calibrate the electromagnet.

Exercise VI .

Make up sentences of your own with the following word combinations: depend on, crucial keys, be placed in contact with each other, flow in one direction, leave behind, at each step, take care with, increase something to a maximum of, reduce to zero, make sure

Exercise VII.

Determine whether the statements are true or false. Correct the false statements:

1. When p-type and n-type materials are placed in contact with each other, the junction behaves very differently than either type of material alone.
2. The behaviour of semiconductors varies widely depending on the material composition which in turn affects the energy band structure of the material.
3. The open circles on the right side of the junction above represent "holes" or deficiencies of electrons in the lattice which can act like positive charge carriers.

4. When a p-n junction is formed, some of the free electrons in the n-region diffuse across the junction and combine with holes to form positive ions.
5. In the n-type region there are holes from the acceptor impurities and in the p-type region there are extra electrons.
6. When a p-n junction is formed, some of the electrons from the n-region which have reached the conduction band are free to diffuse across the junction and combine with holes.
7. Filling a hole makes a positive ion and leaves behind a negative ion on the n-side.
8. For conduction in the device, electrons from the N region must move to the junction and combine with holes in the P region.
9. The semiconductor parameters can be determined from electrical measurements of a semiconductor when a magnetic field is applied to it.
10. The magnitude and polarity of the Hall voltage depend on the carriers within the material.

Exercise VIII .

Match the words to the definitions in the column on the right:

sensor	the large size or importance of something
magnetic field	the degree to which a substance prevents the flow of an electric current through it
equilibrium	a substance used to produce a desired electrical characteristic in a semiconductor

polarity	a device that is used to record that something is present or that there are changes in something
voltage	the action or process of calibrating something
dopant	a region around a magnetic material or a moving electric charge within which the force of magnetism acts.
calibration	a state in which opposing forces or influences are balanced
resistance	the standard unit used to measure how strongly an electrical current is sent around an electrical system
electromagnet	the quality of being opposite
magnitude	a device made from a piece of iron that becomes magnetic when a changing current is passed through the wire that goes around it

<u>Exercise IX</u>.

Summarize the article "Conduction Properties of Semiconductors using the Hall Effect."

Part 2

<u>Exercise I.</u>

Identify the part of speech the words belong to.

personal, domestic, entertainment, technology, equipment, composition, fast, crucial , solid, state, electronics

Exercise II .

Form adverbs from the following words:

basic (1), nature (1), real (5), perpendicular (5), near(7)

Exercise III.

Find synonyms to the following words. Translate them into Russian:

household(1), apparatus (1), the universe(1), range(1), compound(1), thickness(1), segment(1), hard(1), backward (4), immensity(5)

Exercise IV .

Find antonyms to the following words. Translate them into Russian:

public(1), stationary(1), slow(1), liquid (2), surplus(2), unavailable(2), dependent(3), imbalance(4), weakness(4)

Exercise V .

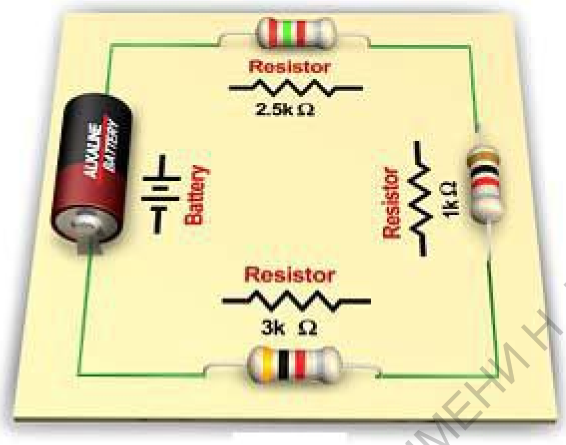
Match the words to make word combinations:

space	computers
reverse	equipment
semiconductors	carriers
crucial	diode
medical	devices
negative	impurities
basic	keys
negative	biased
personal	technology

acceptor	ions

Exercise VI.

QUIZ



1. What is shown in this picture?

A. Resistors connected in parallel
B. Batteries connected in parallel
C. Resistors connected in series
D. Batteries connected in series

2.Why can birds sit on a power line?
A. Because birds have minimal resistance compared to household electronics, so current is diverted to the houses instead
B. Because the wire is in the air and air has infinite resistance so no current flows through the wire
C. Because birds' feet are insulated so current is not conducted through them
D. Because both feet are on the same voltage line, so there is no potential difference, so current does not flow through the bird

3. What if a bird sat on a power line that was very close to the ground, placing one foot on the wire and one foot on the ground?
A. No current would flow through the bird, so nothing would happen

B. The bird would experience a voltage difference between the wire and the ground and would get fried

C. The bird's feet are insulated, so it doesn't matter what it touches

4. A certain steam iron carries a current of 6.4 A when connected to a 120 V source. What is the resistance of the steam iron?

A. 1.875 Ω

B. 0.05 Ω

C. 768 Ω

D. 18.75 Ω

5. The resistance of a hotplate is 48 Ω . How much current does the plate carry when connected to a 120-V source?

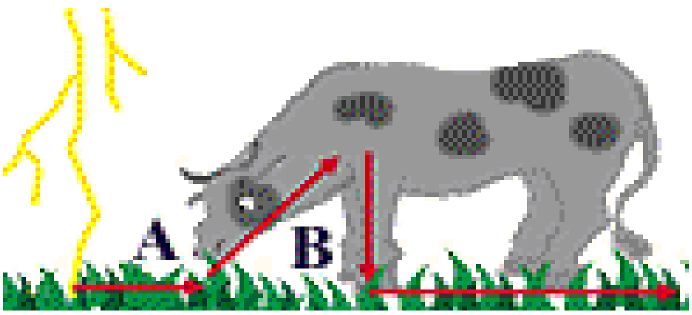
A. 120 A

B. 2.5 A

C. 5760 A

D. 0.4 A

6. What ultimately happens to the cow in this situation?During a thunder storm, if a lightning hits the ground near a cow, then the current starts to spread out in the groud. Since the ground is wet, it is easier to spread horizontally, and also, the ground is somewhat positively charged.When the current starts to spread while a cow is eating grass, the current flows from the cow's mouth (A), goes through its leg (B), and goes back to the ground. The current will flow until the voltage becomes zero. Because cow's hind leg (D) has lower potential energy than its front leg (C) , the current can flow through the cow. The cow becomes a part of electric circuit.



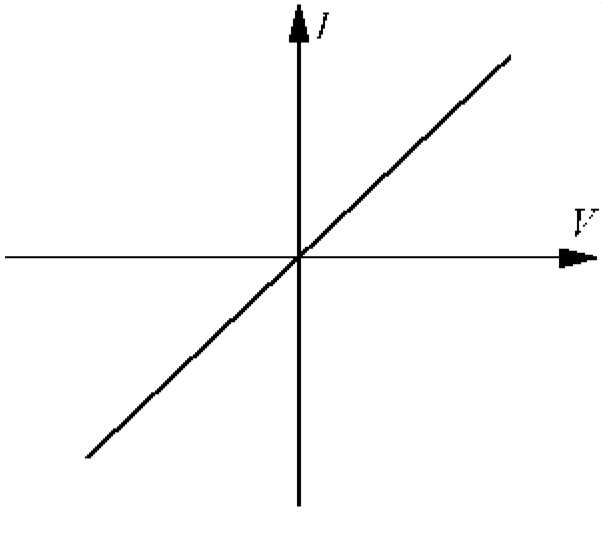
A. All the current builds up in the cow's bell which will shock the rancher later.
B. Nothing happens to the cow.
C. The cow feels a slight tingle but continues eating.
D. The cow gets a big electric shock and probably dies.

7. A typical size-D battery has about how many volts?
A. 0.05 V
B. 100 V
C. 1.5 V
D. 9 V

8. Voltage is a measurement of what?
A. Radiant energy of a light bulb in a circuit
B. Kinetic energy of a motor in a circuit
C. Potential energy stored in a battery
D. The flow of electrons

9. What is current?
A. The flow of charges, usually in the form of electrons
B. The newness of a battery or resistor
C. Something that blocks or slows the flow of electrons
D. The potential energy stored in a battery

10. In this graph, what does the slope of the line represent?



A. Constant voltage
B. Constant current
C. Constant energy
D. Constant resistance

4. The LED's Dark Secret

Part 1

Exercise I .

Say what Russian words help to guess the meaning of the following words: secret, industry, dominate, television, dollar, niche, global, analyst, cent, architecture

Exercise II

Make sure you know the following words and word combinations.
the blue light-emitting diode (1), incandescent light bulbs (1), fluorescent tubes (1), nitride-based compound semiconductors (3), aluminum (4), indium (4), zinc (5), magnesium (5), semiconductor's crystalline lattice (6), gallium nitride (6), gallium arsenide (6)

THE LED'S DARK SECRET

The blue light-emitting diode, arguably the greatest optoelectronic advance of the past 25 years, harbors a dark secret: crank up the current and its efficiencies will plummet. The problem is known as droop, and it's not only puzzling the brightest minds in the field, it's also threatening the future of the electric lighting industry. Tech visionaries have promised us a bright new world where cool and efficient white LEDs, based on blue ones, will replace the wasteful little heaters known as incandescent lightbulbs. More than a dozen countries have already enacted legislation that bans, or will soon ban, incandescent bulbs. But it's hard to imagine LEDs dislodging incandescents and coming to dominate the world electric lighting industry, unless we can defeat droop. In flashlights, in backlights for screens in cellphones and now televisions, and in a bunch of other applications, white LEDs already constitute a multibillion-dollar market. But that's just a US $5 billion niche compared to the overall lighting industry, whose sales next year should reach $100 billion, according to the market research firm Global Industry Analysts. The trick will be to make LEDs turn electricity into light efficiently enough to offset their relatively high cost—roughly 16 cents per lumen, at lightbulb-type brightness, as opposed to about 0.1 cents or less for incandescents.Look at the competition and you'd think the job was easy. Today's incandescent bulbs aren't much different from the ones Thomas Edison sold more than a century ago. They still waste 90 percent of their power, delivering roughly 16 lumens per watt. Fluorescent tubes do a lot better, at more than 100 lm/W, but even they pale next to the best LEDs. The current white LED pumps out around 250 lm/W, and there's no reason why that figure won't reach 300 lm/W. Unfortunately, these LEDs perform at their best only at low power—the few milliamps it takes to backlight the little screen on your mobile phone, for instance. At the current levels needed for general lighting, droop kicks in, and down you go, below 100 lm/W. (1)

LED Architecture: At the heart of every white LED is a semiconductor chip. The chip is traditionally positioned on top of the cathode lead. Applying several volts across this device makes the chip emit blue light. Passing the light through a yellow phosphor yields white light. (2)

The first-ever report of light emission from a semiconductor was by the British radio engineer Henry Joseph Round, who noted a yellowish glow emanating from silicon carbide in 1907. However, the first devices at all similar to today's LEDs arrived only in the 1950s. Researchers fabricated orange-emitting devices; green, red, and yellow equivalents followed in the '60s and '70s, all of them quite inefficient. The great leap toward general lighting came in the mid-1990s, when Shuji Nakamura in Japan developed the first practical bright-blue LED using nitride-based compound semiconductors. (Nakamura's achievement won him the 2006 Millennium Technology Prize, the approximate equivalent in engineering of a Nobel Prize.) Once you've got blue light, you can get white by passing the blue rays through a yellow phosphor. The phosphor absorbs some of the blue and reradiates it as yellow; the combination of blue and yellow makes white. (3)

All LEDs are fabricated as aggregated sections, or regions, of different semiconductor materials. Each of these regions plays a specific role. One region serves as a source of electrons; it consists of a crystal of a compound semiconductor into which tiny amounts of an impurity, such as silicon, have been introduced. Each such atom of impurity, or dopant, has four electrons in its outer shell, compared with the three in an atom of gallium, aluminum, or indium. When a dopant takes a place that one of these other atoms would normally occupy, it adds an electron to the crystalline lattice. The extra electron moves easily though the crystal, acting as a carrier of negative charge. With this surfeit of negative charges, such a material is called n-type. (4)

At the opposite end of the LED is a region of p-type material, so called because it has excess positive-charge carriers, created by doping with an element such as zinc or magnesium. These metals are made up of atoms with only two electrons in their outer shell. When such an atom sits in place of an atom of aluminum, gallium, or a chemically similar element (from group III in the periodic table), the lattice ends up an electron short. That vacancy behaves as a positive charge, moving throughout the crystal like the missing tile in a puzzle. That mobile vacancy is called a hole. In the middle of the sandwich are several extraordinarily thin layers. These constitute the active region, where light is produced. (5)

Some layers made of one semiconducting material surround a central layer made of another, creating a "well" just a few atoms thick—a trench so confined that the laws of quantum mechanics rule supreme. When you inject electrons and holes into the well by applying a voltage to the n- and p-type regions, the two kinds of charge carriers will be trapped, maximizing the likelihood that they will recombine. When they do, a photon pops out. To make an LED, you must grow a series of highly defined semiconductor layers on a thin wafer of a crystalline material, called a substrate. The substrate for red, orange, and yellow LEDs is gallium arsenide, which works wonderfully because its atoms are spaced out identically to those of the layers built on top of it. Hardly any mechanical strain develops in the semiconductor's crystalline lattice during fabrication, so there are very few defects, which would quench light generation. Unfortunately, blue and green LEDs lack such a good platform. They're called nitride LEDs because their fundamental semiconductor is gallium nitride. The n-type gallium nitride is doped with silicon, the p-type with magnesium. The quantum wells in between are gallium indium nitride. To alter the light color emitted from green to violet, researchers vary the gallium-to-indium ratio in the quantum wells. A little indium produces a violet LED; a little more of it produces green. Such LEDs would ideally be manufactured on gallium nitride substrates. But it has proved impossible to grow the large, perfect crystals of gallium nitride that would be necessary to make such wafers. Unipress, the world leader in this field, cannot make crystals bigger than a few centimeters, and then only by keeping the growth chamber at a temperature of 2200 C and a pressure of almost 20 000 atmospheres. So the makers of blue LEDs instead typically build their devices on wafers of sapphire, whose crystalline structure does not quite match that of the nitrides. And that discrepancy gives rise to many defects—billions of them per square centimeter. It is amazing that such LEDs work at all. Any arsenide-based red, orange, or yellow LED that contained as many defects would emit absolutely no light. To this day, researchers, including Nakamura himself can't agree on the cause of the phenomenon. Perhaps the solution to this problem may also explain droop. (6)

Exercise III.

Find paragraphs, dealing with the following:

optoelectronic, defeat, cathode, orange-emitting, reradiate, crystalline, surfeit, zinc, trench, quench

<u>Exercise IV</u>.

Answer the following questions:

1. What does LED stand for?

2. What type of diode uses a compound of gallium arsenide in its construction?

3. What kind of breakdown does Zener diodes exhibit?

4. When is the depletion region removed in a swmiconductor diode?

5. What is the typical operating current for a light-emitting diode (approximately)?

6. In normal (conducting) operation, what will be the voltage that appears between the base and emitter of an NPN bipolar junction transistor (approximately)?

7. Explain the term 'covalent bonding'.

8. What is the resistance of a diode in its non-conducting state?

9. What do we call the zone in a semiconductor diode where no free charge carriers exists?

10. When a diode is in its conducting state what happens to the current?

11. In a metal-cased bipolar transistor, which of the three connections of the transistor are often connected directly to the conducting case: base, collector or emitter?

12. A silicon diode measures a low value of resistance with the meter leads in both positions. What is the trouble: the diode is open or the diode is shorted to the ground or the diode is internally shorted?

13. When does a diode conduct current under normal conditions: when it is reverse-biased or forward-biased or avalanched or saturated?

14. As the forward current through a silicon diode increases, what happens to the internal resistance?

15. For a forward-biased diode, what happens to the barrier potential as temperature increases?

16. Explain the condition of a reverse breakdown of a diode.

Exercise V.

Fill in the gaps according to the text.

1. Tech visionaries have promised us a bright new world where cool and efficient white LEDs, based on blue ones, will replace the wasteful little heaters known as incandescent…………..
2. At the heart of every white LED is a semiconductor……….
3. The phosphor absorbs some of the blue and reradiates it as yellow; the combination of blue and yellow makes…………
4. Each such atom of impurity, or………, has four electrons in its outer shell, compared with the three in an atom of gallium, aluminum, or indium.

5. The extra electron moves easily though the crystal, acting as a ……….of negative charge.
6. That mobile vacancy is called a………...
7. To make an LED, you must grow a series of highly defined semiconductor layers on a thin wafer of a crystalline material, called a…………...
8. The substrate for red, orange, and yellow LEDs is…………, which works wonderfully because its atoms are spaced out identically to those of the layers built on top of it.
9. They're called ……….LEDs because their fundamental semiconductor is gallium nitride.
10. The n -type gallium nitride is ………..with silicon, the p -type with magnesium.

Exercise VI .

Make up sentences of your own with the following word combinations: perform at ones best, at low power, at the opposite end, be made up of, keep something at a temperature of, to this day, agree on the cause of, emit absolutely no light, emit light, give rise to many defects

Exercise VII.

Determine whether the statements are true or false. Correct the false statements:

1. The blue light-emitting diode, arguably the greatest optoelectronic advance of the past 15 years, harbors a dark secret: crank up the current and its efficiencies will plummet.

2. More than a dozen countries have already enacted legislation that bans, or will soon ban, incandescent bulbs.

3. That's just a UK $5 billion niche compared to the overall lighting industry, whose sales next year should reach $100 billion, according to the market research firm Global Industry Analysts.

4. The trick will be to make LEDs turn electricity into light efficiently enough to offset their relatively low cost—roughly 16 cents per lumen, at lightbulb-type brightness, as opposed to about 0.1 cents or less for incandescents.

5. Today's incandescent bulbs are much different from the ones Thomas Edison sold more than a century ago.

6. The chip is traditionally positioned on the bottom of the cathode lead.

7. Passing the light through a yellow phosphor yields yellow light.

8. The first-ever report of light emission from a semiconductor was by the British radio engineer Henry Joseph Round, who noted a yellowish glow emanating from silicon carbide in 1900.

9. The first devices at all similar to today's LEDs arrived only in the 1960s.

10. Researchers fabricated orange-emitting devices; green, red, and yellow equivalents followed in the '60s and '70s, all of them quite efficient.

Exercise VIII .

Match the words to the definitions in the column on the right:

volt	a flat surface in a cinema, on a television, or as a part of computer, on which pictures or words are shown
chip	Illumination from behind
incandescent	a unit for measuring the amount of light something produces
backlight	very bright, tube-shaped electric lights, often used in offices
lumen	producing a bright light from a heated filament or other part
flashlight	the standard unit used to measure how strongly an electrical current is sent around an electrical system
light bulb	one thousandth of an ampere, a measure for small electric currents
fluorescent	a small light that is held in the hand and usually gets its power from batteries
milliamp	a rounded glass container with a thin thread of metal inside that produces light when an electric current goes through it
screen	a tiny wafer of semiconducting material used to make an integrated circuit

<u>Exercise IX</u>.

Summarize the article "The LED's Dark Secret."

Part 2

Exercise I.

Identify the part of speech the words belong to.

optoelectronic, harbor, current, plummet, wasteful, heaters, incandescent, legislation, dominate, defeat

Exercise II .

Form nouns from the following words:

compare (1), bright (1), efficient (1), wasteful (1), high (1), roughly (1), different (1), perform (1), traditionally (2)

Exercise III.

Find synonyms to the following words. Translate them into Russian: drop (1), last (1), hide (1), confidence (1), effectiveness (1), endanger (1), swear (1), useless (1), visualize (1), prevail (1)

Exercise IV .

Find antonyms to the following words. Translate them into Russian:

bright (1), warm (1), useless (1), cooler (1), permit (1), exactly (1), conserve (1), luckily (2), bottom (3), absorb (3)

Exercise V .

Match the words to make word combinations:

yellow	lead
semiconductor	tubes
cathode	devices
incandescent	phosphor
orange-emitting	chip

aggregated	charge
crystalline	vacancy
positive	sections
mobile	light bulbs
fluorescent	lattice

Exercise VI.

QUIZ:

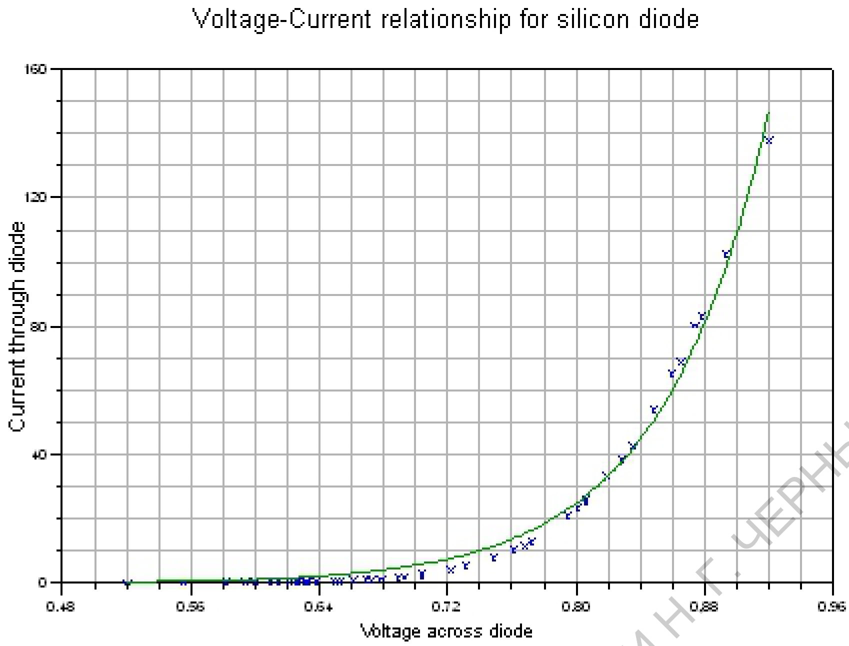
1. PN-junction diodes and transistors are fabricated by implanting impurities. The process is called:

   a. Defraction
   b. Diffusion
   c. Emission
   d. Conduction
   e. Fusion
   f. Fission

2. In the equation

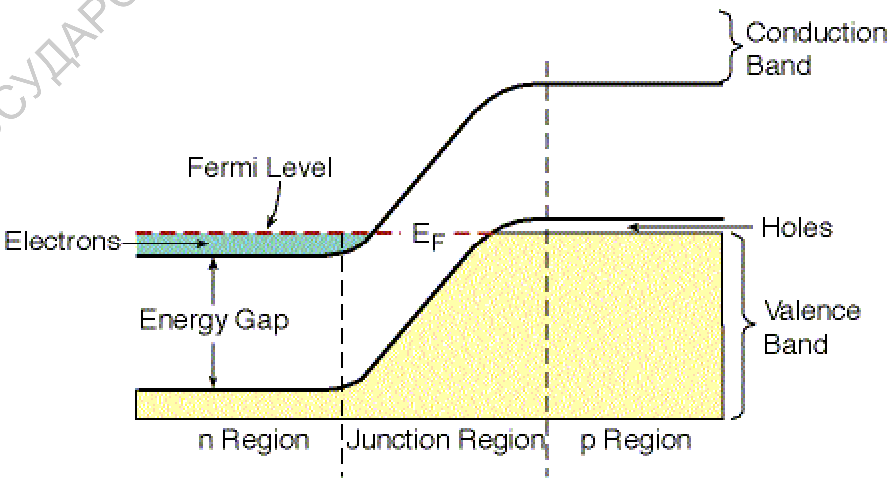
$$VD=mVT\ln(ID/IS),$$

why is VD (diode voltage) temperature dependent?



a.
Because VT is temperature dependent
b. Because IS is temperature dependent
c. Because VT is current dependent
d. Because IS is voltage dependent
e. a and b
f. b and c
g. b and d

3. The depletion region of a PN junction acts like which kind of device?



a. Current-dependent plate capacitor

b.Voltage-dependent resistor

c. Voltage-dependent plate capacitor

d. Current-dependent resistor

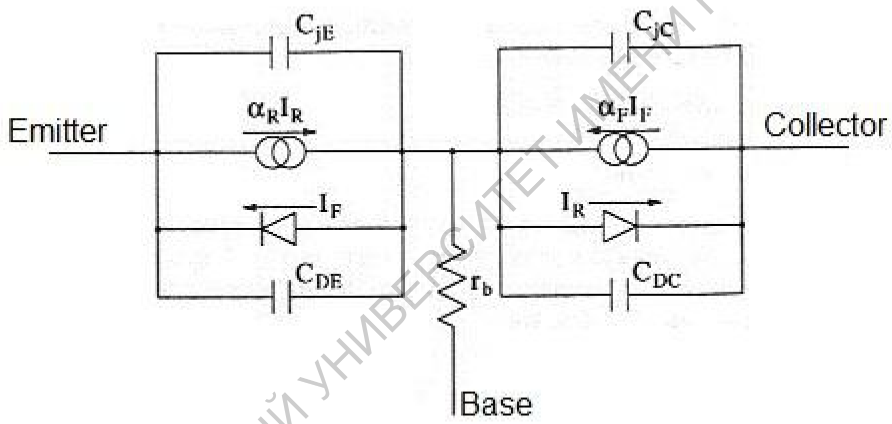
e. Voltage-dependent plate inductor

f. a and c only

g. b and e only

h. d and e only

4. The circuit below represents a high-frequency large-signal equivalent circuit model for an NPN bipolar junction transistor. To make the model linear, which components do you replace?



a. Replace reverse-biased base-collector diode with a high-value resistor
b. Replace reverse-biased base-collector diode with a low-value resistor
c. Replace forward-biased base-emitter diode with a low-value resistor.
d. Replace forward-biased base-emitter diode with a high-value resistor.
e. a and b only
f. a and c only
g. b and c only
h. b and d only
i. None of the above

SUPPLEMENTARY READING

Semiconductors. Atomic Structure.

Semiconductors have electrical properties somewhere between those of insulators and conductors. The use of semiconductor materials in electronic components is not new; some devices are as old as the electron tube. Two of the most widely known semiconductors in use today are the JUNCTION DIODE and TRANSISTOR. These semiconductors fall under a more general heading called solid-state devices. A SOLID-STATE DEVICE is nothing more than an electronic device, which operates by virtue of the movement of electrons within a solid piece of semiconductor material. Since the invention of the transistor, solid-state devices have been developed and improved at an unbelievable rate. Great strides have been made in the manufacturing techniques, and there is no foreseeable limit to the future of these devices. Solid-state devices made from semiconductor materials offer compactness, efficiency, ruggedness, and versatility. Consequently, these devices have invaded virtually every field of science and industry. In addition to the junction diode and transistor, a whole new family of related devices has been developed: the ZENER DIODE, LIGHT-EMITTING DIODE, FIELD EFFECT TRANSISTOR, etc. One development that has dominated solid-state technology, and probably has had a greater impact on the electronics industry than either the electron tube or transistor, is the INTEGRATED CIRCUIT. The integrated circuit is a minute piece of semiconductor material that can produce complete electronic circuit functions.

The universe, as we know it today, is divided into two parts: matter and energy. Matter, which is our main concern at this time, is anything that occupies space and has weight. Rocks, water, air, automobiles, clothing, and even our own bodies are good examples of matter. From this, we can conclude that matter may be found in any one of three states: SOLIDS, LIQUIDS, and GASES. All matter is composed of either an element or combination of elements. As you know, an element is a substance that cannot be reduced to a simpler form by chemical means. Examples of elements with which you are in contact everyday are iron, gold, silver, copper, and oxygen. At present, there are over 100 known elements of which all matter is composed. As we work our way down the size scale, we come to the atom, the smallest particle into which an element can be broken down and still retain all its original properties. The atoms of one element, however, differ from the atoms of all other elements. Since there are over 100 known elements, there must be over 100 different atoms, or a different atom for each element. Now let us consider more than one element at a time. This brings us to the term "compound." A compound is a chemical combination of two or more elements. Water, table salt, ethyl alcohol, and ammonia are all examples of compounds. The smallest part of a compound, which has all the characteristics of the compound, is the molecule. Each molecule contains some of the atoms of each of the elements forming the compound. Consider sugar, for example. Sugar in general terms is matter, since it occupies space and has weight. It is also a compound because it consists of two or more elements. Take a lump of sugar and crush it into small particles; each of the particles still retains its original identifying properties of sugar. The only thing that changed was the physical size of the sugar. If we continue this subdividing process by grinding the sugar into a fine power, the results are the same. Even dissolving sugar in water does not change its identifying properties, in spite of the fact that the particles of sugar are now too small to be seen even with a microscope. Eventually, we end up with a quantity of sugar that cannot be further divided without its ceasing to be sugar. This quantity is known as a molecule of sugar. If the molecule is further divided, it is found to consist of three simpler kinds of matter: carbon, hydrogen, and oxygen.

These simpler forms are called elements. Therefore, since elements consist of atoms, then a molecule of sugar is made up of atoms of carbon, hydrogen, and oxygen. As we investigate the atom, we find that it is basically composed of electrons, protons, and neutrons. Furthermore, the electrons, protons, and neutrons of one element are identical to those of any other element. There are different kinds of elements because the number and the arrangement of electrons and protons are different for each element. The electron carries a small negative charge of electricity. The proton carries a positive charge of electricity equal and opposite to the charge of the electron. Scientists have measured the mass and size of the electron and proton, and they know how much charge each possesses. Both the electron and proton have the same quantity of charge, although the mass of the proton is approximately 1,827 times that of the electron. In some atoms there exists a neutral particle called a neutron. The neutron has a mass approximately equal to that of a proton, but it has no electrical charge. According to theory, the electrons, protons, and neutrons of the atoms are thought to be arranged in a manner similar to a miniature solar system. Notice the helium atom in figure 1-2. Two protons and two neutrons form the heavy nucleus with a positive charge around which two very light electrons revolve. The path each electron takes around the nucleus is called an orbit. The electrons are continuously being acted upon in their orbits by the force of attraction of the nucleus. To maintain an orbit around the nucleus, the electrons travel at a speed that produces a counterforce equal to the attraction force of the nucleus. Just as energy is required to move a space vehicle away from the earth, energy is also required to move an electron away from the nucleus. Like a space vehicle, the electron is said to be at a higher energy level when it travels a larger orbit. Scientific experiments have shown that the electron requires a certain amount of energy to stay in orbit. This quantity is called the electron's energy level. By virtue of just its motion alone, the electron contains kinetic energy. Because of its position, it also contains potential energy. The total energy contained by an electron (kinetic energy plus potential energy) is the main factor that determines the radius of the electron's orbit. For an electron to remain in this orbit, it must neither gain nor lose energy.

The orbiting electrons do not follow random paths, instead they are confined to definite energy levels. Visualize these levels as shells with each successive shell being spaced a greater distance from the nucleus. The shells, and the number of electrons required to fill them, may be predicted by using Pauli's exclusion principle. Simply stated, this principle specifies that each shell will contain a maximum of 2n2 electrons, where n corresponds to the shell number starting with the one closest to the nucleus. By this principle, the second shell, for example, would contain 2(2) 2 or 8 electrons when full. In addition to being numbered, the shells are also given letter designations starting with the shell closest to the nucleus and progressing outward as shown in figure 1-3. The shells are considered to be full, or complete, when they contain the following quantities of electrons: 2 in the K(1st) shell, 8 in the L(2nd) shell, 18 in the M(3rd) shell, and so on, in accordance with the exclusion principle. Each of these shells is a major shell and can be divided into subshells, of which there are four, labeled s, p, d, and f. Like the major shells, the subshells are also limited as to the number of electrons they contain. Thus, the "s" subshell is complete when it contains 2 electrons, the "p" subshell when it contains 6, the "d" subshell when it contains 10, and the "f" subshell when it contains 14 electrons. Inasmuch as the K shell can contain no more than 2 electrons, it must have only one subshell, the s subshell. The M shell is composed of three subshells: s, p, and d. If the electrons in the s, p, and d subshells are added together, their total is found to be 18, the exact number required to fill the M shell.

Valence is an atom’s ability to combine with other atoms. The number of electrons in the outermost shell of an atom determines its valence. For this reason, the outer shell of an atom is called VALENCE SHELL, and the electrons contained in this shell are called VALENCE ELECTRONS. The valence of an atom determines its ability to gain or lose an electron, which in turn determines the chemical and electrical properties of the atom. An atom that is lacking only one or two electrons from its outer shell will easily gain electrons to complete its shell, but a large amount of energy is required to free any of its electrons. An atom having a relatively small number of electrons in its outer shell in comparison to the number of electrons required to fill the shell will easily lose these valence electrons. The valence shell always refers to the outermost shell. As stated earlier, orbiting electrons contain energy and are confined to definite energy levels. The various shells in an atom represent these levels. Therefore, to move an electron from a lower shell to a higher shell a certain amount of energy is required. This energy can be in the form of electric fields, heat, light, and even bombardment by other particles. Failure to provide enough energy to the electron, even if the energy supplied is just short of the required amount, will cause it to remain at its present energy level. Supplying more energy than is needed will only cause the electron to move to the next higher shell and the remaining energy will be wasted. In simple terms, energy is required in definite units to move electrons from one shell to the next higher shell. These units are called QUANTA. Electrons can also lose energy as well as receive it. When an electron loses energy, it moves to a lower shell. The lost energy, in some cases, appears as heat. If a sufficient amount of energy is absorbed by an electron, it is possible for that electron to be completely removed from the influence of the atom. This is called IONIZATION. When an atom loses electrons or gains electrons in this process of electron exchange, it is said to be ionized. For ionization to take place, there must be a transfer of energy that results in a change in the internal energy of the atom. An atom having more than its normal amount of electrons acquires a negative charge, and is called a NEGATIVE ION. The atom that gives up some of its normal electrons is left with fewer negative charges than positive charges and is called a POSITIVE ION. Thus, we can define ionization as the process by which an atom loses or gains electrons. Up to this point in our discussion, we have spoken only of isolated atoms. When atoms are spaced far enough apart, as in a gas, they have very little influence upon each other, and are very much like lone atoms. But atoms within a solid have a marked effect upon each other. The forces that bind these atoms together greatly modify the behavior of the other electrons. One consequence of this close proximity of atoms is to cause the individual energy levels of an atom to break up and form bands of energy.