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Improving the Teaching Process of Semiconductor Topics Based on an Innovative Approach

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Abstract. *This article presents a method for improving the teaching process of semiconductor topics in the curriculum for the subject "Electricity and Magnetism" in higher education based on interactive methods.*

Key words: *pedagogical technology, interactive methods, T-scheme method, Venn diagram method, SWOT analysis method, cluster method, FSMU method.*

Introduction

Today, educational activities should serve as an experimental platform for the thorough development and implementation of interactive methods of teaching pedagogical and information technologies in the educational process. When organizing and conducting a modern educational process, the teacher must, first and foremost, aim to ensure its effectiveness and complete mastery of the topic by students. For this reason, it is necessary to use various methods of organizing training sessions.[1]

Currently, various options for the structure of educational activities are being used by educators in practice. These structural and technological maps are presented as examples, and the teacher can approach them creatively based on the topic and goals of the lesson. Below we will discuss what to pay attention to when presenting a new topic, when constructing the structure of the lesson, and how to construct it.

The structure of the new topic presentation training is as follows:

- announcing the purpose of the lesson, in which the teacher defines the goal to be pursued and announces it at the beginning of the communication [1];
- it is necessary to encourage students to study a new topic, to indicate methods of encouraging students who have achieved the goal set by the teacher faster and more effectively;
- step-by-step presentation of new concepts or information on the topic in small parts;
- emphasizing the main concepts and basic information on the topic, highlighting them;
- Demonstration of practical exercises aimed at strengthening the materials of the new topic;
- practical exercises aimed at reinforcing the new material performed by students;
- monitoring the results of the initial assimilation of new materials by students;

- independent consolidation of new knowledge and skills based on the repetition of acquired knowledge;
- use and practical application of basic concepts and supporting materials in order to consolidate acquired knowledge;
- assessment of newly acquired knowledge and skills;
- summarize the lesson and assign homework.

Educational activities based on pedagogical technologies are organized in a specific sequence. A technological map will help us organize a systematic training session. It defines the stages of implementation of the training, which consists of three stages, which include the introductory, main, and final stages.[1]

Based on the aforementioned considerations, a technological map of lecture sessions on semiconductors, presented in the curriculum for the subject "Electricity and Magnetism," was compiled. When compiling the technological map, the number of lecture topics on semiconductors presented in the curriculum ("Semiconductors," "Electrical Conductivity of Semiconductors," "Pure and Mixed Electrical Conductivity," "Acceptor and Donor Zones," "Semiconductor Diode") was taken into account, as well as the limited time for their illumination and the reflection of innovations in the field of semiconductor physics in education. Therefore, semiconductor topics were summarized for 6 hours. **Topics related to these semiconductors are:**

1. "Semiconductors and semiconductor devices"
2. Laboratory work "Investigation of a Transistor"
3. Using silicon with some element or impurity (research lesson).
4. Technological map of the lecture "Semiconductors and Semiconductor Instruments".

Table 1

Training occupation stages	**Activity Content**		**Recommendation admissible methods**
	Teacher Activity	**Student Activity**	
Intro Stage (15 minutes)	Your homework will be reviewed and evaluated The topic, plan, and goal of the new lesson are outlined. Students are asked questions on a new topic and activate their knowledge.	Provide homework, record it, and answer questions	Spoken. Intellectual assault.
Key Stage (50 minutes)	The difference between semiconductors and metals is explained (Table 1 of the system of logical tables)	Listen and record	Spoken. Intellectual assault.
	Semiconductor substances. Information is provided about the specific and mixed conductivity in them (Tables 2 and 3 of the system of logical tables)	Listen and record	Venn diagram method, The "T-scheme" method

	Electron-hole transition. Semiconductor diode and its types (Table 3 of the logic table system)	Listen and record	SWOT analysis method
	Semiconductor devices and their types (Table 4 of the logic table system)	Listen and record	Cluster method
Final stage (15 minutes)	Strengthens the topic by asking quick questions	Answer questions	FSMU method
	It draws a final conclusion on the topic, draws the attention of participants to important aspects, and answers questions of interest to students on the topic.	Ask questions	
	Gives homework	Record assignment	“Keys stadi” method

The structure and technological map of the aforementioned training sessions are based on interactive technologies, which will serve as the foundation for the effective organization and conduct of this process, as well as for students' better understanding of the requirements of the state educational standard. Such classes create opportunities for students to work together. By completing practical exercises on the remaining problem, they can independently solve the problem and develop creativity. This contributes to the improvement of the quality and effectiveness of training.

Based on this technological map, the teaching of the topic "Semiconductors and Semiconductor Instruments" is as follows:

Topic: Semiconductors and semiconductor devices

The purpose of the lesson is to develop in students information about the types of semiconductors and semiconductor devices, their production, and their use.

Plan:

1. Difference between semiconductors and metals
2. Semiconductor substances, their specific and mixed conductivity
3. Electron-hole transition. Semiconductor diode and its types
4. Semiconductor devices and their types

In order to activate students' knowledge, the following questions are asked:

1) What types of semiconductor substances do you know?
2) What does the specific and mixed conductivity in semiconductors depend on?
3. What types of semiconductor diodes are there?
4) For what purposes are semiconductor devices used? After the students have answered the questions, the first table of the logic table system, "Comparison in reality and imagination" (Table 1), is displayed on the electronic board screen. With the help of this table, it is possible to distinguish free charge carriers in substances that have the property of conducting electricity in nature, their specific resistance depending on temperature, and the use of such substances in the electronics industry. The difference between metals and semiconductors can be explained to students using the symbols + ρ (T) and - ρ (T). For metals, the symbol + ρ (T) indicates that as the temperature (T) in metals increases (+), its specific resistance (ρ) also increases. This is because with increasing temperature, the amplitude of ion oscillations in metals increases. As a

result, the ordered movement of free electrons is hindered by ion oscillations, and the current strength decreases, and the specific resistance of the metal increases. The formula $\rho = \rho 0 (1+\alpha T)$ means that the specific resistance of metals increases linearly with increasing temperature.
The electrical conductivity of semiconductor substances increases with increasing temperature. The reason is that the atoms that make up semiconductors are covalently bound to each other. The oscillatory motion of the semiconductor atom increases under the influence of temperature, and because the covalent bond is weak, the electrons of the atoms break off these bonds and become free electrons, leaving vacancies in their place, which are called holes. Under the influence of an external electric field, the vacancy of an electron - a hole - can be filled by another electron in a neighboring covalent bond. In this case, the cavity also replaces the displaced electron. If this process continues, it will be as if the hole is moving in the opposite direction of the electron's motion. In other words, a charge with a positive sign, the charge of which is equal to the charge of an electron, is shifted. The sign (T) indicates that the specific resistance (ρ) of the semiconductor decreases with increasing temperature (T). The formula $\rho=\rho\_0 \in (-\Delta E) /kT)$ indicates that the specific resistance of the semiconductor decreases exponentially with increasing temperature. Here ρ and $\rho 0$ are the specific resistances of the semiconductor at temperatures T and 0°C, ΔE is the energy that depends on the nature of the semiconductor and is in the range of 1 - 2 eV [4].
Therefore, the difference between metals and semiconductors lies in the dependence of their specific electrical conductivity on temperature.
The second table of the logic table system, "Information about some semiconductor substances," can be used to explain the second plan of the topic[2]. The types of semiconductors presented in this table, depending on their various properties, information on their production and application in technology, are logically arranged based on each other. Educational literature on the subject of "Electricity and Magnetism" in higher education institutions provides more information about elementary semiconductors, namely silicon and germanium. This table shows the structure of the crystal lattice of semiconductor substances (monocrystalline, polycrystalline, liquid, organic), composition (elementary, binary compound), and conductivity (private and mixed). Information on the production of these substances using various methods and their application in the production of semiconductor devices is also important in increasing students' interest in the subject.

Partial and mixed conductivity in semiconductors:

The information about this plan can be explained using zonal theory as follows:
In chemically pure semiconductors, the number of electrons passing into the conduction band is equal to the number of holes formed in the valence band, and both of them participate in the generation of electric current. However, since the mobility of electrons is greater than that of holes, the hole current cannot be equal to half the total current. However, the specific conductivity of semiconductors consists of the sum of the electronic and hole conductivities. Since charge carriers, i.e., electrons and holes, are private carriers, the conductivity they create is called private conductivity.[3]

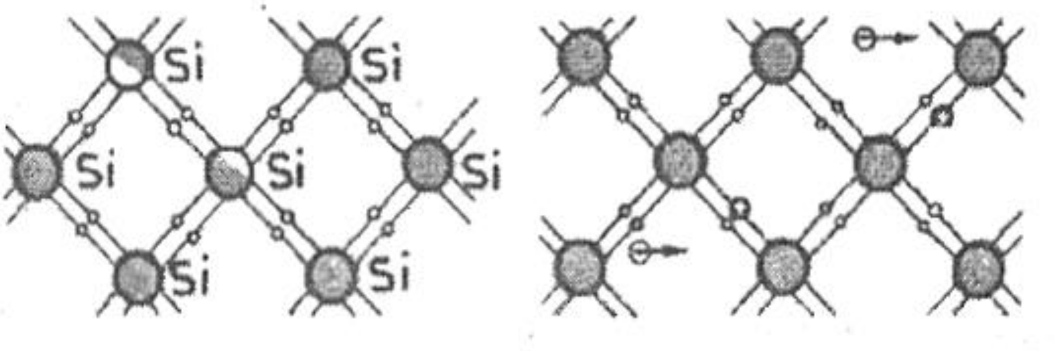

Figure 1. Electron-hole pair formation

Mixed conductivity in semiconductors. As noted above, the conductivity of semiconductors depends on the concentration of electrons and holes and their mobility. Therefore, various methods are used to increase the number of charge carriers in semiconductors. One such method is the introduction of mixtures. Adding impurities to most semiconductors improves their electrical conductivity. There are two types of mixtures: donor and acceptor.

1) Donor mixture. If atoms of phosphorus, arsenic, antimony, and similar substances with five valence electrons are introduced into the crystal lattice of four-valence silicon as impurities, the concentration of electrons in the semiconductor will increase sharply. This is due to the fact that four of the electrons of the impurity atom participate in the formation of a chemical bond with the silicon atom, while the fifth is empty. As a result, its bond with its own atom is very weak and can easily leave it and become a "free" electron (Fig. 2) [3]. In this case, therefore, the mixture is called a donor mixture because the atoms give off their electrons, i.e., they are electron donors. Since electrical conductivity in a donor mixture is the result of the movement of free electrons, it is called electronic or p-type conductivity.

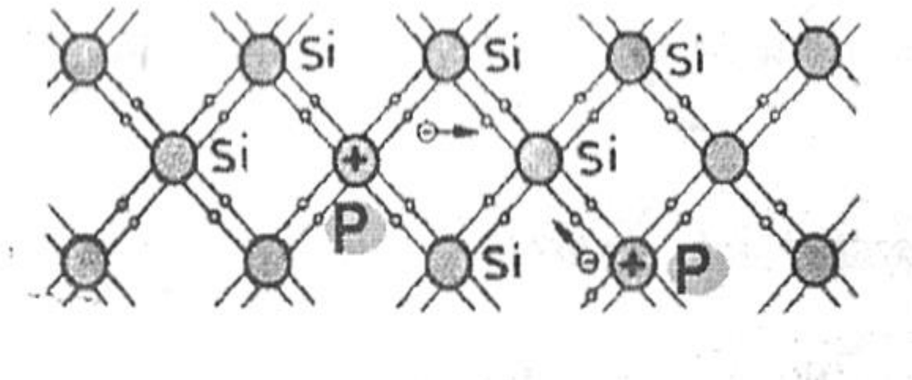

Figure 2. Electron conductivity formation

2) The acceptor mixture. If atoms of boron, indium, gallium, and similar substances with three valence electrons are introduced into the silicon crystal lattice as impurities, the nature of the semiconductor conductivity changes. This is because the indium atom lacks one electron to form a double bond with the silicon atom. In other words, an unfilled valence bond, i.e., a hole, is formed between these two atoms, and therefore the mixture is called an acceptor mixture (Fig. 3). The number of holes in the crystal is equal to the number of impurity atoms. Since electrical conductivity in an acceptor mixture is the result of hole movement, it is called porous or p-type conductivity.

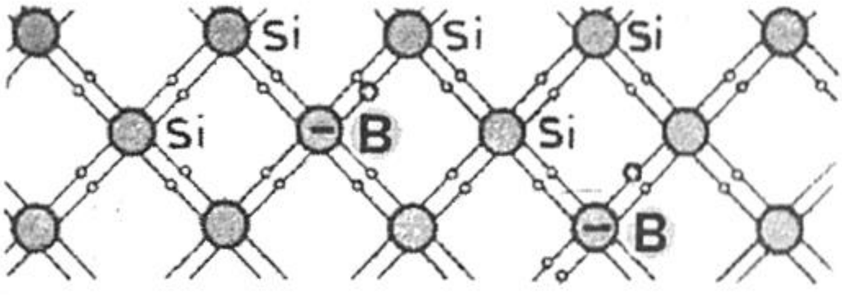

Figure 3. Formation of hole conductivity

Improving the content of semiconductor topics based on an innovative approach will be crucial for students to master semiconductor topics in a short period of time. Therefore, the research focused on the targeted and effective use of semiconductor topics in a system of logic tables.

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