International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Special Issue 30(August, 2015), PP. 96-100

ANALYSIS OF STUDENTS' VIEWS ABOUT MICROSCOPIC FEATURES OF DC ELECTRICAL CIRCUITS

Safoura shirin noush[1], Fatemeh Ahmadi[2]
Department of Physics
Shahid Rajaaei Teacher Training University,
Tehran,Iran
[1]shirinnoosh20@yahoo.com
[2]Fahmadi @ srttu.edu

Abstract— This paper investigates and analyzes the students' views about the microscopic features of DC electrical circuit. These views have been obtained by means of the interviews with 5 physics students. The results show that there are three misunderstanding models in understanding microscopic features of DC electrical circuits which are connected to each other and their origin can be either textbooks or educational software.

KeyWords: Electrical Circuit, Microscopic, Misunderstanding

I. Introduction

Many investigations have been done about understanding DC circuits, and several tables have been prepared about common learners' misconceptions in different levels Borges and Gilbert 1999). But there are less investigations about the reasons for the formation of these misconceptions. In some researches, the information which learners bring to science classes from their routines experiences have been discussed as one of the effective factors on learners correct understanding of DC circuits(Zacharia,2007). As McDermott and Shaffer (1992) states, there are misconceptions even after formal training in different educational levels. Also, investigating the results of researches which have done with the goal of dispelling these misconceptions suggests that the used methods in all cases only partially led to correct misconceptions, and some people preserve their misconceptions even after specific trainings(Borghi et al 2007 ; Kallunki 2013 ; Hirvonen 2007; Jaakkola and Nurmi 2008). On this basis, it can be concluded that many factors can lead to the formation and preservation of this type of misconceptions in the learners' minds. So it is better to examine the learners view about DC circuits' features from different aspects to identify the origin of these misconceptions.

Investigations that have been carried on DC circuits often investigate the learners' view about macroscopic features of DC circuits. However, each of physics quantities are able to be studied from either macroscopic or microscopic view. So, it is better to identify learners' view about microscopic features of DC circuits, too. Thus, by recognizing one of the factors of forming these misconceptions, it can be reduced the possibility of appearing these kinds of misconceptions.

Since the learners information about microscopic features are obtained by means of various methods such as photos of textbooks and some educational software, so in this article some photos of textbooks and educational software like Phet are also investigated in order to investigate the recognition of students' misconceptions about microscopic features of DC circuits, the existence of relationship between students misunderstanding models, and showing these sources of microscopic world.

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II) Method

Data Collection

A questionnaire with 23 questions was prepared in order to collect the students' views about microscopic features of electrical circuit. 8 questions chose from diagnostic instrument, Determining and interpreting resistive electric circuits concepts (DIRECT v1.2), (Appendix A), and the rest of the questions had made by the investigator.

The content of questions were set so that the students information of microscopic features of electrical circuit from classic mechanic's view such as (formation way of electric field inside and outside wires, energy transmission manner in circuit, the speed and movement path of electrons and …) can be measured.

The prepared questionnaire was implemented for semi-structured interviews with five physics students who have passed basic physics lesson 2 and the laboratory. Each interview lasted about 1.5 hours and the content of all interviews were recorded. During the interviews, respondents were asked to select the desired option, and then orally explain the cause of their choice, and at the end asked them to introduce the studies' sources which they have used in this interview in the selection of options.

After each interview, the content of the debates and issues that every student was explained in response to questions was separately investigated by two people. Then in a meeting, every respondent's views were classified consistently. Comments of two students are as follows:

II. Student A: The student chooses a model in which the electrons push each other like beads inside the tubes and their place is changed on the move from one atom to another. The student equals electric field inside connection wire in circuit and lamp filament to zero, as a result electrons play the role of energy carriers from batteries to lamps. In this case, the student believes that increasing the number of collisions of electrons with the ionic lattice is the reason for more energy consumption. But with this model, the student faces inconsistency in explaining some issues. For example, he believes that the path of the electrons inside the wire is the straight line, so that the atomic circuits' model is maintained. But he has no imagination about the formation of such path, also the student can't provide clear descriptions about the speed of electrons movement. Because on one hand due to the instantaneous lamp power, the student considers the speed of the electrons in the circuit equals to the speed of light. On the other hand, according to a problem that has been solved in basic physics lesson 2, knows that drift speed is very low and is about millimeter per second.

III. Student B: This student in response to a question which compares the amount of current in different branches of an electrical circuit with each other, chose an option which showed that he believes the amount of current reduces after passing the lamp. On one hand, it confirmed the correctness of the phrase "battery replaces electrical charges which were consumed in the circuit". In another question which asked energy consumption in two circuits with the same batteries and different resistance, the student solved the problem with the assumption of equal current in two circuits. In this case, the student in response to the question that do charges use in the production of lighting a lamp? answered : "He hasn't thought about that before". Also, he believed that the speed of electrons movement in a simple circuit including battery and lamp is too high and is about light speed from battery to lamp, and after passing the lamp, it is too low, and chose the path of swinging electrons movement. The student believed that electric field inside the circuit in all parts of the circuit is equal and non-zero, but explained that the reason of the formation of electric field inside wires is the current inside the wires. But he didn't provide clear explanations about how circuit current produces such field. This student also believed that electrons are energy carriers in the circuit.

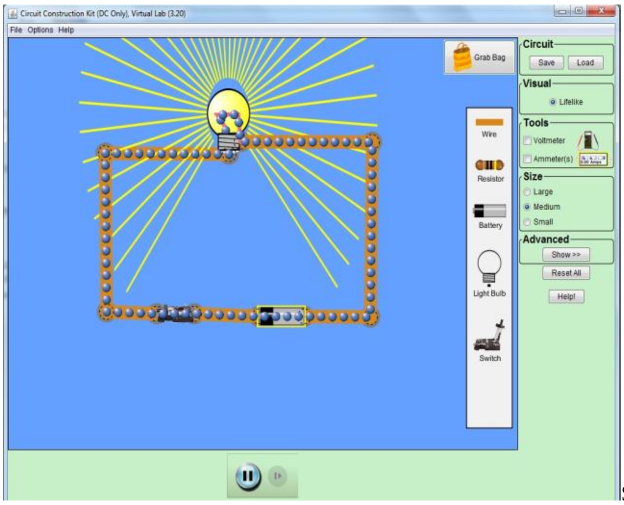
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Fig1.circuit construction kit

Also, figure (2) shows electrons movement in a straight path (Knight, p: 951). Such figure is often used in physics books and classrooms to present electric current calculating formula.

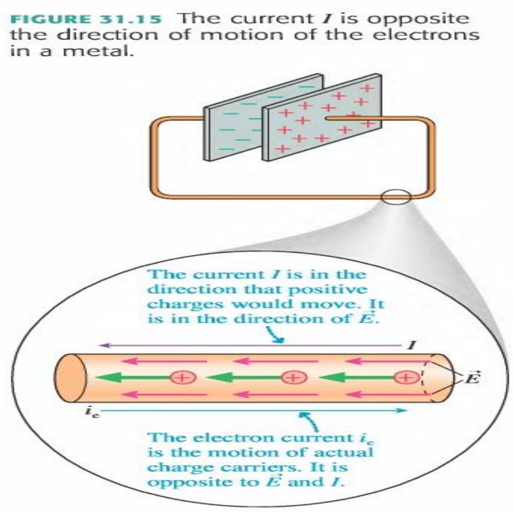


Fig2. The path follows by electron between collisions

On the other hand, figure (3) shows zigzag path for electrons movement (Halliday and Resnick 2011, P.693). Although for figure explanations, it has written that after establishment of electric field in wire, the electrons movement is parable.

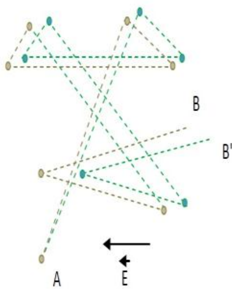


Fig.26-12 The gray lines show an electron moving from A to B, making six collision route . The green lines show what the electron's path might be in the present of an applied electric field $\vec{E}$. Note the steady drift in the direction of - $\vec{E}$. (Actually, the green lines should be slightly curved. to represent the parabolic paths follow by the electrons between collisions, under the influence of an electric field.)

Fig3. The paths follow by electron between collisions

A model which knows electrons as energy carriers in the circuit is partly induced in learners' mind through some of the educational software. For example, in figure (4) which is prepared by Phet software, there are electrons that enter to one end of the battery and go out from the other end of it and enter to the circuit. In this software, only the existence of electrons was shown, so this subject is induced that electrons transfer received energy from battery to the consumer.

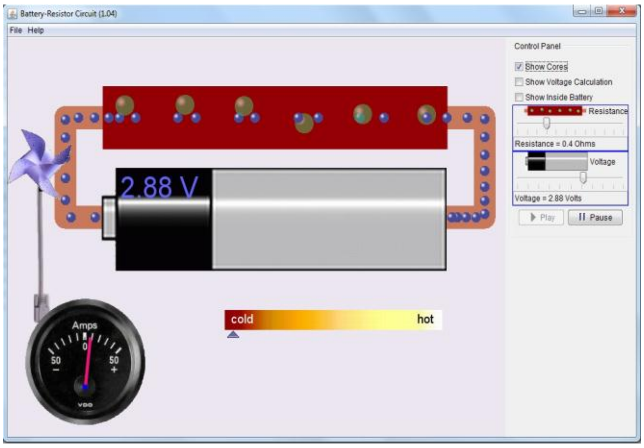


Fig 4.battery- resistor circuit

III) Data Analysis

After setting the content of the interviews, all of the wrong chosen options were written, and a point which led to choose wrong option was noted in front of them. Table 1 shows some of these classifications. After setting the table, the problems which had led to choose wrong options were classified and summarized.

Table (1) Classification wrong options was selected

	Wrong chosen options in response to the questionnaire	The points which are the origin of choosing the wrong options.
1	After circuit connection, electrons pass the zigzag paths, but their movement tendency is to the opposite direction of the electric field inside the wire.	The student doesn't know the electron movement path inside the wire.
2	In an electrical circuit, when the switch is interrupted, free electrons are still passing through the lamp, but due to their low number, the lamp does not light up.	The student doesn't know the role of electrons in the circuit.
3	Time interval among electron collision in some areas of conductive wire which is thinner than its adjacent areas, is more than other areas.	The student is not able to compare the quantity of time average among collisions in different conditions.
4	Electrons are energy carriers from battery to the lamp.	The student doesn't know energy transmission process in a circuit.
5	Electric field which forms inside circuit's components is equal in all areas of the circuit.	The student doesn't know manner of the distribution of surface charges on wires.

After final review, three misunderstanding models in understanding microscopic features of DC circuits were identified. These misunderstandings are as follows: 1- The learners ignore energy transmission process in the circuit (contains: manner of the distribution of surface charges on the outer surface of the wire, and the existence of electromagnetic field inside and outside wires) and the role of poynting vector. 2- Learners don't know the role of electrons in an electrical circuit and their movement features (contains: the speed and the path of electron movement …). 3- Learners are unable to compare examinable microscopic quantities in different parts of electrical circuit with each other (contains: electrons drift speed, mean time between collision, electron density …).

IV) Conclusions

This article, by using interview method, has been recognizing misunderstanding models which the students have for microscopic features of electric circuit. These misunderstandings can be induces by textbooks' photos or educational software. Due to this reason, presenting information in these educational sources must be so accurate that in addition to simplification of scientific concepts, it does not lead to create new misunderstandings. Recognition of these misunderstandings can lead to prepare more scientific educational software and to innovate more effective methods to dispel learners' common misunderstandings of DC circuits.

Appendix A. questions that was chosen from diagnostic instrument, Determining and interpreting resistive electric circuits concepts (DIRECT v1.2)

1) Are charges used up in the production of light in a light bulb?
(A) Yes, charge is used up. Charges moving through the filament produce "friction" which heats up the filament and produces light.
(B) Yes, charge is used up. Charges are emitted as photons and are lost.
(C) Yes, charge is used up. Charges are absorbed by the filament and are lost.
(D) No, charge is conserved. Charges are simply converted to another form such as heat and light.
(E) No, charge is conserved. Charges moving through the filament produce "friction" which heats up the filament and produces light.

2) Why do the lights in your home come on almost instantaneously when you turn on the switch?
(A) When the circuit is completed, there is a rapid rearrangement of surface charges in the circuit.
(B) Charges store energy. When the circuit is completed, the energy is released.
(C) Charges in the wire travel very fast.
(D) The circuits in a home are wired in parallel. Thus, a current is already flowing.
(E) Charges in the wire are like marbles in a tube. When the circuit is completed, the charges push each other through the wire.

3) Is the electric field zero or non-zero inside the bulb filament?
(A) Zero because the filament is a conductor.
(B) Zero because a current is flowing.
(C) Zero because there are charges on the surface of the filament.
(D) Non-zero because a current is flowing which produces the field.
(E) Non-zero because there are charges on the surface of the filament which produce the field.

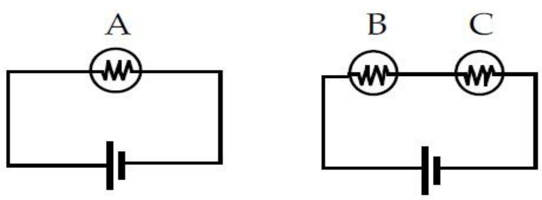
4) Immediately after the switch is opened, what happens to the resistance of the bulb?
(A) The resistance goes to infinity.
(B) The resistance increases.
(C) The resistance decreases.
(D) The resistance stays the same.
(E) The resistance goes to zero.

5) If you double the current through a battery, is the potential difference across a battery doubled?
(A) Yes, because Ohm's law says V= IR.
(B) Yes, because as you increase the resistance, you increase the potential difference.
(C) No, because as you double the current, you reduce the potential difference by half.
(D) No, because the potential difference is a property of the battery.
(E) No, because the potential difference is a property of everything in the circuit.

6) Compare the current at point 1 with the current at point 2. At which point is the current LARGEST?
(A) Point 1
(B) Point 2
(C) Neither, they are the same. Current travels in one direction around the circuit.
(D) Neither, they are the same. Currents travel in two directions around the circuit.

7) Compare the energy delivered per second to each light bulb shown below. Which bulb or bulbs have the LEAST energy delivered to them per second?
(A) A
(B) B
(C) C
(D) B = C
(E) A = B = C

8) Rank the currents at points 1, 2, 3, 4, 5, and 6 from HIGHEST to LOWEST.
(A) 5, 3, 1, 2, 4, 6
(B) 5, 3, 1, 4, 2, 6
(C) 5 =6, 3 = 4, 1 =2
(D) 5 = 6, 1 = 2 = 3 = 4
(E) 1 = 2 = 3 = 4 = 5 = 6



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