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Pre-Service and In-Service Physics Teachers' Ideas about Simple Electric Circuits

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The aim of the study is to determine pre-service and high school physics teachers' ideas about simple electric circuits. In this study, a test contains eight questions related to simple electric circuits was used to the pre-service physics teachers (32 subjects) graduated from Balıkesir University, Necatibey Faculty of Education, the department of physics education and working as physics teachers (25 subjects) in various High Schools in Turkey to determine their ideas about in the same subjects. As a result, it is found that, in partial, while the physics teachers have alternate conceptions about "sequential reasoning", "source of stationary current", and "current usage", the pre-service of physics teachers have unscientific ideas about "source of stationary current", "The concept of current, energy and potential differences are used one another by mistaken", "current usage" and "sequential reasoning".

Keywords: Electric Circuits, Physics Education, Pre-Service Physics Teacher, In-Service Physics Teacher

INTRODUCTION

In the last 20-25 years, many researches, especially research in Europe and the United States; have found that students in every levels have some preconceived ideas about their world that contradict with scientific one. Many different names are used for these kinds of ideas. Well known and frequently used names for these ideas are: "alternate conceptions", "misconceptions", "children science", "conceptual misunderstanding", "spontaneous ideas", "intuitive 'law' or spontaneous reasoning", "conceptual framework, students' unscientific beliefs or students' conceptual categories", "spontaneous models" (Gilbert and Watts, 1983; Marin et. all 2000).

Many researches (Kärrqvist 1985; Lee and Law 2001; McDermott and Shaffer 1992; Shipstone at all. 1988; Osborne 1983; Tiberghien 1983; Küçüközer 2003) have been done to determine (primary, secondary and university) students' ideas about simple electric circuits. From those studies, in general, students have the following unscientific ideas about simple electric circuits:

- Current have been consumed by its closed circuits components (like bulb, resistance, etc.).Therefore, the current diminishes when it returns to battery.
- Current as collisions. The current comes both polar of the battery, when they collide on the bulb, the bulb gives the light.
- One polar current model. The only need is one connection between battery and bulb. Second connection to the other polar of the battery is not necessary for giving the light.
- Battery to be seen as stationary source of current.
- The more battery in the circuits, the more brightness of the bulb.
- Using the concept of current, energy, and potential difference for one another.
- The thought of brightness of the bulb to bee seen as "sequential reasoning" model. (when it consider the path of the current is one way in the series circuits), according to this current path, some changes before or in front of the bulb,

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affect the brightness of the bulb, but some changes after or backward of bulb does not affect the brightness of the bulb.
- When bulbs are connected each other with parallel, the current splits as equally to bulbs no matter bulb's value of the resistance is low or high.

There are few researches (Pardhan and Bano, 2001; Webb 1992; McDermott et al., 2000; Stocklmayer and Treagust, 1996) have been done about similarity of science and physics teachers' ideas on simple electric circuits that those of students have. The following results are found based on teachers' concept of simple electric circuits.

- The source-consumer model (battery is source of electrons/energy; whereas the bulb is a consumer)
- Current is not conserved.
- Clashing current and; the current comes both polar of the battery, and than they collide on the bulb, as a result of this, the light gets on.
- Current as unipolar model; the only need is one connection between battery and bulb. Second connection to the other polar of the battery to bulb is not necessary for getting the light on.
- Current as equally sharing model; in the series circuits, the current is shared equally by the bulbs
- Sequential reasoning or "attenuation" model; in the series circuits, some changes before or in front of the bulb, affect the brightness of the bulb, but some changes after or backward of bulb does not affect the brightness of the bulb
- Mechanical model; in this model, it is seen that electrons moves as a mechanical particle in the wire; and this is the cause of the current.

The main aim of the study is to determine pre-service and high school physics teachers' ideas about simple electric circuits. In this purpose, the following question is going to be answered:

What kinds of ideas do in-service and pre-service high school physics teachers have about simple electric circuits?

METHODOLOGIES

Sampling

The sample was chosen sample of convenience from 25 High school in-service physics teachers held by Ministry of Education. Also 32 pre-service physics teachers (12 of them were male, 17 of them were female) in the last semester before graduation from physics education department at Balikesir University, Necatibey Faculty of Education. In the study there were 25 in-service physics teachers (3 of them were female and 22 of them were male) came from 25 different High Schools in various regions in Turkey (participated teachers in service course was chosen randomly from applicants of physics teachers) ranging their age between 26 to 49 years old and experience in their teaching between 5 to 24 years.

Collecting and Analyzing Data

In the study there was one instrument, the concept test about simple electric circuits, to collect data. This concept test which consists of eight partly open ended questions, was developed to determine in-service physics teachers' and pre-service physics teachers' ideas about simple electric circuits. The test had high reliability (r=0.75) coefficient (the multiple choice question part) and was developed to use as a part of Küçüközer's (2004) doctoral dissertation (the test is given in the appendix). Then this test was adopted to use in this study. To analyze the data the following procedures was followed:

- First, participants' correct answer was determined for each question.
- Then, these correct answers, according to their open ended explanations, divided into two parts as being scientifically correct or wrong.
- Then, explanations of the scientifically correct answers were classified into two parts as being exact correct answer or partly correct answer.
- Next, explanations of the wrong answers were similarly classified into categories among the answers.
- Finally, after analyzing the correct and wrong answer and explanations, results were summarized into tables for each question.

RESULTS

In this part, only four questions are analyzed (out of eight) and their results are given:

Stationary Current Sources

In the following question, in the first part, it is aimed to determine participants' ideas about "batteries as stationary current source". In the second part (part b), participants' opinion about "battery's run out time" was asked to be tested. This question is given in appendix (question 3) and results about first part are given in Table 1.

It can bee seen in Table 1 that 88 % of the physics teachers and 69 % of the pre-service of physics teachers marked the correct answer. Only 8% of the physics teachers gave the exact correct answer with relating the brightness of the bulb with power of the bulb. 64 % of

Table 1. Participants' results about the first part of third question.

Question No	Number (Freq. in %)	
3-a	**In-service Physics Teacher**	**Pre-service Physics Teacher**
The Correct Answer is: A = D = E > B = C		
Scientifically Acceptable Correct Answers		
a) Exactly Correct answer		
- The brightness of the bulbs is proportional to power of the bulb ($P=V^2/R$)	2 (8)	5 (16)
- The brightness of the bulbs is proportional to power of the bulbs." ($P=I^2R$)	-	1 (3)
b) Partly Correct answer		
- In this answer, participants did not mention any of bulbs' power but used to compare brightness according to bulbs' potential differences.	16 (64)	15 (47)
- In this answer, participants did not mention any of bulbs' power but used to compare brightness according to bulbs' current.	-	1 (3)
c) the correct answer but no explanation is given	4 (16)	-
Wrong Answers		
1) A > B = C > D = E		
- In this answer participant focus on effective resistance and gave this answer: *"Because of the total resistance, B and C less bright than A. Also the bulb of D and E less bright than the others."*	1 (4)	-
- wrong answer but no explanation is given	1 (4)	1 (3)
2) A = B = C > D = E		
- In this choice participants have seen batteries as stationary current sources.	1 (4)	8 (25)
- The bulbs that parallel with the battery share same potential differences; therefore brightness differentiates according to this.	-	1(3)

Table 2. Participants' results about the first part of second question.

Question No	Number (Frequency in %)	
2a	**In-ser. Phy. T.**	**Pre-ser. Phy.T.**
Correct Answer: increases		
Scientifically Acceptable Correct Answers		
a) exact correct answer		
- The brightness of the bulbs is proportional to power of the bulb (decreasing resistance causes increase of current according to ohm law; increase of the current is proportional to power and brightness of bulb ($P= I^2 R$) therefore the bulb's brightness is going to increase*).*	5 (20)	7 (22)
b) Partially correct		
- Some compared brightness of bulb only bulbs' current they did not mention bulbs' power. Other words, the current and brightness are proportional to each other.	17 (68)	12 (37)
- The brightness of the bulbs is proportional to potential differences of the bulbs. (R_1 decreases the potential difference of bulb and R_2 increase; then potential difference is proportional to brightness of the bulb).	-	6 (19)
c) Wrong Explanations	3 (12)	6 (19)
- Sequential Reasoning		
Wrong Choice: Remain the same		
- Increase of resistance of system causes decrease of current then this does not affect the brightness of the bulb.	-	1 (3)

the physics teachers just related the potential differences with the brightness of the bulb.

Of the given correct answers, only 19 % of the pre-service of physics teachers used power concept to explain the brightness of the bulb.

There were two approaches to explain the answer. One approach was current, and the other was potential difference. For example, one teacher and one student explained the exact correct answer like this "the brightness is proportional to power of the bulbs. The power is proportional to square of current ($P=I^2R$). When one battery and bulb are in the circuit, if the main current was I, then when added the second bulb to circuit in series, the main current becomes I/2; when added the second bulb to circuit in parallel, the main current become 2I, but each bulb shares the current of I. According to given formula; therefore, the correct answer becomes B=C < A=D=E". Another student approached the correct answer with potential differences, and stated: "the potential differences of A, D, and E are the same and the potential differences of these bulbs twice as than bulb of B and C. The power of the bulbs is given P=V2/R, therefore the correct answer becomes B=C < A=D=E." Most of the teachers and students gave the correct answer but stated their partially correct answer that the brightness was proportional to current or potential differences of the bulbs, and they did not mention the power of the bulbs. For example, one teacher and one student stated as: "the more potential differences, the more brightness. A, D, E have potential of V, and B and C have a potential of V/2; therefore the correct answer is B=C < A=D=E." 12 % of the physics teachers and 31% of the pre-service physics teachers have marked the wrong

Table 3. Participants' results about the first part of second question

Question No	Number (Frequency in %)	
2-b	In-ser. Phy. T.	In-ser. Phy. T.
Correct Answer: increases		
Scientifically Acceptable Correct Answers		
a) exact correct answer		
- The brightness of the bulbs is proportional to power of the bulb (increasing resistance causes decrease of current according to ohm law; decrease of the current is proportional to power and brightness of bulb ($P= I^2 R$), therefore the bulb's brightness is going to decrease).	4 (16)	6 (19)
b) Partially correct		
- Some compared brightness of bulb only bulbs' current they did not mention bulbs' power. Other words, the current and brightness are proportional to each other. The decrease of current, the decrease of brightness of the bulb.	18 (72)	13 (40)
- The brightness of the bulbs is proportional to potential differences of the bulbs. (R_2 increases the potential difference of bulb and R_1 increase; then potential difference is proportional to brightness of the bulb).	-	6 (19)
No explanation given	3 (12)	-
Wrong choice: remain the same		
- Sequential Reasoning	-	6 (19)
- no explanation given	-	1 (3)

Table 4. Participants' results about the second part of fifth question

Question No	Number (Frequency in %)	
5-b	In-ser. Phy. T.	In-ser. Phy. T.
The correct answer is: 0, 3, 3 Volts, respectively		
Scientifically Acceptable Correct Answers		
a) exact correct answer		
- The explanation of the correct answer is given: *"The resistance of the wire is almost "zero" and the potential difference between the given two points is zero. Also the series connection of the bulbs share equally of the battery's potentials."*	18 (72)	18 (56)
b) Scientifically not Acceptable explanations		
- *"there is a short cut between 1 and 2 points and the potentials of the points are zero. Between 2 and 3; and 3 and 4 are connected to each other in series, therefore the potential differences of those points should equal to battery's potentials."*	-	1 (3)
- *"Because of the series connection of the bulb's resistance, there should not be any change of the current. The current of each bulb shares equally of 3 Volts."*	-	1 (3)
No explanation is given	4 (16)	8 (25)
Wrong choices		
1) 6, 6, 6 Volt		
- No explanation is given	1 (4)	-
2) 0, 3, 0 Volt		
- No explanation is given	1 (4)	-
2) 0, 6, 6 Volt		
"the series connection between the two points does not affect the results the potential differences should be 6 Volts"	-	1 (3)
3) 6, 3, 3 Volt		
- "the bulbs are connected in series; therefore, the potential differences of the battery is divided halves into bulbs" .	-	1 (3)
- no explanation is given	-	2 (6)
No answer is given	1 (4)	-

answers. When analyzing the wrong answer, it can be seen that 4 % of the physics teachers and 25 % of the pre-service physics teachers have chosen the wrong answer that related the unscientific ideas about "battery is stationary current source." For example, one teacher and one student stated their reasoning like this: "In series circuits the same current flow over the circuits, but in parallel circuits current are divided into two parts; therefore the more current gives the more brightness".

Sequential Reasoning

In the following question, it is aimed to determine participants' ideas about "sequential reasoning". This question is given in appendix (question 2) and related results are given in Table 2 and 3, respectively. It can bee seen in Table 3 (part b) that 100 % of the physics teachers and 78 % of the pre-service of physics teachers marked the correct answer. Only 16 % of the physics teachers and 19 % of the pre-service of physics teachers gave the exact correct answer with relating the brightness of the bulb with power of the bulb. 72 % of the physics teachers and 40 % of the pre-service of physics teachers just related the current with the brightness of the bulb. 19 % of the pre-service of physics teachers just related the potential difference with the brightness of the bulb. 19 % of the pre-service physics teachers have given incorrect explanation and that is also related the unscientific ideas about "sequential reasoning". For example, one student stated their reasoning like this: "Because the resistance of R_2 is in next to the bulb, decreasing the value of resistance causes increase of bulb's current; but, the brightness of bulb *remains the same".*

It can be seen in Table 2 (part a) that 100 % of the physics teachers and 97 % of the pre-service of physics teachers marked the correct answer. Only 20 % of the physics teachers and 22 % of the pre-service of physics teachers gave the exact correct answer with relating the brightness of the bulb with power of the bulb. 68 % of the physics teachers and 37 % of the pre-service of physics teachers just related the current with the brightness of the bulb. 19 % of the pre-service of physics teachers just related the potential difference with the brightness of the bulb. 12 % of the physics teachers and 19 % of the pre-service physics teachers have given the wrong explanation and that is related the

Table 5. Participants' results about sixth question

Question No	Number (Frequency in %)	
6	In-ser. Phy. T.	In-ser. Phy. T.
The correct answer is: 1 = 2		
Exact correct answer		
- Conservation of the current (in series circuits the current is the same all over of the circuits. The current does not change when it passes through the bulbs)	17 (68)	24 (75)
No explanation is given	7 (28)	6 (19)
Wrong Choice: 1 < 2		
- Consume of the current	1 (4)	1 (3)
No answer is given	-	1 (3)

unscientific ideas about "sequential reasoning". For example, one teacher and one student stated their reasoning like this: "Because the resistance of R_1 is in front of bulb, decreasing value of the resistance causes increase of bulb's current; however, the brightness of bulb *is not going to be changed*".

To determine participants' responses about potential difference the fifth question has been asked. The

question is shown in appendix (question 5) and the results are given in Table 4. It can be seen that in question 5, the question consists of two parts. Similarity of the results, it is given only second part of the question in Table 4.

It can be seen in Table 4 that 88% of the physics teachers and 62 % of the pre-service physics teachers have marked the correct answer of b section of the question five. Of the given correct answer, 72 % of the physics teachers gave the exact explanation while 16 % of them did not give any explanation. On the other hand, 9 % of the pre-service physics teachers gave the exact explanation while 47 % of them gave the partially correct explanation and 9% of them explained incorrectly. Also 8% of the physics teachers and 13 % of the pre-service physics teachers have marked the incorrect answer. The teacher that gave the incorrect answer also did not give any explanation of the reasoning of the question, but when we look at the explanation of the candidate physics teachers' responses, it can be said that they are confused about potential differences and current concepts.

Consume of current by circuit components

To determine participants unscientific ideas about the concept of "circuits component consumes the current", sixth question have been asked. This question and its results are given in appendix (question 6), and Table 5.

Table 6. The summary of the participants' misconceptions about electric circuits

Unscientific Conceptions	Number (Freq. in %)	
	In-ser. Phy. T.	In-ser. Phy. T.
- The more battery, the more brightness of the bulbs (the first question).	-	1 (3)
- Current is consumed by its component. (4 and 6th question).	1 (4)	1 (3)
- Batteries are seen as stationary current sources (the third question).	1 (4)	8 (25)
- The concept of current, energy and potential differences are used one another by mistake (the fifth question).	-	4(13)
-"sequential reasoning"; in the series circuits, some changes before the bulb, affect the brightness of the bulb, but some changes after do not affect the brightness of the bulb (second question)	-	6 (19)
-"sequential reasoning"; in the series circuits, affect the brightness of the bulb, (second question)	4 (16)	6 (19)
- Using ammeter and voltmeter in circuits incorrectly (7th question).	3 (12)	4 (13)
- 8th question.	-	-

Potential Differences

It can be seen in Table 5 that 96% of the physics teachers and % 94 of the pre-service physics teachers have marked the correct answer. Of the given correct answer, 68 % of the physics teachers gave the exact explanation of "conservation of the current" while 28 % of them did not give any explanation. On the other hand, 75% of the pre-service physics teacher gave the exact explanation while 19 % explained incorrectly. 4% of the physics teachers and 6% of the pre-service physics teachers have marked the incorrect answer. As the explanation of choosing the answer of (1<2), the one teacher and one student gave the similar explanation, they said "the current has a big value when it closes the negative pole of the battery. Because, when the current passes through the bulb, the current is lessened"

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main aim of the study is to determine pre-service and high school physics teachers' ideas about simple electric circuits. In this purpose a test, contains eight questions related to simple electric circuits, was used to determine the high school physics teachers' and

pre-service physics teachers' ideas about same subjects. The summary of the high school physics and pre-service physics teachers' unscientific conceptions is given in Table 6. In this last session, we are going to answer the research question:

What kind of ideas do high school pre-service and in-service physics teachers have about simple electric circuits?" It can be said from Table 6 that even though the high school physics teachers have very low percentage of unscientific ideas about simple electric circuits than those of pre-service physics teachers have, however, the high school physics teachers have alternative conceptions about simple electric circuits. Those are: "Current is consumed by its component" (4 %), "Using ammeter and voltmeter in circuits incorrectly" (12 %), "Batteries are seen as stationary current sources" (4 %), and "sequential reasoning" (16%).

It can be seen in Table 6 that pre-service physics teacher have unscientific ideas about seven out of eight questions. These are: "The more battery, the more brightness of the bulbs" (3%), "Current is consumed by its component" (3%), "The concept of current, energy and potential differences are used one another by mistake" (13%), "Using ammeter and voltmeter in circuits incorrectly" (13 %), "sequential reasoning" (19 %), "In the series circuits, some changes before the bulb, affect the brightness of the bulb, but some changes after do not affect the brightness of the bulb" (12 %) and "Batteries are seen as stationary current sources" (25%).

As a result, high school and pre-service physics teacher have many unscientific ideas or alternative conceptions about simple electric circuits. Finding of this study results have similarities those researches from the literature (Pardhan and Bano, 2001; Webb 1992; Engelhart and Beichner 2004), and those kinds of conceptual ideas are not depend on any culture or nation (Driver and Erickson, 1983; Shipstone et al 1988; Küçüközer 2003).

Recommendations

From this study results and experience, the following recommendations can be made:

- From the most percentage of pre-service physics teachers' unscientific ideas, those kinds of alternative conceptions have to be considered in graduate level and pay attention by university lecturers or professors to overcome these ideas (like, activities about conceptual change, preparing the new syllabus, hands-on and mind-on experiences, etc.).
- A number of definitions and statements about the concept of brightness of the bulb in the physics textbooks are relating only bulb's current or potential difference but power of the bulb. The publishers and authors of physics textbooks have many responsibilities when stating and/or emphasizing some unscientific concepts or alternate concepts
- After determining students' and/or teachers' alternate conceptions about simple electric circuits, teachers should be informed and have to aware of and overcome those kinds of ideas with arranging in service courses by ministry of education department as frequently as possible.
- Students should not avoid asking any kinds of questions and/or participating classrooms activities when they do not understand or their thoughts or concepts contradict with anything different than those of teachers have.
- The physics teachers, instructors, or professors have to follow educational researches about their related topics or current physical issues or alternate conceptions to get up-to-date scientific information with using magazines, research papers, internet or what so ever any medium.

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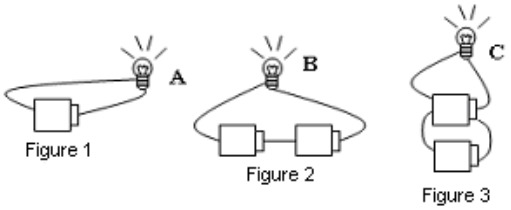
APPENDIX
Basic Circuit Conceptual Survey

The following test consists of eight questions to survey your conceptual response about basic circuits. Please answer all questions and explain your reasoning provided spaces for each question. Your responses are very important to us. Thank you your cooperation.

Questions

1.



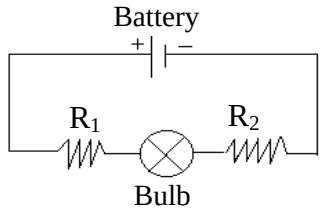
Each bulb in the given figures is identical. In figure 2, the second battery is added as serie; in figure 3, the second battery is added as parallell to first battery.
After adding the scond battery, how do you list the brightness of the bulb? Please choose(x mark) one of the following and than explain your reasoning.

❑ A>B>C ❑ B>A>C ❑ B>A=C
❑ A=B=C ❑ B=C>A ❑ .....

Explain your reasoning

---

2. The following basic circuit is given. After making given changes, please choose one of the given answer and than explain your reasoning.



a) If the value of R_1 decreases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning

---

b) If the value of R_2 increases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning

---

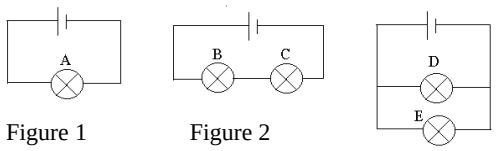
c) If the value of R_1 increases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning

---

d) If the value of R_2 decreases, the brightness of bulb will
❑ Increase ❑ Decrease ❑ Remain the same

Explain your reasoning



3. In the figures above, the bulbs and batteries are identical.
a) In the above figures the bulbs are connected as shown. Please choose one answer about the brightness of the bulbs and then explain your reasoning.

❑ A>B=C=D=E ❑ A=B=C>D=E ❑ A>B=C>D=E
❑ A=D=E>B=C ❑ A=B>C>D>E ❑ .....

Explain your reasoning:

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b) If the battery of figure 1 is run out exactly in one hour, ow many does it take to run out of the batteries of igure 2 and figure 3

The battery of figure 2 …… hour (s) The battery of figure 3 …… hour (s)

Explain your reasoning:

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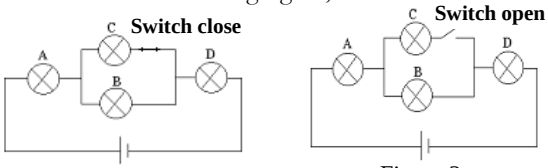
4. In the following figure, the bulbs are identical.



a) In figure 1 the switch is closed. Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

❑ A=D>B=C ❑ A>B=C>D ❑ C>A=D>B ❑ A=B=C=D
❑ when the switch is closed, no bulbs give light ❑ .....

Explain your reasoning

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b) In figure 2, when the switch is opened. Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

❑ A>B=C>D ❑ A>B=D, C gives no light ❑ A=B= C=D
❑ A=D>B=C ❑ A>B>D, C gives no light
❑ when the switch is opened, no bulbs give light ❑.....

Explain your reasoning

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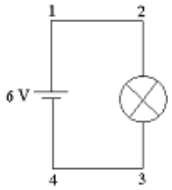
5. In the following given both circuits the bulbs are identical. What are the potential differences between given two points? Please mark the correct answer and then explain your reasoning.

a)



❑ Between 1 and 2 = **6** Volt, 2 and 3 = **6** Volt, 3 and 4 = **6** Volt
❑ Between 1 and 2 = **6** Volt, 2 and 3 = **3** Volt, 3 and 4 = **3** Volt
❑ Between 1 and 2 = **0** Volt, 2 and 3 = **6** Volt, 3 and 4 = **0** Volt
❑ Between 1 and 2 = **2** Volt, 2 and 3 = **2** Volt, 3 and 4 = **2** Volt
❑ .....

Explain your reasoning:

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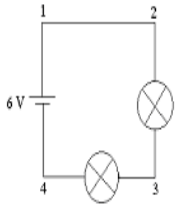
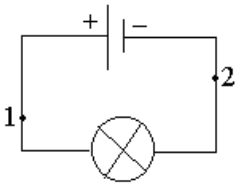
b)



- ❑ Between 1 and 2 = **6** Volt, 2 and 3 = **6** Volt, 3 and 4 = **6** Volt
- ❑ Between 1 and 2 = **6** Volt, 2 and 3 = **3** Volt, 3 and 4 = **0** Volt
- ❑ Between 1 and 2 = **0** Volt, 2 and 3 = **3** Volt, 3 and 4 = **0** Volt
- ❑ Between 1 and 2 = **2** Volt, 2 and 3 = **2** Volt, 3 and 4 = **2** Volt
- ❑ Between 1 and 2 = **0** Volt, 2 and 3 = **3** Volt, 3 and 4 = **3** Volt
- ❑ .....

Explain your reasoning:

6.



- ❑ 1>2
- ❑ 1=2
- ❑ 1<2

In the figure, what is the current between given 1 and 2 points? Mark the correct the answer and then explain your reasoning.

Explain your reasoning:

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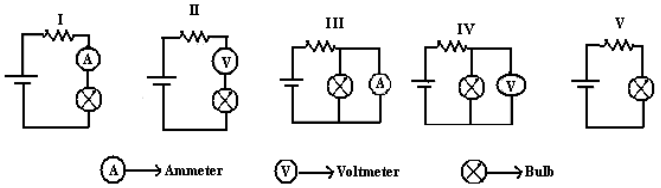
7. In the following figures; the bulbs, resistances, and batteries are identical.



Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.

❑ I=II=V>III=IV ❑ I=II=V>III=IV ❑ V>I=II>III=IV
❑ I=IV=V, II and III do not give light
❑ I=II=III=IV=V ❑ .....

Explain your reasoning:

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8. a)

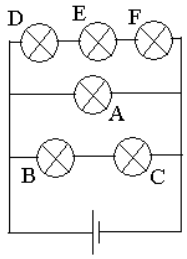

Figure1

In the left figure, the bulbs are identical Please rank the brightness of the bulbs, choose one answer and then explain your reasoning.
❑ A=B=C=D=E=F ❑ A>B=C>D=E=F
❑ B=C>A>D=E=F ❑ A>B>C>D>E>F ❑ B=C>A>D=E=F
❑ ……

Explain your reasoning

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b) When bulb B and C are taking off from circuit in Figure 1, how effect this change the brightness of the other bulbs of A, D, E and F; and then explain your reasoning.

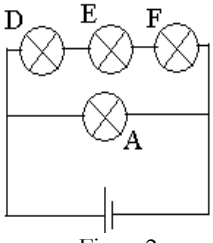

Figure2

Bulb A: ❑ increases ❑ remain the same ❑ decreases
Bulb D: ❑ increases ❑ remain the same ❑ decreases
Bulb E: ❑ increases ❑ remain the same ❑ decreases
Bulb F: ❑ increases ❑ remain the same ❑ decreases

Explain your reasoning
