Investigating Students' Conceptions of Some Electricity Concepts

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(Received 6 April 2009, accepted 10 May 2009)

Abstract
The aim of this study is to determine university students' conceptions about some electricity concepts. The data were obtained from 177 undergraduate students by means of a concept test developed by the researchers. The concept test is named as Electricity Concept Test (ECT) consisting of eight sub-topics and including 23 two-tier conceptual questions. In the first tier, the students are supposed to select correct choice out of four and in the second tier, the students are asked to write their reasoning. Answering percentages of the participants are analyzed and understanding levels for every question which is extracted from their full reasoning were determined. The results have shown that students have some common misconceptions. Finally further suggestions were presented.

Keywords: Physics Education, Conception, Electricity.

Resumen
El objetivo de este estudio es determinar las concepciones de los estudiantes universitarios sobre algunos conceptos de electricidad. Los datos fueron obtenidos de 177 estudiantes por medio de un test conceptual desarrollado por los investigadores. El test conceptual se llama Test de Conceptos sobre Electricidad (TEC) que consta de ocho sub-temas y entre ellos 23 preguntas conceptuales de dos niveles. En el primer nivel, los estudiantes tienen que seleccionar la elección correcta de los cuatro y en el segundo nivel, se les pide que escriban su razonamiento. Los porcentajes de respuestas de los participantes son analizados y se determinan los niveles de comprensión para todas las preguntas de las que se extrae su razonamiento completo. Los resultados han demostrado que los estudiantes tienen en común algunas ideas erróneas. Por último, se presentaron otras sugerencias.

Palabras clave: Educación en Física, Concepción, Electricidad.

PACS: 01.40-d, 01.40.Fk, 01.40.Ha **ISSN 1870-9095**

I. INTRODUCTION

In the last 25 years, there has been a considerable physics education research on students' conceptions of various topics [1, 2]. Physics educators have begun to look more closely at what their students understand about certain concepts and the term misconception is used to refer the students' incorrect pattern of response [3]. This concerns the persistence over time and resistance to change of a variety of prior non scientific conceptions that students bring to our classes [4].

According to constructivist models of learning, the process of learning involve the "building up" knowledge structures [5]. Constructivist models of learning assume that existing knowledge and understanding are the basis for deeper and lasting learning [6]. Theories of memory processing suggest that long term retention of knowledge involves the consolidation of knowledge, through changes that which increase the levels of integration of recent learning with well established knowledge structure [7].

The role of students' pre-instructional conceptions that are not in accordance with scientific concepts has proven to be important in learning. If students do not understand concepts as scientists do, this situation is described as misconceptions [8, 9], alternative conceptions [10] and alternative frameworks [11] by different researchers. Students' conceptions are surprisingly similar in different student age groups and similar conceptions are held by adults and some teachers [12], also educators need to worry about misconceptions for meaningful learning [13, 14].

In order to determine student understanding on certain concepts, e.g. magnetism [15], mechanics [16], optics [17], heat and temperature [18], many studies have been carried out. Electricity is one of the basic scientific topics with relevance to everyday life. Research on misconceptions in electrostatics mainly focuses on electrical force and electric field concepts [19, 20, 21, 22, 23, 24, 25]. According to the findings of these researches [19, 20, 21, 22, 23, 24, 25], most of the students do not have clear understanding and difference of the concepts of electric field, field lines, field intensity and electrical force. The researchers underline that immature understanding of electrical and magnetic fields as vector fields is one of the reasons that could explain the students' difficulties to shift from Coulombian conceptual profile to Maxwellian one [22]. Otherwise, understanding on some static electricity concepts, e.g. electric charge, charge transfer, electrical potential, potential difference and capacitance, are searched by Başer and Geban [26].

Research on understanding electricity is focused on current, potential difference and especially brightness of bulbs in parallel or series dc circuits [2, 27, 28, 29, 30, 31]. Common misconceptions detected in those papers are based on electric current and can be summarized like "current is consumed by circuit components", "current comes out from the both poles of the battery and clashes in the bulb to light it", "current comes out from the (+) pole of battery and enters to the bulb where it is consumed to light the bulb which is not affected by the second wire connected between the (-) pole and itself". There are few research connecting electricity and magnetism concepts and Newtonian mechanics [32, 33, 34].

These and several other studies have shown that the misconceptions can be seen in all age groups, students, teachers and adults. All these reports highlight the complexity of the development of some scientific concepts but one realizes that there is not enough study on students' misconceptions especially on electrical potential, Gauss' law and capacitors.

In the light of studies and the ideas aforementioned above, following research questions were formed:

1. What are the understanding levels of university students on some electricity sub-topics?
2. What are the misconceptions of university students on some electricity sub-topics?

II. METHOD

A. Research Model

This study is a qualitative research, in which data were collected by Electricity Concept Test **(ECT)** to determine university students' understanding levels and misconceptions.

B. Participants

The ECT was employed to 177 undergraduate students from different departments (106 Physics Education, 35 Elementary Science Education, 24 Elementary Mathematics Education, 12 Computer and Technology Education) studying electricity in General Physics Course in Education Faculty of Buca at Dokuz Eylül University.

Electricity is an imported subject of General Physics Courses, taken during the second semester for Physics and Elementary Science Education Departments and taken during the fourth semester for Elementary Mathematics and Computer and Technology Education Departments at Dokuz Eylül University. It should be pointed out that these students had previously been taught the topics of this research.

C. Electricity Concept Test (ECT)

ECT includes a problem case and relating questions for every sub-topic. A total number of 23 two-tier questions and explanation part were employed to find out understanding levels and common misconceptions. Table I shows the test items diversity to the sub-topics.

TABLE I. Test items diversity to the sub-topics

Items	*Sub-Topics*
1,2	Electrical force
3,4,5	Motion in an electric field
6,7,8	Conductors and insulator in an electric field
9,10,11	Charge transfer
12,13,14	Work between equipotential lines
15,16,17	Charging and discharging in a DC circuit
18,19,20	Current in a DC circuit
21,22,23	Charging and discharging of a capacitor

KR-20 reliability coefficient of ECT is determined as 0.73. Item discrimination index ranges from 0.24 to 0.59 and item difficulty index ranges from 0.08 to 0.88.

In the first tier there are four choices for every question. Only one of the choices is correct and the distracters are selected from the related literature about students' conceptions, and explanations. In the second tier, students wrote their reasons for their choices. The participants were asked to write their explanation as fully as possible.

D. Data Analysis

Answering percentages of the choices for every question were analyzed. In the analysis the letters A, B, C and D are coded for possible answers and the letter E is used for coding empty choices. To assess students' explanations in the ECT, a four-item criterion for understanding level is used as follows:

1. Correct Explanation (CE): Responses that include all components of the scientifically accepted ideas.
2. Wrong Explanation (WE): Students' explanations that were not scientifically accepted rank in this category.
3. Uncodable Explanation (UE): This category includes explanations that are not matched category A and B, in other words explanations that are unclear.
4. No Explanation (NE): If students do not write any explanation supporting their choice or if they repeat the choice, their explanations match this criterion.

III. RESULTS AND DISCUSSION

The responses of the students to the ECT are presented by giving the answering percentages and explanation percentages individually. In the table, the correct choices and explanations were given in bold face.

The first two questions of the test deal with students' understanding on electrical force and distribution of the answers are shown in Table II.

TABLE II. Percentages of the choices and explanations for the questions 1 and 2.

Item No	*Choices (%)* *A*	*B*	*C*	*D*	*E*	*Explanations (%)* *CE*	*WE*	*UE*	*NE*
1	10	3	**87**	0	0	**84**	15	1	0
2	16	**63**	20	0	1	**60**	34	3	3

According to analysis of the first question, it was found that the students were aware of that two charged particles exert equal forces on each other. The analysis of the second question, on the other hand, clearly showed confusion on interpreting Newtonian Laws in an electric field. The two alternative conceptions of students were like these: *The body having a larger charge exerts bigger force (N=15)* and *two particles having equal force exerting on each other would move with a same speed even their masses are different (N=34).* However other students did consider the mass of the particles and gave scientifically accepted explanations by using 'Coulomb's Force is equal to the Newton's force: $F = k\frac{q_1 q_2}{r^r} = ma$.

The aim of the questions 3, 4 and 5 was to determine students' understanding of charged particles in a uniform electric field. The students' responses to these questions are shown Table III.

TABLE III. Percentages of the choices and explanations for the questions 3, 4 and 5.

Item No	*Choices (%)* *A*	*B*	*C*	*D*	*E*	*Explanations (%)* *CE*	*WE*	*UE*	*NE*
3	2	2	2	**93**	1	**83**	5	8	4
4	**79**	7	3	9	2	**75**	12	6	7
5	22	18	2	**53**	5	**34**	41	14	11

The analysis of the students' answers indicates that they know any charged static particle would move in an electric field. The majority of the students also know that positive charges move in the direction of electric field and negative charges move in the opposite direction of the field (N=133). The other point, here is to be told that majority of the students seem to be knowing the charged particle motion in a field but only few of them mention the force concept and use '*F=qE*' (*N=14*). Itza-Ortiz, Rebello and Zollman [32] wanted students to describe the motion of the charged sphere moving with a constant speed in a uniform electric field if magnitude of electric field and charge of sphere is doubled. They found that electric field contexts were not frequently related to the use of Newton's law, students did use the Newtonian model, when appropriate, if they recalled basic principles and similar to our result, a few of the students used the equation '*F = qE*' and drew arrows before responding but all students answered that the force is proportional to the magnitude of the charge and that of the electric field [32]. The other alternative conceptions, seen in explanations of questions 3, 4 and 5, are that *any charged particle independent of the charge polarity moves in the direction of the electric field (N=15)*, *charged particles in a uniform electric field move with a constant velocity (N=29), particles moving in the opposite direction of the field always slow down (N=31)* and lastly, *only charged particles on the electric field line is effected by electric filed (N=5).* Similar to the last alternative conception, the view "*there is no force acting on the charge because there is no line passing through it"* is also pointed out by Pocovi [20, 21]. It is known that students have alternative concepts and reasoning models concerning the electric field lines as an essential presentation of the electric field [24].

The next problem case is designed to investigate students' understanding on what happens when conductors and insulators inserted in a uniform electric filed by questions 6, 7 and 8 presented in Table IV. One immediately sees that very few students have correct conceptual understanding of internal electrical field of neutral conductors and insulators inserted in an electric field.

TABLE IV. Percentages of the choices and explanations for the questions 6, 7 and 8.

Item No	*Choices (%)* *A*	*B*	*C*	*D*	*E*	*Explanations (%)* *CE*	*WE*	*UE*	*NE*
6	33	30	13	**19**	5	**17**	55	12	16
7	**15**	8	12	60	5	**9**	50	19	22
8	36	15	24	**21**	4	**9**	61	12	18

Most of the students seem to be known that an internal polarization and consequently opposite and equal internal electric field occurs, nevertheless none of them mentions the reality that over all electric field must be zero. Students also express that *a neutral insulator put in an electric field would cause any charge movement so current consequently electric field cannot penetrate inside the insulator* (*N=37*). The other important point here is that the students seem to be confusing the concept of electric field and the current. They assume *no free charge so no electrical current means no electrical field inside the insulators*. As noted by Viennot and Rainson [25], the students fail to explain the fields inside an insulator for two reasons: the insulator is said to prevent the electric field 'traveling' through the media and that the electric field cannot exist if the charges inside the insulator do not move.

The questions 9, 10 and 11 deal with understanding of students on grounding. Almost all of the students accept that charged bodies loose their charge and become neutral by grounding the body (Table V).

TABLE V. Percentages of the choices and explanations for the questions 9, 10 and 11.

Item No	*Choices (%)*					*Explanations (%)*			
	A	*B*	*C*	*D*	*E*	*CE*	*WE*	*UE*	*NE*
9	6	**93**	0	0	1	**84**	2	6	8
10	**95**	1	1	1	2	**79**	2	6	13
11	2	4	21	**64**	9	**53**	13	15	19

The other point ought to be expressed is that the students have some difficulties to relating induced electricity to the grounding. They always consider *any grounded body would be neutral without considering the induced electricity.*

Questions 13, 14 and 15 are designed to investigate students' understanding on work and electrical potential energy.

TABLE VI. Percentages of the choices and explanations for the questions 12, 13 and 14.

Item No	*Choices (%)*					*Explanations (%)*			
	A	*B*	*C*	*D*	*E*	*CE*	*WE*	*UE*	*NE*
12	22	3	**65**	2	8	**50**	23	12	15
13	4	**88**	1	6	7	**63**	9	13	15
14	6	10	**70**	6	8	**64**	11	5	20

Majority of the students have the knowledge that charged particles create have equal potential surfaces on which charged the particle can be move without any work, on the other hand in order to move any charged particle from one to other equipotential surface would need work to be done. Some students express that the electric field on any equipotential surface is constant therefore charge movement on these surfaces can be achieved without exerting any force on the particle. That means no work is done. Some students have alternative conception that *the larger the path on the surface, the bigger the work is needed (N=10).* This conception is based on information '$W=F.\Delta x$' that learned in Newtonian mechanics. The larger the distance separation is the larger the work to be done, ignoring the change in potential. This type of conception is also determined by Maloney [34].

The questions 15, 16 and 17 examine students' understanding of charging two metallic plates (charging of capacitors). The results of these questions are given in table VII.

TABLE VII. Percentages of the choices and explanations for the questions 15, 16 and 17.

Item No	*Choices (%)*					*Explanations (%)*			
	A	*B*	*C*	*D*	*E*	*CE*	*WE*	*UE*	*NE*
15	**81**	10	1	7	1	**57**	14	12	17
16	25	6	2	**61**	6	**53**	22	9	16
17	25	**54**	10	7	4	**49**	28	5	18

The first point should be made is that some students believe that inserting an insulator between two conducting parallel plates prevents any current going through the circuit therefore the plates have no charge (*N=10*). The other point is that about half of the students have clear difficulties of understanding capacitor effects and capacitance. The main conceptual misunderstanding is that *inserting an insulator between two conductor parallel plates reduces capacitance of the system due to preventing charge transfer from one plate to another so preventing the actual electrical current*. In their study, Thacker, Ganiel and Boy asked students to explain the source of the charges on the capacitor plates. The most common incorrect statement in that study was that the charges only originate in the battery [31]. Apparently the roles of the conductor and the battery need to be given more attention during instruction.

This problem case is structured to explore students' understanding of closed and open circuits; also current going through a serial circuit by means of questions 18, 19, and 20 (Table VIII).

TABLE VIII Percentages of the choices and explanations for the questions18, 19 and 20.

Item No	*Choices (%)*					*Explanations (%)*			
	A	*B*	*C*	*D*	*E*	*CE*	*WE*	*UE*	*NE*
18	4	3	1	**92**	0	**80**	8	4	8
19	25	**40**	30	1	4	**30**	51	4	15
20	44	**40**	12	1	3	**23**	58	3	16

Most of the students know what the open circuit means but a few students think that the *current exist in a serial circuit till the broken end (N=11).* The main alternative conception relating this situation is the relation between resistance and the cross sectional area of any resistor. They believe in opposite of scientific reality that *the larger the cross sectional area, the larger the resistance (N=40)*. The other important alternative conception is that *considering two resistors in a serial circuit, the larger resistor has the lower current (N=63).*

The questions of 21, 22 and 23 are designed to investigate students' understanding on current during the charging and discharging of the capacitor.

TABLE IX. Percentages of the choices and explanations for the questions 21, 22 and 23.

Item No	*Choices (%)*					*Explanations (%)*			
	A	*B*	*C*	*D*	*E*	*CE*	*WE*	*UE*	*NE*
21	20	6	**42**	70	2	**30**	50	4	16
22	3	3	47	**37**	5	**25**	44	8	23
23	4	5	**78**	9	4	**75**	2	6	17

Some of the students believe that *there would be no current in a capacitor containing circuit until the capacitor is fully charged (N=30)*. This is because of *empty plates in a capacitor must be fully charged first and then they allow the current to pass (N=40).* Some students interestingly write that *the lamp before the capacitor eliminates but the lamp in the other half of the circuit cannot eliminate* (*N=31*). The students think that the plate connect to the positive terminal of the battery is charged first therefore the current exist here. The other plate of the capacitor cannot be charged until the first plated is fully charged. So there would be no current in the other half of the circuit. The other misconception is the belief that *any charged capacitor can be considered as the battery.* Similar like these alternative conceptions, the most common misunderstanding that was determined about a basic RC circuit was the order of the elements mattered: the capacitor filled with charge flowing through one part of the circuit only [31].

IV. CONCLUSIONS

This research is carried out on eight selected sub-topics of electricity, based on our teaching experience and relating literature, namely electrical force, motion in an electric field, conductors and insulator in an electric field, charge transfer, work between equipotential lines, charging and discharging in a DC circuit, current in a DC circuit, and finally charging and discharging of a capacitor. The study intends to illuminate some important conceptual problems some of which are well known within the literature and some of which are detected through the present work. The misconceptions that are not come across in the literature and detected in this study are summarized below.

- The body having a larger charge exerts bigger force
- Two particles having equal force exerting on each other would move with a same speed even their masses are different
- Any charged particle independent of the charge polarity moves in the direction of the electric field
- Charged particles in a uniform electric field move with a constant velocity
- Particles moving in the opposite direction of the field always slow down
- The larger the cross sectional area of a resistance, the larger the resistance
- Considering two resistors in a serial circuit, the larger resistor has the lower current

Finally the conclusions of the work illuminate students, teachers and in general educators. The data of the present work is detected by only means of Electricity Concept Test. Hence the present work can be enriched by employing different data collection techniques, namely face to face interview and inner classroom observation.

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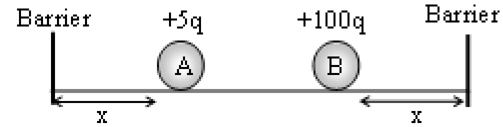
APPENDIX. Electricity Concept Test (ECT)

Information for Q1 and Q2. Two objects have the same mass and placed with the same distance to the barriers. The object A has a charge of +5C and the object B has charge of +100C.



Q1. If the objects A and B are released at the same time, which one hits the barrier first?

A) Object A hits the barrier first.
B) Object B hits the barrier first.
C) They hit the barrier at the same time.
D) They do not move at all.

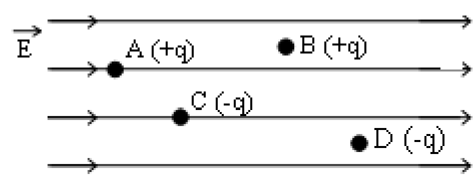
Justify your answer:……………………………….………

Q2. If only the mass of the object A is doubled then which one hits the barrier first?

A) Object A hits the barrier first.
B) Object B hits the barrier first.
C) They hit the barrier at the same time.
D) They do not move at all.

Justify your answer:………………………………………

Information for Q3, Q4 and Q5: Consider the objects A and B with charge of +q and the object C and D with charge of –q are placed in a uniform electric field as shown in the figure below. Suppose that all the objects have the same mass and the electrical interaction between the particles is negligible.



Q3. Which one of the following is relating to the motion of the objects after they are freed?

A) The objects A and B start to move but the objects C and D standstill.
B) The objects A and B standstill but the objects C and D start to move.
C) The objects A and C start to move but the objects B and D standstill.
D) All of the objects start to move.

Justify your answer:………………………………………

Q4. Which one is correct relating to the direction of the objects in motion?

A) The objects A and B move in the same direction with the electric field, the objects C and D move in the opposite direction with the electric field.

B) The objects A and B stand still, the objects C and D move in the opposite direction with the electric field.
C) The object A moves in the same direction with the electric field, the object C moves in the opposite direction with the electric field and the objects B and D stand still.
D) All of the objects move in same direction with the electric field.

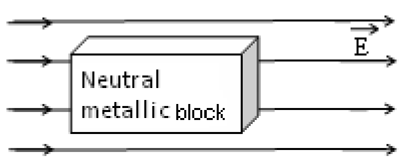
Justify your answer:………………………………………

Q5. If all the objects are released, which one is correct relating to the motion process?

A) The objects A and B accelerate but the objects C and D standstill.
B) All the objects in motion move with constant speed.
C) The objects C and D accelerate but the objects A and B standstill.
D) All the objects in motion accelerate.

Justify your answer:………………………………………

Information for Q6, Q7 and Q8. A neutral metallic block is placed in a uniform external electric field represented with field lines as shown in the diagram below.



Q6. Which one is correct relating to the internal electric field of the block?

A) Internal electric field has the same the magnitude and direction with the external one.
B) Internal electric field has the same direction but smaller than the external one.
C) Internal electric field has the opposite direction and smaller than the external one.
D) No internal electric field exists in the block.

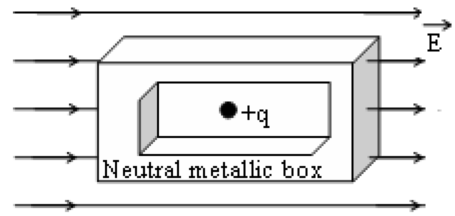
Justify your answer:………………………………………

Q7. If an insulator block is placed instead of metallic one, which one is correct relating to internal electric field of the block?

A) Internal electric field has the same the magnitude and direction with the external one.
B) Internal electric field has the same direction but smaller than the external one.
C) Internal electric field has the opposite direction and smaller than the external one.
D) No internal electric field exists in the block.

Justify your answer:………………………………………

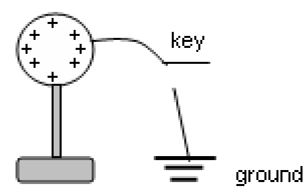
Q8. A neutral metallic box with a positive particle inside it is placed in a uniform electric field as shown in the figure below. Which one is correct relating to the motion of the particle? (Suppose that gravity is negligible.)



A) Particle accelerates in the same direction with the external electric field.
B) Particle moves with a constant speed in the same direction with the external electric field.
C) Particle accelerates in the opposite direction with the external electric field.
D) Particle standstill.

Justify your answer:………………………………………

Information for Q9, Q10 and Q11: A conducting sphere with a charge of +Q is placed on an insulating rod and is connected to the ground with a conducting wire attached to a key that is open.



Q9. If the key is closed, which one is correct relating to the charge of the sphere?

A) All the positive charges on the sphere go to the ground and the sphere finally becomes neutral.
B) Negative charges go the sphere from the ground and the sphere finally becomes neutral.
C) Some amount of negative charge goes the sphere from the ground but the sphere is still charged positively.
D) There will be no charge transfer so the charge of the sphere is same.

Justify your answer:………………………………………

Q10. If the sphere is replaced with a conducting sphere having a charge of –Q, which one is correct relating to the charge of the sphere when the key is closed?

A) Negative charges on the sphere go to the ground and the sphere finally becomes neutral.
B) Positive charges go the sphere from the ground and sphere finally becomes neutral.

C) Some amounts of negative charge go the sphere from the ground and sphere is still negatively charged.
D) There will be no charge transfer.

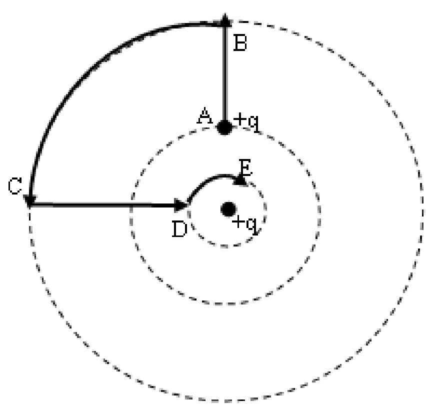
Justify your answer:………………………………………

Q11. When the key is open, a positively charged rod bring closer to the positively charged sphere from the left hand side. As the rod is hold as it is the key is closed and opened for a minute. Which one is correct relating to the final charge of the sphere?

A) Positive charges move to the ground and the sphere is finally neutral.
B) Some amount of positive charge move the ground from the sphere and the sphere has a final positive charge.
C) Negative charges move to the sphere from the ground and the sphere finally becomes neutral.
D) Negative charges move to the sphere from the ground and the sphere finally becomes negatively charged.

Justify your answer:………………………………………

Information for Q12, Q13 and Q14. An object having a charge of +q is fixed to a point and the equipotential lines are represented with dotted lines as shown in the figure. Another charge of +q is moved along the path of ABCDE. (Suppose that gravity is negligible.)



Q12. Along which path, electrical potential energy of the moving particle increases?

A) Only in the path from A to B
B) Only in the path from B to C
C) Only in the path from C to D
D) Only in the path from D to E

Justify your answer:………………………………………

Q13. In which path or paths, an electrical work is done?

A) In the paths from A to B and C to D
B) In the paths from B to C and D to E
C) In all paths.
D) No work is done in any path.

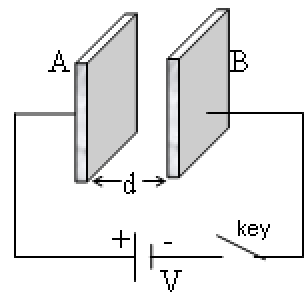
Justify your answer:………………………………………

Q14. In which path the maximum work is done?

A) In the path from A to B
B) In the path from B to C
C) In the path from C to D
D) In the path from D to E

Justify your answer:………………………………………

Information for Q15, Q16 and Q17. A parallel plate capacitor is formed by using the identical metallic plates A and B. The distance between the plates is d and the space between the plates is empty. The capacitor is connected to a battery by means of a key.



Q15. Which one is correct relating to the amount of charge on the plates when the key is closed?

A) Plate A has a positive charge and plate B has the same amount of negative charge.
B) Plate A has a negative charge and plate B has the same amount of positive charge.
C) Only plate B is charged negatively.
D) None of the plates is charged.

Justify your answer:………………………………………

Q16. What happens if the free space between the plates A and B is filled with a conducting matter when the key is closed?

A) Plate A has a positive charge and plate B has the same amount of negative charge.
B) Plate A has a negative charge and plate B has the same amount of positive charge.
C) Only plate B is charged negatively.
D) None of the plates is charged.

Justify your answer:………………………………………

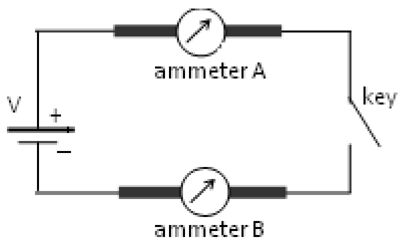
Q17. The key is closed a long time to fully charge the plates then the key is opened and a dielectric block is replaced between the plates. Which one is correct relating to the capacitance?

A) Capacitance decreases to a certain level.
B) Capacitance increases.

C) Capacitance does not change
D) Capacitance decreases to zero.

Justify your answer:………………………………………

Information for Q18, Q19 and Q20. A circuit is formed by using two conducting wires having equal cross sectional area and length, a battery, a key and two ammeters as shown in the figure below.



Q18. If the key is open, which ammeter measures a current?

A) Only A
B) Only B
C) A and B
D) None

Justify your answer:………………………………………

Q19. Which one is correct relating to the currents I_A and I_B, measured by ammeters A and B respectively when the cross sectional area of the wire A is replaced with the thinner one?

A) $I_A < I_B$
B) $I_A = I_B \neq 0$
C) $I_A > I_B$
D) $I_A = I_B = 0$

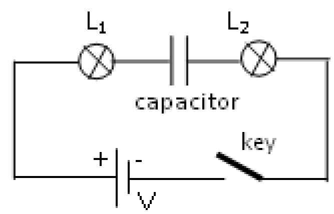
Justify your answer:………………………………………

Q20. Which one is correct relating to the currents I_A and I_B, measured by ammeters A and B respectively when the temperature of the only wire A is increased?

A) $I_A < I_B$
B) $I_A = I_B \neq 0$
C) $I_A > I_B$
D) $I_A = I_B = 0$

Justify your answer:………………………………………

Information for Q21, Q22 and Q23. The circuit as shown below is formed by using two identical lambs, L_1 and L_2, a capacitor, a key and a battery of that internal resistance is negligible.



Q21. Which lambs shine at the moment that the key is closed?

A) Only lamb L_1.
B) Only lamb L_2.
C) Lamb L_1 and L_2.
D) None.

Justify your answer:………………………………………

Q22. After the key is closed and the capacitor is fully charged which lambs shine?

A) Only lamb L_1.
B) Only lamb L_2.
C) Lamb L_1 and L_2 .
D) None.

Justify your answer:………………………………………

Q23. After the capacitor is fully charged the battery is moved from the circuit and the circuit is reconnected with a wire. When key is closed, which lambs shine?

A) Only lamb L_1.
B) Only lamb L_2.
C) L_1 and L_2.
D) None.

Justify your answer:………………………………………