Journal of Turkish Science Education, 2022, *19*(4), 1119-1134.
DOI no: 10.36681/tused.2022.165

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

Blended Learning and Simulation for Teaching Electrical Concepts to High School Pupils

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ABSTRACT
Teaching physical science has been challenging for educators for quite some time, and with the Covid-19 pandemic, the situation has even worsened which made the adoption of blended learning in the different cycles of education only a matter of time. This paradigm requires nevertheless a certain command when it comes to using some specific tools dedicated to the simulation of some physical science knowledge laboratories. The objective of this research is to study the effect of integrating the "Simulation Program with Integrated Circuit Emphasis" simulator tool in a blended learning environment on the conceptual learning of electricity. To achieve this goal, we adopted a quantitative methodology to assess the outcome of the experience which involved 40 pupils. The experimental group teacher used blended learning and integrated the simulation to teach the electricity module. The same teacher adopted traditional teaching with the control group (40 pupils). The instrument used is a test instrument in the form of a quiz which consists of 20 questions. All questions were in the form of multiple-choice questions to facilitate a more efficient analysis. The results of this research report the positive effects of integrating simulation into a blended learning environment with a statistically significant difference. Moreover, the experiment shows that 90 per cent of the pupils in the experimental group passed the test, as opposed to 75 per cent of the control group.

RESEARCH ARTICLE

ARTICLE INFORMATION
Received: 03.03.2022
Accepted: 09.03.2022

KEYWORDS:
Blended learning, electricity, physics education, simulation.

To cite this article: Chekour, M., Seghroucheni, Y.Z., Tadlaoui, M.A., & Hafid, M. M. (2022). Blended learning and simulation for teaching electrical concepts to high school pupils. *Journal of Turkish Science Education, 19*(4), 1119-1134.

Introduction

COVID-19 amplifies the difficulties that pupils are already facing to receive a quality education (Sumardi & Nugrahani, 2021). Even before this pandemic, there were already 258 million out-of-school children worldwide, mainly due to poverty, poor governance or living or fleeing from an emergency or conflict (Hut et al., 2020). Although there are programs to end the current education crisis around the world, the dramatic escalation due to the new coronavirus shift the worldwide education strategy towards a more flexible educational approach (Tadlaoui & Chekour, 2021). Blended learning has generated remarkable interest in educational research. This interest is being studied more and more in COVID-19 times (Olatunji & Adewumi, 2021). The blended learning method combines learning in the classroom and distance learning (Dridi et al., 2020). The philosophy of this teaching method is quite simple as it tries to take advantage of the strengths of the two teaching modes: face-to-face and distance learning (Tadlaoui & Chekour, 2021). Thus, Blended learning can encourage the independence of learners in facilitating learning. Another study concludes that mobile technology has the potential to increase accessibility and communication in a blended learning course (Bosch et al., 2019). However, the implementation of blended learning is not mature enough and poses real problems in the scripting of the educational content to be taught (Bayyat, 2020). Also, blended learning must take into account the nature of the topic taught. Admittedly, practical activities take a central place in the process of learning physics. However, the big problem of teaching physics and especially electricity in the Covid era is the absence of practical activities. These can be replaced by using simulations (Sasmito & Sekarsari, 2022). The simulator used in a blended learning environment should be easy enough to handle so as not to generate problems in learners' learning process. On the contrary, it must make learning physical phenomena easier and more pleasant. The main aim of this research is to study the effect of integrating the PSPICE (Simulation Program with Integrated Circuit Emphasis) simulator in a blended learning environment on the learning of electrical concepts in Moroccan high school pupils. Studies highlight the importance of integrating blended learning into the process of learning electrical concepts among Moroccan high school pupils (Bukit, 2020; Sales et al., 2022; Zamroni et al., 2020). Also, the integration of the PSPICE simulator with the inquiry process has a positive effect on the performance of learners and the combination of physical and virtual manipulation enhances learner engagement in their learning processes (Uğur et al., 2020). The innovative aspect of this research lies in questioning the impact of the PSPICE simulator combination in a blended learning-based environment.

Conceptual Framework of Study

The Added Value of Blended Learning for Teaching Physical Sciences

The philosophy of blended learning is quite simple: it aims to combine online platforms with traditional classrooms (Snyman & Kasirye, 2021; Swartz et al., 2018). Blended learning provides more learning opportunities that motivate pupils to participate inside and outside the classroom (Bosch et al., 2019). Blended learning can also be used as alternative learning for teachers to support pupils learning progress (Tadlaoui & Chekour, 2021). Another research concludes that blended learning based on problem-based learning is effective in improving the critical thinking skills of learners (Taylor et al., 2019). However, to apply this mode of teaching, teachers must develop their levels of computer skills (Bosch et al., 2019). Researchers conclude that there is a positive effect of integrating blended learning on critical thinking skills in the learning of physical concepts (ElSayary, 2021). Also, blended learning aims to facilitate learning and develop students' knowledge through meaningful interactions (Sales et al., 2022). Certainly, education systems need to prepare as the use of online learning platforms has become increasingly dictated by the dominance of educational technologies in an increasingly connected world (Adi et al., 2021). Other research shows blended learning did not significantly affect student achievement test scores, but did significantly affect their self-report scores (Chang et al., 2014). Therefore, real development in blended learning requires a revolution in educational approaches (Chekour et al., 2018) as well as online part of courses should require mandatory synchronous participation (Tadlaoui & Chekour, 2021).

Impact of the PSPICE Simulator to Teach Electricity to High School Pupils

In the literature, there are several definitions of computer simulation. These definitions show sometimes complementary visions but are quite different (Ambusaidi et al., 2018). According to the same researchers, the best definition of simulation is given by Purcell and Jones: A simulation is a reality of function in a simulated and structured environment. In scientific disciplines, the computer was used very early on because of the computational capacities it offers. The speed of computer offers a new opportunity to check the job hypotheses. By simulating the results of a theory, one can quickly assess its validity and progress much faster in the process of developing that theory. This approach consists of progressing in the understanding of a real phenomenon by proposing a digital model. In this way, we can compare the results produced by a simulation of this model and the results of the phenomena studied in the real world (Chekour, 2018). Educators stress the importance of the integration of simulation to facilitate the cognitive task of learners and to provide quality education in physical sciences and particularly in electricity (De Jong et al., 2013). Indeed, simulation makes it possible to simplify the real systems studied (Arnold & Wade, 2017). Also, the simulation is flexible and adapts to the learning style of the pupils (Perez & Poole, 2019). In certain situations, simulation is presented as a "unique" didactic tool to overcome the problems generated by experiments which require long, dangerous or expensive manipulations (Chekour et al., 2015). In addition, simulation allows for virtual experiments by giving pupils the opportunity to interact with the simulation software (Shih & Kuo, 2021). The results of another study show that the use of simulation can serve to enhance students' achievement (Marczynski et al., 2022). Also, the simulations can also be used as a complementary tool in the laboratory (De Jong et al., 2013). Indeed, the combination of simulations and laboratory experimentation saves time by reducing the duration of the laboratory session (De Jong et al., 2013) and also helps to support reasoning based on student models (Develaki, 2017).

The Choice of Pedagogical Approaches for Effective Teaching of Electricity

Physics focuses on natural phenomena and its learning process requires understanding concepts and critical thinking (Kotluk & Kocakaya, 2016). However, due to abstract phenomena, learners generally find learning physics unpleasant (Mellu & Baok, 2020). Other researchers claim that traditional teaching methods and the lack of experimental activities are responsible for the birth of misconceptions among learners (Chekour, 2018). Misconceptions occur in most areas of physics. There have been 300 studies on mechanics, 159 studies on electricity and 70 studies on misconceptions about heat, optics, and materials. Students' misconceptions cannot be dispelled but corrected so that they are not mistaken (Mellu & Baok, 2020). In the literature, there are several pedagogical approaches to teaching electricity. However, there is no one-sided approach to the didactics of the physical sciences and electricity. Time for teachers to develop teaching methods for such pupils is scarce (Chekour et al., 2018). Therefore, teachers of physical sciences are encouraged to choose the appropriate teaching approaches according to the performance and limitations of each approach to facilitate the acquisition of physical phenomena. In the review article, researchers recommend combining the PSPCE simulator with the historical inquiry approach to teach electricity to high school pupils (Chekour et al., 2018). To help physical science teachers to operationalize this combination of technology (simulation) and pedagogy (historical investigation), a detailed pedagogical scenario has been proposed to achieve this goal (Chekour et al., 2018). In the first phase of the proposed scenario, the teacher asks a question to trigger a scientific debate. The debate is moderated to identify a scientific problem that can be solved by the pupils. After identifying the problem, the teacher encourages the learners to suggest hypotheses. Each hypothesis must be accepted by the scientific micro committee: the class. After formulating the hypothesis, the class comes up with the most appropriate virtual experiment to test the hypothesis. Then the class begins to analyze, discuss, and interpret the results. The class checks whether the hypothesis has been confirmed or invalidated and whether the initial problem has been solved.

In this paper, we will focus on electricity: one of the most important branches of physical science. Studies show that electrical circuits are rarely mastered by high school pupils (Ponto, 2020) and they encounter many difficulties in acquiring the concepts of electric current and voltage (Chekour et al., 2018). Analysis of their reasoning shows that they have retained naive representations of the notions of intensity and tension despite formal education (Halim et al., 2019). The existence of multiple currents in a circuit, the degradation of the current in a circuit, and the analysis of each electrical circuit element in terms of before and after (sequential reasoning) are just examples of such misconceptions (Chekour et al., 2018).

In the literature, several studies conclude that the environment provided by blended learning has a positive effect on the performance of physical science learners (Bukit, 2020; Lane et al., 2021; Suana et al., 2020). Also, the integration of simulation into physical science courses is recommended by many researchers (Park, 2019). However, the combination of blended learning and simulation in the teaching of electricity is little studied in the literature (Adeyele & Aladejana, 2022). The present research aims to bridge this gap. Indeed, the objective of this research is to study the effect of the use of the PSPICE simulator in a blended learning environment on the learning of electricity for Moroccan high school pupils.

Methods

Research Design

Our research aims at Moroccan high school pupils in the physical sciences section. To achieve the objectives of this research, a test was given to eighty pupils. To achieve the objectives of this research, we adopted a quantitative methodology based on the comparison of the performance of pupils in the experimental group (the first class) and a control group (the second class) following a test at the end of the session. We randomly chose two high school classes qualifying. Moreover, the answers are comparable: the same questions are asked in the same terms to each respondent. We chose multiple choice questions to facilitate the process of the data analysis. To make the questionnaire usable, we submitted the draft questionnaires to the physical science teachers. Their recommendations were taken into consideration.

Participants

A total of 80 high school pupils aged between 17 and 19 voluntarily participated in this experiment. Each participant was randomly and individually assigned to the experimental conditions. The overall duration of the experiment was four months.

The participants were grouped into two groups: An experimental group and a control group. Each group consists of forty pupils.

Instruments and Procedures

The physics teacher in the experimental group integrates the PSPICE simulator to teach the electricity module. Blended learning is the mode of learning of this experimental group. The same teacher adopts traditional teaching with the control group: face-to-face and without recourse to the use of simulation in the teaching of electricity. A test consisting of 20 questions was carried out to verify that the educational objectives of the course were met. The twenty questions have the same weight (see the appendix). In the cognitive domain, Bloom's taxonomy is used to classify these educational objectives according to the level of thinking in the learning processes (Tarman & Kuran, 2015). It is made up of six classes organized in a hierarchical framework. David Krathwohl's revision of Bloom's taxonomy retained the original number of classes (Krathwohl, 2002). However, the taxonomy has undergone significant changes (Talan & Gulsecen, 2019). Three categories have been renamed, the order of two has been swapped, and the selected category names have been changed to verbal form to match their use in objectives. To evaluate the cognitive performance of the pupils, the test of this research includes questions of the various levels of the taxonomy of the cognitive objectives of Bloom. In this research, we adopted the Bloom Taxonomy review performed by David Krathwohl (Krathwohl, 2002).

Data Analysis

In order to assess practical and theoretical knowledge, participants are asked to answer a test consisting of 20 multiple-choice questions (see the appendix for more details). Knowledge test results were aggregated using total scores. The descriptive results reveal that participants in the experimental group achieved higher overall scores in practical knowledge.

In the test of this research, we classified the questions into two categories. The first category focuses on the assessment of basic knowledge and skills: it is used to question the first three levels of Bloom's taxonomy "Remember-Understand-Apply" (see the appendix - theoretical part). The second category focuses on the assessment of cognitive skills at high levels which are "Analyze, Evaluate and Create" (see the appendix - practical part). For our test of this research, we programmed 10 questions for each category. Category 1 questions are theoretical in nature (it represents the three lower levels of Bloom's taxonomy) while Category 2 questions are practical in nature (it represents the superior levels of Bloom's taxonomy). The following table illustrates the characteristics of the two categories of test questions for this research.

Table 1

Characteristics of the two categories of test questions

Test		Bloom's taxonomy class	Description	Nature
10 questions for each Category	Category 1	To remember	To assess basic knowledge and skills	Theoretical
		Understand		
		Apply		
	Category 2	Analyze	To assess high-level cognitive skills	Practical
		Evaluate		
		Create		

The data collection required permission from school principals. As for the high school pupils, they were informed of the objectives and the progress of this research.

Findings

In this work, the integration of blended learning and simulation in the teaching of electricity follows the following scenario: The online portion of blended learning provides an opportunity for learners to delve deeper into the concepts studied in the classroom. It is an opportunity for the learner to become a real researcher who detects problems, formulates hypotheses and verifies their accuracy using simulation. The role of the teacher is important in this learning process. He/she monitors the progress of learning using the tools offered by the online learning platforms. In this way, the face-to-face course sessions will be more attractive since they will be an opportunity to present and discuss the results of the virtual experiments produced by the learners.

Comparison of the Results of the Control Group and the Experimental Group

To estimate the level of knowledge of the pupils in relation to the targeted skills, we used an evaluation through a test carried out at the end of the session for the target audience of the control group and the experimental group.

The results of this test are shown in table 2. We see that the experimental group has an average of 15.25. The latter is higher than the mean of the control group (13.40). This shows that there is a positive effect of integrating simulation in a blended learning environment on the learning of electrical concepts.

Table 2

Descriptive Test Results

Group	Mode of teaching	Average
Control group	Traditional	13.40
Experimental group	Blended Learning and Simulator	15.25

To further analyse the test results. We have classified pupils scores into six categories (see the following table)

Table 3

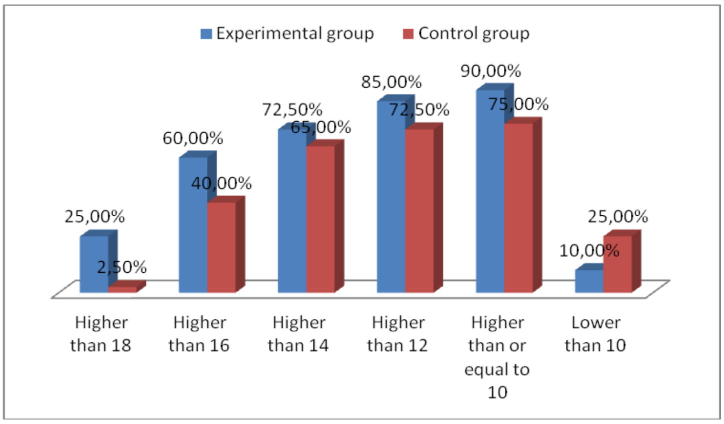
Description of the Six Levels

Level	Description
Level 1	Pupils who failed to achieve a GPA (Score <10)
Level 2	Pupils with a grade above 10
Level 3	Pupils with a grade above 12
Level 4	Pupils with a grade above 14
Level 5	Pupils with a grade above 16
Level 6	Pupils with a grade above 18

The following figure illustrates the percentage of the number of pupils classified into six categories:

Figure 1

Comparison of Test Scores for the Two Groups



Analysis of the results in Figure 1 shows that the experimental group performed higher in all six categories. Most of the pupils in the experimental group (90%) have a mark higher than 10. On the other hand, three quarters of the control group have a mark higher than 10. For the other categories, we see that there is a significant difference in favour of the experimental group.

Comparison of the results of the two groups according to the type of question (theoretical - practical)

To analyse in depth the results of our test. We divided the test questions into two parts. The first part concerns the theoretical capacities of the studied concepts. And the second part focuses on the practical skills of these concepts. The following two figures illustrate the percentage of learners (Experimental group and control) who provided the correct answer to the 20 questions.

Figure 2

Percentage of learners who provided the correct answer to theoretical questions

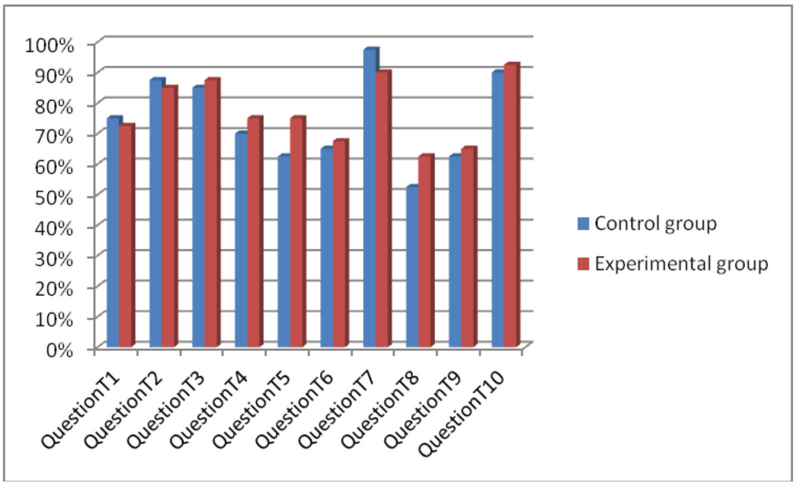
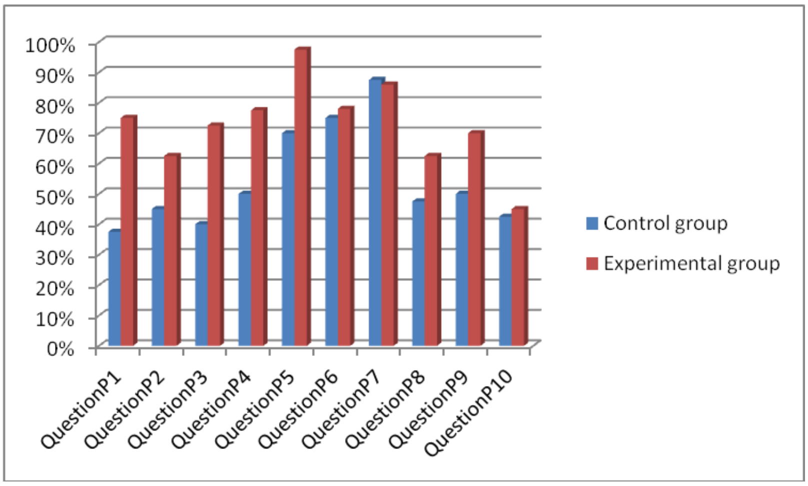


Figure 3

Percentage of Learners Who Provided the Correct Answer to the Practical Questions



Regarding the theoretical questions, the results are almost identical for the two groups. While for practical questions, there is a remarkable difference between the results of the experimental group and the control group. Indeed, if we exclude question number 7, the experimental group shows a stronger performance than the control group.

On the side of the two teachers who supervised their pupils during this mode of teaching based on simulation in a blended learning environment, they consider that the integration of PSPICE software has remarkably motivated their pupils and has enabled these pupils to build their knowledge by modifying the parameters of the simulation software and immediately view the results of their modifications. This explains the gap between the theoretical and practical capacities of the control group.

Discussion

Physics is an experimental discipline, and only observations can decide if a model is correct or not. The phenomena that can be visualized using a simulator can only be beneficial for learning this kind of discipline (Diez-Tejedor et al., 2018). Also, the simulation presents itself as a unique solution to do practical activities in a learning mode based on e-learning (Chekour, 2019). In the test of this research, the experimental group has an average of 15.25. The latter is higher than the mean of the control group (13.40). Also, the experimental group has shown much stronger performance compared to the control group. This is because the experimental group had the opportunity to work with the simulator. The latter offers this group the opportunity to carry out virtual experiences using the PSPICE simulator. This explains the deeper understanding of the concepts studied, which is in line with a recent study(Sasmito & Sekarsari, 2022). In short, the results of this research show that there is a positive effect of the integration of our mode of teaching based on simulation in a blended learning environment on the academic performance of the learners of the experimental group compared to the group of witnesses. This is in harmony with previous studies (Sales et al., 2022). Indeed, the integration of blended learning into the teaching of electrical concepts is a source of motivation for pupils (Fitriyana et al., 2021). Tasks performed online are beneficial and prepare pupils in an appropriate way to build their new knowledge. Also, the integration of the PSPICE simulator in the learning of concepts in electricity is an opportunity for the pupils to be active players in their learning. It offers these learners the opportunity to practice the experimental approach individually and collectively. It is for this reason that the experimental group demonstrates an advanced mastery of high-level skills and therefore shows more sophisticated performance than the control group.

Conclusion and Implications

Blended learning is becoming more and more trendy thanks in particular to the flexibility, a higher engagement rate of learners and the efficiency it offers (Jahjouh, 2014). There are many teaching models for learning (Mulyeni et al., 2019). The education and vocational training sector have benefited from many pioneers and the way learners acquire knowledge today is very different from a few decades ago. Much of this innovation is linked to the advent and development of technology. Computers have become extremely valuable teaching tools and have opened up a whole new world of online learning (Shatri, 2020). Strict and traditional learning approaches are gradually giving way to new technologies (Chekour, 2020). We can say based on the results we presented in this paper that blended learning is consistently better. Especially while teaching scientific subjects that need experiments and simulations to break down complex notions. While using this blended learning approach alongside simulation we have noticed with the results presented in this paper, that learner's score has increased in both the theoretical and practical sides of teaching electricity. Giving learners the possibility of studying at their own rhythm by using the blended approach has increased their learning capacities in the theoretical side of the subject. And using the simulation to explain the practical side of the subject made the average score of the learners in comparison to the results of the same learners while using the traditional approach. Although this approach could be considered effective for teaching scientific subjects, using the blended approach with simulations for teaching required both materials and training for teachers and pupils in using new technologies for education. We are willing to continue testing this approach with a larger-scale learner, especially in the university. To test and measure the effectiveness of the approach with the different subjects taught and with a different type of audience.

Recommendation

Research, based on other methodological approaches and other simulators, on the link between simulation and blended learning and school performance will be necessary, faced with the growing development of ICT in education. Such research would be useful for strengthening the results of this research.

Limitations

The main limit of this research is the sampling of the quantitative component which is not very representative given the massive number of Moroccan high school pupils. So, it would be important to carry out other research to reproduce this research based on a wider sample.

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Appendix

Part 1 : Theoretical test of electrical circuits

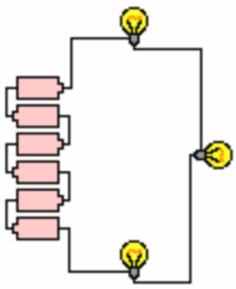
1. What is electricity?
   - ☐ power source
   - ☐ a form of energy
   - ☐ heat
   - ☐ None of the above
2. What is an electrical circuit?
   - ☐ lets you turn the energy on and off
   - ☐ stop electricity from flowing through
   - ☐ a closed path where electricity flows
   - ☐ None of the above
3. A material that does NOT allow electricity to flow is called _____.
   - ☐ a conductor
   - ☐ an insulator
   - ☐ a fuse
   - ☐ a transformer
4. A material which allows electrical current to pass through it is called
   - ☐ A connection
   - ☐ A conductor
   - ☐ A cell
   - ☐ An insulator
5. What is a battery?
   - ☐ Switch
   - ☐ power source
   - ☐ insulator
   - ☐ conductor
6. Besides cells, or batteries, what the other source of electrical power?
   - ☐ Electricity mains
   - ☐ Petrol
   - ☐ Motors
   - ☐ Lightbulbs
7. The potential difference between two points in a circuit is called __________.
   - ☐ Resistance
   - ☐ Current
   - ☐ voltage
   - ☐ None of the above
8. The measurement unit for voltage is the __________.
   - ☐ Amps
   - ☐ Volt
   - ☐ Joule
   - ☐ Newton
9. The intensity of electric field unit is :
   - ☐ Amps

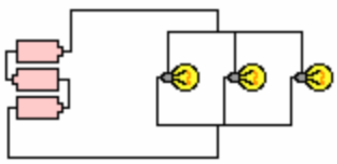
- ☐ Volt
- ☐ Joule
- ☐ Newton

10. Ohm's Law Equation is :
    - ☐ V = IR
    - ☐ V=I/R
    - ☐ I= V / R
    - ☐ I= VR

Part 2 : Practical test of electrical circuits

1. Why might a circuit fail to work?
    - ☐ It might have a dead battery
    - ☐ It might have a break in the circuit
    - ☐ It might have two leads connected to the positive pole of the battery and none connected to the negative
    - ☐ All of the above
2. A __________ is used to measure voltage between two points of a circuit
    - ☐ Ohmmeter
    - ☐ Voltmeter
    - ☐ Ammeter
    - ☐ Multimeter
3. An __________ is used to measure electric current
    - ☐ Ohmmeter
    - ☐ Voltmeter
    - ☐ Ammeter
    - ☐ Multimeter
4. A voltmeter should be connected to a component
    - ☐ in series
    - ☐ vertically
    - ☐ in parallel
    - ☐ horizontally
5. An ammeter should be connected to a circuit
    - ☐ in series
    - ☐ vertically
    - ☐ in parallel
    - ☐ horizontally
6. If we have several light bulbs connected to a battery in parallel...

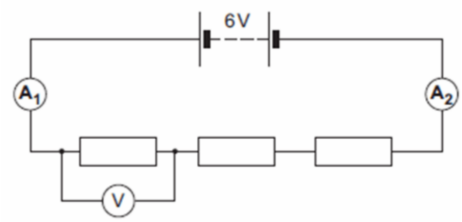


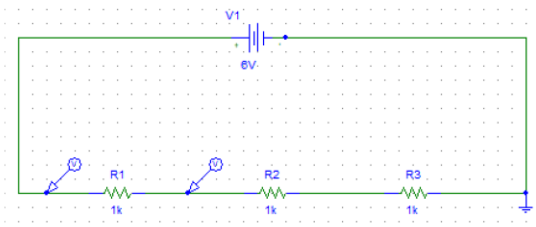


    - ☐ The voltage will be the same across each bulb

- ☐ The current will be the same through each bulb
- ☐ the current will be the same across each bulb
- ☐ The resistance will be the same across each bulb

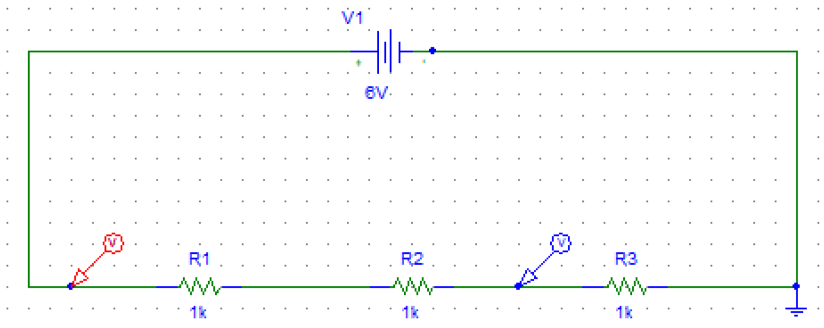
7. What would the voltmeter read?





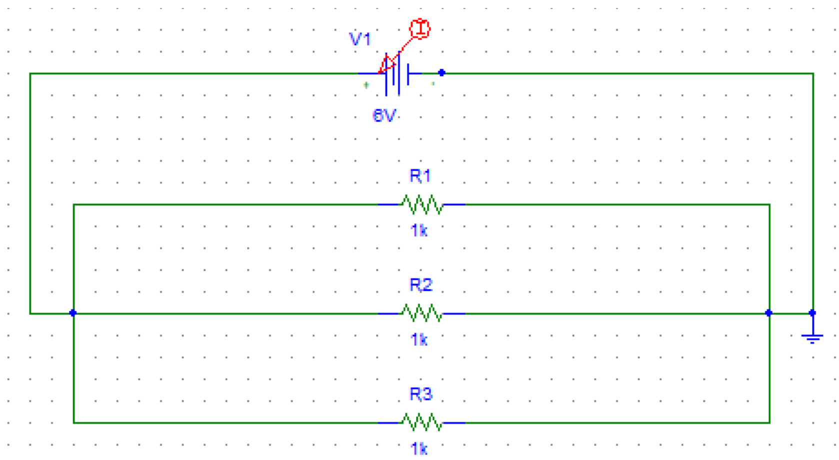
- ☐ 1 V
- ☐ 2 V
- ☐ 4 V
- ☐ 6 V

8. What would the voltmeter read?



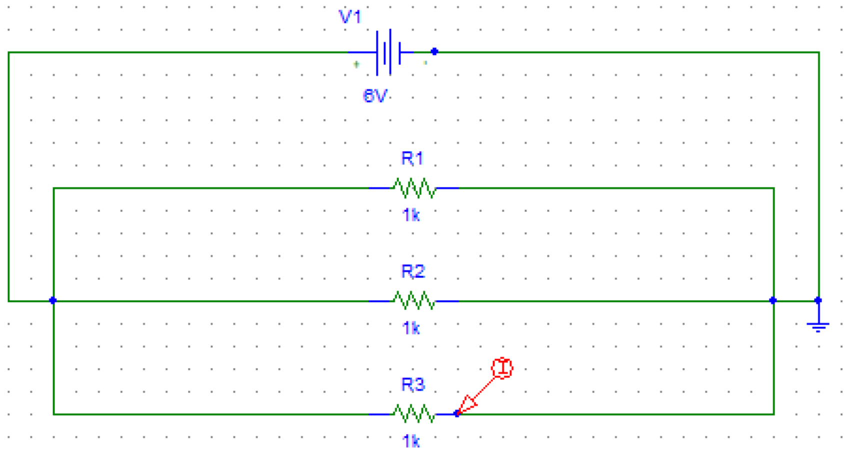
- ☐ 1 V
- ☐ 2 V
- ☐ 4 V
- ☐ 6 V

9. What would the ammeter read?



- ☐ 18 mA
- ☐ 12 mA
- ☐ 6 mA
- ☐ 1 mA

10. What would the ammeter read?



- ☐ 18 mA
- ☐ 12 mA
- ☐ 6 mA
- ☐ 1 mA