

Analysis of Series and Parallel Circuit Based on Virtual Simulation Using the PhET Simulation Application

Alvin Rahman¹, Ahmad Suhadi², Ibnu Jati Pramono³, Moh. Nafingudin⁴, Ade Ayu Parwati⁵, Lailatul Istianah⁶, Novita Ramadani⁷, Nurul Fitiriyah⁸, Siti Fatimah⁹

^{1,2,3,4,5,6,7,8,9} Author Info. (IAINU
Kebumen, Kebumen, Indonesia,
efaff123@gmail.com)
 ORCID: -

Corresponding Author:
Siti Fatimah, ¹Author Info.
(IAINU Kebumen, Kebumen,
Indonesia,
stfatimah@gmail.com)

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Abstract

PhET atau the Physics Education Technology sering disebut juga Laboratorium Virtual merupakan sebuah aplikasi atau website untuk memudahkan dalam mengeksplorasi konsep fisika ataupun matematika tanpa harus bereksperimen dalam laboratorium. Tujuan penelitian ini untuk mengevaluasi dampak penggunaan rangkaian seri-paralel serta menyajikan simulasi rangkaian seri-paralel PhET sebagai alat pendidikan yang powerful yang memanfaatkan visualisasi dan eksplorasi interaktif untuk memfasilitasi pengalaman belajar yang bermakna dalam pendidikan listrik dan elektronika. Metode penelitian yang digunakan adalah pengamatan serta percobaan langsung menggunakan aplikasi PhET. Hasil penelitian ini adalah pada rangkaian seri menunjukkan bahwa ketika nilai sumber tegangan listrik (V-total) semakin dinaikkan atau dibiarkan, maka nilai kuat arus listrik (I) akan naik pula dengan ketetapan nilai hambatan baik resistor 1 dan resistor 2 yaitu nilainya sama atau tetap. Pada rangkaian Paralel menunjukkan bahwa ketika nilai sumber tegangan listrik (V-total) semakin dinaikkan atau dibiarkan, maka nilai kuat arus listrik (I) akan naik pula dengan ketetapan nilai hambatan baik resistor 1 dan resistor 2 yaitu nilainya sama atau tetap, menyebabkan lampu semakin terang.

Introduction

The Physics Education Technology or PhET interactive simulation is a project developed by a team from the University of Colorado, USA in the form of an interactive Internet simulation using Java and Flash programming languages where integrating computer technology is applied to learning. This PhET Simulation contains a teaching understanding of the concepts of science subjects (biology, chemistry, and physics). The convenience offered in PhET Simulation is that it makes it easier to explore physics concepts without having to conduct laboratory experiments (Muna, Tandililing, & Oktavianty, 2023)

PhET interactive simulations are very interesting because they are more fun, easy and challenging. The use of PhET simulations can be carried out both *online* and *offline*. *Online*, it can be run directly from the website using a standard web browser. In addition, users can also download or install the entire website for *offline* use. This PhET simulation works best on a PC (*personal computer*). In learning through PhET, simulation provides convenience where users can see with the naked eye or something abstract, such as atoms, electrons, protons, and magnetic fields. Interactions that are tried such as pressing buttons, sliding objects and entering data, then the interactions carried out will be seen immediately. For quantitative exploration, this PhET simulation has measuring tools in it such as rulers, stopwatches, voltmeters, and thermometers (Zona, 2022).

The PhET Interactive Simulation Project has developed a specific simulation to explore series-parallel circuit configurations, a key topic in the introductory electrical and electronics course. This simulation allows students to build virtual circuits by combining resistors in series and parallel arrays, measuring potential currents and differences, and observing the behavior of realistic circuit elements.

This article presents an in-depth analysis of the PhET series-parallel series simulation, highlighting its pedagogical value and its alignment with research-based learning strategies. This simulation is designed to overcome students' common misconceptions and challenges in understanding the characteristics of series and parallel series (Atmoko & Wasis, 2015; Yanuikie et al., 2017). Through interactive manipulation and real-time feedback, students can find relationships between currents, resistances, and potential differences in various network arrays.

Specific features of these simulations were examined, including the ability to visualize electron flows, explore the effects of circuit modifications, and quantitatively analyze circuit behavior using virtual ammeters and voltmeters (Zona, 2022: 26-27). This article also discusses how simulations can be effectively integrated into classroom learning, laboratory activities, and self-paced learning experiences, thereby encouraging active engagement and improving conceptual understanding.

Furthermore, this article reviews empirical studies that have evaluated the impact of the use of PhET series-parallel series simulations on student learning outcomes. These studies provide evidence of the effectiveness of simulation in improving conceptual understanding, problem-solving skills, and retention of key concepts related to series analysis.

Overall, this article presents PhET series-parallel series simulations as a powerful educational tool that leverages interactive visualization and exploration to facilitate meaningful learning experiences in electrical and electronics education.

Methods

This research is a *virtual simulation-based* experimental research with a simulated PhET application. This research was conducted by the researcher based on the results of observations

on the learning of Basic Science courses. Data collection is carried out by adding the value of the voltage source (battery) in each series and parallel series, measuring the electrical voltage at each resistance to the resistor or lamp, measuring the strength of the electric current between the cable and the resistance (resistor or lamp) and also at the output of the current from the voltage source (battery) to find out the total value of the strong electric current.

The data analysis technique is by proving the results of series and parallel series observations with Ohm's law equations. First, by doing an equation of series and parallel resistor circuits to calculate the resistance value based on the number of resistors used. In general, the resistance values in series resistor circuits and parallel resistor circuits are as follows:

$$R_s = R_1 + R_2 + R_3 + \dots + R_n \quad (1)$$

$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3 + \dots + 1/R_n \quad (2)$$

where R_s is the sum of resistance or resistance values arranged in series (Ohm) and R_p is the sum of resistance or resistance values arranged in parallel (Ohm). Second, calculating the strong value of the electric current at each resistor using Ohm's law equation as follows:

$$I = V/R \quad (3)$$

where I is the rated electric current flowing at the resistor circuit (Ampere). Third, calculating the voltage value of each resistor using Ohm's law equation as follows:

$$V = I.R \quad (4)$$

where V is the sum of the electrical voltage at each resistor (Volts).

The tools and materials used are (1) A set of computers/laptops/HandPphones; (2) PHET interactive simulation application; (3) Electrical circuit work board; (4) Connecting cables; (5) Volt meter; (6) Amperemeter; (7) Battery; (8) LED lights; (9) Switch on/off.

Result And Discussion

From the results of measurement and data processing, data is obtained as seen in the following table:

Table 1. Results of observation of obstacle analysis in series

No.	V-1 (V)	V-2 (v)	V-tot al (v)	I-1 (A)	I-2 (A)	I-tot al (A)	R-1 (Ω)	R-2 (Ω)	R-tot al (Ω)
1	4.5 0V	4.5 0V	9.0 0V	0. 45 A	0. 45 A	0. 45 A	10.00 a.m. Ω	10.00 a.m. Ω	8:0 0 p. m. Ω
2	7.5 0V	7.5 0V	15. 00 V	0. 75 A	0. 75 A	0. 75 A	10.00 a.m. Ω	10.00 a.m. Ω	8:0 0 p. m. Ω



3	9.0 0V	9.0 0V	18. 00 V	0. 90 A	0. 90 A	0. 90 A	10.00 a.m. Ω	10.00 a.m. Ω	8:0 0 p. m. Ω
4	15. 00 V	15. 00 V	30. 00 V	1. 50 A	1. 50 A	1. 50 A	10.00 a.m. Ω	10.00 a.m. Ω	8:0 0 p. m. Ω
5	20. 00 V	20. 00 V	40. 00 V	2. 00 A	2. 00 A	2. 00 A	10.00 a.m. Ω	10.00 a.m. Ω	8:0 0 p. m. Ω

Information:

V : difference in potential or electrical voltage (volts)

I : Strong electric current (A)

R : resistance (Ω)

Table 1 shows that when the value of the source of the electrical voltage (V-total) is increased or increased, the strong value of the electric current (I) will also increase with the determination of the resistance value of both resistor 1 and resistor 2, i.e. the value is the same or fixed. The value of the electrical voltage at resistors 1 and 2 can be determined by measuring using a voltmeter, namely by installing it on each resistor. The difference in voltage values in both V1 and V2 is obtained depending on the resistor. The total electrical voltage (V-total) value is measured by installing voltmeters on both simultaneously or combined. The strong value of the electric current (I) can be determined by measuring it using an ammeter installed between the cable and the resistor, while the I-total is installed at the outlet of the electric current from the voltage source (battery). The strong value of the electric current generated in the series series is the same because the electric current has only one conductive path ($I-1 = I-2 = I \text{ Total}$). The resistance value of both resistors 1 and resistor 2 can be determined by pressing the resistor feature, then the resistance value will appear at the bottom of the application display of the practicum work screen. The total resistance value (total R) in the series circuit can be determined by adding the two resistance values at resistor 1 and resistor 2 with the formula ($\text{total R} = R1 + R2$).

Table 2. Observation results of parallel obstacle analysis

No.	V-1 (V)	V-2 (v)	V- tot al (v)	I-1 (A)	I-2 (A)	I- tot al	R-1 (Ω)	R-2 (Ω)	R - t o
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						(A)			t al (Ω)
1	9.0 0V	9.0 0V	9.0 0V	0. 90 A	0. 90 A	1. 80 A	10.00 a.m. Ω	10.00 a.m. Ω	5 Ω
2	15. 00 V	15. 00 V	15. 00 V	1. 50 A	1. 50 A	3. 00 A	10.00 a.m. Ω	10.00 a.m. Ω	5 Ω
3	18. 00 V	18. 00 V	18. 00 V	1. 80 A	1. 80 A	3. 60 A	10.00 a.m. Ω	10.00 a.m. Ω	5 Ω
4	30. 00 V	30. 00 V	30. 00 V	3. 00 A	3. 00 A	6. 00 A	10.00 a.m. Ω	10.00 a.m. Ω	5 Ω
5	35. 00 V	35. 00 V	35. 00 V	3. 50 A	3. 50 A	7. 00 A	10.00 a.m. Ω	10.00 a.m. Ω	5 Ω

Information:

V : difference in potential or electrical voltage (volts)

I : Strong electric current (A)

R : resistance (Ω)

Table 2 shows that when the value of the source of the electrical voltage (V-total) is increased or increased, the strong value of the electric current (I) will also increase with the determination of the resistance value of both resistor 1 and resistor 2, i.e. the value is the same or fixed. The value of the electrical voltage at resistors 1 and 2 can be determined by measuring using a voltmeter, namely by installing it on each resistor. The total electrical voltage (V-total) value is measured by installing voltmeters on both simultaneously or combined. The voltage value equation is obtained depending on the resistor, namely because the two resistors are connected in parallel according to the formula ($V_1 = V_2 = V_{Total}$). The strong value of the electric current (I) can be determined by measuring it using an ammeter installed between the cable and the resistor, while the I-total is installed at the outlet of the electric current from the voltage source (battery). The difference in the strong value of the electric current is because there is a branch. The resistance value of both resistors 1 and resistor 2 can be determined by pressing the resistor feature, then the resistance value will appear at the bottom of the application display of the practicum work screen. The total resistance value (total R) in a parallel circuit can be determined by summing the two resistance values at resistor 1 and resistor 2 with the formula ($1/R_{total} = 1/R_1 + 1/R_2$).



Table 3. Results of observation of the analysis of the series of lamps

No.	V-1 (V)	V-2 (v)	V-total (v)	I-1 (A)	I-2 (A)	I-total (A)	R-1 (Ω)	R-2 (Ω)	R-total (Ω)
1	4.50V	4.50V	9.00V	0.45A	0.45A	0.45A	10.00 Ω	10.00 Ω	8:00 p.m. Ω
2	7.50V	7.50V	15.00V	0.75A	0.75A	0.75A	10.00 Ω	10.00 Ω	8:00 p.m. Ω
3	9.00V	9.00V	18.00V	0.90A	0.90A	0.90A	10.00 Ω	10.00 Ω	8:00 p.m. Ω
4	15.00V	15.00V	30.00V	1.50A	1.50A	1.50A	10.00 Ω	10.00 Ω	8:00 p.m. Ω
5	20.00V	20.00V	40.00V	2.00A	2.00A	2.00A	10.00 Ω	10.00 Ω	8:00 p.m. Ω

Information:

V : difference in potential or electrical voltage (volts)

I : Strong electric current (A)

R : resistance (Ω)

Table 3 shows that when the value of the source of the electrical voltage (V-total) is increased or increased, the strong value of the electric current (I) will also increase with the determination of the resistance value of both resistor 1 and resistor 2, i.e. the value is the same or fixed. In addition, it also causes the lights to get brighter. The value of the electrical voltage

at resistors 1 and 2 can be determined by measuring using a voltmeter, namely by installing it on each resistor. The difference in voltage values in both V1 and V2 is obtained depending on the resistor. The total electrical voltage (V-total) value is measured by installing voltmeters on both simultaneously or combined. The strong value of the electric current (I) can be determined by measuring it using an ammeter installed between the cable and the resistor, while the I-total is installed at the outlet of the electric current from the voltage source (battery). The strong value of the electric current generated in the series circuit is the same because the electric current has only one conductive path ($I-1 = I-2 = I \text{ Total}$). The resistance value of both resistors 1 and resistor 2 can be determined by pressing the resistor feature, then the resistance value will appear at the bottom of the application display of the practicum work screen. The total resistance value (total R) in the series circuit can be determined by adding the two resistance values at resistor 1 and resistor 2 with the formula ($\text{total } R = R_1 + R_2$).

Table 4. The results of the observation of the analysis of the lamp series in parallel.

No.	V-1 (V)	V-2 (v)	V-total (v)	I-1 (A)	I-2 (A)	I-total (A)	R-1 (Ω)	R-2 (Ω)	R-total (Ω)
1	9.00V	9.00V	9.00V	0.90A	0.90A	1.80A	10.00 Ω	10.00 Ω	5 Ω
2	20.00V	20.00V	20.00V	2.00A	2.00A	4.00A	10.00 Ω	10.00 Ω	5 Ω
3	30.00V	30.00V	30.00V	3.00A	3.00A	6.00A	10.00 Ω	10.00 Ω	5 Ω
4	35.00V	35.00V	35.00V	3.50A	3.50A	7.00A	10.00 Ω	10.00 Ω	5 Ω
5	40.00V	40.00V	40.00V	4.00A	4.00A	8.00A	10.00 Ω	10.00 Ω	5 Ω

Information:

V : difference in potential or electrical voltage (volts)

I : Strong electric current (A)

R : resistance (Ω)



Table 2 shows that when the value of the source of the electrical voltage (V-total) is increased or increased, the strong value of the electric current (I) will also increase with the determination of the resistance value of both resistor 1 and resistor 2, i.e. the value is the same or fixed. In addition, it also causes the lights to get brighter. The value of the electrical voltage at resistors 1 and 2 can be determined by measuring using a voltmeter, namely by installing it on each resistor. The total electrical voltage (V-total) value is measured by installing voltmeters on both simultaneously or combined. The voltage value equation is obtained depending on the resistor, namely because the two resistors are connected in parallel according to the formula ($V_1 = V_2 = V_{\text{Total}}$). The strong value of the electric current (I) can be determined by measuring it using an ammeter installed between the cable and the resistor, while the I-total is installed at the outlet of the electric current from the voltage source (battery). The difference in the strong value of the electric current is because there is a branch. The resistance value of both resistors 1 and resistor 2 can be determined by pressing the resistor feature, then the resistance value will appear at the bottom of the application display of the practicum work screen. The total resistance value (total R) in a parallel circuit can be determined by summing the two resistance values at resistor 1 and resistor 2 with the formula ($1/R_{\text{total}} = 1/R_1 + 1/R_2$).

Table 5. Observation results of lamp analysis in series and parallel with scalar/off propagation

It	Network Picture	Scalar 1	Scalar 2	Scalar 3	Lamp 1	Light 2	Light 3
1	Figure 5.1.1 Series	<i>On</i>	<i>On</i>	<i>On</i>	Flame	Flame	Flame
	Figure 5.1.2 Series	<i>Off</i>	<i>On</i>	<i>On</i>	Die	Die	Die
2	Figure 5.2.1 Parallel	<i>On</i>	<i>On</i>	<i>On</i>	Flame	Flame	Flame
	Figure 5.2.2 Parallel	<i>Off</i>	<i>On</i>	<i>On</i>	Die	Flame	Flame
	Figure 5.2.3 Parallel	<i>On</i>	<i>Off</i>	<i>On</i>	Flame	Die	Flame
	Figure 5.2.4 Parallel	<i>On</i>	<i>On</i>	<i>Off</i>	Flame	Flame	Die



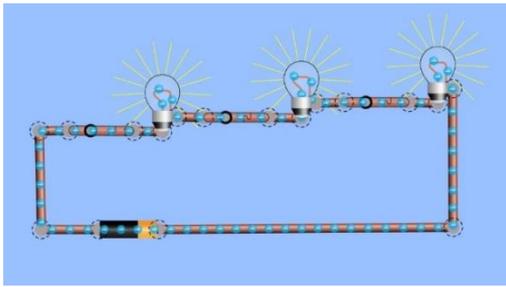


Figure 5.1.1 Series
Switch 1; scalar 2; scalar 3, turned on. Light 1; lamp 2; Light 3, on

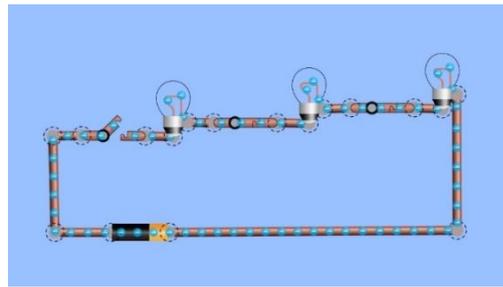
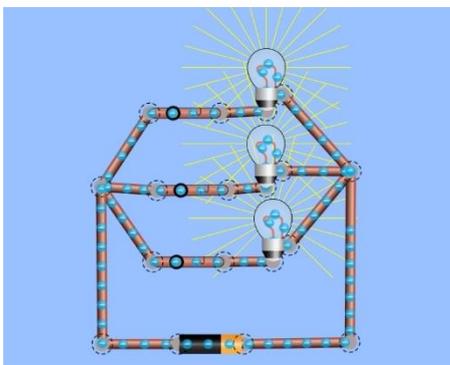
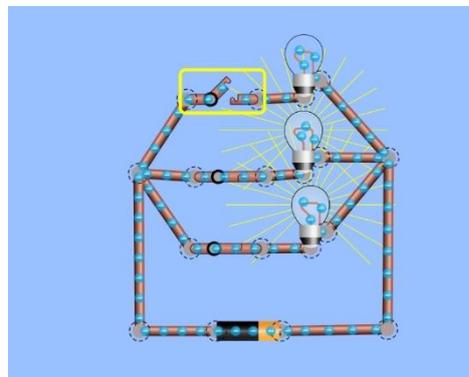


Figure 5.1.2 Series
One of the scalars (scalar 1) is turned off. Light 1; lamp 2; light 3, all turned off.



Gambar 5.2.1 Pararel
Saklar 1; skalar 2; skalar 3, dihidupkan (on). Lampu-1; lampu-2; lampu-3, menyala.



Gambar 5.2.2 Pararel
Skalar 1 dimatikan (off); skalar 2 dihidupkan (on); skalar 3 (on). Lampu-1 mati; lampu-2 nyala; lampu-3 nyala.

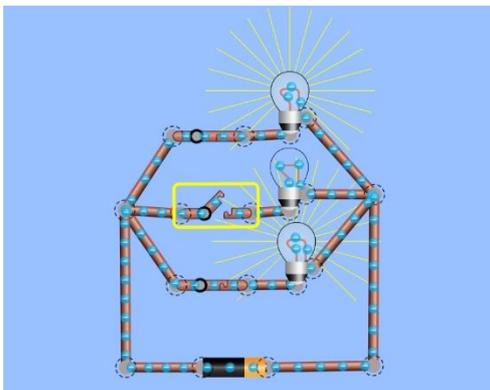


Figure 5.2.3 Parallel
Scalar 1 is turned on (on); scalar 2 is turned off; scalar 3 is turned on (on). Lamp-1; light-2 is off; 3 lights on.

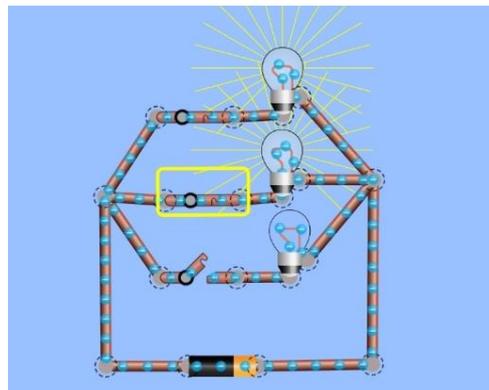


Figure 5.2.4 Parallels
Scalar 1 is turned on (on); scalar 2 is turned on (on); Scalar 3 is turned off. Lights-1 are on; light-2 on; Light 3 off

Table 5 shows different results. On a series circuit when one of the switches is turned off, all lights will not turn on (off). This happens because the line conducts the electric current that passes through the three lights in one line. All three lights will turn on if all switches are turned on. Meanwhile, in parallel circuits, if one of the switches is turned off, the light turns off only on the switch that is turned off (off). The electric current only flows on the switch that is turned on (on). This is because there is a branch that connects the three lights.

Conclusion

A series circuit is a type of electrical circuit that is arranged in sequence (series). This circuit consists of two or more electrical loads connected to a power source through a single pass. A parallel circuit is a type of electrical circuit that is arranged in parallel (parallel). This circuit has more than one pass to carry the current. There is a series series showing that when the value of the source of the electrical voltage (V_{total}) is increased or increased, the strong value of the electric current (I) will also increase with the determination of the resistance value of both resistor 1 and resistor 2, i.e. the value is the same or fixed, and in the lamp circuit causes the lamp to become brighter. On this series circuit, when one of the switches is turned off, all lights will not turn on (off). This happens because the line conducts the electric current that passes through the three lights in one line. All three lights will turn on if all switches are turned on. In the Parallel circuit, it shows that when the value of the source of the electrical voltage (V_{total}) is increased or increased, the strong value of the electric current (I) will also increase with the determination of the resistance value of both resistor 1 and resistor 2, i.e. the value is the same or fixed, and in the lamp circuit causes the lamp to be brighter. In this parallel circuit, if one of the switches is turned off, the light turns off only on the switch that is turned off (off). The electric current only flows on the switch that is turned on (on). This is because there is a branch that connects the three lights. Tools and Materials Series and Parallel Series in PhET Simulation, (1) A set of computers/laptops/Handphones; (2) PHET interactive simulation application; (3) Electrical circuit work board; (4) Connecting cables; (5) Volt meter; (6) Amperimeter; (7) Battery; (8) LED lights; (9) Switch on/off. PhET simulation is an interactive simulation that has benefits as visualization, experimentation, concept reinforcement, as a virtual lab, and accessibility .

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