The Effect of the Amount of Charge on the Force and the Direction of the Force on Coulomb's Law Using Phet Simulation

Misykah Auliya Al Baits[1*], Hilma Nurul Fajrin[2], Muhammad Fikri Assiddiqi[3]
[1,2,3] Physics Education Program, Sunan Gunung Djati State Islamic University, Indonesia
* Corresponding Author

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ABSTRACT

This experiment aims to determine the effect of the magnitude of the charge on the direction of the force generated. Data collection was carried out using the PhET Simulation Coulomb's Law. The method used in conducting research is a combination research method. The results of the research found that the amount of charge given will affect the direction of the force generated. This is important so that there are no misunderstandings in understanding the concept of the material.

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1. INTRODUCTION

The existence of the COVID-19 pandemic has led us to be more creative in finding other alternatives in conducting practicums, one of which is using the PhET virtual lab. Phet is an online web that can provide interactive simulations about science and mathematics. This online simulation is shown to carry out effective learning for students and students who have limitations in tools and time to do practicum. In its development, today's society is very attached to electricity, but most people do not know that in the flow of electricity there is a charge called Coulomb. Electricity has two types, namely dynamic and static electricity, where dynamic electricity is a flowing electric charge (electrodynamics), while static electricity is electricity that does not flow (electrostatics). The result of friction of objects that cause static electricity is electrostatic. Where electrostatic has the concept of electric flux, electric field, electric charge, electric potential, Coulomb's law and Gauss's law. In 1785, Coulomb and Cavendish found an equation to explain the force between two objects with their electric charge, the force was named electrostatics. After that Coulomb's law was born from the magnitude of the force that depends on the type of medium in which the two charged objects are located, and this law is the first law in electricity [1]–[3].

Coulomb's law has been widely studied by previous researchers. A comparative study between the Amontons–Coulomb and Dieterich–Ruina friction laws for the cyclic response of a single degree of freedom system was investigated by Cabboi [1]. The virtual element method for the contact friction problem with normal adherence was investigated by Wu [4]. The recognition and application of anion-anion dimers based on anti-electrostatic hydrogen bonds (AEHBs) was investigated by Zhao [3].

Friction Shear of R6M5 Steel on Grade 45 Steel in Litol-24 Grease with Zinc Powder and Cadmium Additives was investigated by Breki [5]. Electrons that repel each other can form bonded pairs investigated by Claro [6]. General Relativistic Charged Dustballs with Conformal Flatness studied by Kumar [7].

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Qualitative Symmetry and Falseness Analysis of the Two Reaction Wheel Pendulum was investigated by Ruiz [11]. The thermal conductivity and viscosity in a strongly coupled doubly charged fully ionized plasma was investigated by Bronin [2]. The linear correlation of vertical ionization energies and partial charges on acetaldehyde and methyl formate radicals in various solvents was investigated by Zeinalipour-Yazdi [12].

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Phet Simulation is used to explain Coulomb's Law with the conclusion that the greater the charge, the greater the resulting coulomb force. This experiment was carried out with the aim of knowing the effect of the magnitude of the charge on the coulomb force and the direction it will produce using the Phet Simulation web.

2. METHODS

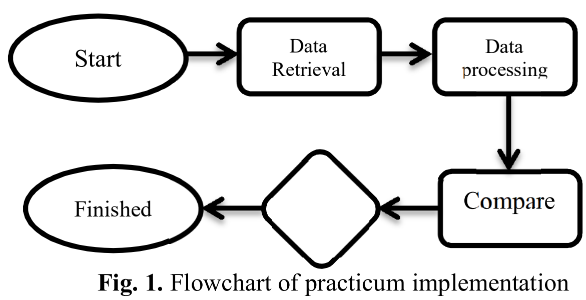

Fig. 1. Flowchart of practicum implementation

The research method used is a combination research method consisting of quantitative methods and qualitative methods. The quantitative method is carried out by conducting experiments, while the qualitative method is carried out by examining and comparing the results of previous studies.

The system schematic in Figure 1 can be detailed, namely starting research by collecting data using phet simulation. The data collection step was carried out by changing the Q_1 variable starting with a charge size of -10μC up to a charge size of 10μC. Then set the charge Q_2 with a charge size of 10μC and the distance between charges is 3 cm as a fixed variable.

Data processing is carried out after collecting 11 data, followed by comparing the data results from phet simulation with the results of manual calculations that have been carried out using the Coulomb's law equation as follows:

$$F = k\frac{qq'}{r^2} \text{ (scalar shape) or } F = k\frac{qq'}{r^2}\hat{r} \text{ (vector shape)} \quad (1)$$

The purpose of comparing the data is to prove that the data taken from the phet simulation experiment is in accordance with the calculations using the existing Coulomb's law formula.

After all the procedural schemes have been carried out, conclusions are drawn as the end of the practical experiment proving the relationship between the change in the magnitude of the charge and the resulting force in Coulomb's law.

3. RESULTS AND DISCUSSION

Table 1. Payload Q_1, with Q_2 stay in numbers 10, distance = 3 and $r^2 = 9$

Payload Q_1	F_{12} (N)	Direction from F_{12}	F_{21} (N)	Direction from F_{21}
-10	$9,99 \times 10^2$	Right	$9,99 \times 10^2$	Left
-8	$7,99 \times 10^2$	Right	$7,99 \times 10^2$	Left
-6	$5,99 \times 10^2$	Right	$5,99 \times 10^2$	Left
-4	$3,99 \times 10^2$	Right	$3,99 \times 10^2$	Left
-2	$2,00 \times 10^2$	Right	$2,00 \times 10^2$	Left
0	0	-	0	-
2	$2,00 \times 10^2$	Left	$2,00 \times 10^2$	Kanan
4	$3,99 \times 10^2$	Left	$3,99 \times 10^2$	Kanan
6	$5,99 \times 10^2$	Left	$5,99 \times 10^2$	Kanan
8	$7,99 \times 10^2$	Left	$7,99 \times 10^2$	Kanan
10	$9,99 \times 10^2$	Left	$9,99 \times 10^2$	Kanan

Table.1 is a table of observational data with Q1 as the independent variable and Q2 and r as the fixed variables.

Table 2. Payload Q_2, with Q_1 stay in numbers 10, distance = 3 and $r^2 = 9$

Payload Q_2	F_{12} (N)	Direction from F_{12}	F_{21} (N)	Direction from F_{21}
-10	$9,99 \times 10^2$	Right	$9,99 \times 10^2$	Left
-8	$7,99 \times 10^2$	Right	$7,99 \times 10^2$	Left
-6	$5,99 \times 10^2$	Right	$5,99 \times 10^2$	Left
-4	$3,99 \times 10^2$	Right	$3,99 \times 10^2$	Left
-2	$2,00 \times 10^2$	Right	$2,00 \times 10^2$	Left
0	0	-	0	-
2	$2,00 \times 10^2$	Left	$2,00 \times 10^2$	Right
4	$3,99 \times 10^2$	Left	$3,99 \times 10^2$	Right
6	$5,99 \times 10^2$	Left	$5,99 \times 10^2$	Right
8	$7,99 \times 10^2$	Left	$7,99 \times 10^2$	Right
10	$9,99 \times 10^2$	Left	$9,99 \times 10^2$	Right

Table.2 is a table of observational data with Q2 as the independent variable and Q1 and r as the fixed variables.

Judging from the two tables above, it shows that there is a change in the resulting Coulomb force when the Q1 charge is changed in table.1 and the Q2 charge is changed in table.2. From the table above, if the charge Q1 is given a small charge, the force generated will also be smaller. For example, when Q1 is set at -10 µC, the result is 9.99 x 102 N under the Coulomb force. When Q1 is set at -8 µC, a result of 7.99 x 102 N is obtained under the Coulomb force. When Q1 is set at -6 µC, a result of 5.99 x 102 N is obtained under the Coulomb force. Likewise, changes in Q2 produce the same changes, that is, if the charge on Q2 is smaller, the force generated will also be smaller.

From the two tables it can be seen that the change in direction of the Coulomb force can also be seen. If the charge Q1 is adjusted to the magnitude of the negative charge, the direction of the force generated on F12 is to the right and F21 to the left. Meanwhile, if Q1 is set with a positive charge, then F12 goes to the left and

F21 goes to the right. This shows that the magnitude of the positive and negative charges will affect the change in the direction of the resulting force.

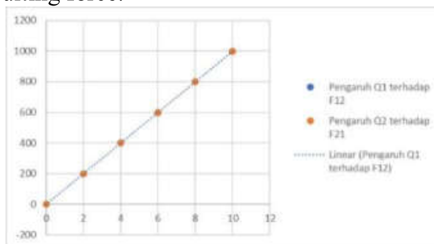

Fig. 2. Graph of charge affecting force

The graph above emphasizes the results when the charges Q1 and Q2 are given a small charge, the resulting force is also smaller according to Coulomb's law.

Table 3. Data Processing

Q_1	Q_1^2	Direction from F_{12}
10	100	$\bar{Q} = \frac{60}{11} = 5{,}4$
8	64	
6	36	$S_q = \frac{1}{11}\sqrt{\frac{(11)440 - (60)^2}{11-1}}$
4	16	
2	4	
0	0	$= \frac{1}{11}\sqrt{\frac{4840 - 3600}{11-1}}$
2	4	
4	16	
6	36	$= \frac{1}{11}\sqrt{124} = \frac{1}{11} \times 11{,}13 = 1{,}01$
8	64	
10	100	$KSR = \frac{1{,}01}{5{,}4} \times 100\% = 0{,}1\%\ (4AP)$
		$Q = 5{,}40 \pm 1{,}01$
$\sum = 60$		

Table 4. Data Processing

F_1	F_1^2	Direction from F_{12}
$9{,}99 \times 10^2$	998001	$\bar{X} = \frac{5992}{11} = 544{,}72$
$7{,}99 \times 10^2$	638401	
$5{,}99 \times 10^2$	358801	$S_v = \frac{1}{11}\sqrt{\frac{(11)4388808 - (5992)^2}{11-1}}$
$3{,}99 \times 10^2$	159201	
$2{,}00 \times 10^2$	40000	
0	0	$= \frac{1}{11}\sqrt{\frac{48276888 - 35904064}{11-1}}$
$9{,}99 \times 10^2$	998001	
$7{,}99 \times 10^2$	638401	
$5{,}99 \times 10^2$	358801	$= \frac{1}{11}\sqrt{\frac{12372824}{10}} = \frac{1}{11}\sqrt{1237282{,}4}$
$3{,}99 \times 10^2$	159201	
$2{,}00 \times 10^2$	40000	
		$= \frac{1}{11} \times 1112{,}33$
		$= 101{,}2$
		$KSR = \frac{101{,}2}{544{,}72} \times 100\% = 0{,}1\%\ (4AP)$
		$Q = 544{,}7 \pm 101{,}2$
$\sum 5992$	$\sum F_1^2 = 4388808$	

The data processing above provides an explanation regarding the accuracy of the data taken from the Phet Simulation comparable to the data obtained directly.

Table 5. Calculation

Data ex	Is know	Coulumb's law
1	$Q_1 = -10\ \mu C = -10 \times 10^{-6}$ C	$F = k\frac{q_1 q_2}{r^2}$

	$Q_2 = 10\ \mu C = 10 \times 10^{-6}$ C r = 3 cm = 3×10^{-2} m $r^2 = 9 \times 10^{-4}$ m k = $9 \times 10^9\ Nm^2/C^2$ atau 8,988 x $10^9\ Nm^2/C^2$	$F = 9 \times 10^9 \frac{(10 \times 10^{-6})(10 \times 10^{-6})}{9 \times 10^{-4}}$ $F = 9 \times 10^9 \frac{100 \times 10^{-12}}{9 \times 10^{-4}}$ $F = \frac{900 \times 10^{-3}}{9 \times 10^{-4}} = 100\ \times 10^1 = 10 \times 10^2 N$
2	$Q_1 = -8\ \mu C = -10 \times 10^{-6}$ C $Q_2 = 10\ \mu C = 10 \times 10^{-6}$ C r = 3 cm = 3×10^{-2} m $r^2 = 9 \times 10^{-4}$ m k = $9 \times 10^9\ Nm^2/C^2$ atau 8,988 x $10^9\ Nm^2/C^2$	$F = k\frac{q_1 q_2}{r^2}$ $F = 9 \times 10^9 \frac{(8 \times 10^{-6})(10 \times 10^{-6})}{9 \times 10^{-4}}$ $F = 9 \times 10^9 \frac{80 \times 10^{-12}}{9 \times 10^{-4}}$ $F = \frac{720 \times 10^{-3}}{9 \times 10^{-4}} = 80\ \times 10^1 = 8 \times 10^2 N$
3	$Q_1 = -6\ \mu C = 10 \times 10^{-6}$ C $Q_2 = 10\ \mu C = 10 \times 10^{-6}$ C r = 3 cm = 3×10^{-2} m $r^2 = 9 \times 10^{-4}$ m k = $9 \times 10^9\ Nm^2/C^2$ atau 8,988 x $10^9\ Nm^2/C^2$	$F = k\frac{q_1 q_2}{r^2}$ $F = 9 \times 10^9 \frac{(6 \times 10^{-6})(10 \times 10^{-6})}{9 \times 10^{-4}}$ $F = 9 \times 10^9 \frac{60 \times 10^{-12}}{9 \times 10^{-4}}$ $F = 60\ \times 10^1 = 6 \times 10^2 N$
4	$Q_1 = -4\ \mu C = 10 \times 10^{-6}$ C $Q_2 = 10\ \mu C = 10 \times 10^{-6}$ C r = 3 cm = 3×10^{-2} m $r^2 = 9 \times 10^{-4}$ m k = $9 \times 10^9\ Nm^2/C^2$ atau 8,988 x $10^9\ Nm^2/C^2$	$F = k\frac{q_1 q_2}{r^2}$ $F = 9 \times 10^9 \frac{(4 \times 10^{-6})(10 \times 10^{-6})}{9 \times 10^{-4}}$ $F = 9 \times 10^9 \frac{40 \times 10^{-12}}{9 \times 10^{-4}}$ $F = 40\ \times 10^1 = 4 \times 10^2 N$

Table.5 explains and emphasizes that the results of the Phet Simulation are in accordance with calculations done manually with the applicable Coulomb's law formula.

4. CONCLUSION

In accordance with Coulomb's law, the greater the charge applied, the greater the force generated. This is in accordance with the results of experiments that have been carried out that, the greater the charge produced, the greater the force generated. It can be seen from table.1 and table.2. If one of the charges is negative, the direction of the force is towards the right. Based on the results of the data taken from the phet simulation, it is relevant to the results of the manual calculations performed.

DECLARATION

Author Contribution

The research method used is a combination research method consisting of quantitative methods and qualitative methods.

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Conflict of Interest
The authors declare no conflict of interest.

REFERENCES

[1] A. Cabboi, L. Marino, and A. Cicirello, "A comparative study between Amontons–Coulomb and Dieterich–Ruina friction laws for the cyclic response of a single degree of freedom system," *Eur. J. Mech. - A/Solids*, vol. 96, p. 104737, Nov. 2022.
[2] S. Y. Bronin, B. B. Zelener, and B. V Zelener, "Thermal conductivity and viscosity in fully ionized multiple-charged strongly coupled plasma," *Plasma Sources Sci. Technol.*, vol. 30, no. 11, p. 115018, Nov. 2021.
[3] W. Zhao, A. H. Flood, and N. G. White, "Recognition and applications of anion–anion dimers based on anti-electrostatic hydrogen bonds (AEHBs)," *Chem. Soc. Rev.*, vol. 49, no. 22, pp. 7893–7906, 2020.
[4] B. Wu, F. Wang, and W. Han, "Virtual element method for a frictional contact problem with normal compliance," *Commun. Nonlinear Sci. Numer. Simul.*, vol. 107, p. 106125, Apr. 2022.
[5] A. D. Breki, S. G. Chulkin, A. G. Kolmakov, A. E. Gvozdev, O. V. Kuzovleva, and E. E. Baranov, "Sliding Friction of R6M5 Steel on Grade 45 Steel in Litol-24 Grease with Zinc and Cadmium Powder Additives," *Russ. Metall.*, vol. 2022, no. 10, pp. 1300–1306, Oct. 2022.
[6] F. Claro and P. Robles, "Can repelling electrons form bound pairs," *Eur. J. Phys.*, vol. 43, no. 1, p. 015403, Jan. 2022.
[7] S. Kumar, "General Relativistic Charged Dust Sphere with Conformal Flatness," *Int. J. Emerg. Technol. Adv. Eng.*, vol. 10, no. 10, pp. 9–11, Oct. 2020.
[8] M. Dosaev, "Algorithm for controlling an inertioid robot with a flywheel and an unbalance in conditions of restrictions on the angular acceleration of the unbalance," *Appl. Math. Model.*, vol. 109, pp. 797–807, Sep. 2022.
[9] Z. Ma, J. Cao, X. Xu, and J. Xu, "A shear stress model of water-based magnetorheological polishing fluids," *J. Intell. Mater. Syst. Struct.*, vol. 33, no. 1, pp. 160–169, Jan. 2022.
[10] Y. Kim, W. S. Chung, and H. Hassanabadi, "Deviation of inverse square law based on Dunkl derivative: deformed Coulomb's law," *Rev. Mex. Física*, vol. 66, no. 4 Jul-Aug, pp. 411–417, Jul. 2020.
[11] A. Ruiz, C. H. C. C. Basquerotto, J. F. S. Trentin, and S. Da Silva, "On a Qualitative and Lie Symmetry Analysis for a Pendulum with Two Reaction Wheels," *Q. J. Mech. Appl. Math.*, vol. 75, no. 3, pp. 235–256, Aug. 2022.
[12] C. D. Zeinalipour-Yazdi and K. Lam, "Linear correlation of vertical ionization energies and partial charges on acetaldehyde and methyl formate radicals in various solvents," *Chem. Phys. Lett.*, vol. 746, p. 137311, May 2020.
[13] J. Cheng, P. Xu, and Y. Xiong, "An improved artificial electric field algorithm and its application in neural network optimization," *Comput. Electr. Eng.*, vol. 101, p. 108111, Jul. 2022.
[14] A. Kasri, "A piezoelectric contact problem with slip dependent friction and damage," *J. Appl. Anal.*, vol. 27, no. 1, pp. 73–86, Jun. 2021.
[15] V. Ivchenko, "Coulomb's and Ohm's laws in an anisotropic medium," *Eur. J. Phys.*, vol. 42, no. 6, p. 065201, Nov. 2021.
[16] H. Zheng, J. Gao, J. Xiong, G. Yao, H. Cui, and L. Zhang, "An Enhanced Artificial Electric Field Algorithm with Sine Cosine Mechanism for Logistics Distribution Vehicle Routing," *Appl. Sci.*, vol. 12, no. 12, p. 6240, Jun. 2022.
[17] M. Magliulo, J. Lengiewicz, A. Zilian, and L. A. A. Beex, "Frictional interactions for non-localized beam-to-beam and beam-inside-beam contact," *Int. J. Numer. Methods Eng.*, vol. 122, no. 7, pp. 1706–1731, Apr. 2021.
[18] Z.-F. Wang, Q.-H. Li, and J.-X. Hou, "Non-Coulomb effect on the Timoshenko oscillation," *Eur. J. Phys.*, vol. 42, no. 5, p. 055012, Sep. 2021.
[19] H. Ustunel and D. Toffoli, "Tribology at the atomic scale with density functional theory," *Electron. Struct.*, vol. 4, no. 2, p. 023002, Jun. 2022.
[20] H. Dodig, "Direct Derivation of Liénard–Wiechert Potentials, Maxwell's Equations and Lorentz

Force from Coulomb's Law," *Mathematics*, vol. 9, no. 3, p. 237, Jan. 2021.

[21] S. Lee, J. Lee, and M. Joun, "On critical surface strain during hot forging of lubricated aluminum alloy," *Tribol. Int.*, vol. 141, p. 105855, Jan. 2020.

[22] B. Cai, Z. Shi, and J. Zhao, "Novel spatial and temporal interpolation algorithms based on extended field intensity model with applications for sparse AQI," *Multimed. Tools Appl.*, vol. 81, no. 14, pp. 19215–19236, Jun. 2022.

[23] F. Liu, R. Feng, and K. D. Tsavdaridis, "A novel progressive grid generation method for free-form grid structure design and case studies," *J. Build. Eng.*, vol. 34, p. 101866, Feb. 2021.

[24] A. D. Breki, S. G. Chulkin, A. E. Gvozdev, and A. G. Kolmakov, "A Generalized Mathematical Model of External Sliding Friction in Solids," *Inorg. Mater. Appl. Res.*, vol. 13, no. 4, pp. 967–971, Aug. 2022.

[25] B. Laassem, A. Idarrou, L. Boujlaleb, and M. Iggane, "Label propagation algorithm for community detection based on Coulomb's law," *Phys. A Stat. Mech. its Appl.*, vol. 593, p. 126881, May 2022.

[26] F. Tan, B. Wang, and D. Wei, "A new structural entropy measurement of networks based on the nonextensive statistical mechanics and hub repulsion," *Math. Biosci. Eng.*, vol. 18, no. 6, pp. 9253–9263, 2021.

[27] A. M. Kolesnikov, "An initially cylindrical highly elastic membrane enclosing of a rigid ellipsoid," *Int. J. Solids Struct.*, vol. 242, p. 111493, May 2022.

[28] A. D. Breki, S. G. Chulkin, A. E. Gvozdev, and A. G. Kolmakov, "Sliding Friction of R6M5 Steel on Grade 45 Steel Using a Litol-24 Lubricant Modified by MoS2 Particles," *Russ. Metall.*, vol. 2022, no. 4, pp. 424–429, Apr. 2022.

[29] E. V. Vikhrov, S. Y. Bronin, A. B. Klayrfeld, B. B. Zelener, and B. V. Zelener, "Simulated expansion and ion front formation of ultracold plasma," *Phys. Plasmas*, vol. 27, no. 12, Dec. 2020.

[30] H.-K. Chan, "A theory for like-charge attraction of polarizable ions," *J. Electrostat.*, vol. 105, p. 103435, May 2020.