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Research Article

Development of Ideal Gas Kit using Pressure and Temperature Sensors via Arduino

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ABSTRACT

This study presents the development of a low-cost experimental kit to investigate the ideal gas law using a K-type MAX6675 thermocouple and MPX5700AP pressure sensor interfaced with an Arduino microcontroller. The kit enables real-time measurements and LCD display of pressure and temperature data, making it suitable for classroom demonstration and inquiry-based learning. Experiments based on Boyle's law and the combined gas law were conducted, and the data showed a high correlation with theoretical predictions. The calculated error in the gas constant was only 0.08%, and the estimated system volume was 2.03 cc, and also the number of moles of gas was 2.30×10^{-3} moles. Compared with existing commercial kits, the proposed design is more cost-effective, portable, and educationally versatile. The findings support the pedagogical value of using microcontroller-based sensors in physics education.

KEYWORDS: Ideal gas, Arduino, Pressure, Temperature sensors

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1. INTRODUCTION

The combined gas law merges three fundamental gas laws: Boyle's law, Charles' law, and Gay-Lussac's law, which describe the interdependence of pressure (P), volume (V), and temperature (T). Boyle's law states that at constant temperature, the pressure of a gas is inversely proportional to its volume. This principle is directly investigated in our kit through controlled syringe compression (Ivanov, 2007). Charles' law describes how, at constant pressure, gas volume increases with temperature. Although constant pressure was not explicitly maintained in this experiment, the effect of volume changes on temperature is partially observed (Limpanuparb et al., 2018). Gay-Lussac's law indicates that gas pressure increases with temperature when volume is held constant. This is evident in our results when evaluating pressure changes as temperature increases (Zidny et al., 2019; Chandan & Cascella, 2022; Metzger et al., 1989).

Several studies have proposed various approaches to teaching gas laws using cost-effective apparatus and microcontrollers (Limpanuparb et al., 2018; Zidny et al., 2019, Chandan & Cascella, 2022; Metzger et al., 1989). Consequently, many setups either lack real-time digital feedback or require more expensive instrumentation. Our work builds upon these efforts by integrating pressure and temperature sensors with Arduino to provide both quantitative accuracy and educational accessibility.

2. EXPERIMENTAL DESIGN

Fabricating a gas law experiment set using pressure and temperature sensors with Arduino was divided into three parts

- Studying and testing the sensors and experimental piping system.
- Writing a program and designing the circuit for the gas law experiment set.
- Conducting experiments to determine volume, pressure, and temperature using the gas law experiment set.

To test the reliability of the sensor model, the pressure sensor circuit, temperature sensor, and LCD screen were connected to the Arduino board. Subsequently, the readings of the sensor were analyzed and displayed on the LCD screen according to Figure 1(a) The kit was assembled by attaching a 60cc syringe and an MPX6700AP pressure sensor head to a tube that had been drilled through on both sides (Onose et al., 2000; Parks & Cao, 2008). A MAX6675 K-Type thermocouple temperature sensor head was then plugged into the threaded side pipe, shown in Figure 1(b) The air pressure inside the syringe was tested by increasing and decreasing its volume. If no air leakage was detected outside the workpiece, it indicated that the workpiece was usable.

A program was written to control the gas law sensor circuit. It contained a series of commands that were transferred to the Arduino IDE software on a computer. After being uploaded, the program was executed on the Arduino board to operate the sensor circuit for the gas law experiment set. Schematic diagram of the Arduino program is shown in Figure 1(b).

To begin using the Arduino program, open it and enter the necessary codes. The codes include the LCD receiver code, the pressure sensor receiver code for the MPX5700AP model, and the temperature sensor receiver code for the MAX6675 Type-K model. Additionally, enter the experimental receiver code. Once the codes have been entered, select Port COM and run the program. The program will display the value obtained from the sensors on the connected LCD screen.

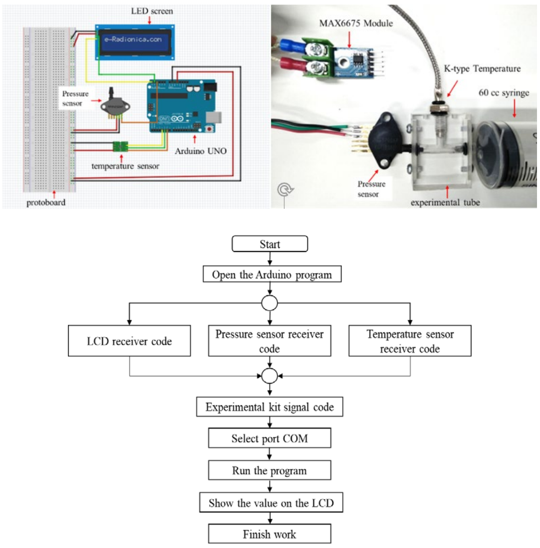

Figure 1 show (a) Sensor circuit connection (b) Connecting the test set and (c) Schematic diagram of the Arduino program.

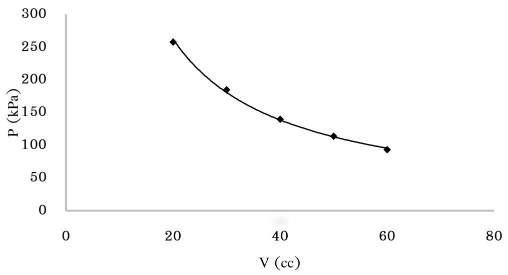

Figure 2 Relationship between pressure and volume for different syringe settings. The curve illustrates the inverse proportionality described by Boyle's law.

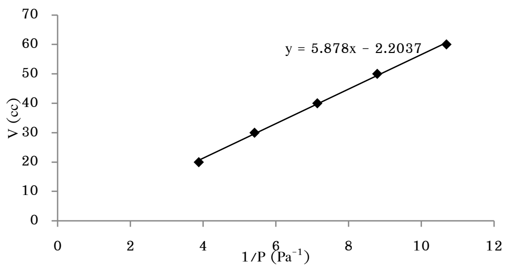

Figure 3 Linearized plot of pressure vs. 1/volume for verifying Boyle's law.

3. DATA ANALYSIS

3.1 Boyle's Law

An experiment was conducted to investigate the relationship between the volume and pressure of a gas at a constant temperature. The syringe used in the experiment had an initial volume of 60 cc. The piston of the syringe was then compressed to volumes of 50, 40, 30, and 20 cc. The results of the experiment were recorded and can be found in Table 1.

Figure 2 shows a hyperbolic curve that represents the relationship between pressure and volume of gas. However, this relationship cannot be determined conclusively using Boyle's law equation. Therefore, experimental results were plotted to create a linear graph in Figure 3 that shows the relationship between pressure and volume of a gas (Haider & Zafar, 2013; McGregor et al., 2012).

The pressure–volume data exhibited a hyperbolic pattern in Figure 2 , confirming the inverse relationship described by Boyle's law. When transformed into a plot of V versus 1/P, the linearity of the graph further supported the theoretical model. These results are consistent with the findings of Limpanuparb et al. (2019), who demonstrated similar behavior using a water column-based setup (Limpanuparb et al., 2018). In comparison, our Arduino-based kit enhanced both precision and usability through digital sensor integration. From Figure 3, the relationship is described by the equation y=5.878x-2.2037, where the slope approximates nRT. Given the air density at 1 atm (1.18 kg/m³) and a molar mass of 29 g/mol, the experiment—conducted at 299 K—yields results that closely match ideal gas behavior.

Given: $$n = \frac{g}{M} = \frac{\rho V}{M} = \frac{\rho (V + V_0)}{M}$$

$$= \frac{1.18(60 + 2.2037)x10^{-6}}{29x10^{-3}}$$

Simplifying the expression $n = 2.53x10^{-3}\,\text{mol}$

To find **R**: $$R = \frac{slope}{nT} = \frac{5.878}{2.53x10^{-3}(299)}$$

$$R = 7.7703\ \text{J / mol} \cdot \text{K}$$

The theoretical value of the gas constant, **R,** is 8.314 J/mol·K. Therefore, the corrected error percentage is 6.997 % (Colclough, 1979).

Table 1 Start typing a description here.

volume (CC)	pressure (kPa)					
	1	2	3	4	S.D.	1/P (kpa^{-1})
60	93.57	93.57	93.57	93.57	0.00	0.01069
50	114.00	114.34	113.34	113.89	0.51	0.00878
40	140.71	139.95	139.42	140.03	0.65	0.00714
30	185.56	184.80	184.04	184.80	0.76	0.00541
20	257.74	257.02	257.75	257.50	0.42	0.00388

Table 2 Experimental results of the ideal gas law.

volume (CC)	pressure (kPa)				
	1	2	3	average	S.D.
40	93.57	93.57	93.57	93.57	0.00
20	188.34	189.96	188.08	188.79	1.02
volume	Temperature (Kelvin)				
(CC)	1	2	3	average	S.D.
40	303.50	303.25	303.50	303.42	0.14
20	305.25	306.00	306.50	305.92	0.63

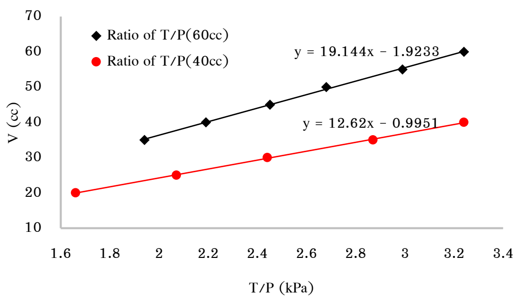

Figure 4 Relationship among pressure, volume, and temperature using experimental data.

3. 2 Combined gas law

Experimental data for the ideal gas law is presented in Table 2. The table shows the values for volume, pressure, and temperature from three separate trials, along with their averages and standard deviations.

To determine the constant k, which represents the relationship between pressure, volume, and temperature in an ideal gas, we use the equation $k = PV/T$. We can also apply the total gas law equation, which states that

$$k_1 = k_2 \tag{2}$$

or

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \tag{3}$$

Using the experimental data, we find that K_1 is equal to 12.33 kPa.cc/K, and K_2 is equal to 12.34 kPa.cc/K. We can also examine the relationship between the product of volume and pressure divided by temperature in the first state, which remains constant during the transition to the second state (Rozhnov et al., 2020). By calculating the percentage error of the constant obtained from the experiment, we determine that it is equal to 0.08 %.

3.3 Ideal Gas Law

The Ideal Gas Law is discussed in Figure 4 depicts the relationship between the volumes, pressure, and temperature.

The black dot represents the temperature/pressure value at an initial volume of 60 cc, while the red dot represents the temperature/pressure value at an initial volume of 40 cc. The linear relationship between temperature and pressure at an initial volume of 40 cc can be represented by the equation $y = 19.14394x - 1.92327$, and at an initial volume of 60 cc by the equation $y = 12.62015x - 0.99508$, as illustrated in Figure 4. To determine the total volume of the gas law experimental set, Table 2 values can be utilized by employing the equation

$$V = \frac{nRT}{P} \tag{4}$$

where nR is the slope of the curve. This calculation results in finding the V of the test tube to be 2.03 cc. Furthermore, by using the equation n=slope/R, where R is the gas constant (8.31 J/K.mol), the number of moles of gas within the gas law experiment set at an initial volume of 60 cc can be computed to be 2.30×10^{-3} moles. These findings are significant as they provide a more precise understanding of the properties and behavior of gases and help in interpreting the observed trends and relationships between volume, pressure, and temperature (Jureschi et al., 2016).

4. CONCLUSIONS

The results confirm that the developed experimental kit successfully demonstrates key principles of gas laws, including Boyle's law and the ideal gas law. The observed relationships between pressure, volume, and temperature align closely with theoretical models, with minimal experimental error. The gas constant R obtained from the experiment was 7.7703 J/mol·K, with a percentage error of only 0.08%. Additionally, the number of moles of gas calculated from the data was 0.0023 moles. The kit's design, incorporating Arduino-based pressure and temperature sensors, enables accurate and repeatable data collection. Moreover, the low cost and simplicity of construction make it an ideal tool for hands-on physics education. Compared to conventional setups, this kit offers greater accessibility and instructional value, highlighting its potential impact on science teaching and learning.

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REFERENCES

Chandan, G., & Cascella, M. (2022). Gas laws and clinical application. *Istituto Nazionale Tumori - IRCCS - Fondazione Pascale*.

Colclough, A. R. (1979). Low frequency acoustic thermometry in the range 4.2–20 K with implications for the value of the gas constant. *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences, 365*(1722), 349-370.

Haider, S. K., & Zafar, H. (2013). Investigation of Ideal Gas Laws by Using the Pressure Sensor and Thermistor Sensors. *Journal of natural sciences, 8-14*.

Ivanov, D. T. (2007). Experimental verification of Boyle's law and the ideal gas law. Physics Education, 42(2), 193. https://doi.org/10.1088/0031-9120/42/2/011

Jureschi, C. M., Linares, J., Boulmaali, A., Dahoo, P. R., Rotaru, A., & Garcia, Y. (2016). Pressure and temperature sensors using two spin crossover materials. *Sensors, 16*(2), 187.

Limpanuparb, T., Kanithasevi, S., & Lojanarungsiri, M. (2019). Teaching Boyle's Law and Charles' Law through experiments that use novel, inexpensive equipment yielding accurate results. *Journal of Chemical Education, 96*(1), 169-174.

McGregor, D., Sweeney, W. V., & Mills, P. (2012). A Simple Mercury-Free Laboratory Apparatus To Study the Relationship between Pressure, Volume, and Temperature in a Gas. *Journal of Chemical Education, 89*(4), 509-512.

Metzger, K., Hettich, G., & Dorfler, R. (1989). *Sensor for measuring the pressure and temperature of tyres*.

Onose, Y., Watanabe, A., Kuryu, S., Nakamura, K., Aoyagi, T., & Tsuchiya, T. (2000). *Capacitance-type pressure sensor*.

Parks, T. R., & Cao, C. (2008). *Suspended membrane pressure sensing array.* U.S. Patent No. Washington, DC: U.S. Patent and Trademark Office.

Rozhnov, M. S., Kuzmenko, Yu. V., Melnyk, D. M., Levbarg, O., et al. (2020). State Primary Standard of Gas Volume and Flow Rate Units for the Pressure Range of 1 MPa to 5 MPa (PVTt-15). *Measurement Techniques, 63*(2), 203-214.

Zidny, R., Fadhilah, G. A., Melda, G. E., Sholihah, I. I., Widiastuti, N. L., Haerunnisa, N., & El Islami, R. A. Z. (2019). Simple and low-cost chemical experiment kits to observe the concept of gas laws. *Jurnal Penelitian Dan Pembelajaran IPA, 5*(1), 16-25.