

Pre Lab: Pressure and Temperature

2. Gay-Lussac's Laws

a) Mathematical Expressions and Interpretations

Ideal Gas Law:

$$PV = nRT$$

This equation relates the Pressure (P), Volume (V), and Absolute Temperature (T) of a gas, where n is the number of moles and R is the universal gas constant. It states that the product of pressure and volume is directly proportional to the absolute temperature of the gas.

"Gay-Lussac's Law"

$$\frac{P}{T} = k$$

(where k is a constant), or more commonly,

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

This law states that for a given mass of gas at a constant volume, the pressure exerted by the gas is directly proportional to its absolute temperature.

b) Relationship Between Pressure and Temperature

Within a fixed volume (where V and n remain constant), both laws indicate a direct linear relationship between pressure and temperature.

As the temperature of the gas increases, the kinetic energy of the molecules increases, leading to more frequent and forceful collisions with the walls of the container, which increases the pressure.

If the absolute temperature doubles, the pressure also doubles, provided the volume is held constant.

c) Pressure Variation in a Small Fixed Volume

At a given (constant) temperature, the pressure inside a small fixed volume remains constant and uniform throughout the volume.

- According to the Ideal Gas Law ($P = \frac{nRT}{V}$), if the temperature (T), volume (V), and amount of gas (n) are all fixed, the pressure (P) must also be a fixed value.
- On a microscopic level, while individual molecules are moving and colliding, the statistical average of these collisions against the container walls results in a steady, non-varying macroscopic pressure

3. Review and Resubmit Previous Lab Results

3.3) Characterizing the phyphox Pressure Tool

- The pressure readings sample a Normal (Gaussian) PDF.
- The readings are stable, as they fluctuate randomly around a constant mean value (approximately 1014.540 hPa).
- The estimated scale uncertainty is ± 0.01 hPa, which is the smallest increment displayed by the digital tool.

3.4) Accuracy and Precision

- A measurement is considered accurate if the true value of the measurand falls within the confidence interval around the estimate.
- A precise measurement is one where the relative uncertainty (ratio of uncertainty to the measured value) is small.
- In the reaction time trials, the spread was dominated by Type A statistical uncertainty ($s = 0.120$ s), which was much larger than the scale precision (0.01 s)

3.5) Means and Standard Deviations

- The mean is the sum of the discrete values divided by the number of measurements, and the sample standard deviation is the square root of the variance.
- For the reaction time trials ($N = 20$), the mean was 0.0605 s and the sample standard deviation was 0.120 s.
- The statistical standard uncertainty (uncertainty of the mean) for the paper-fall data was 0.054 s.

3.6) Fitting Data

- The seventh computing task used the linear model $y = mx + b$ to fit the data.
- Coefficient of Determination (R^2): The fit for the cart velocity yielded an $R^2 = 0.98$ (rounded from 0.976), indicating the model explained most of the variability.
- Reduced Chi-Squared (χ_v^2): The value was 0.53, which is less than 1, suggesting the linear model is consistent with the data within the measurement uncertainties

4. Measurement and Uncertainty Review

Problem 16 (Anscombe's Quartet):

The four data sets demonstrate that different data distributions can result in the same linear fit parameters and R^2 values, emphasizing the necessity of plotting residuals to identify systematic effects or outliers.

Problem 17 (Constant Acceleration):

- The assumption of constant acceleration was considered reasonable because the reduced chi-squared value ($\chi_v^2 = 0.53$) was less than 1, indicating the linear model was consistent with the data
- The calculated acceleration (slope) was $-2.07 \pm 0.14 \text{ m/s}^2$
- The velocity at the start of the incline ($t = 10\text{s}$) was approximately 10.5 m/s

Problem 18 (Effective Variance):

When the independent variable (x) has significant uncertainties, the effective variance method is used to adjust the uncertainty of the dependent variable (y) before refitting.

- For the frictionless cart in Table 6, the mass M is determined by fitting the Force (F) and acceleration (a) data.