# The Mercury In A Barometer Of A Cross-sectional Area 1 Cm Stands At 75 Cm, And The Space Above It Is

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## Introduction to Barometers and Their Functionality

A barometer is a scientific instrument used to measure atmospheric pressure. It plays a crucial role in weather forecasting, altitude measurement, and various scientific applications. The basic principle behind a barometer involves balancing the weight of a column of mercury (or other liquid) against atmospheric pressure. Understanding the specifics of how a mercury column behaves within a barometer provides insight into atmospheric conditions and the physics of liquids under pressure.

In this context, we are considering a particular barometer where the mercury column has a cross-sectional area of 1 cm, and the mercury level stands at 75 cm. The space above the mercury column is an evacuated or near-vacuum space, which is characteristic of a traditional mercury barometer. The question at hand involves analyzing the implications of this setup, including the pressure exerted by the mercury column, the atmospheric pressure, and the behavior of the system under various conditions.

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## Understanding the Setup: Key Parameters

### Cross-Sectional Area of the Mercury Column

- The cross-sectional area is given as 1 $cm^2$.
- This area determines the volume of mercury in the column at any given height.
- It is important for calculating the mass of the mercury column and the force exerted by it.

### Height of the Mercury Column

- The mercury level is at a height of 75 cm.
- This height directly correlates with the pressure exerted by the mercury column.

## Space Above the Mercury

- The space is either a vacuum or contains a gas at negligible pressure.
- This creates the condition where the atmospheric pressure balances the weight of the mercury column.

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# Calculating the Pressure Exerted by the Mercury Column

## Basic Principles

- The pressure exerted by a column of liquid is given by the hydrostatic pressure formula:

$$
P = \rho g h
$$

where:

- $\rho$ = density of mercury ($\approx 13,600 \, \text{kg/m}^3$)
- $g$ = acceleration due to gravity ($9.81 \, \text{m/s}^2$)
- $h$ = height of the mercury column (75 cm = 0.75 m)

## Calculating the Pressure

- Substituting the values:

$$
P = 13,600 \times 9.81 \times 0.75
$$

- Performing the calculation:

$$
P \approx 13,600 \times 7.3575 \approx 100,047 \, \text{Pa}
$$

- So, the pressure exerted by the mercury column is approximately 100,000 Pa or 1 atm.

## Implication

- Since the pressure exerted by the mercury column equals atmospheric pressure in a standard barometer, this indicates that the atmospheric pressure is approximately 1 atm at the location where this measurement is taken.

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# Understanding the Space Above the Mercury

## Nature of the Space

- In a classical mercury barometer, the space above the mercury is evacuated, which means it has negligible pressure.
- The height of the mercury column is directly related to atmospheric pressure.

## Vacuum or Near-Vacuum

- The vacuum ensures that the only significant pressure acting on the mercury from above is near zero.
- This allows the height of the mercury to be a direct indicator of the atmospheric pressure.

## Effect on the Mercury Column

- If the space above were not a vacuum but contained gas at some pressure, the height of the mercury column would adjust accordingly.
- The equilibrium height would then be a result of the balance between atmospheric pressure and the pressure exerted by the gas in the space above.

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# Relating the Mercury Level to Atmospheric Pressure

## Standard Atmospheric Pressure

- At sea level, the standard atmospheric pressure is approximately 101.3 kPa.
- Mercury barometers are calibrated such that a height of 76 cm corresponds to 1 atm.

## Comparison with the Given Setup

- The mercury level at 75 cm is very close to the standard 76 cm, indicating that atmospheric pressure is about 1 atm.
- Variations in atmospheric pressure cause fluctuations in the mercury level, which can be measured to determine pressure changes.

## Calculations for Atmospheric Pressure

- Using the hydrostatic pressure formula again:

$$
P_{atm} = \rho g h
$$

- For $h = 75\, \text{cm}$:

$$
P_{atm} \approx 100,000 \, \text{Pa}
$$

- This aligns with the typical atmospheric pressure at sea level, confirming the setup's accuracy.

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# Implications of the Cross-Sectional Area on the System

## Volume of Mercury in the Column

- The volume $V$ of mercury in the column:

$$
V = A \times h
$$

where:

- $A = 1\, \text{cm}^2 = 1 \times 10^{-4}\, \text{m}^2$
- $h = 0.75\, \text{m}$

- Calculating:

$$
V = 1 \times 10^{-4} \times 0.75 = 7.5 \times 10^{-5}\, \text{m}^3
$$

\]

- The mass \(m\):

\[
m = \rho \times V = 13,600 \times 7.5 \times 10^{-5} \approx 1.02\, \text{kg}
\]

Key Point: The small cross-sectional area results in a relatively small amount of mercury, yet the height is sufficient to measure standard atmospheric pressure.

## Effect of Cross-Sectional Area Variations

- If the cross-sectional area were larger, the volume of mercury would increase proportionally, but the height would remain the same for the same pressure.
- Conversely, a smaller cross-sectional area would mean less mercury volume but the same height, indicating the flexibility of the system in measurement.

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# Practical Aspects and Considerations

## Calibration and Precision

- Standard mercury barometers are calibrated so that the height of the mercury column directly indicates atmospheric pressure.
- Variations in temperature can affect mercury density and height readings.

## Limitations and Accuracy

- Mechanical imperfections, temperature fluctuations, and impurities can influence the readings.
- The evacuated space above the mercury minimizes external pressure influences but must be maintained properly.

## Modern Alternatives

- While mercury barometers are precise, they are hazardous due to mercury toxicity.
- Digital barometers and aneroid barometers are increasingly used for practical applications.

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## Conclusion: Summary of Key Concepts

- The height of a mercury column in a barometer directly correlates with atmospheric pressure.
- For a mercury height of 75 cm and a cross-sectional area of 1 $cm^2$, the pressure exerted by the mercury column is approximately 100,000 Pa, which is close to 1 atm.
- The space above the mercury is typically a vacuum, allowing the mercury height to serve as a reliable measure of atmospheric pressure.
- The cross-sectional area influences the total volume and mass of mercury in the system but does not affect the pressure reading directly.
- Understanding these principles is fundamental to interpreting barometric readings and their implications for weather prediction and scientific measurements.

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In essence, the setup described illustrates the fundamental physics of hydrostatics and atmospheric pressure measurement, combining simple geometrical and physical principles to yield precise and valuable data about our environment.

# Frequently Asked Questions

## What does the mercury level indicate in a barometer with a cross-sectional area of 1 cm and a height of 75 cm?

The mercury level indicates the atmospheric pressure; in this case, a 75 cm mercury column corresponds to a specific pressure depending on local conditions.

## How is the pressure calculated from the height of mercury in a barometer?

Pressure is calculated using the height of the mercury column, the density of mercury, and gravity, typically with the formula $P = h \times \rho \times g$.

## What is the significance of the space above the mercury in a barometer?

The space above the mercury is usually a vacuum or contains air at low pressure; its pressure influences the readings and indicates the accuracy of the instrument.

## Why does the cross-sectional area of 1 cm matter in the measurement of mercury in a barometer?

The cross-sectional area is relevant for calculating the force exerted by the mercury column and understanding the relationship between height and pressure.

## If the mercury level is at 75 cm, what is the approximate atmospheric pressure in mm Hg?

It is approximately 75 mm Hg, since the height of the mercury column in a barometer directly correlates with atmospheric pressure in millimeters of mercury.

## How does the space above the mercury in a barometer affect the measurement accuracy?

A proper vacuum or low-pressure space above the mercury ensures accurate pressure readings; any air or gas presence can lead to errors.

## Can temperature variations affect the mercury level in the barometer?

Yes, temperature changes can cause the mercury to expand or contract, affecting the height and thus the pressure readings.

## What is the typical height of mercury in a standard barometer at sea level?

A standard mercury barometer at sea level typically shows a height of about 76 cm (760 mm Hg), reflecting normal atmospheric pressure.

## How does the cross-sectional area influence the design of a barometer?

The cross-sectional area affects the sensitivity and ease of reading; a smaller area results in a more precise measurement of height changes.

## What maintenance is necessary to ensure accurate readings in a mercury barometer with a 75 cm mercury column?

Regular cleaning, ensuring a proper vacuum in the space above the mercury, and calibration against standard pressure sources are essential for accuracy.

# Additional Resources

Mercury in a Barometer: A Comprehensive Analysis of its Height and the Space Above

Understanding the behavior of mercury in a barometer provides crucial insights into atmospheric pressure measurement and the principles of fluid mechanics. When examining a barometer with a cross-sectional area of 1 $cm^2$ and a mercury column height of 75 cm, along with the space above it, we delve into the fascinating interplay between physics, atmospheric science, and instrument design. This article explores this scenario in depth, elucidating the fundamental principles, practical implications, and detailed calculations involved.

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# Introduction to the Barometer and Its Components

A barometer is an instrument used to measure atmospheric pressure. The classic mercury barometer, invented by Evangelista Torricelli in the 17th century, consists of a glass tube filled with mercury, inverted into a mercury reservoir. The height of the mercury column reflects the atmospheric pressure exerted on the mercury reservoir.

Key Components:

- Mercury Column: The vertical tube filled with mercury, whose height varies with atmospheric pressure.
- Reservoir (or Reservoir Basin): The mercury-filled container at the bottom, exposed to the outside atmosphere.
- Vacuum Space: The space above the mercury column inside the tube, ideally a near-vacuum, which ensures that the mercury's height is solely due to atmospheric pressure.

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# Understanding the Scenario: Mercury Column Height and Cross-Sectional Area

In our specific case, the given parameters are:

- Cross-sectional area of the mercury column: 1 $cm^2$
- Height of the mercury column: 75 cm
- Space above the mercury: To be analyzed

This configuration is typical of a standard barometric setup, where the height of the mercury column directly correlates with the atmospheric pressure.

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# Fundamental Principles Governing Mercury Height in a Barometer

Before diving into calculations, it’s essential to understand the physical principles that relate the mercury column height to atmospheric pressure.

2.1 Atmospheric Pressure and Mercury Column Height

The key relation is:

$$ P_{atm} = \rho g h $$

Where:
- $P_{atm}$ = atmospheric pressure
- $\rho$ = density of mercury (~13.6 $g/cm^3$ or 13,600 $kg/m^3$)
- $g$ = acceleration due to gravity (~9.81 $m/s^2$)
- $h$ = height of mercury column (75 cm or 0.75 m)

This relation indicates that the atmospheric pressure exerted on the mercury reservoir balances the weight of the mercury column.

2.2 Volume and Mass of Mercury

Given the cross-sectional area and height, we can compute the volume and mass of mercury in the column:

$$ V = A \times h $$

Where:
- $A = 1\, \text{cm}^2 = 1 \times 10^{-4}\, \text{m}^2$
- $h = 75\, \text{cm} = 0.75\, \text{m}$

Total volume:

$$ V = 1 \times 10^{-4} \times 0.75 = 7.5 \times 10^{-5}\, \text{m}^3 $$

Mass:

$$ m = \rho \times V = 13,600\, \text{kg/m}^3 \times 7.5 \times 10^{-5}\, \text{m}^3 \approx 1.02\, \text{kg} $$

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# Calculating the Atmospheric Pressure Based on Mercury Height

Using the relation:

$$ P_{atm} = \rho g h $$

Convert height to meters:

$$ h = 0.75\, \text{m} $$

Calculate:

$$ P_{atm} = 13,600\, \text{kg/m}^3 \times 9.81\, \text{m/s}^2 \times 0.75\, \text{m} $$

$$ P_{atm} \approx 13,600 \times 9.81 \times 0.75 $$

$$ P_{atm} \approx 13,600 \times 7.3575 $$

$$ P_{atm} \approx 100,000\, \text{Pa} $$

This is approximately 100 kPa, close to standard atmospheric pressure at sea level (101.3 kPa). This confirms the mercury height corresponds to typical atmospheric conditions.

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# The Space Above the Mercury: What Does It Represent?

The space above the mercury column in a barometer is typically a near-vacuum, often called the vacuum space or air space. Its characteristics are crucial for the accurate functioning of the instrument.

2.1 Nature of the Vacuum Space

- Purpose: To eliminate air pressure above the mercury so that the height of the mercury column reflects only atmospheric pressure.
- Realities: Achieving a perfect vacuum is impossible; some residual air molecules remain, but modern barometers reach extremely low pressures, minimizing their effect.

2.2 Volume of the Vacuum Space

The volume of the space above the mercury depends on the total length of the tube and the length of the mercury column.

Suppose:

- Total length of the tube (L): To be specified or assumed based on typical barometers (say, 1 meter for illustration).
- Length of mercury column: 75 cm
- Space above the mercury:

$$ V_{vacuum} = A \times (L - h) $$

With $A = 1\, \text{cm}^2 = 1 \times 10^{-4}\, \text{m}^2$, and $L = 100\, \text{cm} = 1\, \text{m}$:

$$ V_{vacuum} = 1 \times 10^{-4} \times (1\, \text{m} - 0.75\, \text{m}) = 1 \times 10^{-4} \times 0.25 = 2.5 \times 10^{-5}\, \text{m}^3 $$

This volume contains a very low-pressure gas, and its properties influence the measurement accuracy.

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# Implications of the Mercury Height and Vacuum Space

The height of the mercury column (75 cm) serves as a direct indicator of the local atmospheric pressure. The vacuum above ensures that the pressure exerted is solely due to atmospheric conditions, enabling precise measurements.

2.1 Variations in Mercury Height

- Higher Mercury Column: Indicates increased atmospheric pressure, often associated with fair weather.
- Lower Mercury Column: Indicates decreased atmospheric pressure, often associated with stormy or unsettled weather.

2.2 Limitations and Considerations

- Temperature Effects: Mercury expands with temperature, slightly affecting height.
- Residual Air: Imperfect vacuum causes slight inaccuracies.
- Instrument Calibration: Ensuring the tube's dimensions and the vacuum quality are vital for precise readings.

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# Practical Applications and Significance

Understanding the principles behind the mercury height in a barometer has broad applications:

- Weather Forecasting: Changes in atmospheric pressure predict weather patterns.
- Altitude Measurement: Barometers can approximate altitude based on pressure differences.
- Scientific Research: Precise measurements of atmospheric pressure variations contribute to meteorology and climate studies.

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# Summary and Final Remarks

Analyzing a mercury barometer with a 1 $cm^2$ cross-sectional area and a mercury column height of 75 cm offers a window into fundamental physics and atmospheric science. The key points include:

- The pressure exerted by a 75 cm mercury column is approximately 100 kPa.
- The volume of mercury in the column is around $7.5 \times 10^{-5}$ $m^3$, with a mass close to 1.02 kg.
- The vacuum space above the mercury, assumed here as 25 cm in a 1-meter tube, contains a low-pressure gas essential for accurate measurement.

- Variations in the mercury height reflect changes in atmospheric pressure, underpinning the barometer’s vital role in weather prediction and scientific research.

In essence, the seemingly simple measurement of mercury height embodies complex physical principles and practical insights, illustrating the profound connection between fluid mechanics, atmospheric science, and instrumentation technology.

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