Determine The Specific Weight Of Air At An Elevation Of 2500ft; Assume The Air At Sea Level Has A Specific

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Understanding the specific weight of air at various altitudes is essential in fields such as meteorology, aeronautical engineering, and environmental science. It influences everything from aircraft performance to weather prediction models. In this article, we will explore how to determine the specific weight of air at an elevation of 2500 feet, assuming the specific weight of air at sea level is known. We will delve into the physical principles involved, relevant formulas, and practical calculation steps to enable accurate assessment of air properties at different elevations.

What Is Specific Weight of Air?

The specific weight of air, often denoted as γ (gamma), is defined as the weight of a unit volume of air. It is expressed in units such as N/m^3 (Newtons per cubic meter). The specific weight is a critical parameter because it relates the density of air (ρ) to gravitational acceleration (g):

- **Specific weight (γ) = density (ρ) × gravitational acceleration (g)**

Since gravity varies slightly with location and altitude, but for most practical purposes near Earth's surface, it is considered constant at approximately $9.80665\ m/s^2$.

Factors Influencing Specific Weight of Air

The specific weight of air depends primarily on:

- Temperature
- Pressure
- Humidity (moisture content)
- Altitude

As altitude increases, atmospheric pressure and temperature generally decrease, resulting in a reduction in the density and consequently the specific weight of air.

Standard Conditions at Sea Level

Before calculating the specific weight at 2500 ft, it's important to establish the known conditions at sea level:
- Standard atmospheric pressure, P_0: 101.325 kPa (or 101,325 Pa)
- Standard temperature, T_0: 15°C (or 288.15 K)
- Specific weight of air at sea level, γ_0: approximately 12.01 N/m^3

These values serve as baseline parameters for our calculations.

Approach to Determine Specific Weight at 2500ft

To find the specific weight of air at 2500 feet, the following approach can be used:

1. Determine the atmospheric pressure at 2500 ft.
2. Estimate the temperature at that elevation.
3. Calculate the air density at 2500 ft using the ideal gas law.
4. Compute the specific weight using the relation $\gamma = \rho \times g$.

Let's explore each step in detail.

1. Atmospheric Pressure at 2500 Feet

The barometric formula describes how atmospheric pressure decreases with altitude:

$$
P = P_0 \times \left(1 - \frac{L \times h}{T_0}\right)^{\frac{g \times M}{R \times L}}
$$

where:
- P = pressure at altitude h,
- P_0 = sea level standard pressure,
- L = temperature lapse rate (approx. 0.0065 K/m),
- h = altitude in meters,
- T_0 = standard temperature at sea level,
- g = acceleration due to gravity,
- M = molar mass of Earth's air (~0.029 kg/mol),
- R = universal gas constant (8.314 J/(mol·K)).

Alternatively, for altitudes below 11 km, a simplified barometric formula can be used:

$$
P = P_0 \times e^{-\frac{g \times M \times h}{R \times T}}
$$

Given the relatively modest elevation of 2500 ft (~762 meters), we can approximate pressure using the standard atmosphere model.

Approximate pressure at 2500 ft:

$$
P \approx P_0 \times \left(1 - 0.0065 \times \frac{762}{288.15}\right)^{5.256}
$$

Calculating:

$$
\frac{L \times h}{T_0} = \frac{0.0065 \times 762}{288.15} \approx 0.0172
$$

Thus:

$$
P \approx 101.325 \times (1 - 0.0172)^{5.256} \approx 101.325 \times (0.9828)^{5.256}
$$

Calculating the exponent:

$$
(0.9828)^{5.256} \approx e^{5.256 \times \ln(0.9828)} \approx e^{5.256 \times (-0.0173)} \approx e^{-0.091} \approx 0.913
$$

Finally:

$$
P \approx 101.325 \times 0.913 \approx 92.55\, \text{kPa}
$$

Result: Atmospheric pressure at 2500 ft is approximately 92.55 kPa.

2. Estimating Temperature at 2500ft

Temperature decreases with altitude at a lapse rate of approximately 6.5°C per 1000 meters. Assuming standard conditions:

$$
T = T_0 - L \times h
$$

where:
- $T_0 = 15°C = 288.15\,K$,
- $L = 6.5\,°C / 1000\,m$,
- $h = 762\,m$.

Calculating:

$$
T = 15 - 6.5 \times 0.762 \approx 15 - 4.95 \approx 10.05°C
$$

In Kelvin:

$$
T = 10.05 + 273.15 \approx 283.2\,K
$$

Result: Estimated temperature at 2500 ft is approximately 10°C (283.2 K).

3. Calculating Air Density at 2500ft

The ideal gas law relates pressure, density, and temperature:

$$
\rho = \frac{P}{R_{specific} \times T}
$$

where:
- $R_{specific} = \frac{R}{M} \approx 287\, J/(kg·K)$ for dry air.

Using the pressure in Pascals:

$$
P = 92,550\, Pa
$$

and temperature:

$$
T = 283.2\,K
$$

Calculate density:

$$
\rho = \frac{92,550}{287 \times 283.2} \approx \frac{92,550}{81,219.84}
\approx 1.14\,kg/m^3
$$

Result: Air density at 2500 ft is approximately 1.14 kg/m³.

4. Computing Specific Weight at 2500ft

Finally, the specific weight is:

$$
\gamma = \rho \times g
$$

Assuming $g = 9.80665\, m/s^2$:

$$
\gamma = 1.14 \times 9.80665 \approx 11.17\, N/m^3
$$

Result: The specific weight of air at 2500 feet is approximately 11.17 N/m^3.

Summary of Calculated Values

Parameter	Value at 2500 ft
Atmospheric pressure	~92.55 kPa
Temperature	~10°C (283.2 K)
Air density	~1.14 kg/m^3
Specific weight	~11.17 N/m^3

Practical Implications of Specific Weight Variations

Understanding how the specific weight varies with altitude is crucial for multiple applications:

- Aviation: Aircraft lift and engine performance depend on air density and specific weight.
- Meteorology: Weather models require accurate air property data at different elevations.
- Environmental Science: Air quality and pollutant dispersion calculations depend on atmospheric conditions.

Additional Factors to Consider

While the above calculations provide a good approximation, real-world conditions introduce complexities:

- Humidity: Moist air is less dense than dry air, affecting specific weight.
- Temperature Variations: Local temperature anomalies can significantly influence results.
- Gravitational Variations: Slight changes in gravity with latitude and

elevation may be negligible but are relevant for precise calculations.

Conclusion

Determining the specific weight of air at a given elevation involves understanding atmospheric pressure and temperature profiles, applying the ideal gas law, and considering the physical properties of air. At 2500 feet, the specific weight is approximately 11.17 N/m³, slightly lower than at sea level due to reduced pressure and temperature. These calculations are vital for engineers, meteorologists, and scientists working with atmospheric data, ensuring accurate modeling and decision-making.

By mastering these principles and formulas, professionals can reliably assess air properties at various altitudes, supporting safe aviation operations, effective weather forecasting, and environmental management.

Frequently Asked Questions

What is the typical specific weight of air at sea level?

The specific weight of air at sea level is approximately 0.0765 kN/m³ (or 9.81 kN/m³ divided by the density at sea level).

How does elevation affect the specific weight of air?

As elevation increases, the air density decreases, leading to a lower specific weight of air at higher altitudes.

What is the approximate specific weight of air at 2500 ft elevation?

At 2500 ft elevation, the specific weight of air is approximately 0.0386 kN/m³, assuming standard conditions and a linear approximation based on altitude.

What assumptions are made when calculating the specific weight of air at 2500 ft?

It is assumed that the air behaves as an ideal gas, standard atmospheric conditions apply, and the temperature remains constant with altitude (isothermal assumption) for simplicity.

How can the specific weight of air at a given elevation be calculated precisely?

By using the barometric formula and the ideal gas law, considering local temperature and pressure conditions, to determine air density and then multiplying by gravitational acceleration.

Why is it important to determine the specific weight of air at different elevations?

Knowing the specific weight helps in designing and analyzing air-supported structures, ventilation systems, and aerodynamic calculations that depend on air density and pressure at various altitudes.

What is the impact of temperature variation on the specific weight of air at 2500 ft?

Higher temperatures decrease air density, thus reducing the specific weight, while lower temperatures increase density and specific weight; accurate calculations should account for local temperature conditions.

Additional Resources

Determine The Specific Weight Of Air At An Elevation Of 2500ft; Assume The Air At Sea Level Has A Specific

Understanding the specific weight of air at various elevations is crucial in many fields such as meteorology, aeronautical engineering, civil engineering, and environmental sciences. The specific weight (also known as unit weight) of air influences calculations related to pressure, density, buoyancy, and structural design. This detailed review explores the methods to determine the specific weight of air at an elevation of 2500 feet, assuming the known specific weight at sea level, and delves into the underlying principles, formulas, and real-world applications.

Fundamental Concepts of Specific Weight of Air

What Is Specific Weight?

Specific weight (γ) of a substance is defined as the weight per unit volume:

\[

$$
\gamma = \frac{W}{V}
$$

where:
- W is the weight of the air (force),
- V is the volume.

It is measured in units such as N/m^3 (newtons per cubic meter) or lb/ft^3 (pounds per cubic foot). Unlike density, which is mass per unit volume, specific weight accounts for gravitational effects, making it particularly useful in civil and mechanical engineering for load calculations.

Relationship Between Specific Weight, Density, and Gravity

The specific weight of a gas like air relates directly to its density (ρ) and the acceleration due to gravity (g):

$$
\gamma = \rho \times g
$$

where:
- ρ is the density of air (kg/m^3),
- g is the acceleration due to gravity (m/s^2).

At sea level, the standard gravity is approximately 9.80665 m/s^2, but this can vary slightly with altitude and geographic location.

Standard Conditions at Sea Level

Before calculating the specific weight at 2500 ft, it is essential to establish the known parameters at sea level:

- Standard atmospheric pressure: $P_0 = 101.325\, \text{kPa}$
- Standard temperature: $T_0 = 15^\circ C = 288.15\, K$
- Specific weight of air at sea level: approximately $\gamma_0 = 12.01\, \text{N/m}^3$ (or 0.0765 lb/ft^3)

These values serve as the baseline for calculations involving changes with altitude.

Effects of Elevation on Air Properties

As altitude increases, atmospheric pressure and temperature decrease, which in turn affects the density and specific weight of air. The primary factors influencing these changes include:

1. Atmospheric Pressure Decrease: The weight of the air column above decreases with altitude.
2. Temperature Variation: Usually decreases with altitude in the troposphere, affecting density.
3. Gravity Variations: Slightly decrease with altitude and latitude but are generally considered constant for most practical purposes.

Methodology for Calculating Specific Weight at 2500 ft

To determine the specific weight of air at 2500 ft, we typically use the barometric formula combined with the ideal gas law.

1. Determine Atmospheric Pressure at 2500 ft

The pressure at a given altitude can be estimated using the barometric formula:

$$
P = P_0 \times \left(1 - \frac{L h}{T_0}\right)^{\frac{g M}{R L}}
$$

where:
- P_0 = sea level standard atmospheric pressure,
- L = temperature lapse rate (~0.0065 K/m),
- h = altitude in meters,
- T_0 = standard temperature in Kelvin,
- M = molar mass of air (~0.029 kg/mol),
- R = universal gas constant (~8.314 J/(mol·K)),
- g = acceleration due to gravity (~9.80665 m/s²).

Conversion of altitude:
- 2500 ft = approximately 762 meters (since 1 ft ≈ 0.3048 m).

Calculating pressure at 762 m:
Using the simplified version of the barometric formula valid for the troposphere:

\[
P = P_0 \times \left(1 - \frac{L h}{T_0}\right)^{\frac{g M}{R L}}
\]

Plugging in the values:

\[
P = 101.325\, \text{kPa} \times \left(1 - \frac{0.0065 \times 762}{288.15}\right)^{5.256}
\]

Calculations:
- \(\frac{0.0065 \times 762}{288.15} \approx 0.0172 \),
- \(1 - 0.0172 = 0.9828 \),
- Exponent \(\frac{g M}{R L} = 5.256 \),

Thus,

\[
P \approx 101.325 \times (0.9828)^{5.256}
\]

Calculating:

\[
(0.9828)^{5.256} \approx e^{5.256 \times \ln(0.9828)} \approx e^{5.256 \times (-0.0173)} \approx e^{-0.091} \approx 0.9129
\]

Finally,

\[
P \approx 101.325 \times 0.9129 \approx 92.53\, \text{kPa}
\]

Result: The atmospheric pressure at 2500 ft (~762 m) is approximately 92.53 kPa.

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2. Determine Temperature at 2500 ft

Temperature decreases approximately 6.5°C per 1000 m in the troposphere:

\[

T = T_0 - L \times h
\]

\[
T = 15^\circ C - 6.5^\circ C/1000\,m \times 762\,m \approx 15 - 4.95 \approx 10.05^\circ C
\]

Converted to Kelvin:

\[
T = 10.05 + 273.15 = 283.2\, K
\]

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3. Calculate Air Density at 2500 ft

Using the ideal gas law:

\[
\rho = \frac{P M}{R T}
\]

Where:
- \(P = 92.53\, \text{kPa} = 92530\, \text{Pa} \),
- \(M = 0.029\, \text{kg/mol} \),
- \(R = 8.314\, \text{J/(mol·K)} \),
- \(T = 283.2\, K \).

Calculating:

\[
\rho = \frac{92530 \times 0.029}{8.314 \times 283.2} = \frac{2680.87}{2352.23} \approx 1.139\, \text{kg/m}^3
\]

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4. Determine Specific Weight at 2500 ft

Now, multiply density by gravity:

\[
\gamma = \rho \times g
\]

Assuming g remains close to standard but slightly decreases with altitude:

$$
g_{2500ft} \approx 9.80665\, \text{m/s}^2 - 0.000003 \times h\, (\text{for small variations})
$$

At 762 m:

$$
g \approx 9.80665 - (0.000003 \times 762) \approx 9.80665 - 0.0023 \approx 9.8044\, \text{m/s}^2
$$

Therefore,

$$
\gamma \approx 1.139 \times 9.8044 \approx 11.17\, \text{N/m}^3
$$

Comparison and Practical Implications

The specific weight of air decreases from approximately 12.01 N/m^3 at sea level to about 11.17 N/m^3 at 2500 ft. This reduction impacts various engineering and scientific calculations:

- Structural Design: Support structures must accommodate lower buoyant forces at higher elevations.
- Aerodynamics: Aircraft performance calculations depend on air density and weight.
- Meteorology: Accurate weather prediction models require precise atmospheric property data.
- Environmental Monitoring: Pollutant dispersion models rely on density and specific weight variations.

Additional Considerations and Limitations

While the calculations above provide a solid estimate, real-world conditions may vary due to:

- Temperature anomalies: Weather systems can cause deviations from standard

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lapse rates.
- Localized gravity variations: Slight differences based on latitude and
Earth's shape.
- Non-ideal gas effects: At higher pressures or unusual conditions,
deviations from ideal gas law occur.
- Humidity influences: Moist air is less dense than dry air; humidity can
significantly affect density and specific weight.

In practical applications, engineers often consult atmospheric data specific
to their location and time of year for more precise
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