

# Planetary Atmospheres - Equation and Value Tables

Group Effort

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## 1 Gasses and Equation of State

Mole-based Equation	Mass-based Equation
Ideal Gas Constant ( $R$ ) $pV = nRT$ ( $n = \text{mol}$ )	Specific Gas Constant ( $R_s$ ) $pV = mR_sT$ ( $m = \text{mass}$ )

Table 1: Comparison of Mole-based and Mass-based Ideal Gas Equations

Symbol	Unit	Note
$p$	Pa	Pressure
$V$	$\text{m}^3$	Volume
$m$	kg	Mass
$R_s$	$\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$	Specific Gas Constant
$R$	$\text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$	Ideal Gas Constant
$T$	K	Temperature
$M$	$\text{kg}\cdot\text{mol}^{-1}$	Molecular Weight (Molar mass)
$n_V$	$\text{m}^{-3}$	Number of molecules per unit volume
$\rho$	$\text{kg}\cdot\text{m}^{-3}$	Density
$\alpha$	$\text{m}^3\cdot\text{kg}^{-1}$	Specific Volume
$n$	–	Moles
$N$	$\text{kg}\cdot\text{m}\cdot\text{s}^{-2}$	Newton (force)
Pa	$\text{kg}\cdot\text{m}^{-1}\cdot\text{s}^{-2}$	Pascal (pressure)
$J$	$\text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$	Joule (energy)
$N_A$	$\text{mol}^{-1}$	Avogadro's Number ( $6.022 \times 10^{23}$ particles/mol)

Table 2: Physical symbols, units, and associated meanings

## 2 Wave Symbols and Quantities

Symbol	Name	Meaning (Wave Context)
$\lambda$	Lambda	Wavelength – distance between wave crests (m)
$\nu$	Nu	Frequency – cycles per second ( $\text{Hz} = 1/\text{s}$ )
$\bar{\nu}$	Nu-bar	Wave number – cycles per meter ( $1/\text{m}$ )
$k$	k	Angular (circular) wave number – $k = 2\pi/\lambda$ (rad/m)
$\omega$	Omega	Angular (circular) frequency – $\omega = 2\pi\nu$ (rad/s)
$T$	T	Period – time per cycle (s)
$v_p$	v-sub-p	Phase speed – speed at which wave phase propagates (m/s)

Table 3: Wave Symbols and Their Meanings

	$\lambda$	$\nu$	$\bar{\nu}$	$k$	$\omega$
$\lambda$	1	$\frac{c}{\nu}$	$\frac{1}{\bar{\nu}}$	$\frac{2\pi}{k}$	$\frac{2\pi c}{\omega}$
$\nu$	$\frac{c}{\lambda}$	1	$c\bar{\nu}$	$\frac{2\pi k}{c}$	$2\pi\omega$
$\bar{\nu}$	$\frac{1}{\lambda}$	$\frac{\nu}{c}$	1	$\frac{2\pi}{k}$	$\frac{2\pi\omega}{c}$
$k$	$\frac{2\pi}{\lambda}$	$\frac{\nu c}{2\pi}$	$\frac{\bar{\nu}}{2\pi}$	1	$\frac{1}{c\omega}$
$\omega$	$\frac{2\pi c}{\lambda}$	$\frac{\nu}{2\pi}$	$\frac{2\pi\bar{\nu}}{c}$	$ck$	1

Table 4: Conversion between wave parameters

## 3 Radiometric Quantities

Quantity	Symbol	Units	Physical Meaning	Equation
Radiant Power (Radiative Flux)	$\Phi, F$	W	Total radiant energy emitted, transferred, or received per second.	$\Phi = \frac{dQ}{dt}$
Radiant Energy (Thermal energy)	$Q_e, E, W$	J	Total electromagnetic energy accumulated over time.	$Q = \int \Phi(t) dt$
Radiant Power per Unit Area (Irradiance, Radiative Flux Density, Exitance)	$E, I$	$\text{W m}^{-2}$	Power received per unit surface area (in, through, or out).	$E = \frac{d\Phi}{dA}$
Radiance (Specific Intensity)	$L$	$\text{W m}^{-2} \text{sr}^{-1}$	Radiant power per unit area per solid angle in a specific direction.	$L = \frac{d^2\Phi}{dA \cos \theta d\omega}$

Table 5: Radiometric Quantities: Symbols, Units, and Definitions

Equation	Name of Equation	Units of Result
$L_{\star} = 4\pi R_{\star}^2 \sigma T_{\star}^4$	Stefan–Boltzmann Law (Star Luminosity)	W (watts)
$F = \frac{L_{\star}}{4\pi d^2}$	Solar Constant / Stellar Flux at Planet	W/m <sup>2</sup>
$T_p = \left( \frac{(1-A)F}{\sigma} \right)^{1/4}$	Effective Temperature of a Planet	K (kelvin)

Table 6: Key equations for planetary energy balance

# 4 Energy Balance

Equation	Name of Equation	Units of Result
$L_{\star} = 4\pi R_{\star}^2 \sigma T_{\star}^4$	Stefan–Boltzmann Law (Star Luminosity)	W (watts)
$F = \frac{L_{\star}}{4\pi d^2}$	Solar Constant / Stellar Flux at Planet	W/m <sup>2</sup>
$T_p = \left( \frac{(1-A)F}{\sigma} \right)^{1/4}$	Effective Temperature of a Planet	K (kelvin)

Table 7: Key equations for planetary energy balance

## Definition of Values in above Equations:

- $\sigma = 5.67 \times 10^{-8} \text{ W} \cdot \text{m}^{-2} \cdot \text{K}^{-4}$  — Stefan–Boltzmann constant
- $R_{\star}$  = Radius of the star
- $d$  = Distance from star to planet
- $T_{\star}$  = Effective temperature of the star
- $T_p$  = Effective temperature of the planet
- $L_{\star}$  = Stellar luminosity
- $F$  = Flux at the planet
- $A$  = Albedo of the planet

## Useful Reference Values:

- $R_{\odot} = 6.96 \times 10^8 \text{ m}$  — Solar radius
- $\text{AU} = 1.496 \times 10^{11} \text{ m}$  — Astronomical unit