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)	Specific Gas Constant (R_s)
$pV = nRT \quad (n = \text{mol})$	$pV = mR_sT \quad (m = \text{mass})$

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

Symbol	**Unit**	**Note**
p	Pa	Pressure
V	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	m^{-3}	Number of molecules per unit volume
ρ	$\text{kg}\cdot\text{m}^{-3}$	Density
α	$\text{m}^3\cdot\text{kg}^{-1}$	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	mol^{-1}	Avogadro's Number (6.022×10^{23} particles/mol)

Table 2: Physical symbols, units, and associated meanings

2 Wave Symbols and Quantities

Symbol	Name	Meaning (Wave Context)
λ	Lambda	Wavelength – distance between wave crests (m)
ν	Nu	Frequency – cycles per second (Hz = 1/s)
$\bar{\nu}$	Nu-bar	Wave number – cycles per meter (1/m)
k	k	Angular (circular) wave number – $k = 2\pi/\lambda$ (rad/m)
ω	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

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

Table 4: Conversion between wave parameters

3 Radiomentric Quantities

Quantity	Symbol	Units	Physical Meaning	Equation
Radiant Power (Radiative Flux)	Φ, 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	$\mathrm{W\,m^{-2}}$	Power received per unit surface area (in, through, or out).	$E = \frac{d\Phi}{dA}$
Radiance (Specific Intensity)	L	$\mathrm{W\,m^{-2}\,sr^{-1}}$	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)
$F = \dfrac{L_\star}{4\pi d^2}$	Solar Constant / Stellar Flux at Planet	W/m^2
$T_p = \left(\dfrac{(1-A)F}{\sigma}\right)^{1/4}$	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)
$F = \dfrac{L_\star}{4\pi d^2}$	Solar Constant / Stellar Flux at Planet	W/m^2
$T_p = \left(\dfrac{(1-A)F}{\sigma}\right)^{1/4}$	Effective Temperature of a Planet	K (kelvin)

Table 7: Key equations for planetary energy balance

Definition of Values in above Equations:

- $\sigma = 5.67 \times 10^{-8}\,\mathrm{W \cdot m^{-2} \cdot K^{-4}}$ — 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:

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

5 Lee

5.1 Beers Law

Gives the change of intensity of light as it passes through a medium;

$$\underset{.}{I}_\lambda = I_\lambda(s + \underset{.}{s}) - I_\lambda(s)$$

or integrating out

$$I_\lambda(s_2) = I_\lambda(s_1) \exp\left[-\int_{s_1}^{s_2} \beta_e(s)\underset{.}{s}\right] \tag{1}$$