ASTR 101 — Midterm 2 Equation Sheet

Spring 2026 | Dr. Anna Rosen | Cumulative: Module 1 + Module 2

Light & Radiation

$$c = \lambda\nu$$

$$E = h\nu = \frac{hc}{\lambda}$$

$$E = mc^2 \text{ (mass–energy)}$$

$$\lambda(\text{nm}) = \frac{1240}{E(\text{eV})}$$

Thermal (Blackbody) Radiation

$$\lambda_{\text{peak}} = \frac{2.90 \times 10^6 \text{ nm} \cdot \text{K}}{T}$$

$$L = 4\pi R^2 \sigma T^4$$

$$F_{\text{surface}} = \sigma T^4 \text{ (per unit area)}$$

$$F = \frac{L}{4\pi d^2}$$

F = apparent brightness (flux at observer); d = distance

Atomic Spectra

$$E_n = -\frac{13.6 \text{ eV}}{n^2} \quad (n = 1, 2, 3, \ldots)$$

Bohr energy levels of hydrogen; photon energy of a transition is $|E_{\text{final}} - E_{\text{initial}}|$

Temperature

$$T_K = T_C + 273$$

Gravity & Orbits

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$F_g = \frac{GMm}{r^2} \quad g = \frac{GM}{r^2}$$

$$W = mg$$

$$a_c = \frac{v^2}{r} \quad F_c = \frac{mv^2}{r}$$

$$v_{\text{orb}} = \sqrt{\frac{GM}{r}} \quad v_{\text{esc}} = \sqrt{\frac{2GM}{r}}$$

$$P^2 = a^3 \text{ (yr, AU, around Sun)}$$

$$P^2 = \frac{4\pi^2}{GM} a^3 \text{ (general)}$$

$$r_p = a(1-e) \quad r_a = a(1+e)$$

Motion & Distance

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

$\Delta\lambda = \lambda_{\text{obs}} - \lambda_{\text{rest}}$. $v > 0$: recession; $v < 0$: approach.

$$\text{distance} = \text{speed} \times \text{time}$$

Angular Geometry

$$\theta \approx \frac{D}{d} \text{ (θ in radians)}$$

D = physical size, d = distance; for small angles

$$h_{\text{noon}} = 90° - |\varphi - \delta|$$

Sun's noon altitude from observer latitude φ and declination δ

Telescope Performance

$$\theta_{\min} \approx 1.22 \frac{\lambda}{D} \text{ (resolution)}$$

$$\text{Light-gathering power} \propto D^2$$

Distance & Parallax

$$d(\text{pc}) = \frac{1}{p('')}$$

p in arcseconds; 1 pc ≈ 3.26 ly

Binary Stars

Total mass (Kepler III)

$$M_1 + M_2 = \frac{a^3}{P^2} \text{ (solar units)}$$

a in AU, P in yr, masses in $M_\odot$

$$P^2 = \frac{4\pi^2}{G(M_1 + M_2)} a^3$$

Mass ratio (center of mass)

$$M_1 v_1 = M_2 v_2 \quad \frac{M_2}{M_1} = \frac{v_1}{v_2}$$

The faster-moving star is the less massive one

Main-Sequence Scaling

$$L \propto M^{3.5}$$

$$t_{\text{MS}} \propto \frac{M}{L} \propto M^{-2.5}$$

$$t_{\text{MS}}(1M_\odot) \approx 10^{10} \text{ yr}$$

Compact-Object Limits

$$R_s = \frac{2GM}{c^2}$$

$$R_s \approx 3 \text{ km } (M/M_\odot) \text{ (anchor)}$$

$$R_{\text{WD}} \propto M_{\text{WD}}^{-1/3}$$

White-dwarf mass–radius relation from electron degeneracy pressure

$$M_{\text{Ch}} \approx 1.4 M_\odot \text{ (WD max)}$$

$$M_{\text{TOV}} \approx 2\text{–}3 M_\odot \text{ (NS max)}$$

Qualitative Reference

Spectral Classification

Hot → Cool: O — B — A — F — G — K — M
O: $\gtrsim$ 30,000 K G (Sun): $\sim$ 5800 K M: $\sim$ 3000 K

Spectra

- **EM spectrum order (low E → high E):** radio → microwave → IR → visible → UV → X-ray → gamma

Kirchhoff's Three Spectral Laws

- **Continuous:** a hot, dense opaque source (solid, liquid, or dense gas) emits a smooth blackbody spectrum.
- **Emission-line:** a hot, low-density gas emits light at discrete wavelengths set by its atomic transitions.
- **Absorption-line:** a cooler gas in front of a continuous source removes light at those same discrete wavelengths.

Reference Tables

Constants, astrophysical values, math rules, and unit conversions

Physical Constants

Constant	Symbol	Value
Speed of light	c	3.00×10^8 m/s
Gravitational const.	G	6.67×10^{-11} N m² kg⁻²
Stefan-Boltzmann	σ	5.67×10^{-8} W m⁻² K⁻⁴
Planck's constant	h	6.63×10^{-34} J s
Earth surface gravity	$g_\oplus$	9.8 m/s²
H ionization energy	$\lvert E_1 \rvert$	13.6 eV

Astrophysical Reference Values

Quantity	Symbol	Value
Solar luminosity	$L_\odot$	3.8×10^{26} W
Solar radius	$R_\odot$	7.0×10^8 m
Solar mass	$M_\odot$	2.0×10^{30} kg
Solar surface temp.	$T_\odot$	5800 K
Solar peak wavelength	$\lambda_{\text{peak},\odot}$	≈ 500 nm
Solar core temp.	$T_{\text{core},\odot}$	$\sim 1.5 \times 10^7$ K
Solar MS lifetime	$t_{\text{MS},\odot}$	$\sim 10^{10}$ yr
Earth–Sun distance	1 AU	1.50×10^{11} m
Light-year	1 ly	9.46×10^{15} m
Parsec	1 pc	3.09×10^{16} m ≈ 3.26 ly
Earth radius	$R_\oplus$	6.4×10^6 m
Earth mass	$M_\oplus$	6.0×10^{24} kg

Exponent & Scaling Rules

Rule	Example
$10^a \times 10^b = 10^{a+b}$	$10^3 \times 10^5 = 10^8$
$10^a / 10^b = 10^{a-b}$	$10^8 / 10^5 = 10^3$
$(10^a)^b = 10^{ab}$	$(10^3)^2 = 10^6$
$x^{1/2} = \sqrt{x}$	$4^{3/2} = 8$
$x^{-n} = 1/x^n$	$10^{-3} = 0.001$

Scaling / ratio method: if $A \propto B^n$, then

$$\frac{A_2}{A_1} = \left(\frac{B_2}{B_1}\right)^n$$

Example (Stefan-Boltzmann ratio):

$$\frac{L_2}{L_1} = \left(\frac{R_2}{R_1}\right)^2 \left(\frac{T_2}{T_1}\right)^4$$

Unit Conversions

Category	Conversion
Angles	$1° = 60' = 3600''$
	1 rad $\approx 57.3°$ $\quad 2\pi$ rad $= 360°$
Length	1 nm $= 10^{-9}$ m $\quad 1$ km $= 10^3$ m
	1 pc ≈ 3.26 ly $= 3.09 \times 10^{16}$ m
	1 ly $\approx 9.46 \times 10^{15}$ m
Energy	1 eV $= 1.6 \times 10^{-19}$ J
	1 J = 1 kg m² s⁻²
Time	1 yr $\approx 3.15 \times 10^7$ s
	1 day = 86,400 s
Temperature	$T_K = T_C + 273$ (use K in Wien / Stefan-Boltzmann)