UNIVERSITY OF KANSAS
Department of Physics and Astronomy
ASTR 691 — Prof. Crossfield — Fall 2022

Midterm #1
Wednesday, 2022/10/05 — 1000 Central Time

This exam is worth **56 points**. Please complete all FOUR questions in the exam. As always, be sure to: show your work, circle your final answer, and use the appropriate number of significant figures, and appropriately label all plots. Unlike a problem set for this midterm you may use only this equation sheet, the OoMA factoid sheet, and a 'dumb' calculator.

$$\textbf{Stefan}-\textbf{Boltzmann Law}:\quad L = (\text{surface area}) \times \sigma_{SB} T^4 \tag{1}$$

$$\textbf{Wien's Law}:\quad \frac{\lambda_{max}}{1\ \mu\text{m}} \approx \frac{3000\ \text{K}}{T} \tag{2}$$

$$c = \lambda\nu \qquad E_{\text{photon}} = h\nu \qquad \frac{E_{\text{photon}}}{1.2\ \text{eV}} \approx \frac{\lambda}{1\ \mu\text{m}} \tag{3}$$

$$P = nk_BT \qquad n = \frac{\rho}{\langle m_{\text{particle}}\rangle} \tag{4}$$

$$L = \frac{E}{\Delta t} \qquad F = \frac{L}{\text{area}} \qquad F_\lambda = \frac{F}{\Delta\lambda} \qquad I_\lambda = \frac{F_\lambda}{\Omega} \tag{5}$$

$$E = \int L dt \qquad L = \int F\, dA \qquad F = \int F_\lambda\, d\lambda \qquad F_\lambda = \int I_\lambda\, d\Omega \tag{6}$$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1} \qquad B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{\frac{h\nu}{k_B T}} - 1} \tag{7}$$

$$d\tau_\lambda = \alpha_\lambda dx \qquad \alpha_\lambda = n\sigma_\lambda \qquad S_\lambda = \frac{j_\lambda}{\alpha_\lambda} \tag{8}$$

$$\frac{dI_\lambda}{d\tau_\lambda} = S_\lambda - I_\lambda \qquad I_\lambda(\tau_\lambda) = I_{\lambda,0}e^{-\tau_\lambda} + S_\lambda\left(1 - e^{-\tau_\lambda}\right) \tag{9}$$

$$E_n = (-13.6\ \text{eV})\frac{Z^2}{n^2} \qquad E_\ell = h\nu_0\left(\ell + \frac{1}{2}\right) \qquad E_J = \frac{\hbar^2}{2I}J\,(J+1) \tag{10}$$

$$j_\nu = \frac{1}{4\pi}h\nu\, A_{UL}\, n_u\, \phi(\nu) \qquad \alpha_\nu = \frac{1}{4\pi}h\nu\, B_{LU}\, n_L\, \phi(\nu) \tag{11}$$

OoMA Fact Sheet

$G = (2/3) \times 10^{-10}$ N-m^2/kg^2
$c = 3 \times 10^8$ m/sec
$k = (1/7) \times 10^{-22}$ J/K
$h = (2/3) \times 10^{-33}$ J-sec
$\hbar = 10^{-34}$ erg-sec
$N_A = 6 \times 10^{26}$ nucleons/kg
$m_p/m_e = 1836$ $\quad$ $m_pc^2 = 938$ MeV
$m_e \approx 10^{-27}$ gm $\quad$ $m_ec^2 = 511$ keV
$e = 4.8 \times 10^{-10}$ esu $= 1.6 \times 10^{-19}$ Coulomb
$\alpha = e^2/\hbar c = 1/137$
$L_\odot = 4 \times 10^{26}$ W
Fusing H to He yields 0.7% of mc^2
He to C & C to Fe about 0.1% of mc^2 each
Solar Constant = 1.4 kW/m^2 at 1 AU
$R_\odot = 7 \times 10^8$ m $\quad$ $M_\odot = 2 \times 10^{30}$ kg
$R_\oplus = 6371$ km $\quad$ $M_\oplus = 3 \times 10^{-6} M_\odot$
$\pi R_\oplus \approx 20000$ km (by revolutionary fiat)
$M_J = 10^{-3} M_\odot$
Hubble radius $= c/H_\circ = 1.3 \times 10^{30}$ m
Critical density $\sim 10^{-26}$ kg/m^3
$\sigma_T = (2/3) \times 10^{-28}$ m^2
$\sigma_{SB} = 5.67 \times 10^{-8}$ J/m^2/sec/K^4
Flux from a blackbody surface is $\sigma_{SB} T^4$
1 gram calorie = 4.2 Watt-sec or Joules
Dietary calories are really kilocalories.
1 kiloton (kT) of TNT = KE of 1000 metric tonnes @ 2.9 km/sec. [1 kT = 10^9 kg-cal exactly]
Supernova kinetic energy $= 10^{44}$ J
1 AU $= (3/2) \times 10^{11}$ m
1 radian $= 2 \times 10^5$ arc-seconds
1 square arcsec $= 2.4 \times 10^{-11}$ steradians
1 pc $= 2 \times 10^5$ AU $= 3 \times 10^{16}$ m
1 J $= 10^7$ erg $= 6 \times 10^{18}$ eV
1 eV $\sim 12,000$ K $\quad$ 1 eV ~ 1.2 μm
$hc/k \approx 0.014$ m-K
1 Jy $= 10^{-26}$ J/m^2/sec/Hz
1 year $\approx \pi \times 10^7$ seconds
1 Mpc is 1 km/sec for 1000 Gyr
One atmosphere or 1 bar $= 10^5$ N/m^2
Maximum mass for white dwarfs: 1.4 M$_\odot$
Typical mass of neutron stars: 1.4 M$_\odot$

Stellar spectra – from "early" = hot to "late" = cool:
Oh Be A Fine (Guy/Gal) Kiss Me Later Tonight
Luminosity class – the Roman numeral:
"I" = supergiant = low surface gravity
"III" = giant, "V" = dwarf = main sequence star = high surface gravity.

Sp.Type	$\log(L/L_\odot)$	M/M$_\odot$	T$_{eff}$ K
O5V	5.82	40	40,000
B0V	4.66	18	28,000
B5V	2.94	9	15,500
A0V	1.78	3	9900
A5V	1.15	2	8500
F0V	0.88	1.7	7400
F5V	0.54	1.3	6580
G0V	0.15	1.1	6030
G5V	-0.11	0.9	5520
K0V	-0.38	0.8	4900
K5V	-0.78	0.7	4130
M0V	-1.22	0.5	3480
M5V	-1.90	0.2	2800
L0	-3.65		2200
L5	-4.11		1700
T0	-4.57		1300
T5	-5.02		1000
Y0	-6.23		500

1 magnitude is -4 db
A decibel (db) is a factor of $10^{0.1}$ in power.
0^{th} mag at V $\approx 10^7$ photons/m^2/sec/Å.
$m_{bol} = 0$ for 2.5×10^{-8} W/m^2.
Bands central wavelengths in μm:
U = 0.36, B = 0.44, V = 0.55, R = 0.7, I = 0.9, Z = 1.0, J = 1.25, H = 1.6, K = 2.2, L = 3.5, M = 4.6, N = 10, Q = 20
AB magnitudes have the same zeropoint flux in F_ν (3631 Jy) in all bands.
Johnson or "Vega" magnitudes have zeropoints that follow the spectrum of an A0V star.

$10^{n/10} = 1.26, 1.6, 2, 2.5, 3.2, 4, 5, 6.3, 8.$