UBC
ASTRONOMY 205
Stars and Stellar Populations
First Midterm Examination
February 8, 2019 – 50 Minutes

This exam consists of 10 pages. There are 7 numbered questions, please attempt all of them. Write directly in the space provided on the exam. A simple hand-held calculator is also allowed – no graphing or programmable ones permitted. There is a blank page at the end for rough work – it will NOT be marked. A formula sheet together with useful constants is found on the following page.

STUDENT NAME: ______________________________

STUDENT NUMBER: ____________________________

Some of the following constants and equations might prove useful.
speed light $c = 3x10^8$ m/sec;
1 AU = $1.5x10^8$ km; 1 light year = $9.5x10^{12}$ km;
1 parsec = 3×10^{13} km
Wien's Law $\lambda_{max} = 3x10^6/T$, λ_{max} is in nanometers, T in degrees K;
Stefan-Boltzman law $F = \sigma T^4$; $\sigma=5.67x10^{-8}$ W/m^2K^4;
Kepler's Third Law $p^2 = 4\pi^2 a^3/G(M_1+M_2)$;
Gravitational Force $F=GM_1M_2/r^2$;
206265 arcsec/radian;
$F = L/4\pi d^2$ where F is the flux, L the Luminosity and d the distance;
$G=6.67x10^{-11}$ Nm^2/kg^2;
$\theta_{radian} = 1.22\lambda/D$;
1 micrometer $=10^{-6}$m;
1 nanometer (nm) = 10^{-9}m;
Mass of Sun=$2x10^{30}$ kg;
Radius of Sun=$7x10^8$ m;
Luminosity Sun=$4x10^{26}$ watts;
Latitude Vancouver = 49 Degrees;
Distance (pc) = $1/\pi$, π in arcsec;
Velocity-Redshift $\Delta\lambda/\lambda = v/c$, c is speed light, v is velocity;
m2 – m1 = 2.5 log(b1/b2), m's are magnitudes b are fluxes
(m-M) = 5 log (d/10) + A; m apparent mag, M absolute mag, d distance in pc,
A is extinction = 3E(B-V) where E is the colour excess;
$B_\lambda(T) = (2hc^2/\lambda^5)(1/e^{hc/\lambda kT} - 1)$ w m^{-2} m^{-1} $sterad^{-1}$ B(T) is Planck Function
$1/\lambda = R_H(1/4 - 1/n^2)$ R_H Rydberg Constant = 1.09677×10^7 m^{-1}
Boltzmann Formula: $N_B/N_A = D\, e^{-(X_{AB}/kT)}$ N's are the numbers in various states, D depends on state, X_{AB} is energy difference between states, k is Boltzmann constant = 1.38×10^{-23} m^2 kg s^{-2} K^{-1},T temperature
$F(m) = pv^3/2\pi G$ is mass function p is period v velocity

1. Our Sun will eventually evolve to a red giant star and then to a white dwarf. A typical white dwarf is about the size of the Earth (radius 6000 km) with a temperature of about 25,000 K while a red giant has a typical temperature of 3,000 K and a radius ~100,000 times that of the white dwarf. Compare the radiated energy per unit area and the total radiated energy for these two types of stars. **[4 marks]**

Per unit area

$$\frac{F_{RG}}{F_{WD}} = \frac{T^4_{RG}}{T^4_{WD}} = \frac{(3000)^4}{(25{,}000)^4} = 2.1 \times 10^{-4}$$

$$\frac{L_{RG}}{L_{WD}} = \frac{R^2_{RG}\, T^4_{RG}}{R^2_{WD}\, T^4_{WD}} = (10^5)^2 \times 2.1 \times 10^{-4}$$

$$= 2.1 \times 10^6$$

2. The Luyten 726-8 star system contains two stars, one with apparent magnitude m=12.5 and the other with m=12.9. What is the combined apparent magnitude of the two stars? **[3 marks]**

Let $m=12.5$ star have 100 units of flux. (F_1).

$\therefore m=12.9$ star has $2.5 \log \frac{F_1}{F_2} = m_2 - m_1$

$\therefore m_2 - m_1 = 0.4 \qquad \therefore \frac{F_1}{F_2} = 10^{0.4(0.4)}$

$= 1.45 \Rightarrow F_2 = 69$ units

$\therefore \Sigma$ flux $= 169. \qquad \therefore (m_1 - m_{Total}) = 2.5 \log \frac{F_{Total}}{F_1}$

$m_1 - m_{Total} = 2.5 \log (1.69) = 0.57 \Rightarrow m_{Total} = m_1 - .57$

$= 11.93$

(b) What is the right ascension and declination of the Sun when it is located at 1) the autumnal equinox and 2) the winter solstice? **[2 marks]**

(1) $RA = 12^h \quad \delta = 0^\circ \qquad$ 2) $RA = 18^h \quad \delta = -23^\circ$

(c) Is there a latitude on Earth where the Sun will never set when it is at the vernal equinox? If so, where? **[1 mark]**

No – 12^h day and night everywhere

(d) At what latitude(s) on Earth will the Sun never set when it is at the winter solstice? **[1 mark]**

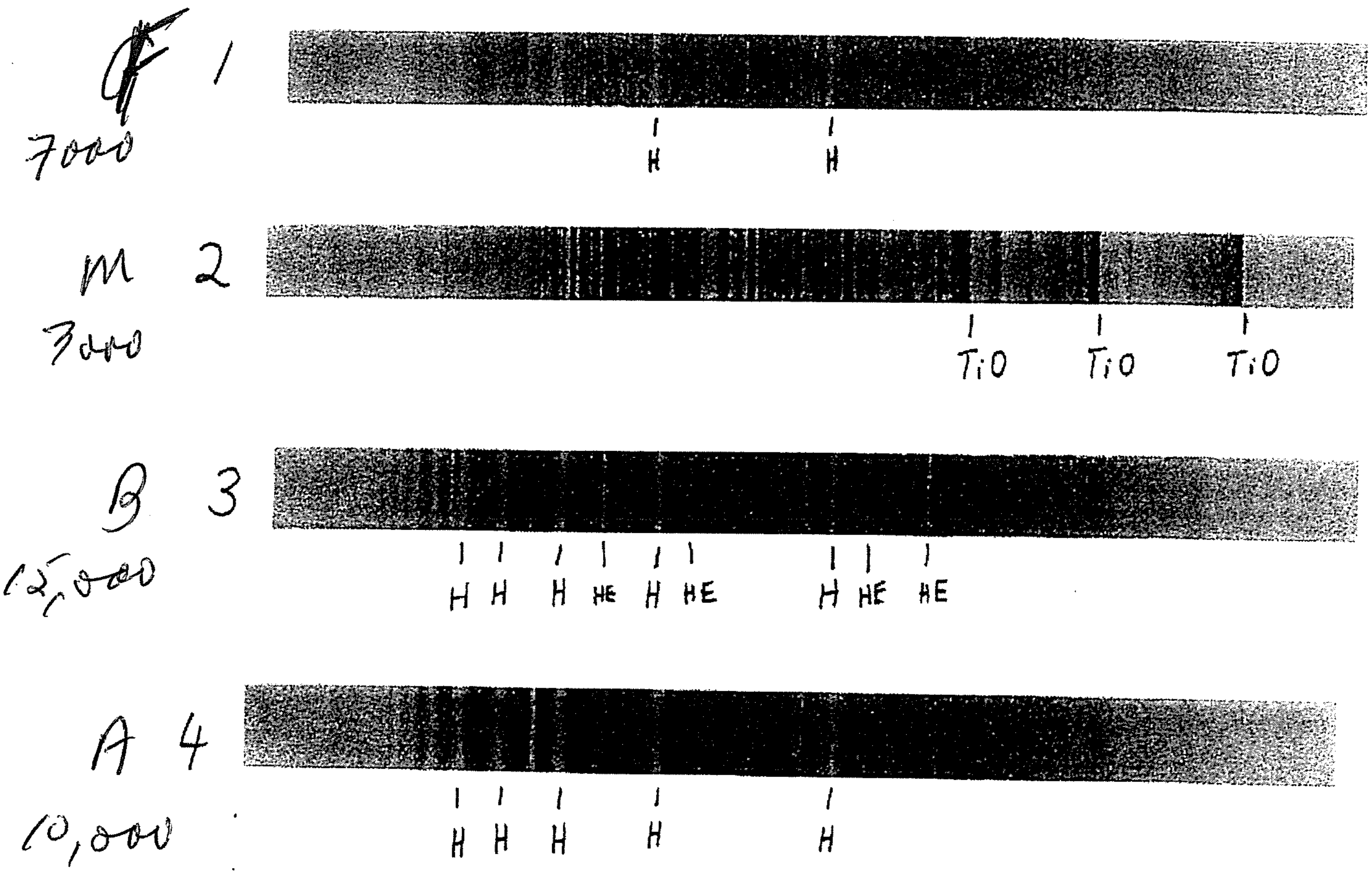
$\ell < -67^\circ$

(e) What is the approximate Right Ascension and Declination of the Sun today (February 8)? **[1 mark]**

About 1.5 months after Winter Solstice
($\therefore \sim 4.5$ months after Autumnal Equinox ($RA=12^h, \delta=0^\circ$)
& ~1/2 way to Vernal Equinox

$\therefore \sim 21^h$ RA, $\delta = -12^\circ$

3. Below are the spectra of 4 stars. Provide a spectral classification of each of these stars. All stars are main sequence stars (ie dwarfs). Indicate a rough temperature also for each star. H=hydrogen, He=helium, TiO=titanium oxide molecule. **[4 marks]**



4. The typical absolute visual magnitude of a B1I star like ζ Sco is M_V = -6.7. The apparent V magnitude of ζ Sco is 4.7 yielding a distance modulus corresponding to about 2,000 pc. This is probably not a very accurate distance to ζ Sco. Why? Is the actual distance likely to be more than 2,000 pc, or less than 2,000 pc? Why? **[3 marks]**

$(m - M) = 5 \log \frac{r}{10}$

$(4.7 + 6.7) = 5 \log \frac{r}{10} \Rightarrow r \simeq 1900\ pc$

not accurate as extinction not included in calculation. Need to use

$(m - M) = 5 \log \frac{r}{10} + A_V$

because A_V always positive r will be LESS than 2000 pc. Eg take $A_V = 1.0$ mag (reasonable) then

$r = 1200$ pc.

5. You have access to the (current) largest optical telescope in the world, the Keck 10m diameter instrument. You hope to resolve and measure the diameter of the red supergiant Betelgeuse. Will you be able to successfully carry out this experiment? A simple yes or no doesn't get you any marks. **[3 marks]**

Here are some potentially useful data:
Distance to Betelgeuse: 222 pc
Surface Temperature: 3590 K
Apparent V magnitude: 0.5
(B-V) colour: +1.85
Absolute visual magnitude: -5.85
Radius: $6.2x10^{11}$ m
Mass: $1.5x10^{31}$ kg
Radial velocity: +21.9 km/sec
Proper motion: 30 milli-arcseconds/year

Resolution Keck at optical (500 nm)

$\theta = 1.22\ \lambda/D$, $\lambda = 500\,nm$, $D = 10^{10}\,nm$

$\therefore\ \theta = 6 \times 10^{-8}$ Radians ($.0126''$)

What is angular size of Betelgeuse as seen from Earth?

$\theta = \frac{Diam}{distance} = \frac{2 \times 6.2 \times 10^{11}\ m}{222 \times 3 \times 10^{16}\ m} \times 206265$

$= .038''$

So yes should just be able to resolve it

6. A star 20 parsecs from the Sun has a proper motion of 0.5"/year. What is the star's transverse velocity (in km/sec)? If the star's spectral lines are observed to be redshifted by 0.01 percent, calculate its three-dimensional velocity relative to the Sun.
[3 marks]

$\theta = \frac{arc}{rad} = \frac{0.5''}{yr} = \frac{D}{20pc} \Rightarrow D = 20pc \times 0.5''$

$D = 4.85 \times 10^{-5}$ pc/year $= \frac{4.85 \times 10^{-5} \times 3 \times 10^{13}}{3 \times 10^{7}}$ km/s $= 48$ km/s

$\frac{\Delta\lambda}{\lambda} = \frac{V}{c} \therefore V = \frac{\Delta\lambda}{\lambda} \times c = 30$ km/s

$\frac{\Delta\lambda}{\lambda} = 10^{-4}$

$\therefore$ 3D vel $= \left[(30)^2 + (48)^2\right]^{1/2} = 56.6$ km/s

7) Answer the following questions using the following data. **[1 mark each]**

Star Name	Mv Abs. Mag	V Apparent Mag	Spectral Type	Luminosity Class
1 Canopus	-4.7	-0.7	F0	I
2 Wolf 359	16.7	13.5	M8	V
3 Gacrux	-2.5	1.6	M3	II
4 λ Ser	4.4	4.4	G0	V
5 EL Nath	-1.1	1.7	B7	III
6 α UMa	-0.7	1.8	K0	III
7 α Aqr	-3.8	3.0	G2	I
8 Achernar	-2.5	0.5	B3	V
9 β Aqr	-3.5	2.9	G0	I
10 Deneb	-8.4	1.3	A2	I

a) Which star would look second brightest in the sky? ACHENAR
b) Which star could not be seen with the unaided eye? WOLF 359
c) Which star is most similar to the Sun? λ Ser
d) Which star is intrinsically the brightest? DENEB
e) Which star has the highest surface temperature? ACHENAR
f) Which star has the lowest surface temperature? GACRUX
g) Which star is at 10 pc? λ Ser