UBC
ASTRONOMY 205
Stars and Stellar Populations
Final Examination
April 18, 2017 - 2.5 Hours

This exam consists of 16 pages, the last one is left blank and can be used for scribbling. This page will NOT be marked. There are 12 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. 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 $F = \sigma T^4$; σ=5.67x10^{-8} W/m^{2}K^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
$F(m) = m_2^3\sin^3 i/(m_1 + m_2)^2$
$L \alpha M^{3.5}$
P.E. = $-3GM^2/5R$
$P=(1/\mu)k\rho T/m_H$ $\quad$ $dP/dr = - GM_r\rho(r)/r^2$
$dM(r)/dr = 4\pi r^2\rho(r)$ $\quad$ $dL(r)/dr = 4\pi r^2\rho(r)\varepsilon(r)$
$dT/dr = (-3/4ac)\,(\kappa\rho(r)/T^3)\,(L_r/4\pi r^2)$
mass hydrogen atom 1.67×10^{-27} Kg

1. The mass of Jupiter is about 10^{-3} that of the Sun. Assume a Jovian-mass planet orbits a sun-like star with a period of 10 days and 0 eccentricity. (a) If the orbital plane is edge-on to us, what is the maximum observed Doppler shift ($\Delta\lambda/\lambda$) of spectral lines from the planet? Find the same quantity for spectral lines from the star. [**5 marks]**

2. Consider a spherically symmetric star in which the density as a function of radius scales as

$$\rho(r) = \rho_0[1-(r/R_s)^2]$$

where ρ_0 is a constant and R_s is the radius of the star.

a) Calculate the total mass of the star. **[3 marks]**

b) Calculate the pressure of the star at the centre. **[3 marks]**

3. (a) Would it be possible to measure the parallax to a nearby star (2 parsecs away) with a small (3cm) optical telescope? A simple yes or no gets you no marks. **[3 marks]**

(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]**

(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]**

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

(e) What is the approximate declination of the Sun today (April 18)? **[1 mark]**

4. (a) What are the physical processes that broaden spectral lines? **[2 marks]**

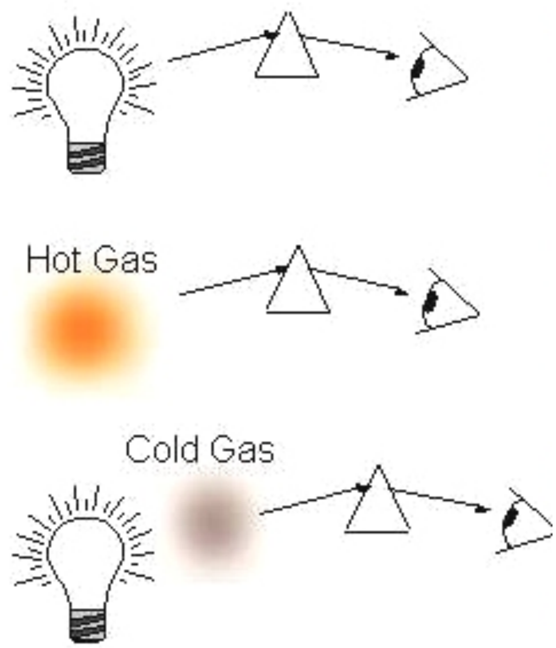
(b) Given the energy per reaction in nuclear reactions in the Sun and its mass and luminosity, how would you go about estimating its main sequence lifetime? **[2 marks]**

(c) White dwarfs have an upper limit to their mass. Do neutron stars? Explain. **[2 marks]**

(d) What property is the same for all stars on the main sequence? **[1 mark]**

5. Explain in some detail (including numbers) how white dwarf stars can be used to date very old stellar clusters. **[4 marks]**

6. (a) Below are three diagrams for three different ways to produce a spectrum of an object – the triangle in each diagram is meant to represent a prism, the object to the right is the observer. Indicate what kind of spectrum is produced by each set up and mention a type of astronomical object that would have each of these spectra. **[3 marks]**



7. Here are five questions on nuclear reactions **[1 mark each total 5 marks]**

1) ${}_{Z}X^{A}$ – what does each of these symbols mean?

2) What is an isotope?

3) Solve the following equation (ie what are A and Z)?
${}_{86}Rn^{222} \rightarrow {}_{Z}P^{A} + {}_{2}He^{4}$

4) What is an alpha particle?

5) Explain beta decay.

8. A new telescope can detect an object in the visible down to 30th magnitude in V. If the Sun's absolute V magnitude is 4.6, out to what distance in parsecs can this telescope see a sun-like star? **[2 marks]**

9. (a) A cloud of gas can be characterized by at least 2 timescales (there is a third which we do not consider in this question)
1) the dynamical timescale $t_{dyn} \alpha\ 1/ (G\rho)^{1/2}$ giving the timescale over which gravitational effects are most important and
2) the sound crossing time $t_{sound} \alpha\ R/C_s$ (where R is the size of the cloud and C_s is the sound speed) giving the timescale over which pressure effects dominate.

What happens to the gas cloud if **[1 mark each]**

a) $t_{dyn} = t_{sound}$

b) $t_{sound} << t_{dyn}$

c) $t_{dyn} << t_{sound}$

(b) Write short notes on any five of the following topics. **[1 mark each]**

(a) Quantum mechanical tunneling

(b) Interstellar extinction

(c) Opacity

(d) Bolometric Magnitude

(e) UBV System

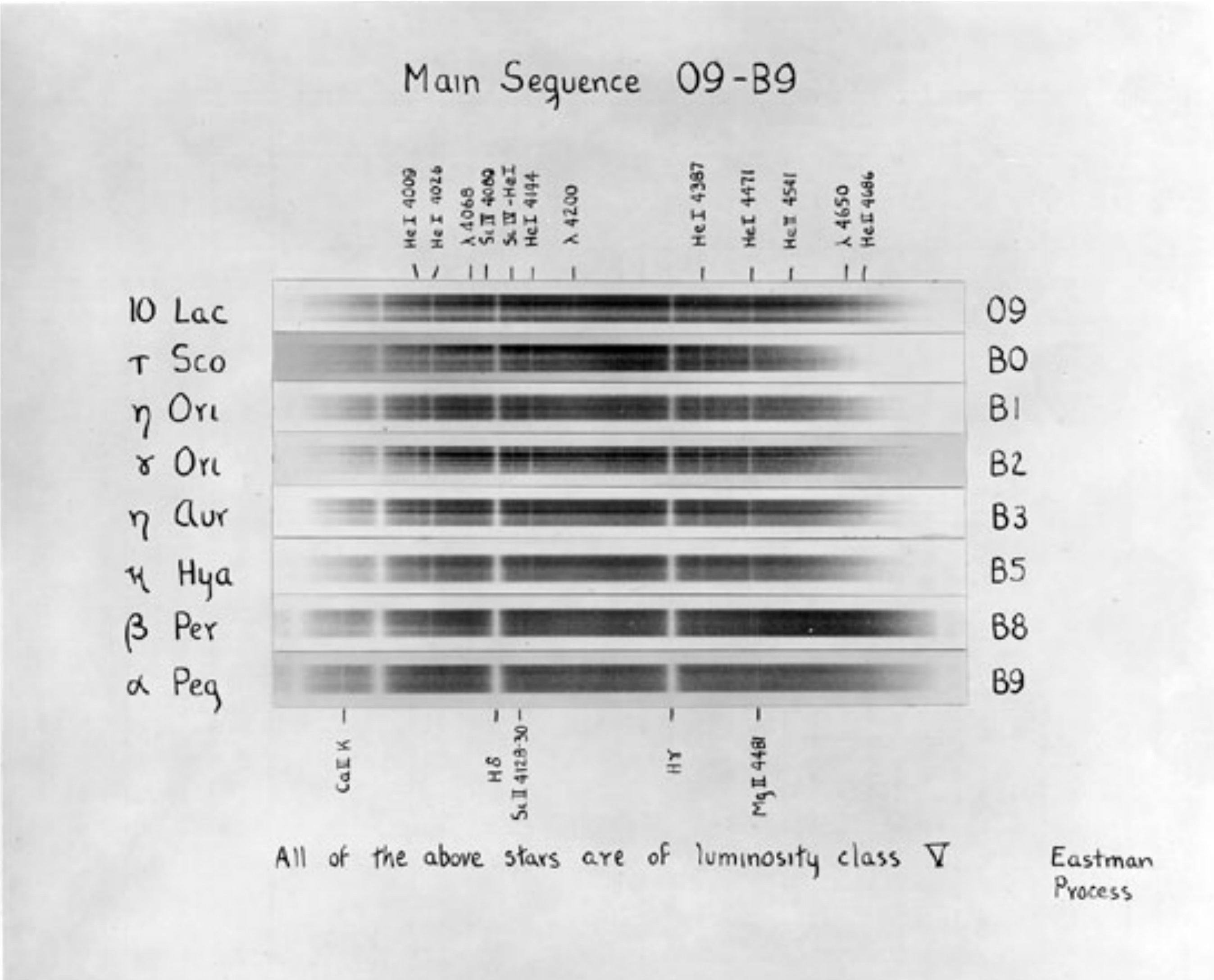
(f) Type II supernovae

(g) Schwarzschild Radius

10. On the next page are spectra of a number of stars. Explain the following features in the spectra with a physical argument.

(1) Why do the Balmer lines increase in strength to later spectral types?
[2 marks]

(2) Why do the He I lines reach a peak near type B2 and then decline **[3 marks]**

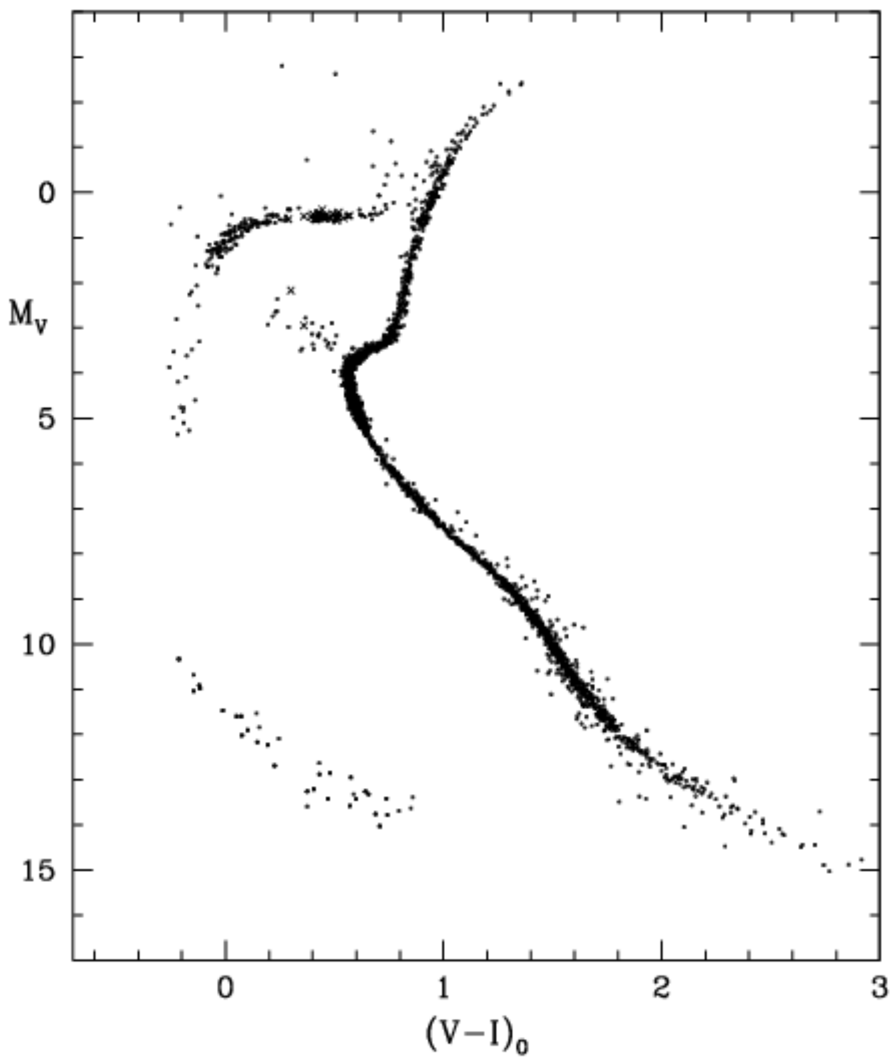


Main Sequence O9-B9
He I 4009
He I 4026
λ 4068
Si III 4089
Si IV - He I
He I 4144
λ 4200
He I 4387
He I 4471
He II 4541
λ 4650
He II 4686
10 Lac
τ Sco
η Ori
γ Ori
η Aur
κ Hya
β Per
α Peg
O9
B0
B1
B2
B3
B5
B8
B9
Ca II K
Hδ
Si II 4128-30
Hγ
Mg II 4481
All of the above stars are of luminosity class V
Eastman Process

11. Attached below is a Hertzsprung-Russell (HR) Diagram for a globular star cluster. The data are in M_V and intrinsic colour $(V\text{-}I)_0$.

(a) On the diagram label as many distinct features of this HR diagram as you can. **[3 marks]**

(b) Sketch the internal structure of stars marked as 1, 2 and 3 in this cluster making sure to indicate nuclear burning and non-burning regions.
[6 marks]



12. (a) For an eclipsing binary system with a period of 30 days, the total duration of the primary eclipse is 8 hours. A flat minimum is seen for 1 hour 18 minutes. The radial velocity amplitude for star 1 is 30 km/s and for star 2 it is 40 km/s. For a circular orbit and inclination of 90 degrees (edge on), how large are the radii of the stars (in km)? **[5 marks]**

(b) What is the ratio of the stellar masses, the sum of their masses and the individual masses of the two stars? **[5 marks]**