PHY2003 Astrophysics I –Assignment 3

As explained in Level 2 induction, submission of this assignment will be via Canvas. If your document is illegible, you will not receive any marks. Your completed assignment must be submitted as a scanned PDF file. A smartphone with a high pixel-count camera scanner app producing pdfs is also an acceptable scanning method. Microsoft Office Lens will automatically upload the images as a pdf: You can find a Microsoft Office Lens Tutorial here. Alternatively, you can use the scanners in the McClay Library to scan your completed assignment.

This assignment consists of 4 questions, each with multiple parts. Points for each part are indicated in square brackets.

Show all calculations/steps in your answers for the questions below. The deadline is 10pm November 17, 2021, but you can submit at any time before then.

Question 1

Astronomers are observing a quadruple system with all stars of the same stellar type. These are split in an eclipsing binary with a semi-major axis of 0.15 AU and a non-eclipsing binary with a semi-major axis of 0.09 AU.

a) Explain the difference between an eclipsing and non-eclipsing binary [4]

b) What stellar properties can we learn from eclipsing binaries. [4]

With a small telescope the quadruple system is unresolved and has an apparent V-band magnitude of $m_V = 7.2$

c) Explain whether the system as a whole can be seen with the naked eye from a dark place on Earth. [3]

d) Calculate the apparent magnitude of each the individual stars [8]

With the VLT, it is just possible to resolve the system into two components, but the individual binaries are not resolved. From this, the astronomers find that the B-band magnitude for each of the binaries is $m_B = 8.39$.

e) Calculate the colours of the individual stars [8]

f) Using Table 1, determine the absolute magnitude of each of the stars, and from that the distance and parallax of the system. [10]

Table 1: Properties of stars on the main sequence

Spectral Type	T_{eff}	$B-V$	M_V
O5V	$41000\,K$	-0.32	-5.35
B0V	$31000\,K$	-0.30	-3.90
B5V	$16000\,K$	-0.16	-0.85
A0V	$9700\,K$	-0.00	0.99
A5V	$8100\,K$	0.16	2.01
F0V	$7200\,K$	0.30	2.57
F5V	$6600\,K$	0.44	3.37
G0V	$5900\,K$	0.65	4.48
G5V	$5700K$	0.68	4.98
K0V	$5300\,K$	0.82	5.78
K5V	$4400\,K$	1.15	7.28
M0V	$3900\,K$	1.42	8.80
M5V	$3100\,K$	1.83	14.15

Question 2

Bolometric magnitudes and stellar sizes

a) Derive an expression for the difference in bolometric magnitudes between two stars, $\Delta M_{bol} \equiv M_{bol,1} - M_{bol,2}$, in terms of their different radii and temperatures [7]

b) In the H-R diagram, giant stars with the same colour as the Sun lie roughly 4 magnitudes above the main sequence, and supergiants are 12 magnitudes brighter. What are their true sizes in AU? [6]

Question 3

An alien astronomer decides to build a telescope on the planet HR8799 b. This planet orbits its star at a distance of 68 AU. The star is located 40.88 pc from Earth and has an absolute magnitude of $M_V = 5.953$.

a) The alien astronomer decides to base that Alien Astronomical Unit on the orbit of HR 8799 b. Calculate the distance for 1 Alien Parsec (APc) based on the AAU in terms of 'our' parsec [10]

b) Calculate the parallax in arcseconds the alien will measure for our Sun. Will this measurement be easier or more difficult than measuring the parallax of HR8799 from the Earth? [10]

c) Calculate the apparent magnitude of HR 8799 the alien will observe from the planet [5]

Question 4

Stellar evolution and the H-R diagram.

a) Calculate the free-fall time in years for a collapsing molecular cloud with a diameter of 0.11 pc, and mass of $2.5\ M_{\odot}$ [10]

b) Draw a theoretical H-R diagram, indicate the Sun and all main components on the diagram. [7]

c) Describe the evolution of a 0.8 $M_{\odot}$ star, and draw this on your H-R diagram from part (b) [8]