UNIVERSITY OF SOUTHAMPTON PHYS1005W1

SEMESTER 1 EXAMINATION 2012/13

INTRODUCTION TO ASTRONOMY AND SPACE SCIENCE

Duration: 120 MINS

Section A *contains 10 multiple choice questions. Maximum marks will be obtained by giving correct answers to all 10 questions. However note that although you will gain 2 marks for every correct answer, you will lose 0.5 marks for every incorrect answer. If you do not answer a question you will neither gain nor lose marks.*

You should answer two ***and only two*** *questions in* ***Section B****.*

Section A carries 1/3 of the total marks for the exam paper and Section B carries 2/3 of the total marks for the exam. You should therefore spend 40 mins on Section A and 80 mins on Section B.

A Sheet of Physical Constants will be provided with this examination paper.

An outline marking scheme is shown in brackets to the right of each question.

Only university approved calculators may be used.

Section A

A1. The microwave background radiation has a spectrum which peaks at a wavelength of 1.1 mm and is identical in shape to that of a black body of temperature 2.7 K. At what wavelength will the spectrum of the Star Sirius A (temperature 9940 K) peak?

A 9036 nm

B 335 nm

C 299 nm

D 34 nm [2]

A2. A telescope, observing in space at a wavelength of 800 nm, has an aperture with a diameter of 5 m. What is its angular resolution?

A 1.95×10^{-7} arcsec

B 4.03×10^{-2} arcsec

C 1.95×10^{-1} arcsec

D 1.6 arcsec [2]

A3. A planet in an elliptical orbit around a star moves at 30 km s^{-1} when at perihelion (1 AU from star). What velocity will the planet have at aphelion (3 AU from star)?

A 10 km s^{-1}

B 30 km s^{-1}

C 90 km s^{-1}

D 156 km s^{-1} [2]

A4. Matter falls onto the surface of a neutron star of mass 1 solar mass and radius 10 km at a rate of 10^{-9} solar masses per year. What is the luminosity of that system?

A 1.32×10^{7} W

B 1.32×10^{16} W

C 4.7×10^{23} W

D 8.3×10^{29} W [2]

A5. A star of magnitude +4 lies at a distance of 100 pc. What is its absolute magnitude?

A +9.0

B +4.0

C +1.49

D -1.0 [2]

A6. The effective temperature of a star decreases from 6000 K to 3000 K whilst its luminosity increases by a factor 100. By what factor does the star's radius change?

A 100

B 40

C 8

D 2 [2]

A7. The redshift of a nearby galaxy is 0.01. If the Hubble constant is 73 km s^{-1} Mpc^{-1}, how far away is the galaxy in Mpc?

A 7.3 Mpc

B 21.9 Mpc

C 41.1 Mpc

D 730 Mpc [2]

A8. The table below lists the extinction in magnitudes, relative to the V band, through the interstellar medium. A star of known spectral type has an intrinsic colour B-V = +0.2 but is observed to have B-V = +4.0. What is the extinction in the V band for the star?

Wavelength	Extinction	Wavelength	Extinction
U (0.36μm)	1.531	I (0.90μm)	0.482
B (0.44μm)	1.324	J (1.22μm)	0.282
V (0.55μm)	1.000	H (1.63μm)	0.175
R (0.70μm)	0.748	K (2.19μm)	0.112

A 1.23 mag

B 3.80 mag

C 5.03 mag

D 11.73 mag [2]

A9. A star at a distance of 30 pc moves at 30 km s^{-1} perpendicular to our line of sight. What is its proper motion in arcsec per year?

A 0.90 arcsec yr^{-1}

B 0.21 arcsec yr^{-1}

C 3.06×10^{-5} arcsec yr^{-1}

D 1.02×10^{-6} arcsec yr^{-1} [2]

A10. The Sun will spend 1.2×10^{10} yr on the main sequence. Given that main-sequence stars obey a mass-luminosity relationship of the form $L \propto M^{3.5}$, what is the lifetime of a $2M_\odot$ star?

A 1.06×10^9 yr

B 6.0×10^9 yr

C 1.06×10^9 yr

D 2.12×10^9 yr [2]

Section B

B1. a) Outline one method for measuring the distance to the Sun. [4]

b) (i) With the aid of a diagram, describe the Moving Cluster method for determining the distance, d, to a nearby star cluster and show that

$$d = \frac{V_R \, tan(\theta)}{4.74\mu}$$

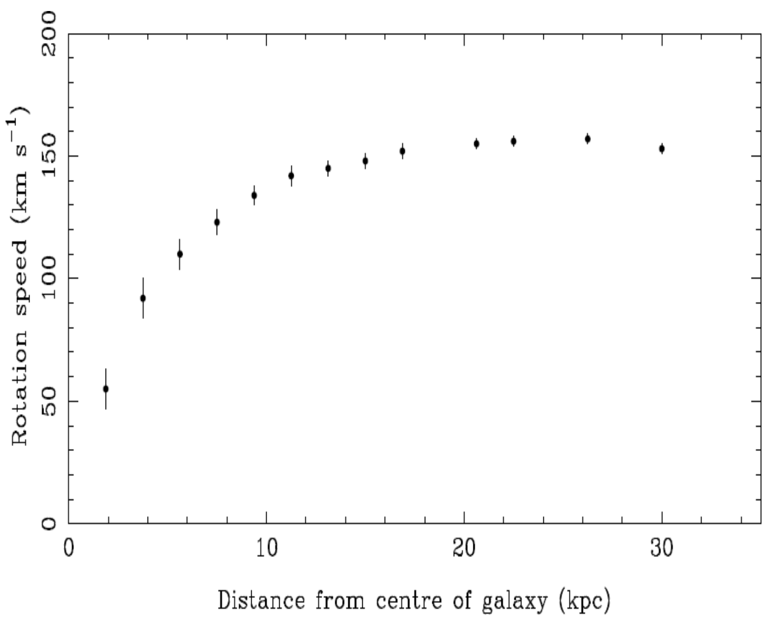
where V_R is the radial velocity of the cluster in km s^{-1}, θ is the angle to the convergence point in degrees and μ is the proper motion of the cluster in arcsec per year. [6]

(ii) For the Hyades cluster, $\theta = 37$ degrees, $V_R = 39$ km s^{-1} and $\mu = 0.11$ arcsec yr^{-1}. Determine the distance to the Hyades cluster in parsecs. [1]

c) The figure below shows measurements of the rotation curve of a galaxy.

(i) Explain quantitatively the shape of the rotation curve in terms of the mass density distribution as a function of radius. [5]

(ii) Estimate the mass, in solar masses, within 30 kpc of the centre of the galaxy. [4]



B2. a) Write down the relationship between change in pressure, dP, and change in radius, dr, in a star of density ρ, i.e. the equation of hydrostatic equilibrium. [1]

b) Assuming that ρ is constant throughout the star, but noting that gravitational acceleration varies with radius, show that the central pressure, P_c, is given by

$$P_c = \frac{3GM^2}{8\pi R^4}.$$ [5]

Hence estimate the central pressure in the Sun. [1]

c) Show that P_c can also be written as

$$P_c = \frac{GM\rho}{2R}.$$ [1]

d) The central density of the Sun is $\sim 10\times$ that of lead. Justify the assumption that material in the centre of the Sun can behave as an ideal gas. [2]

e) Ignoring the factor of 2 in the equation in part (c), and assuming that the Sun behaves like an ideal gas, show that the central temperature in the Sun, T_c, is given by

$$T_c \sim \frac{GM\mu}{kR}$$

where k=Boltzmann's constant and μ is the mean particle mass. [3]

What is the value of μ? [1]

Hence estimate the central temperature in the Sun. [1]

f) The final step of the proton-proton chain involves the collision of two ^3He nuclei. If we make the assumption that the nuclei must reach a separation of 10^{-15}m for fusion to occur, what temperature would be required? [3]

Compare the required temperature with your previous estimate of T_c and comment on the result. [2]

B3. a) Describe the system of magnitudes used by astronomers to measure the brightness of celestial objects. Include in your answer a historical description of how this system arose. [4]

State the relationship which Pogson defined between magnitude and flux. [1]

From Pogson's relationship derive the equation given below linking the fluxes of two stars f_1 and f_2, and their magnitudes m_1 and m_1 respectively.

$$m_2 - m_1 = -\frac{5}{2} \, log_{10} \left(\frac{f_2}{f_1} \right)$$

[4]

b) What is meant by the absolute magnitude of a star? [1]

Hence show that the apparent magnitude m and absolute magnitude M of a star are related by

$$m - M = 5 \, log_{10} \left(\frac{d}{10 \text{ pc}} \right)$$

where d is the distance to the star in pc. [4]

c) Jupiter has a radius of 71,500 km and orbits at a distance of 5.2 AU from the Sun. Calculate the fraction of the Sun's light intercepted by Jupiter. [3]

Given that the apparent magnitude of the Sun is -27, estimate the apparent magnitude of Jupiter at its brightest. State any assumptions that you make. [3]

END OF PAPER