King's College London

UNIVERSITY OF LONDON

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

B.Sc. EXAMINATION

CP/1600 Physical Basis of Astronomy

January 2001

Time allowed: 3 Hours

Candidates should answer SIX parts of SECTION A, and TWO questions from SECTION B.

Separate answer books must be used for each Section of the paper.

The approximate mark for each part of a question is indicated in square brackets.

You must not use your own calculator for this paper.
Where necessary, a College calculator will have been supplied.

TURN OVER WHEN INSTRUCTED

Wavelength of visible light, $\lambda = 5.00 \times 10^{-7}$ m

Speed of light, $c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$

1 parsec = 3.26 light years

Sun's mass, $M_{\odot} = 2.00 \times 10^{30}$ kg

Sun's radius, $R_{\odot} = 6.70 \times 10^{8}$ m

Stefan's constant, $\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-1}}$

1 astronomical unit, AU $= 1.50 \times 10^{11}$ m

The following relationship for a spherical triangle may be assumed

$$\cos(a) = \cos(b)\cos(c) + \sin(b)\sin(c)\cos(A)$$

where the symbols have their usual meanings.

SECTION A – Answer SIX parts of this section

1.1) Describe how hydrostatic equilibrium maintains the stability of a star.

[7 marks]

1.2) State Stefan's law and Wien's law for a blackbody radiator. Calculate the radiant power of the Sun if it is assumed to be a blackbody with a surface temperature of 5 800 K.

[7 marks]

1.3) What features characterise a G2 category of star? What would be star types corresponding to the categories B0 and M0?

[7 marks]

1.4) Show that the distance d to an astronomical object is given by

$$d \approx 10^{(m-M+5)/5} \text{ parsecs}$$

where M is the absolute magnitude and m is the apparent magnitude of the object.

[7 marks]

1.5) Explain the term *colour index* and the significance of the U, B, and V magnitude system.

[7 marks]

1.6) Describe by means of a sketch the shape of our galaxy, the Milky Way. Indicate the position of the Sun, and indicate the regions where globular star clusters and open star clusters are found.

[7 marks]

1.7) Calculate the diffraction-limited angular resolution of an optical telescope with an aperture of 2 m. What baseline would a radio interferometer, operating at 2 GHz, require to achieve the same angular resolution?

[7 marks]

1.8) State Kepler's three laws of planetary motion. Two of the satellite moons of Jupiter, Io and Europa, orbit at distances of 4.21×10^5 km and 6.71×10^5 km from the centre of the planet, respectively. Calculate the approximate orbital period, in days, of Europa if Io has a period of 1.77 days.

[7 marks]

SECTION B – Answer TWO questions

2) Describe the purpose and the principles of operation of an image intensifier as employed as a photon detector. State the range of wavelengths over which this type of detector can be used. Give physical reasons for any cut-off in response. What are the main advantages and disadvantages of this detector compared with those of a Charge Coupled Device (CCD) detector?

[15 marks]

With the aid of a suitable diagram, explain the principles of operation of a Michelson interferometer in the determination of the angular separation of a distant binary star system.

[8 marks]

Estimate the exposure time required to detect 2 500 photons from a star of apparent magnitude +13 when it is imaged by a telescope of aperture 2 m. You may assume an overall transmission and detection efficiency of 5% and the use of a filter transmitting in the wavelength range 450-650 nm. [Note: a zero magnitude star gives rise to approximately 10^8 photons per square metre, per second, per nanometre bandwidth.]

[7 marks]

3) With the aid of suitable diagrams, briefly describe the equatorial co-ordinate system and the horizon co-ordinate system. Define altitude, azimuth, hour angle, right ascension and declination. Deduce the relation between altitude (a), hour angle (H), declination (δ) and latitude (λ), namely,

$$\sin(a) = \sin(\lambda)\sin(\delta) + \cos(\lambda)\cos(\delta)\cos(H)$$

[14 marks]

On March 21st 2000 the right ascension and declination of the planet Mars were (1h 47m, 11^{o}0$'$). Calculate the angular distance between the Sun and Mars at that date.

[8 marks]

Calculate the interval of time for which Mars was visible after sunset for an observer situated in London (50° 31′ N, 0° 10′ W).

[8 marks]

4) Draw a fully-labelled Hertzsprung-Russell diagram. On your diagram show the relative positions of the main sequence, the Sun, the red-giant region and the white-dwarf region.

[15 marks]

Describe the main features of a) galactic (open) star clusters and b) globular star clusters. Discuss the significance of cluster H-R diagrams in theories of stellar evolution.

[15 marks]

5) Describe how visual binary stars can be used in the determination of stellar masses.

[14 marks]

Compare this technique with each of the following methods:

a) eclipsing binary stars;

[4 marks]

b) spectroscopic binary stars;

[4 marks]

c) stellar spectra;

[4 marks]

d) gravitational redshift.

[4 marks]