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 2002

Time allowed: 3 Hours

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

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

Typical 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, $M_{\odot} = 1.99 \times 10^{30}$ kg
Sun's radius, $R_{\odot} = 6.96 \times 10^{8}$ m
Earth's mass, $M_E = 5.98 \times 10^{24}$ kg
Earth's radius. $R_E = 6.38 \times 10^{3}$ km
Gravitational Constant, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Stefan's constant, $\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
1 astronomical unit, AU $= 1.50 \times 10^{11}$ m
A zeroth magnitude star gives rise to 10^8 photons m^{-2} s^{-1} nm^{-1}
1 year $= 3.16 \times 10^{7}$ s

SECTION A – Answer SIX parts of this section

1.1) Draw a labelled diagram to illustrate the equatorial coordinate system. Show the approximate positions of the Sun at 21st June and at 21st September.

[7 marks]

1.2) Explain the principal differences between *long exposure image formation* and *short exposure image formation* using an Earth bound visible light telescope. Define the term *atmospheric seeing.* Compare the angular resolutions of a telescope mirror, diameter 1 m, in the long exposure and the short exposure limits when the atmospheric seeing is 10 cm.

[7 marks]

1.3) Estimate the number of photons arriving per second at a telescope with a mirror of diameter 1 m, in the spectral range 400-500 nm, from a star of apparent magnitude +8.

[7 marks]

1.4) Illustrate the general form of the Hertzsprung-Russell diagram when plotted for a significant number of stars of known absolute magnitude. Mark on your diagram the approximate position of the Sun and illustrate which region contains younger stars.

[7 marks]

1.5) With the aid of suitable diagrams, describe the circumstances which give rise to solar eclipses. Why are lunar eclipses more commonly seen than solar eclipses?

[7 marks]

1.6) Briefly describe the properties of globular star clusters.

[7 marks]

1.7) Write down an expression for the luminosity of the Sun, $L_\odot$, assuming it to be a blackbody with a constant surface temperature, T_s. Given that the mass defect for the fusion of hydrogen to form helium is 0.007, estimate stating your assumptions, a life expectancy for the Sun if $T_s = 5,800$ K.

[7 marks]

1.8) Give a brief outline of how the Davis experiment detects neutrinos from the Sun. What specific properties of the neutrino explain the results of the experiment?

[7 marks]

SECTION B – Answer TWO questions

2) In relation to solar system planetary orbits define, using diagrams as necessary, the following terms: semi-major axis, eccentricity, inclination, ecliptic plane and astronomical unit.

[10 marks]

An artificial satellite is in an elliptical orbit above the solid surface of the planet Venus. The minimum and maximum heights of the orbit are 696 km and 2 601 km respectively and the orbital period is 123 minutes. If the semi-major axis and sidereal period of the Venusian orbit about the Sun are 0.723 AU and 0.615 years, respectively, calculate the radius of Venus. (Mass of Venus is 2.45 $\times 10^{-6}$ that of the Sun)

[20 marks]

3) Briefly describe the principles of operation of the following detectors, stating the main features of each type:

a) the photomultiplier tube;

[10 marks]

b) the charge coupled device;

[10 marks]

c) the "Precision Analogue Photon Address" (PAPA) detector.

[10 marks]

4) Describe how distances to astronomical objects are measured using

a) the moving cluster method;

[6 marks]

b) the method of standard candles;

[6 marks]

c) the red shift method.

[6 marks]

Explain the phrase "Hierarchy of astronomical yardsticks."

[4 marks]

Calculate the distance in parsecs to a star with an apparent magnitude $m = +20$ and an absolute magnitude of $M = +8$.

[8 marks]

5) Sketch the celestial sphere, including the celestial poles, the celestial equator and the vernal equinox. Mark on the sketch the horizon, meridian, zenith and nadir for an observer at (50° N, 15° E) when the Greenwich sidereal time is 9 h. Mark on the diagram the position of the star Betelgeuse (05 h 56 m, 7° 24′).

[10 marks]

Show that the hour angle H, the observer's latitude λ, the star's declination δ and the star's altitude a are related by

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

You may assume the cosine formula for a spherical triangle:

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

[10 marks]

Calculate the local sidereal times of rising and setting of Betelgeuse for an observer at Greenwich (51° 30′ N, 0° 0′ W) on March 21st.

[10 marks]