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

CP1600 Physical Basis of Astronomy

January 2003

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, $c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Atmospheric seeing, $r_0 = 10$ cm
1 parsec = 3.26 light years
Mass of Sun, $M_\odot = 1.99 \times 10^{30}$ kg
Radius of Sun, $R_\odot = 6.96 \times 10^{8}$ m
Mass of Earth, $M_E = 5.98 \times 10^{24}$ kg
Radius of Earth, $R_E = 6.38 \times 10^{3}$ 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
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. spacing

SECTION A – Answer SIX parts of this section

1.1) Draw a diagram to illustrate the ecliptic over the period of a year. Give, also, the approximate equatorial coordinates of the Sun for a date around the 21$^{\mathrm{st}}$ December in any year.

[7 marks]

1.2) As viewed from the Earth, the phases of the Moon repeat every 29.5 days, a period known as the synodic month. Calculate the number of days taken by the Moon to orbit the Earth, relative to a fixed point in the celestial sphere. (Hint: Consecutive new Moons will occur when the Moon has orbited the Earth and then moved on again to lie between the Earth and the Sun).

[7 marks]

1.3) The planet Mars has two moons, Phobos and Deimos, with mean distances from the planet of 9 380 km and 23 460 km respectively. Calculate a value for the sidereal orbital period of Deimos if that of Phobos is 0.319 days.

[7 marks]

1.4) Describe what is meant by the term the *main sequence* of stars. State the most important physical property of a star that governs its relative position on the main sequence and give one reason why the star might leave the main sequence.

[7 marks]

1.5) Calculate the apparent magnitude of a star at a distance of 130 light years with an absolute magnitude of +10.

1.6) Briefly describe the properties of *open* (or *galactic*) star clusters.

[7 marks]

1.7) Calculate the diffraction-limited angular resolution of an optical telescope with a diameter of 4 m. What baseline would a radio interferometer, operating at 2.5 GHz, require to achieve the same angular resolution?

[7 marks]

1.8) State Wien's law for a source of black body radiation. The surface temperature of the Sun is 6 000 K and it radiates as a black body with a peak wavelength 0.5 μm. Calculate the temperature of the filament of an incandescent lamp bulb if its peak wavelength of emission is 1.0 μm.

[7 marks]

SECTION B – Answer TWO questions

2) State the typical angular resolution of a long-exposure image formed by a 2 m diameter Earth-based visible-light astronomical telescope. Compare this with the diffraction-limited resolution of the same instrument and explain the difference.

[10 marks]

Discuss the differences between optical and radio telescopes, including atmospheric influences, instrumental arrangement and any noise sources.

[10 marks]

Estimate the exposure time to detect 10^5 photons from a star of apparent magnitude 9, which is imaged by a 2 m diameter telescope. You may assume an overall transmission and detection efficiency of 10% and the use of a filter transmitting in the wavelength range 450 to 600 nm.

[10 marks]

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

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

[22 marks]

On March 21$^{\text{st}}$ 1988 the right ascension and declination of Venus were (2h 51m, $18^o 50'$). Calculate the angular distance between Venus and the Sun on that day.

[8 marks]

4) What are the main sources of energy that are available to stars? Explain, with reference to theory and observations, why chemical reactions are thought to be unimportant in stars. Describe the energy generation processes which are thought to be taking place in main sequence stars and describe how the rate of energy production is regulated.

[15 marks]

Discuss, giving approximate time scales, the evolution of a star with five times the mass of the Sun, from its arrival on the main sequence to the first giant phase.

[15 marks]

5) Describe how the masses of astronomical objects can be determined using

a) spectroscopic binary stars,

[10 marks]

b) stellar spectral line widths and intensities, and

[10 marks]

c) the mass-luminosity relationship.

[10 marks]