King's College London

UNIVERSITY OF LONDON

B.Sc. EXAMINATION

CP1600 Physical Basis of Astronomy

January 2004

Time allowed: 3 Hours

Candidates should answer no more than SIX parts of SECTION A, and no more than TWO questions from SECTION B. No credit will be given for answering further questions.

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

Physical Constants

Permittivity of free space	ϵ_0	$=$	8.854×10^{-12}	$\mathrm{F\,m^{-1}}$
Permeability of free space	μ_0	$=$	$4\pi \times 10^{-7}$	$\mathrm{H\,m^{-1}}$
Speed of light in free space	c	$=$	2.998×10^{8}	$\mathrm{m\,s^{-1}}$
Gravitational constant	G	$=$	6.673×10^{-11}	$\mathrm{N\,m^2\,kg^{-2}}$
Elementary charge	e	$=$	1.602×10^{-19}	C
Electron rest mass	m_{e}	$=$	9.109×10^{-31}	kg
Unified atomic mass unit	m_{u}	$=$	1.661×10^{-27}	kg
Proton rest mass	m_{p}	$=$	1.673×10^{-27}	kg
Neutron rest mass	m_{n}	$=$	1.675×10^{-27}	kg
Planck constant	h	$=$	6.626×10^{-34}	$\mathrm{J\,s}$
Boltzmann constant	k_{B}	$=$	1.381×10^{-23}	$\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	σ	$=$	5.670×10^{-8}	$\mathrm{W\,m^{-2}\,K^{-4}}$
Gas constant	R	$=$	8.314	$\mathrm{J\,mol^{-1}\,K^{-1}}$
Avogadro constant	N_{A}	$=$	6.022×10^{23}	$\mathrm{mol^{-1}}$
Molar volume of ideal gas at STP		$=$	2.241×10^{-2}	$\mathrm{m^3}$
One standard atmosphere	P_0	$=$	1.013×10^{5}	$\mathrm{N\,m^{-2}}$

SECTION A – Answer SIX parts of this section

1.1) An astronomer is located 3° W of Greenwich and has an observatory clock which is not calibrated to Greenwich sidereal time. A star, with right ascension = 9 h 27 m, crosses the astronomer's meridian at 9 h 40 m by the observatory clock. Calculate by how much, to the nearest minute, and in what sense, the observatory clock is wrong.

[7 marks]

1.2) Light viewed from the Hyades open cluster of stars has a Doppler shift to longer wavelengths, as compared to laboratory sources, of $\frac{\Delta\lambda}{\lambda} = 1.3 \times 10^{-4}$. Calculate the radial velocity of this cluster. This cluster has a convergence angle of 25° and a proper motion of 0.1 arcsecs per year. Calculate the distance to the cluster.

[7 marks]

1.3) It is found that, for certain stars, the luminosities L depend upon their masses M, such that $L \propto M^{3.5}$. Compare the luminosities of the Sun and a star with $M = 5\,M_{\odot}$. Also calculate the time the star spends on the main sequence of stars, if that time for the Sun is 10^{10} years.

[7 marks]

1.4) Observations of the eclipsing binary star system Algol A & B show that the stars are separated by a distance of 0.062 AU, that they complete one orbit in 0.0079 years and that Algol A is approximately 4.5 times the mass of Algol B. Use Kepler's third law to estimate, in solar masses, the masses of Algol A and Algol B.

[7 marks]

1.5) What the dominant energy production process in a main sequence star such as the Sun? How has the energy production process been experimentally verified? Give a reason why the energy production does not run out of control.

1.6) Briefly describe the properties of globular star clusters. Where, in our galaxy, are such clusters found and in what number?

[7 marks]

1.7) The Hubble Space Telescope has a mirror diameter of 2.40 m. Calculate the minimum feature size which could be resolved, for light of wavelength 550 nm, on the surface of the Moon, which is at a distance of 3.5×10^{8} m from the telescope.

[7 marks]

1.8) Describe with the aid of a sketch the shape of our galaxy, the Milky Way. Indicate the position of the Sun, and the regions where open star clusters are more likely to be found. Name two other commonly found galaxy shapes.

[7 marks]

SECTION B – Answer TWO questions

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.

2) Draw a diagram to illustrate and explain the main principles of operation of the photomultiplier when used as an astronomical detector.

[10 marks]

Describe the main advantages and disadvantages of the photomultiplier detector, as compared to other detection systems.

[10 marks]

Barnard's star has an absolute magnitude of +13.40 and is at a distance of 1.7 parsecs. Estimate the number of photons received per second, per nanometre of bandwidth, with a telescope which has a mirror of area $1\,\mathrm{m}^2$. The photon flux from a zeroth magnitude star is $10^8\mathrm{m}^{-2}\mathrm{s}^{-1}\mathrm{nm}^{-1}$.

[10 marks]

3) With the aid of suitable diagrams, derive the relation between altitude a, hour angle H, declination δ and latitude, λ, of an observer, namely,

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

[12 marks]

On a particular day the right ascension and declination of Jupiter were (10 h 56 m, $7°52'$). Calculate, stating which is which, the local sidereal times of rising and setting of the planet, for an observer located at 50° N 0° W.

[18 marks]

4) In relation to the planetary orbits of the solar system, explain the following terms, using diagrams where necessary: semi-major axis, eccentricity, inclination, ecliptic plane, longitude of ascending node, argument of perihelion and time of perihelion passage.

[15 marks]

On June 21^{st} in a particular year, the equatorial coordinates of the planet Venus were ($4\,\text{h}\ 51\,\text{m}$, $21^\circ\ 51'$). Calculate the angular distance between the Sun and Venus at that time.

[15 marks]

5)

(a) Describe how the distances to stars can be determined using the following methods. Your answers should include the distance scales for which the particular technique is appropriate.

(i) trigonometrical parallax,

[6 marks]

(ii) the method of standard candles, and

[6 marks]

(iii) the red shift method and the z parameter.

[6 marks]

(b) Explain what is meant by the phrase *a hierarchy of astronomical yardsticks*.

[4 marks]

(c) A star shows 0.01 arc seconds of parallax and is a million times brighter than an equivalent star, in a distant galaxy, which in turn shows half of the red shift of a further galaxy. Calculate the distances to these astronomical objects.

[8 marks]