King's College London

UNIVERSITY OF LONDON

B.Sc. EXAMINATION

CP/1600 Physical Basis of Astronomy

Summer 2000

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

You may use the following values:

0^{th} magnitude objects produce 10^8 photons $m^{-2}\,s^{-1}$ per nm wavelength.

Stefan's constant $\sigma = 5.7\times 10^{-8}\ W\,m^{-2}\,K^{-1}$.

Electron charge $e = -1.6\times 10^{-19}$ C.

Gravitational constant $G = 6.7\times 10^{-11}\ N\,m^2\,kg^{-2}$.

Mass of Sun $M_\odot = 2.0 \times 10^{30}$ kg.

Mass of Earth $M_E = 6.0 \times 10^{24}$ kg.

Mass of Moon $M_{\mathrm{Moon}} = 3.7 \times 10^{-8}\ M_\odot$

Radius of Sun $R_\odot = 5.0 \times 10^8$ m.

Radius of Earth $R_E = 6.4 \times 10^3$ km.

1 AU = 1.5×10^8 km.

Earth-Moon centre to centre separation = 2.5×10^{-3} AU

1 parsec = 3.3 light years.

Speed of light $c = 3.0\times 10^8\ m\,s^{-1}$.

Change in gravitational potential of a photon leaving the surface of a body mass M and radius R

$$\Delta E = \frac{GM}{Rc^2}$$

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^{st} December in any year.

[7 marks]

1.2) Describe the equatorial telescope mounting scheme explaining its relative merits and disadvantages. Explain why mirrors rather than lenses are used in high quality astronomical telescopes.

[7 marks]

1.3) Calculate the fractional change in wavelength of a photon escaping from the surface of the Sun. State, giving reasons for your choice, a type of astronomical object for which this wavelength shift might be more easily observed.

[7 marks]

1.4) Explain which quantities are related on the Hertzsprung-Russell diagram and illustrate the general form of the diagram when plotted for a significant number of stars. Briefly explain how the position of a star moves on the Hertzsprung-Russell diagram, from its first appearance as a protostar to its death as a white dwarf object.

[7 marks]

1.5) Describe, with aid of a suitable sketch, the principle of operation of a photomultiplier when used as an astronomical detector. Explain the main advantages and disadvantages of using this type of detection device.

[7 marks]

1.6) State Kepler's three laws of planetary motion. Calculate the height above the Earth at which an artificial satellite must be to be in geo-synchronous orbit.

[7 marks]

1.7) Explain why the oceans of the Earth generally experience two tides in a period slightly longer than a day. Calculate the relative strengths of the tidal forces acting upon the Earth, resulting from the gravitational attraction of the Moon and that of the Sun.

[7 marks]

1.8) Describe a solar neutrino experiment and explain the significance of results achieved thus far. Give two possible reasons for the results obtained thus far in this experiment.

[7 marks]

SECTION B – Answer TWO questions

2) 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^o N, 15^o E) when the Greenwich sidereal time is 1h.

[10 marks]

Given that the cosine and sine formulae for a spherical triangle, using the usual angle definitions, may be written in the following form

$$\cos a = \cos b \cos c + \sin b \sin c \cos A, \qquad \frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}$$

obtain a relation between the altitude of a star, its declination, an observer's latitude and the hour angle.

[10 marks]

The equatorial co-ordinates of the star Betelgeuse are (05h 56m, $7^\circ\ 24'$). Calculate the local times of rising and setting of the star for an observer at Greenwich ($51^\circ\ 30'$ N, $0^\circ\ 0'$ W) on March $22^{\rm nd}$.

[10 marks]

3) Describe the characteristics of blackbody radiation and state Wien's law.

[10 marks]

Given that the Sun radiates as a blackbody with a surface temperature of 5 800K and has a peak wavelength emission of 480 nm, calculate the following

a) the peak wavelength of emission of a blackbody at 300 K,

[3 marks]

b) the temperature of a blackbody with a peak wavelength of emission at 0.1 μm.

[3 marks]

A piece of thin black card which is on the Earth is left facing towards the Sun. Assuming that all thermal losses are radiative and that the card achieves thermodynamic equilibrium with the incident radiation field, estimate a maximum temperature which can be reached by the card, assuming it to be an ideal blackbody.

[14 marks]

4) Explain the magnitude system of astronomical brightness classification, distinguishing between absolute magnitudes and apparent magnitude.

[5 marks]

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.

[10 marks]

Calculate the apparent magnitude of a star, which has an absolute magnitude of $+3.7$ and is at a distance of 1 000 light-years.

[7 marks]

Estimate the number of photons arriving per second at a telescope mirror of diameter 1 m and in the wavelength range 450-550 nm from the star with absolute magnitude $+3.7$.

[8 marks]

5) Write an essay on the hierarchy of methods commonly used for the determination of distances to astronomical objects.

[30 marks]