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 : Supplementary Assessment

CP/2620 Astrophysics

Summer 1999

It is the candidates' responsibility to ensure the safe delivery of their full written solutions to:

The Undergraduate Secretary, Dept. of Physics,
King's College London, Strand, London WC2R 2LS

All work must be received by 13 September 1999 at the latest.
It is recommended that any postal submission uses Recorded Delivery.

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

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

TURN OVER WHEN INSTRUCTED

$$\begin{aligned}
\text{gravitational constant G} &= 6.673 \times 10^{-11} \mathrm{Nm^2\ kg^{-2}}\ . \\
\text{mass of the Sun } M_\odot &= 1.989 \times 10^{30}\ \mathrm{kg.} \\
\text{radius of the Sun } R_\odot &= 6.96 \times 10^{8}\ \mathrm{m.} \\
\text{one parsec} &= 3.085 \times 10^{16}\ \mathrm{m.} \\
\text{speed of light } c &= 2.997 \times 10^{8}\ \mathrm{m\,s^{-1}.} \\
\text{elementary charge } e &= 1.602 \times 10^{-19}\ \mathrm{C} \\
\text{electron mass } m_\mathrm{e} &= 9.109 \times 10^{-31}\ \mathrm{kg}\ . \\
\text{Planck constant } h &= 6.626 \times 10^{-34}\ \mathrm{J\,s}\ . \\
\text{Stefan-Boltzmann constant } \sigma &= 5.670 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}\ .
\end{aligned}$$

SECTION A – Answer ALL parts of this section

1.1) Define visual magnitude, absolute magnitude, colour index and luminosity.

[7 marks]

1.2) Describe the method of trigonometrical parallax for finding the distances of stars. Why are results from the Hipparcos satellite important? The trigonometrical parallax of the Hyades cluster is measured as 21.58×10^{-3} arcseconds with an accuracy of 0.12×10^{-3} arcseconds . What is the distance and what is the error in the distance in parsecs ?

[7 marks]

1.3) Why are gamma-ray bursters believed to originate from neutron stars?

[7 marks]

1.4) What observations have made reasonably certain that black holes exist of mass roughly $10^9\ M_\odot$ at the centre of some active Galaxies?

[7 marks]

1.5) What is a black body? Why is a black body used as a standard source in radiation physics? A solitary neutron star that is not a pulsar is at a distance of 120 parsecs. The surface temperature is 10^6 K and the radius 20000 metres. What amount of energy per second from this star would fall on an area of 1 square meter just above the Earth's atmosphere?

[7 marks]

(Black body flux/$\mathrm{m}^2 = \sigma T^4$)

1.6) Why does the frequency of pulsars gradually decrease, and what physical parameter of the pulsar can be derived from the time constant of the decrease ?

[7 marks]

1.7) How may solar neutrinos be detected on the Earth's surface? Why is it important to detect them?

[7 marks]

1.8) Draw a diagram of a modern astronomical interferometer. What information may be obtained from such an interferometer?

[7 marks]

SECTION B – Answer ALL questions

2) Describe the evolution of a star whose mass is $5M_\odot$ from the start of the main sequence to the white dwarf stage.

[20 marks]

How may the mass of a star be estimated directly? What observations are required?

[5 marks]

Detailed analysis of two stars, masses M_1 and M_2, that are in binary orbit shows that their distances from their center of mass are $a_1 = 3.73 \times 10^{10}$ m and $a_2 = 5.27 \times 10^{10}$ m. The period (P) is 105 days. Find their masses.

[5 marks]

($$(M_1 + M_2) = \frac{4\pi^2 (a_1 + a_2)^3}{G\,P^2}$$)

3) What is a gamma-ray burster? Describe the observations that have been made. What evidence shows that some gamma-ray bursts come from distant galaxies.

[20 marks]

A gamma-ray burst from a source that is believed to be in a supernova remnant at a distance of 7 kiloparsec from the Earth produced a signal $7 \times 10^{-6}\mathrm{J/m^2}$ in an Earth satellite. Estimate the total energy of the burst.

The source showed a periodicity of 5.16 seconds which is attributed to the rotation of a neutron star. Assuming a mass $1.0M_\odot$ and a radius 10^4 metres for the neutron star, calculate the rotational kinetic energy. What fraction of the rotational energy is the burst energy?

[10 marks]

(Assume a homogeneous sphere with moment of inertia $(2/5)M\,R^2$)

4) Explain why Cepheid variable stars are used as distance indicators. What are the advantages and limitations of this method.

[20 marks]

Three Cepheid variables in the M100 galaxy in the Virgo cluster have periods P in days and mean *apparent* magnitudes m_v as follows.

P	m_v
53.1	24.8
39.5	25.4
30.1	26.4

The calibration of the mean *absolute* magnitude from the Hipparcos satellite is

$$< M_v >= -1.43(\pm 0.1) - 2.81 \log_{10}(P(\text{days})).$$

Find the distance of each Cepheid variable in parsecs. If the M100 galaxy is receding from the Sun at 1400 ± 80 kilometres/second, deduce the Hubble constant and estimate the error.

[10 marks]

$$(M_v - m_v = 5 - 5 \log_{10}(d))$$

5) Write an essay on pulsars.

[30 marks]