UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE : **PHAS1102**

MODULE NAME : **Physics of the Universe**

DATE : **04-May-07**

TIME : **14:30**

TIME ALLOWED : **2 Hours 30 Minutes**

TURN OVER

Answer ALL SIX questions from Section A and THREE questions from Section B

Numbers in square brackets in the right-hand margin indicate a provisional allocation of maximum possible marks for different parts of each question.

The following may be assumed if required:

Planck constant	h	6.63×10^{-34} J s
Speed of light	c	3.0×10^{8} m s^{-1}
Stefan-Boltzmann constant	σ	5.7×10^{-8} W m^{-2} K^{-4}
Gravitational constant	G	6.7×10^{-11} N m^2 kg^{-2}
Solar radius	$R_\odot$	7.0×10^{8} m
Solar bolometric luminosity	$L_\odot$	3.9×10^{26} W
Solar mass	$M_\odot$	2.0×10^{30} kg
1 parsec	pc	3.1×10^{16} m

Section A

(Answer ALL SIX questions from this section)

1. State the three spectroscopic rules discovered empirically by Gustav Kirchhoff, and give a general astronomical example of each. [7]

2. The spectrum of a star shows an absorption line due to neutral sodium present in a foreground interstellar cloud. If the observed wavelength of this line is 588.965 nm, and its rest wavelength is 588.995 nm, what is the velocity of the interstellar cloud with respect to the observer? Is the cloud moving away or towards us? [3]

   In which spectral band does the absorption line appear? What are the frequency and the energy of the line at rest? (You should specify clearly the units of these quantities.) [3]

3. Define the Hertzsprung-Russell (HR) diagram, and draw an example of it highlighting the locations of the main types of objects that populate it. [5]

   Explain how the HR diagram can be used to obtain distances of stars whose apparent magnitudes and spectral types (or colours) are known. [2]

4. Summarize the main properties, and physical nature, of quasars [7]

5. State Hubble's law (defining all quantities). Show how the Hubble constant gives a *rough* estimate of the age of the universe, and explain the limitations of such an estimate. In what sense is the 'Hubble constant' actually constant? [5]

   A galaxy is observed to have a velocity of recession of 1350 km s^{-1}, at an estimated distance of 18 Mpc. Using this information, estimate the age of the Universe (in years). [2]

6. Summarize the main properties of clusters of galaxies. [6]

Section B

(Answer THREE questions from this Section)

7. Describe briefly how stars are thought to form and what physical processes produce their luminosity. What are the 'PP chains' and the 'CNO cycle' and what temperatures do they require? State which elementary particles are involved in the two cases; in what form the energy that prevents the star from collapse is produced; and in which types of stars the two processes occur. [12]

   State some of the basic physical properties of neutrinos. What is the 'solar neutrino problem' and how has it been solved? In which other astrophysical scenario has the detection of neutrinos confirmed theoretical predictions? [8]

8. A star has a bolometric luminosity of 10^{29} W. What is its surface temperature if its radius is 10 times that of the Sun? Calculate the flux received at Earth if the star is at a distance of 100 parsec. Determine the absolute bolometric magnitude of the star (recalling that the solar absolute bolometric magnitude is +4.75). [6]

   What is the main parameter that determines the evolution of stars? Describe the phases of stellar evolution for different types of star, noting how they depend on this main parameter; and the conditions leading to the formation of a white dwarf, a neutron star, and a black hole. [8]

   What are 'black dwarfs' and 'brown dwarfs' and how do we think they are formed? [3]

   Define what the 'event horizon' is, and give an alternative name for it. Compute the size of the event horizon for a star of mass $10M_{\odot}$. [3]

9. What is a 'standard candle' and how is it used? Discuss the characteristics of Cepheids. What property makes them of make them of particular interest? [8]

   How, in practice, might one estimate the distance to a Cepheid (without using properties intrinsic to the Cepheid itself)? [4]

   Explain, with the aid of a diagram, what is meant by 'parallax' in an astronomical context, and give the definition of 'parsec'. Sirius has a parallax of 0.379 arcsec. What is the distance to Sirius in astronomical units (AU)? [4]

   The star ζ Oph is observed to have $V = 2.56$, $(B-V) = +0.02$; assuming $M(V) = -4.0$ and $(B-V)_0 = -0.30$, what is its distance? What apparent colour do you expect the star to have, and why? [4]

10. Summarize the physical and dynamical properties of spiral galaxies, using our Galaxy as an example. [6]
    Discuss the nature of spiral arms in such galaxies. [5]

    Sketch the *rotation curve* of the Galaxy, and outline how this provides an estimate of the Galaxy's mass. [5]

    Suppose that the Sun orbits the Galactic centre at a distance of 8.5 kpc and that the mass of the Galaxy contained within that orbit is 1.2×10^{11} $M_{\odot}$. Calculate the Sun's orbital velocity (in km s^{-1}), and hence its orbital period (in years). [4]

11. List, without detail, the observational evidence for a 'Big Bang'. [3]

    Outline the general characteristics of *primordial nucleosynthesis*, and [6]
    give a detailed discussion of the expected primordial mass fraction of helium. [11]

END OF PAPER