UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE : **PHAS1102**

ASSESSMENT PATTERN : **PHAS1102A**

MODULE NAME : **Physics of the Universe**

DATE : **10-May-10**

TIME : **10:00**

TIME ALLOWED : **2 Hours 30 Minutes**

TURN OVER

Answer ALL SIX questions from Section A and ANY 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	$L_\odot$	3.8×10^{26} W
Solar mass	$M_\odot$	2.0×10^{30} kg
1 parsec	pc	3.1×10^{16} m
1 year	yr	3.16×10^{7} s
1 AU		1.5×10^{8} km
1 eV		1.6×10^{-19} J

Section A

(Answer ALL SIX questions from this section)

1. Explain what are meant by the 'apparent magnitude', the 'absolute magnitude', and the 'bolometric magnitude' of a star. [3]
   Explain how interstellar extinction affects the observed brightness and colour of stars. State what the 'colour excess' is. [2] [2]

2. For a given temperature, sketch the variation of the logarithmic intensity (per unit frequency range) of black-body radiation as a function of logarithmic frequency, taking care in labelling the axes. How would the graph change if the temperature increased? [3] [1]
   What are the names of the approximate distributions describing black-body radiation at low- and high-frequency limits? [2]

3. Explain why there is no white dwarf with a mass above the Chandrasekhar limit. [4]
   State what the 'Schwarzschild radius' is, and give an alternative name for it. [3]

4. List, without elaboration, the principal ingredients of the 'Standard Model' of Particle Physics. [6]
   What is the special significance of *baryons* in the Universe? [1]

5. What observational properties characterize an 'active galactic nucleus' (AGN)? [4]
   Name one example of a class of object containing an AGN.
   Briefly summarize the processes powering AGN (equations are not required). [2]

6. List the main consituents of a typical spiral galaxy. (A description of physical processes is not required.) [3]
   Sketch the 'rotation curve' of a spiral galaxy. Outline in general terms what this curve tells us about the distribution of matter in a spiral galaxy. [4]

Section B

(Answer ANY THREE questions from this Section)

7. Star 'A' has an apparent visual magnitude $m_V = 9.7$ and an absolute visual magnitude $M_V = -0.3$.

   Star 'A' appears 100 times brighter than star 'B'. What is the *apparent* visual magnitude of star 'B'? Give the general expression relating a flux ratio to a magnitude difference. [3]

   Explain, with the aid of a diagram, what is meant by 'parallax' in an astronomical context, and give the definition of a 'parsec'. [5]

   Ignoring interstellar extinction, calculate the distance (in parsecs) of star 'A'. [2]

   Consider star 'A' emitting as a black-body at 4,000 K and star 'C' emitting as a black-body at 10,000 K. Star 'A' has *double* the radius of star 'C'. How much more energy is emitted by star 'C' than star 'A'? [2]

   If the bolometric correction for star 'A' is $BC_A = -0.7$, and the bolometric magnitude for the Sun is $M_{\mathrm{bol},\odot} = 4.7$, what is the bolometric luminosity (in W) of star 'A'? [3]

   The Sun is a G2V star, while star 'A' is a K2II star. Explain in detail what is meant by these classifications. (Your answer should include a list of the full sequence of Harvard types.) [5]

8. Draw the evolutionary track followed by 1 $M_\odot$ star on a labelled Hertzsprung-Russell diagram, starting from the main sequence. Mark the principal stages of the star's evolution on your sketch (including the end-point), and describe each in a few sentences. [16]

   Explain what a 'Wolf-Rayet star' is. [2]

   Explain what a 'brown dwarf' is. [2]

9. Briefly state the assumptions of Bohr's atomic theory. [2]

   Sketch a labelled diagram of the energy levels of the Bohr model for the hydrogen atom, naming the highest and lowest of these levels. State (without derivation) how the energy of the nth Bohr orbit depends on the quantum number n. [5] [1]

   The ionisation potential of the hydrogen atom is 13.6 eV. From this fact, deduce the approximate wavelength (in nm) of light needed to excite an electron from the $n = 1$ to the $n = 3$ orbit of the hydrogen atom. What is the name of the series of hydrogen transitions whose lower level corresponds to $n = 1$, and the name of the transition between levels with $n = 1$ and $n = 3$? [3] [2]

   Explain what 'collisional excitation' is. [1]

   Describe the process that leads to the formation of absorption lines in spectra, and give two astrophysical examples of this phenomenon. [4]

   The wavelength of the Hα line measured in the laboratory is 656.3 nm. At what wavelength would we observe this line in the spectrum of a star moving away from us at 400 km s^{-1}? [2]

10. Explain what a Cepheid variable is, and why Cepheids make useful 'standard candles'. [5]

Explain how the Baade-Wesselink method can be used to calibrate the intrinsic brightness of Cepheids. [5]

Relate the sequence of events believed to give rise to a Type Ia supernova. [8]

Why are Type Ia supernovae useful 'standard candles', while other supernovae are not? [2]

11. State Hubble's Law (defining all quantities). A galaxy in the Virgo Cluster, at a distance of 18.0 Mpc, is observed to have a redshift of 1,300 km s^{-1}. From this information, estimate a value for the Hubble Constant. [3]

Explain how the Hubble Constant can be used to obtain a rough estimate of the age of the universe, and why this estimate is not exact. What, in years, is the age of the universe implied by your estimate of the Hubble Constant? [5]

Discuss any *two* of the following topics in the context of the 'Big Bang' model: [12]

- the evolution of source counts;
- the cosmic microwave background (include a qualitative discussion of its formation);
- primordial nucleosynthesis (a full answer will outline general processes, but specific details of nuclear reactions are not required).

END OF PAPER