UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE : **PHAS1102**

ASSESSMENT PATTERN : **PHAS1102A**

MODULE NAME : **Physics of the Universe**

DATE : **30-Apr-08**

TIME : **10:00**

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
1 eV		1.6×10^{-19} J
Wien's law:	$\lambda_{max} = 3 \times 10^{-3}/T$ m	
$A(V)/E(B-V) = 3.1$		

Section A

(Answer ALL SIX questions from this section)

1. In quantum physics the forces of Nature are mediated by the exchange of particles. List the four fundamental forces of Nature in order of decreasing strength, and name the corresponding carrier particle for each of them, as well as the particles they act upon. [7]

2. The continuous spectra of two main sequence stars reach maximum intensities at 30 nm and 1.5 μm respectively. Determine the temperature and the approximate spectral classes of the two stars. [5]

   Briefly explain why a G2 star that lies above the main sequence in a Hertzsprung-Russell diagram must have a larger radius than a G2 star that lies on the main sequence. [2]

3. Describe in a few sentences which types of stars are thought to lead to Supernovae Type I (a, b, c) and II, and how they evolve into them. What relation is thought to exist between Supernovae and Gamma Ray Bursts? [5]

   What are pulsars? [2]

4. Give a labelled sketch of the 'Hubble Tuning Fork Diagram' for the classification of galaxies. [3]

   Outline the main characteristics of elliptical galaxies. [4]

5. Explain what a Cepheid Variable is, and why Cepheids make useful 'standard candles'. [5]
How do we calibrate their intrinsic brightness?

6. 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 the value of the Hubble Constant; why might this estimate not be accurate? [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? [4]

Section B

(Answer THREE questions from this Section)

7. (a) Draw a labelled Hertzsprung-Russell diagram and sketch on it the evolutionary track followed by a 1-$M_\odot$ star, starting from the main sequence. Mark the principal stages of the star's evolution on your sketch, and describe them in a few sentences, including the processes involved in a *helium flash.* [12]

(b) Calculate the main sequence lifetime (in years) of a 10-$M_\odot$ star if it has a luminosity of 10^4 $L_\odot$ and 10% of its mass will be converted from hydrogen to helium in the core. What will be the end state of this star? [8]

8. What non-classical assumptions were made by Bohr in his model of a one-electron atom, and why? [3]

State (without derivation) how the energy of the nth Bohr orbit depends on the quantum number n. Sketch a labelled diagram of the energy levels of the hydrogen atom and explain what is meant by *ionisation potential.* [4]

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 $n = 2$ to the $n = 3$ orbit of the hydrogen atom. What is the name of the series of hydrogen transitions whose lower level corresponds to $n = 2$, and the name of the transition between levels with $n = 2$ and $n = 3$? [5]

Describe the process that leads to the formation of absorption lines in the spectra of a hot object seen through a cooler gas, and give three astrophysical examples of this phenomenon. [6]

Sketch the variation of the nuclear binding energy per nucleon versus atomic mass number A, and use this to briefly discuss energy generation by *nuclear fusion* and *nuclear fission.* [2]

9. (a) Explain briefly the terms *apparent magnitude*, *absolute magnitude*, *bolometric magnitude*, *colour index*, and *colour excess*. [5]

Star 'A' appears 10 times brighter than star 'B'. What is the apparent magnitude difference between these two stars? Give the general expression relating flux ratios and magnitude differences. [2]

Ignoring interstellar extinction, use this general expression to derive the relationship between the distance modulus, $(m - M)$, and the distance, d, of a star of apparent magnitude m and absolute magnitude M. How is this relationship modified to allow for 'A' magnitudes of interstellar extinction? [4]

(b) A star has apparent visual magnitude $m_V = 1.0$, colour index $(B-V) = -0.2$, absolute visual magnitude $M_V = -3.4$, and $(B-V)_0 = -0.3$. [3]

Calculate the colour excess of the star. Assuming the standard relationship between colour excess and interstellar extinction in the V band, calculate how many magnitudes of starlight have been extinguished by the interstellar medium between the star and the Earth. What has the extinction done to the colour of the star, and why?

Use the distance modulus relation, including interstellar extinction, to find the distance of the star. [6]

By comparing the absolute magnitudes of the star and the Sun, how many times brighter than the Sun is the star in the V band? (The absolute V magnitude of the Sun is 4.8.)

If the bolometric correction for the star is $BC_\star = -3.0$ and that for the Sun $BC_\odot = -0.1$, what is the luminosity of the star?

10. Sketch a diagram showing the typical form of the 'rotation curve' for spiral galaxies. [3]
Comment on the nature of the rotation curve, and the main inference drawn from it. [3]

Outline three methods for determining the masses of clusters of galaxies. Again, comment briefly on any important inferences. [11]

A star is observed to be in a circular orbit around our Galaxy at a distance of 10 kpc from the centre, with an orbital velocity of 250 km s^{-1}. How long (in years) does this star take to complete one orbit? What is the minimum mass of the Galaxy (in solar masses)? [3]

11. Describe each of the following pieces of evidence supporting a 'Big Bang':

- the evolution of source counts; [5]
- the cosmic microwave background (include a qualitative discussion of its formation); [5]
- primordial nucleosynthesis (a full answer will outline general processes, but specific details of nuclear reactions are not required). [5]

Briefly describe the 'horizon problem' and the 'flatness problem'. [5]

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