UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Sc. *M.Sci.*

Phys & Astro 3301: Techniques and Optics in Astronomy

COURSE CODE	:	**PHAS3301**
UNIT VALUE	:	**0.50**
DATE	:	**03-MAY-06**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

06-C1111-3-30

TURN OVER

Answer ALL SIX questions from Section A and TWO questions from Section B.
The numbers in square brackets in the right hand margin indicate the provisional allocation of maximum marks per subsection of a question

Constants and formulae.

$\pi = 3.14159$

π radians $= 180^{o}$

$h = 6.626 \times 10^{-34}$ J s

$c = 2.998 \times 10^{8}$ m s^{-1}

1 arcsecond $= 4.84 \times 10^{-6}$ rad

1ev $= 1.6 \times 10^{-19}$ J

SECTION A

[Part marks]

1. Give a description, with a sketch, of a Ritchey-Chretien telescope. What are the advantages and disadvantages of such a telescope design? [4]

   What is meant by prime focus? Why would you use prime focus and what are the problems associated with using it? [2]

2. What is the technique of photometry? Describe aperture and profile fitting photometry. [4]

   Using aperture photometry on a astronomical image it is found that a target star gives 20164 counts in a 1 arcsecond diameter circular aperture centred on the star (these counts include the sky background). The sky background alone in an identical sized aperture gives a total of 1270 counts. What is the signal to noise of the measurement of the star's intensity? (Assume that there is no detector noise and that Poisson statistics hold). [2]

   What is meant if an observation is said to be source noise limited? [1]

3. Give a description of the underlying mechanism by which photons are detected by a semiconductor based detector such as a CCD. What limits the detection efficiency of such a device in the blue and near infra-red? If the band gap of silicon is 1.12eV what is the longest wavelength radiation that can be detected? [5]

   Explain why back illuminated, thinned CCDs are used for astronomical imaging. [2]

4. Explain what is meant by 'seeing', in the context of image degradation, and how it is caused. [3]

   Explain how a Shack-Hartmann wavefront sensor detects the phase distribution of light from a distant star. [4]

5. Give a description, with a sketch, of an optical (visible wavelength) astronomical interferometer. What are the particular difficulties of implementing optical, as opposed to, radio interferometry? [4]

   What is meant by the term phase closure? [2]

6. What is a stellar coronograph? Describe, including a sketch, the basic construction of such a coronograph. In particular explain how the intensity distribution of the focal and pupil plane images of an on-axis star is affected by the different components of the coronograph. [5]

   What are the advantages of combining coronography with adaptive optics? [2]

SECTION B

7. What are meant by the terms *far* and *near field*? If a 1cm diameter aperture is illuminated by a plane wave of wavelength 650nm, beyond what distance from the aperture would the diffracted waveform be described by the Fraunhofer diffraction formula? [6]

   A normally incident plane wave of unit amplitude is incident on a square aperture of side length a. Given that the Fraunhofer diffraction formula is given by [14]

$$U(x,y) = \frac{\exp jkz}{j\lambda z}\exp\left[j\frac{k}{2z}(x^2+y^2)\right]\int\int_{-\infty}^{\infty} U(u,v)\exp\left[-j\frac{2\pi}{\lambda z}(xu+yu)\right]dudv$$

   derive the formula for the Fraunhofer intensity distribution of the diffracted image in the x,y plane and give a sketch of the resulting image.

   If the square aperture had a small square central obstruction explain qualitatively how would you expect if to affect the intensity distribution in the diffracted image. [4]

   Give the Rayleigh criteria for telescope resolution. If a telescope has a circular aperture of 4.2m diameter, what is the minimum separation of the stars in double star system at a distance of 30 light years from the Earth that can be resolved at a wavelength of 500nm? (The stars have equal magnitudes and you can assume that there are no atmospheric effects or other aberrations) [6]

8. Explain what the following spectrographic terms mean.

i) Degeneracy and order sorting [3]
ii) Grating blazing [3]
iii) Echelle grating [3]

Give the grating equation, defining all terms. [3]

A high resolution reflection grating spectrograph contains a grating with a line density of 100 lines per millimetre. The angle of diffraction off this grating for the 25^{th} order at a wavelength of 550nm is 45 degrees and the focal length of the final focusing lens on to the detector is 0.5m. Assuming the pixel size of the detector array is the limiting factor in determining the spectral resolution, what must be the minimum size of the pixels to achieve a spectral resolving power of 30,000? [8]

What is an integral field unit? Give a description of the three main types with their advantages and problems. [10]

9. Give brief descriptions of the following radio astronomy devices and techniques:

i) Half wave dipole and its polar diagram [3]
ii) Co-linear and broadside dipole array [3]
iii) Parasitic element [3]
iv) Beam width at first nulls [3]

Give a sketch of a the polar diagram of a 4 element co-linear array with a parasitic reflector. [4]

Explain the technique of *heterodyne detection* including a description of the output components. [5]

Explain the different methods of spectroscopy at radio wavelengths. [9]

10. Give brief explanations of the following

i) Cerenkov radiation [5]
ii) Neutrino production in the Sun [5]

Give a description of a chlorine based neutrino detector [8]

Give a description of a water-based neutrino detector such as the Super-Kamiokande system. Include in your description how such a system can detect neutrino oscillation. [12]

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