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	:	**04–MAY–05**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

05–C1029–3–50

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 $= 180^{o}$

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

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

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

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

SECTION A

[Part marks]

1. Explain the terms interference and diffraction. In what circumstances do the Fraunhofer and Fresnel diffraction formula apply? [4]

   Considering a plane wave of uniform amplitude incident on a rectangular aperture length *a* (Y-direction) and width *a/2* (X-direction). Give a sketch of the resulting Fraunhofer diffraction pattern. [2]

2. In a certain time period the number of counts due to a source alone is given by N_0 and the number of counts due to the background in the same time period is N_B. Detector noise is negligible. Assuming Poisson statistics, show that the signal to noise ratio is given by formula [3]

$$\frac{S}{N} = \frac{N_0}{\sqrt{2N_B + N_0}}$$

   Observations of the sky background produce an average of 120 counts per pixel per second. Observations of a galaxy produces an average of 135 counts per pixel per second including the contribution from the sky background. How long must an observation of the galaxy be to achieve a signal to noise ratio of 20? (Again assume no contribution from detector noise). [4]

3. Describe the structure of a microchannel plate and explain how it produces an amplified signal. Why are the channels in a microchannel plate often made at an angle to the plate surface? [3]

   Describe, with the aid of a diagram, the design of an image intensified CCD detector that uses microchannel plates in the intensifier stage. [4]

4. What is meant by the polarization state of light and by the terms unpolarised, linearly polarised, circularly polarised and elliptically polarised? Why is polarisation important in astronomy? [4]

   What is a half wave plate? If a half-wave plate is made of quartz that has a degree of birefringence J=0.008, how thick must the quartz be to act as a half wave plate at a wavelength of 600nm? [3]

5. In radio astronomy what is the technique of aperture synthesis? Why is this technique easier to implement in the radio regime than in the optical? [4]

   The Very Large Telescope Array is made up of many circular dish telescopes, each of 26m diameter. The maximum separation that can be achieved between telescopes in the array is 27 kilometres. With a radio frequency of 2 GHz, what is the achievable spatial resolution of a single telescope in the array and what is the smallest achievable spatial resolution of the whole array? [2]

6. Explain the sequence of events by which a gamma ray produces Cerenkov light in the Earth's atmosphere. [3]

   Describe a telescope system that uses this effect to detect gamma rays and explain how non-gamma ray events are discriminated from true events in such a telescope? [4]

SECTION B

7. Discuss briefly, with the aid of diagrams, the design of a high resolving power, plane reflection grating spectrograph for use at visible wavelengths. Indicate clearly the function of each component of the spectrograph. What are the main design constraints that determine the resolving power of a grating spectrograph? [12]

   The grating equation is given by [4]

$$m\lambda = a\,(\sin i + \sin\theta)$$

   Derive an expression for the linear dispersion of the spectrograph if the focal length of the final imaging lens is f.

   A reflection grating spectrograph contains a grating with a line density of 100 lines per millimetre. The angle of diffraction off this grating for the 20^{th} order at a wavelength of 650nm is 45 degrees. The pixel size of the detector array is 20 by 20 μm and the focal length of the final imaging lens is 0.5m. Assuming that the pixel size is a limiting factor, what is the spectral resolving power of the spectrograph for this order and wavelength? [4]

   What is a multi-object spectrograph? Explain in your answer the difference between a multi-slit and multi-fibre system. [10]

8. With the aid of diagrams give a description of an adaptive optics system for a telescope and explain how it corrects for the effects of the atmospheric turbulence. Include brief descriptions of the key components of the system. With reference to the term 'coherence length' explain why adaptive optics is easier at infrared wavelengths than at visible wavelengths. [10]

What effective actuator spacing when mapped back to the primary mirror would be needed to achieve a Strehl ratio of 0.8 at wavelength of 2200nm in seeing conditions with a coherence parameter of 0.15m at 500nm? Assume the fitting function K for the deformable mirror is 0.2 and the residual RMS wavefront error σ is given by the formula [6]

$$\sigma^2 = K\left(\frac{d}{r_\lambda}\right)^{\frac{5}{3}}$$

Explain what is meant by multi-conjugate adaptive optics, and what are its benefits and problems. [5]

Explain the following laser guide star terms [9]

i) A Sodium laser beacon
ii) A Rayleigh laser beacon
iii) The cone effect

9. Describe with diagrams the following X-ray detectors

a) Geiger counter. [4]
b) solid state proportional detector [4]
c) scintillation detector [4]

What is a Bragg spectrometer and how does it work? Give the Bragg equation, defining all terms, and discuss its application to a plane crystal illuminated by a parallel beam of X-ray radiation. Explain how the simple crystal system you have described can be adapted in two ways to allow the extended spectra of X-ray sources to be examined. Sketches are required in all your explanations. [12]

A crystal is set to intercept X-rays at an angle of 35 degrees to its surface. What wavelength is reflected off the crystal in the 1st order if its crystal plane spacing is 0.10nm? The crystal is then rotated through an angle $d\theta$, which increases the wavelength reflected by 0.04nm. Calculate $d\theta$ and state whether the angle made with the crystal surface has been increased or decreased. [6]

10. What is meant by n-type and p-type type semiconductors? [4]

With the aid of diagrams and with reference to its basic unit cell structure, describe how a Charge Coupled Detector (CCD) works. Explain in your answer how charge coupling is used to move the image from the pixels to the readout electronics. [12]

What are the main sources and causes of intrinsic noise in such a device? [6]

What are the main advantages and disadvantages of using CCD detectors? What limits the spectral sensitivity range of a CCD? [8]