THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF PHYSICS

EXAMINATION

NOVEMBER 2014

# PHYS3060/3031

# ADVANCED OPTICS

Time Allowed – 2 Hours

Total number of questions – 4

Answer ALL questions

Questions are **NOT** of **EQUAL** value

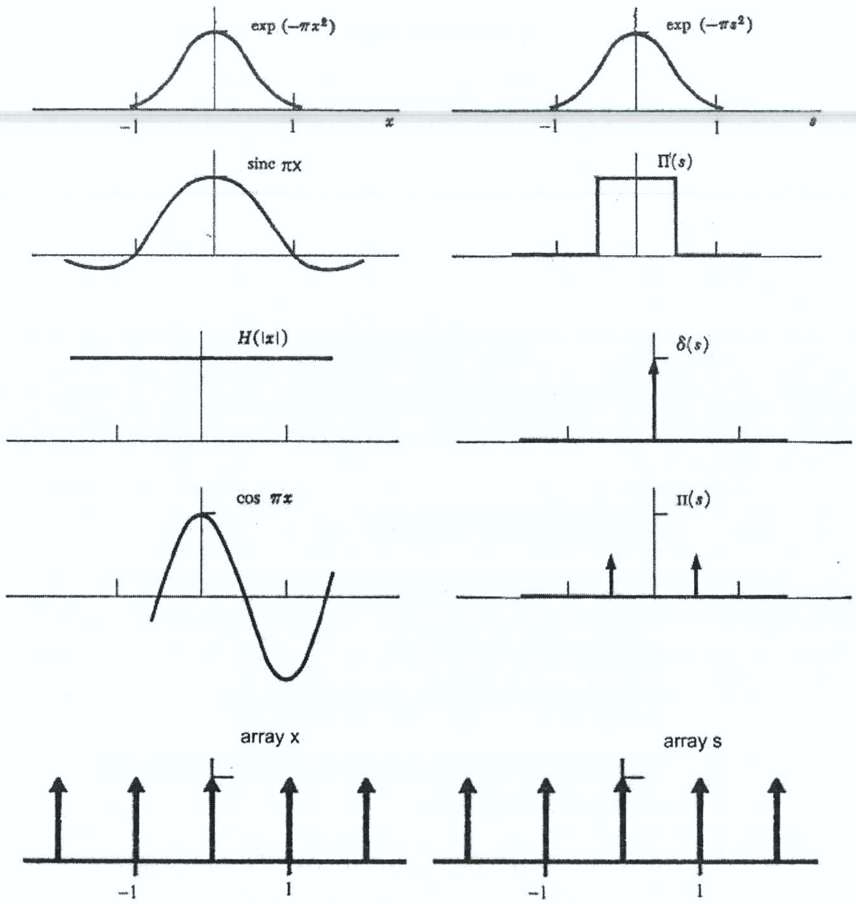
Candidates should provide their own university approved calculator

Answers must be written in ink. Except where they are expressly required, pencils may only be used for drawing, sketching or graphical work.

Candidates may keep the examination script.

$$F(s)=\int_{-\infty}^{\infty} f(x)e^{-2\pi ixs}dx, \quad f(x)=\int_{-\infty}^{\infty} F(s)e^{2\pi ixs}ds,$$

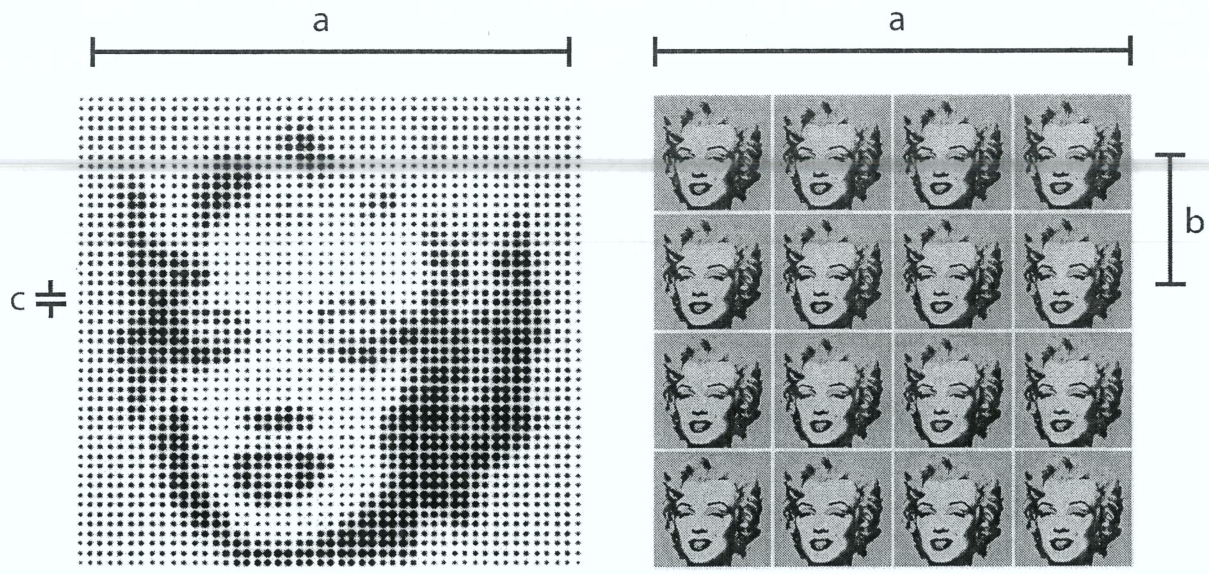
$$e^{i\theta}=\cos(\theta)+i\sin(\theta)$$




| Theorem | $f(x)$ | $F(s)$ |
|---|---|---|
| Similarity | $f(ax)$ | $\frac{1}{\lvert a\rvert}F(\frac{s}{a})$ |
| Linearity | $\alpha f(x)+\beta g(x)$ | $\alpha F(s)+\beta F(s)$ |
| Shift | $f(x-a)$ | $e^{-i2\pi as}F(s)$ |
| Convolution | $f(x)\otimes g(x)$ | $F(s)G(s)$ |

**QUESTION 1** (24 marks)

Consider the following two transmission objects that are to be used in an optical diffractometer experiment.




OBJECT A OBJECT B

OBJECT A is a halftone image of Marilyn Monroe made up of a square array of dots (spacing = c) of different attenuations and OBJECT B is a four by four mosaic of Marilyn Monroe images where the size of each image has dimensions, b. Both objects have total dimension of a, and b = 10c, and a = 4b.

i. For each object write down an expression, f(x,y) for the object function using MM to represent Marilyn in each case. *(4 marks)*

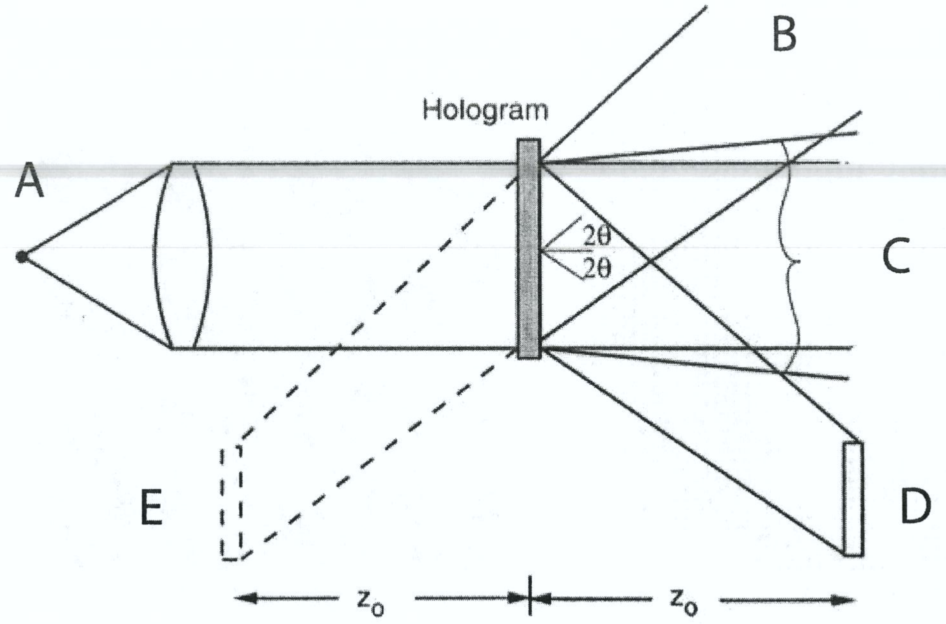
ii. For each object derive an expression for the diffracted field produced at the back focal plane of the diffractometer. *(6 marks)*

iii. A circular aperture is to be used as a spatial filter. For each object write down an expression for the filter that will allow just the zero order diffraction peak to pass. Which aperture would have the largest radius? *(4 marks)*

iv. Derive an expression for the filtered field, f'(x,y), produced in the imaging plane of the diffractometer. Provide a physical interpretation of the expected image in each case. *(6 marks)*

v. If the spatial filter were to be moved to one of the off-axis diffraction peaks, explain how this will influence the observed images in each case. *(4 marks)*

**QUESTION 2 (*15 Marks*)**




**Answer the follow short-answer questions with reference to the above figure.**

a) How is information about an object or scene recorded in a hologram as compared with a conventional image recording device. *(3 marks)*

b) The figure depicts the optical arrangement used to view a transmission hologram. On the diagram there are 5 points marked A to E. Explain the significance of each. *(5 marks)*

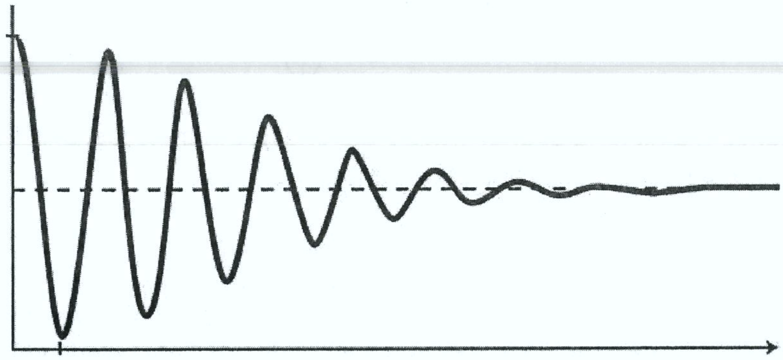
c) If a transmission hologram that is recorded with red light (e.g. 633nm) explain what would be observed if the hologram was viewed using a green light source (e.g 532nm). *(3 marks)*

d) Explain what you would expect to observe if only a small section of a hologram was illuminated. *(2 marks)*

e) Typically transmission holograms are recorded and viewed using a monochromatic source. Explain what you might expect to observe if a transmission hologram was read out using a single colour (e.g. green) incoherent light source such as a green light emitting diode. *(2 marks).*

**QUESTION 3 (*20 Marks*)**

A Michelson Interferometer may be used to measure the temporal (longitudinal) coherence length of light sources.



(i) A typical interferogram produced by a Michelson interferometer is presented in the above figure. What quantities do the axes of this graph represent? Explain the important features? (*4 marks*)

(ii) The depicted interferogram corresponds to an HeNe laser with an emission wavelength of 633 nm, a power of 10mW, a linewidth of 0.02 nm and a beam diameter of 1.5 mm. What is the value on the x-axis, which corresponds to the first miniumum. What is the value on the x-axis when amplitude of the oscillations a first a minimum? (*4 marks*)

The sun is approximately $1.6\text{x}10^8$ kilometres from the earth. It has a diameter of approximately $1.3\text{x}10^6$ kilometres. If you assume that it emits light at 500nm wavelength,

(iii) Determine the transverse coherence of this light on earth. *(2 marks)*
(iv) Using the van Cittert-Zernike theorem, calculate the complex degree of coherence for sunlight. *(4 marks)*
(v) Using the result in (v) determine the minimum separation between two pinholes on a screen which will produce no visible interference fringes. *(4 marks)*
(vi) If this experiment were performed on Mars, how would you expect the results in (v) to differ? (*2 marks*)

hint: $\Delta\lambda/_{\lambda} = \Delta\nu/_{\nu}$

hint: $J_1(3.833) = 0$

**QUESTION 4 (*15 Marks*)**

(i) A quarter-wave plate (QWP) is used to convert light of a particular wavelength between linear and circularly polarised light. How is a wave plate made and what optical properties does it utilise to achieve phase retardation? *(5 marks)*

(ii) Light incident on a quarter waveplate with polarisation oriented horizontally is represented by the Jones vector:

$$E = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

The Jones matrix for a quarter-wave plate oriented with its fast axis at an angle of 45° degrees from the horizontal is given by:

$$W_{\lambda/4} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & -i \\ -i & 1 \end{pmatrix}$$

Calculate Jones vector the for the polarisation state after passing through wave plate and determine if it is right handed or left handed circularly polarised light. *(2 marks)*

(iii) A metallic mirror applied a π phase change to light reflected at normal incidence. Write down a Jones matrix that would describe such an optical effect. *(3 marks)*

(iv) Light passing through the quarter-wave plate is reflected off a metallic mirror and then passes back through the wave plate. Determine the polarisation state of the light upon the second pass of the wave plate. *(5 marks)*