NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHSYICS DEPARTMENT

SPH 1201 – WAVES AND OPTICS

BSc HONOURS PART I: DECEMBER 2002 DURATION: 3 HOURS

ANSWER **ALL** PARTS OF QUESTION 1-IN SECTION A AND ANY **THREE** QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B 60 MARKS

Speed of sound (at 20°C)	343 m/s
Speed of Electromagnetic wave	3.0×10^8 m/s

SECTION A

1. (a) Give an expression for the total energy in a coupled pendulum and define all the quantities and terms involved. [6]

(b) A certain bat produces a sound wave with wavelength of 34 mm. Can a human being hear this sound? Explain. {4]

(c) Give the importance of Fourier analysis in a wave motion. Include a graphical illustration. [5]

(d) A plane sinusoidal acoustic wave falls normally on a quiet air-water surface. Assuming no energy losses at the boundary, find:
(i) the sound power reflection coefficient and . [2]
(ii) the sound power transmission coefficient [2]

(e) The electric field of a plane electromagnetic wave is given as:

$E_x = 0$

$E_y = 0.5\cos\left[2\pi \times 10^8 \left(t - {}^{x}\!/\!_{c}\right)\right]$ ${}^{N}\!/\!_{C}$

$E_z = 0$

What is the wavelength and the direction of propagation of this wave? Explain. [5]

(f) Explain how total internal reflection (TIR) is applied in optical fibres. Give two conditions necessary for TIR to occur. [5]

(g) Illustrate graphically the difference between, non-dispersive, normal dispersive and anomalous dispersive, media. [5]

(h) Comment on the phase difference between successive fringes in Fraunhoffer and Fresnel's diffraction patterns. [4]

(i) What is the difference between randomly polarised light and plane polarised light? [2]

SECTION B

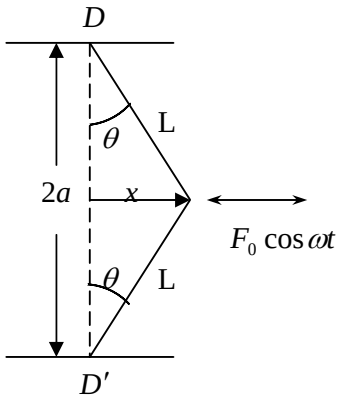
2. A H_2O molecule can be modelled as a system consisting of a central mass, m_2, (O^{16} atom) connected by springs on either side to masses, m_1 and m_3 (H^1 atoms).

(a) Construct and solve the equations of motion for each of the masses for the two normal modes in which the masses oscillate along the line joining them. [12]

(b) Using the fact that $m_1 = m_3 = 1$ amu and $m_2 = 16$ amu, determine the ratio of frequencies of the two modes. [6]

3. (a) Comment briefly on the effect of a symmetric non-linear return force on the vibrational motion of a free undamped oscillator. [5]

(b) A system shown in the figure is set into motion under the action of a driving force, $F_0 \cos \omega\alpha$. Derive the equation of motion for the system given that the. tension in the string is $T = T_0 + s(L - a)$ [12]



(c) By assuming a first approximation solution of $x_1 = A \cos wt$, find the second approximation solution. [5]

[NOTE: $\cos^3 \omega t = \frac{3}{4}\cos \omega t + \frac{1}{4}\cos 3\omega t$]

4. (a) Write down the wave equation governing the propagation of a disturbance along a wave guide. Define the terms appearing in this equation. [3]

(b) The displacement of the waves on a waveguide of width, b is given by
$z = A\sin\left[\omega t - \left(k_1 x + k_2 y\right)\right] + A_2 \sin\left[\omega t - \left(k_1 x - k_2 y\right)\right]$
with boundary conditions, z = 0 at y = 0 and at y = b.
Show that $z = -2A_1 \sin k_2 y \cos\left(\omega t - k_1 x\right)$, and determine the expression for k_2.
Explain the resultant equation, including how the sine term affects the amplitude of the wave. [6]

(c) Show that the phase and group velocities for the equation obtained in part (b) are given by $V_p = \left(\frac{k}{k_1}\right)V$ and $V_g = \left(\frac{k_1}{k}\right)V$ respectively,
where V is the velocity of light. [6]

(d) Explain how the waveguide acts as a frequency filter. [5]

5. (a) Explain how diffraction phenomena are used in distinguishing two distant stars that are at small angular separation. In your answer include an explanation of Rayleigh's criterion. [8]

(b) (i) What is a diffraction grating? [2]

(ii) A parallel monochromatic beam of light is incident normally on a diffraction grating. Under what conditions will a maximum on a distant screen be observed? [5]

(iii) What pattern is observed when the interference factor (due to double slit interference) is multiplied with the diffraction factor (due to diffraction from a single slit)? Explain. [5]

6. (a) (i) Define the term random phase difference. [3]

(ii) In which ranges of the electromagnetic wave is polarisation readily observed? [3]

(b) How is an electromagnetic wave affected
(i) when it is transmitted through a polaroid and [6]

(ii) when it is transmitted through two crossed polarising sheets? [4]

(c) Two polarising sheets are set such that the intensity of the transmitted light is a maximum. Through what angle must either sheet be turned if the intensity is to drop by one half? [4]

- END OF EXAMINATION -