NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1201 - WAVES AND OPTICS
SUPPLEMENTARY EXAMINATION

BSc HONOURS PART I: AUGUST 2004 DURATION: 3 HOURS

ANSWER **ALL** PARTS OF SECTION A AND ANY **THREE** IN SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

Atomic mass of oxygen	=	16 a.m.u
Atomic mass of hydrogen	=	1 a.m.u
Speed of sound in air	=	$341 ms^{-1}$
1 a.m.u	=	$1.66 \times 10^{-27} kg$

SECTION A

1. (a) (i) Define the terms phase velocity, group velocity and dispersion in wave motion. [3]

(ii) Prove by substitution that: $x = x_o \cos(\omega t + \alpha)$ is a solution of the differential equation for simple harmonic motion. [2]

(b) (i) Write the expressions and show on a phase diagram the phase differences between the displacement, velocity and acceleration in simple harmonic motion. [6]

(ii) The atoms of a solid at room temperature vibrate at a frequency of about 10^{13}Hz and with amplitude of 10^{-11}m. If the mass of an atom is 10^{-25}kg and the motion is approximately simple harmonic,find the maximum kinetic energy, the maximum acceleration of an atom as well as the value of the force constant for the motion. [4]

(c) For a stretched string wave, the relation between the displacement, y, of any string element at position x at a time t is given by $y(x,t) = y_m \sin(kx - \omega t)$. Use this relation to define the following quantities:

(i) wave number (k) [3]

(ii) period of oscillation (T) [3]

(d) (i) Explain the difference between Fresnel and Fraunhofer diffraction [5]

(ii) A slit of width a is illuminated using white light, find the value of a for which the first minimum of red light ($\lambda = 650nm$) falls at $\theta = 30^\circ$ as well as the ratio of the slit width to wavelength for this case. [6]

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

(f) What is the difference between ultrasound and infrasound? Give one application ultrasound [3]

SECTION B

2. (a) (i) Write down the equation governing the propagation of a longitudinal wave in a gaseous column, explaining the notation used therein. [2]

(ii) Show that the pressure variations also obey the wave equation. [5]

Show that for the phenomenon of Doppler effect, $\nu' = \nu\left(1 \pm \frac{V}{v}\right)$ where:

ν is the source frequency

ν' is the modified frequency

V $= \left|(V_S \pm V_D)\right|$, V_S and V_D are source and detector velocities.

v is the wave velocity

for the condition V_S and V_D are very small compared to v. [7]

(b) Two car sirens A and B each have a frequency of 500Hz. A is moving to the left away from B with a velocity 50km/h, whilst B is stationary. An observer is between the two sirens, moving to the left with velocity = 6m/s.

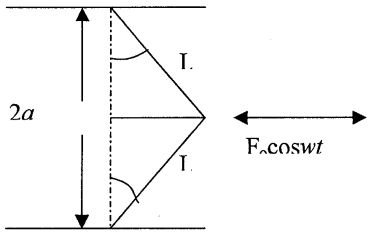
(i) what frequency does the observer hear from siren A? [2]

(ii) what frequency does the observer hear from siren B? [2]

(iii) what is the beat frequency? [2]

3. (a) Briefly outline the meanings of the following: linear restoring force, non-linear "hard" spring, non - linear "soft" spring using a graph for your illustrations. [5]

(b) The system shown below is set into motion under the action of diving force given by, $F_o \cos \omega t$.



The tension in the string is given by $T = T_o + s(L-a)$, where all symbols have their usual meanings. Derive the equation of motion for the system. [10]

(c) By assuming a first approximation solution of $x = A\cos\omega t$, find the second approximation solution.
[NOTE $\cos^3\omega t = \frac{3}{4}\cos\omega t + \frac{1}{4}\cos 3\omega t$] [5]

4. (a) Explain the difference between Fresnel and Fraunhofer diffraction. [6]

(b) A slit of width a is illuminated by white light.
(i) For what value of a will the first minimum of red light $(\lambda = 650nm)$ fall at $\theta = 30^0$? [3]
(ii) What is the ratio of the slit width to wavelength for this case? [3]

(c) In (b) what is the wavelength λ of the light whose diffraction maximum (excluding the central maximum) falls at $\theta = 30^0$, thus coinciding with the first minimum for red light? [4]

(d) What requirements must be met for the central maximum of the envelope of the double slit Fraunhofer pattern to contain exactly 11 fringes? [4]

5. (a) The displacement of a particle at some position x in a continuous media set in motion by a wave travelling to the right, is given by the expression:

$$y = a\sin\frac{2\pi}{\lambda}(x - ct)$$

(i) What are a, x and c in the above equation? [2]
(ii) Write down the expression for the displacement of the particle if it is set in motion by a wave travelling to the left. [2]

(b) A travelling sinusoidal wave is described by:
$y(x,t) = 0.04\sin(74.1x - 2.4t)$, constants are in S.I units.
(i) What is the amplitude of this wave? [1]
(ii) At $t = 0s$, what are the displacements of particles at x = 0.0m, 0.2m and 0.5m? [3]
(iii) At $x = 0.1$m, what is the displacement at t = 0.1s and 0.2s? [1]
(iv) What is the maximum velocity of oscillation of the particles of transmitting medium? [3]
(v) What is the velocity of propagation of the wave in the string? [3]

(c) A particle is under the influence of two combined simple harmonic motions along the same line, their equations are:
$y_1 = y_m\sin(kx - \omega t + \phi)$ and $y_2 = y_m\sin(kx - \omega t)$
Find the resultant equation of motion of the particle and its amplitude. [5]

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

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

(b) Explain how an electromagnetic wave is affected

(i) When it is made incident on a Polaroid and [6]

(ii) When it is made incident on 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 a half? [4]

- END OF EXAMINATION -