NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1201 - WAVES AND OPTICS

SUPPLEMENTARY EXAMINATION

BSc HONOURS PART I: JULY 2005 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) A body of mass 2.2kg stretches a spring 10cm when it hangs vertically in equilibrium. The body is attached to the spring on a frictionless horizontal surface, displaced 4.5cm from equilibrium position and released.

(i) Find its frequency; amplitude; period and phase constant φ. [4]

(ii) What is the minimum velocity of the oscillator and when does it occur? [3]

(b) (i) A simple harmonic oscillator has a period 4π.It passes through a point 0.38m away from origin O, with velocity 3,8m/s. How much time elapses before it next passes through this point? [3]

(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 $\theta = 30^o$ 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) Given that the speed of of sound in a medium is 343m/s, what are the fundamental and first order frequencies and their wavelengths for standing waves in a closed tube of 1m long [4]

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.

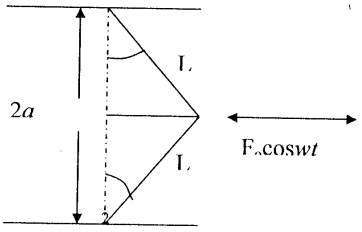
(i) what frequency does the observer hear from siren A? [2]

(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 $x_1 = A\cos\omega t$, 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 $\theta = 30^0$?
(ii) What is the ratio of the slit width to wavelength for this case? [3] [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) An interference pattern is observed on a screen placed a distance d from two light sources S_1 and S_2 of separation a when monochromatic light of wavelength λ is falling normally oon the plane of the sources. Describe the observed pattern and state the conditions for constructive/destructive interference. [6]

(b) Show that the intensity of the resultant motion at any point on the screen is given by:
$I = I_oCos^2(\pi ax/\lambda d)$
Where I_o is the intensity of the centre point. [8]

(c) Explain how Michelson's interferometer can be used to define the metre. [6]

6. (a) For a stretched string wave, the relation between the displacement, Y of any element at position, X at a time t is given by $Y(x,t) = Sin(kx - \omega t)$. Use this relation to define
(i) wave number (K) [2]
(ii) period of oscillation (T) [2]

(b) A travelling sinusoidal wave is described by:
$Y(x,t) = 0{,}05\text{Sin}(74tx - 2.4t)$

(i) What is the amplitude of this wave? [2]

(ii) At t = 0s, what are the displacements of particles at x = 0.0m; 0.2m and 0.5m? [4]

(iii) At x = 0.1m, what is the displacement at t=0.15s and 0.2s? [2]

(iv) What is the maximum velocity of oscillation of the particles of the transmitting medium? [4]

(v) What is the velocity of propagation of the wave in the string? [4]

- END OF EXAMINATION -