NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1201 – WAVES AND OPTICS

BSc HONOURS PART I: *MAY 2005* *DURATION: 3 HOURS*

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

SECTION A

1. (a) (i) A simple harmonic oscillator has a period 4π. It passes through a point 0,39m with velocity 3,9m/s away from origin 0. How much time lapses before it next passes through this point? [2]

(b) A body of mass 2,1kg stretches a spring 8cm 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 maximum velocity of the oscillator and when does it occur? [3]
(iii) A seconds pendulum (whose $T/2$ = 1 second at sea level) is raised to 1 km above sea level. How many seconds will it loose in a day? [4]

(c) The interatomic potential energy for a particular crystal is given by:

$$V(r) = \frac{\ell^2}{4\pi\Sigma_o r}\left[\frac{1}{9}\left(\frac{r_o^o}{r}\right)^8 - 1\right]$$

where all the symbols have their usual meanings.

(i) Find the anticollapse constant β in terms or r_o [4]
(ii) Proove that the rate of expansion of the crystal is a constant value. [5]

(d) Two travelling waves moving in a common direction interfere with each other, amplitude of each is Ym = 10,2mm. The phase difference Φ between them is $\Phi = 107^o$

(i) What is the amplitude Ym^1 of the resultant wave? [2]
(ii) What value of Φ would lead to the resultant wave having the same amplitude as the amplitudes of the combining waves? [3]

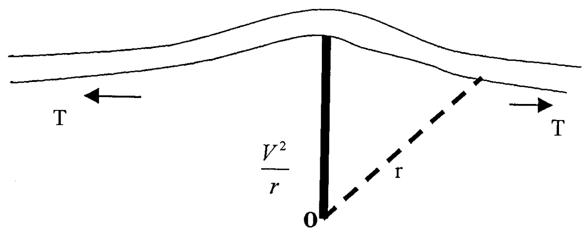
(e) (i) Differentiate between ultrasound and infrasound? Give one application of altrasound. [3]
(ii) The audible frequency range for normal hearing is from about 20Hz to 20KHz. If speed of sound in air (V) is 343m/s, what are the wavelengths of sound waves at these frequencies? [2]

(iii) Given the above speed for sound, what are the fundamental and first order frequencies and their wavelengths for standing waves in closed tube 1m long [4]

(f) Comment on the phase difference between successive fringes in Fraunhoffer and fresnel diffraction patterns. [4]

2. The diagram above shows a string wave pulse where T is the string tension and V is the pulse velocity, r is the radius of the circular arc.

(a)



(i) Show that the velocity of the pulse depend on the properties of the medium and is given by:

$V = \sqrt{\frac{T}{\mu}}$ where μ is the mass linear density of the string. [7]

(ii) State one important assumption made to up with above relation. [2]

(b) (i) Show that for an ideal gas, the velocity of a sound wave travelling through it at under isothermal conditions is in terms of pressure given by:

$V = \sqrt{\frac{P}{P}}$ where P is pressure and P is density. [7]

(ii) Show that in terms of temperature, the above relation becomes

$V = \sqrt{\frac{RT}{M}}$ where R is the universal gas constant, m is the molecular mass. [2]

(iii) The two relations above introduce an error in V. Explain why and how this error should be corrected. [2]

3. (a) Two car sirens A and B have each 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 of 6m/s.

(i) What frequency does the observer hear from sirens A? [2]
(ii) What frequency does the observer hear from siren B? [2]
(iii) What is the beat frequency in this case? [2]

(b) Show that the following shifts occur in the frequencies detected by the receiver:

(i) $f^1 = f\frac{V}{V \pm Us}$ when receiver is stationary and source is moving. [5]

(ii) $f^1 = f\frac{V \pm U_D}{V}$ when receiver is moving and source is stationary. [5]

where: f is source frequency
f^1 is the received frequency
V is the wave velocity
U_s is velocity of source
U_D is velocity of detector

(c) Show that general Doppler effect equation, that is the one in which both source and receiver are moving with respect to the air mass between them is:

$f^1 = f\ \frac{V \pm U_D}{V \pm U_s}$ where all symbols have their usual meanings.

4. (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

$Y(x_1t)$ = Ym Sin (kx – wt). Use this relation to define

(i) wave number (K) [2]
(ii) period of oscillation (T) [2]

(b) A travelling simusoidal wave is described by:

$y(x_1t)$ = 0,04 Sin (74.1 x –2,4t), constants are in S.I units

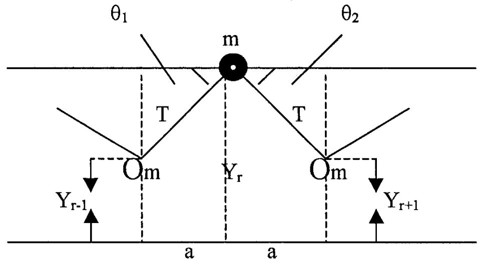
(i) What is the amplitude of this wave? [1]
(ii) At t = Os, what are the displacements of particles at X = 0.0m; 0.2m and 0.5m? [3]
(iii) At x = 0.1m, what is the displacement at t = 0.15 and 0.2s? [1]
(iv) What is the maximum velocity of oscillation of the particles of transmitting medium? [3]
(v) What 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 = Ym Sin (Kx – wt + Φ) and Y_2 = Ym Sin(Kx – wt)

Find the resultant equation of motion of the particle and its amplitude. [5]

5. The figure below illustrates coupled oscillations of a loaded string.



n equal masses are spaced at equal distances, a

(i) Show that the equation of motion for the γ^{th} mass is given by:

$$\ddot{y}_r = \frac{T}{ma}(y_{r-1} + y_{r+1} - 2y_r) \qquad [5]$$

(ii) By considering $y_r = A\gamma e^{iwt}$, show that the above equation can be reduced to:

$$-A_{r-1} + \left(2 - \frac{maw^2}{T}\right)A_r - A_{r+1} = o \qquad [5]$$

(iii) Show how equation (i) by considering appropriate limits, can be used to derive the Wave Equation. [7]

(iv) Show that the dimensions of P/T in the Wave Equation are similar to those of $1/V^2$. [3]

6. (a) An interference pattern is observed on a screen placed a distance d from two light sources S_1 and S_2 of seperation a when haonochromatic light of wavelength λ is falling normally on 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:

$$I = I_o Cos^2(\pi ax / \lambda d]$$

where I_o is none intensity distribution [8]

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

END OF EXAM