

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2201 – WAVES AND OPTICS I

SUPPLEMENTARY EXAMINATION

BSC HONOURS PART I : JULY 2003

DURATION : 3 HOURS

ANSWER ALL QUESTIONS IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

Atomic mass of oxygen	=	16 <i>a.m.u.</i>
Atomic mass of hydrogen	=	1 <i>a.m.u.</i>
Speed of sound in air	=	341 ms ⁻¹
1 a. m. u.	=	1.66 x 10 ⁻²⁷ kg

SECTION A

1. (a) Two identical masses of two pendula are coupled by a weightless spring of spring constant k . The system is set into vibrational motion along the line of the spring.
- (i) State the possible normal modes of vibration for the system and [2]
- (ii) write the equations of motion for each mass. [2]
- (b) Give and explain the differences between (a) linear restoring force (b) non-linear 'hard' spring (c) non-linear 'soft' spring. [4]
- (c) Show that $y = y_m \sin(kx - \omega t)$ may be written in the alternative forms

$$y = y_m \sin k(x - vt), \quad y = y_m \sin [2\pi (x - vt) / \lambda]$$

$$y = y_m \sin w(x/v - t) \quad y = y_m \sin 2\pi (x/\lambda - t/T) \quad [4]$$

- (d) Distinguish between 'phase velocity' and 'group velocity' in wave motion. Include an expression for each in your answer. [4]
- (e) Explain the term *superposition*. Give at least two real life examples where superposition occurs. Under what conditions does the principle of superposition fail? [4]
- (f) Is Young's experiment an interference experiment or a diffraction experiment? Explain. [4]
- (g) State one application of ultrasound in medical physics? Give merits and demerits of ultrasound over x-rays. [4]
- (h) Explain the conditions under which constructive interference between two waves of the same frequency w can occur. Give explanations in support of your answer. [4]
- (f) Express in dB the difference in the intensity of two sound waves, if the pressure amplitude of one is twice that of the other. [4]
- (i) Explain what is meant by plane polarised light and briefly describe two methods by which it can be produced. [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]
- (b) Sound travels through gases with speed $c = (B/\rho)^{1/2}$, where B is the Bulk modulus of the gaseous system and ρ is its density. Compare the velocities of sound propagation at 0°C in oxygen and in hydrogen. [NOTE: Consider the process to be adiabatic with $\gamma = C_p/C_v = 1.40$ for both gases] [7]
- (e) Two car sirens C and D each have a frequency of 600Hz. C is moving to the left away from D with a velocity 80km/h, whilst D is stationary. An observer is between the two sirens, moving to the left with velocity 10 m/s.
- (i) What frequency does the observer hear from siren C? [2]
- (ii) What frequency does the observer hear from siren D? [2]
- (iii) What is the beat frequency? [2]

- 3.. (a) Considering a 2D wave in an environment of rigid boundaries, explain the principle of wave-guides. [6]
- (b) Explain briefly how the principle of wave-guide is used in optical fibres. Discuss the process by which light is bent around corners in a fibre. [6]
- (c) Mention two advantages and two disadvantages of the use of fibre optics. Give two applications of optical fibre. [8]
4. Consider a linear array of $2N$ particles of alternating masses m_1 and m_2 .

0, 1, 2, 3, 4, 5, $2N-1$, $2N$, $2N+1$

The transverse displacement of the p^{th} particle is labeled y_p . We can label all p values with the index r , $1, r, N$, by setting $p=2r$ for even values of p and $p=2r-1$ for odd values of p .

The equations of motion for the $2r^{\text{th}}$ and $2r+1^{\text{th}}$ particles are

$$m_2 \ddot{y}_{2r} + \frac{T}{l} (y_{2r} - y_{2r-1}) - \frac{T}{l} (y_{2r+1} - y_{2r}) = 0$$

$$m_1 \ddot{y}_{2r+1} + \frac{T}{l} (y_{2r+1} - y_{2r}) - \frac{T}{l} (y_{2r+2} - y_{2r+1}) = 0$$

Assume that each displacement is of the form $y_p = A_p \cos(\omega t)$.

- (a) Show that the equations of motion together with the solutions for y_p place the following restrictions on the amplitudes A_p

$$\frac{A_{2r+1} + A_{2r-1}}{A_{2r}} = \frac{2\omega_{02}^2 - \omega^2}{\omega_{02}^2}$$

and

$$\frac{A_{2r+2} + A_{2r}}{A_{2r+1}} = \frac{2\omega_{01}^2 - \omega^2}{\omega_{01}^2}$$

[8]

with $\omega_{01}^2 = T/(m_1 l)$ and $\omega_{02}^2 = T/(m_2 l)$.

- (b) If the amplitudes A_{2r} and A_{2r+1} can be written as

$$A_{2r} = C \sin(2r\theta)$$

$$A_{2r+1} = D \sin((2r+1)\theta),$$

find the allowed values of θ .

[4]

- (c) Using the amplitudes in b) and the relationships from a) show that the mode frequencies can be determined from the expressions

$$\begin{aligned} (2\omega_{02}^2 - \omega^2)C - 2\omega_{02}^2 \cos\left(\frac{n\pi}{2N+1}\right)D &= 0 \\ -2\omega_{01}^2 \cos\left(\frac{n\pi}{2N+1}\right)C + (2\omega_{01}^2 - \omega^2)D &= 0 \end{aligned} \quad [8]$$

5. (a) Explain and illustrate the difference between Fresnel and Fraunhofer diffractions. [6]
- (b) A slit of width a is illuminated by white light.
- (i) For what value of a will the first minimum for red light ($\lambda = 650\text{nm}$) fall at $\theta = 30^\circ$. [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 first diffraction maximum (Excluding the central maximum) falls at $\theta = 30^\circ$, thus coinciding with the first minimum for the 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 eleven fringes? [4]

6. Explain the formation of Newton's rings and comment on the colour pattern of the fringes when white light is used. [5]

Figure 5.1 shows a lens of radius of curvature R resting on a glass plate and illuminated from above by light of wavelength λ . Circular interference fringes appear.

- (a) Find the radii of the circular interference maxima assuming that $r/R \ll 1$. [5]

- (b) The lens in Figure 5.1 is illuminated with sodium light incident normally; if the diameter of the tenth black ring is 1.5cm, find the curvature of the surface (wavelength = 589 nm).

[5]

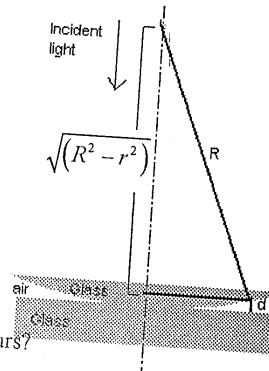


Figure 5.1

Explain what is meant by Newton's scale of colours?

[5]

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