NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF TECHNICAL TEACHER EDUCATION

BACHELOR OF EDUCATION HONOURS DEGREE - PHYSICS

SPH 1201- WAVES AND OPTICS

BSc HONOURS PART 1: SEPTEMBER 2010 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 MARK

Atomic mass of Oxygen	=	16 a.m.u
Atomic mass of Hydrogen	=	1 a.m.u
Speed of sound in air	=	343 ms^{-1}
Speed of light	=	3.. x 10^8m/s
Acceleration due to gravity	g =	9,81 ms^{-2}
Permittivity of free space	ε_0 =	8.854 x 10^{-12} Fm^{-1}
1 a.m.u	=	1.66 x 10^{-27} kg

SECTION A

1. (a) A 3.0 kg particle is in simple harmonic motion in one direction and moves according to the equation:-

$$x = 5\cos\left[\left(\frac{\pi}{3}\right)t - \frac{\pi}{4}\right]$$

(i) At what value of x is the potential energy equal to half the total energy? [3]

(ii) How long does it take the particle to move to this position from the equilibrium position? [2]

(b) Light of intensity I_0 is incident on two ideal linear polarisers whose transmission axes differ by 60^o.

(i) Calculate the intensity of the transmitted light if the incident light is unpolarised. [3]

(ii) Calculate the intensity of the transmitted light if the incident light is linearly polarised along an axis oriented at an angle of 30^o to the axis of the first polarizer. [3]

(c) Define the terms, normal coordinates and normal mode of vibration [4]

(d) A person on a railroad car blows a trumpet sounding at 440 Hz. The car is moving toward a wall at 20 ms^{-1}.Taking the speed of sound to be 343ms^{-1}, Calculate:-

(i) The frequency of the sound as received at the wall [3]
(ii) The frequency of the reflected sound arriving back at the source. [3]

(e) Two traveling waves, moving in a common direction, interfere with each other, the amplitude of each wave is 9.7mm and the phase difference between them is $\varphi = 110°$.

(i) What is the amplitude y_m of the resultant wave? [4]
(ii) What value of φ would lead to the resultant wave having the same amplitude as the amplitudes of the combining waves? [4]

(f) A slit of with '***a***' is illuminated by white light.

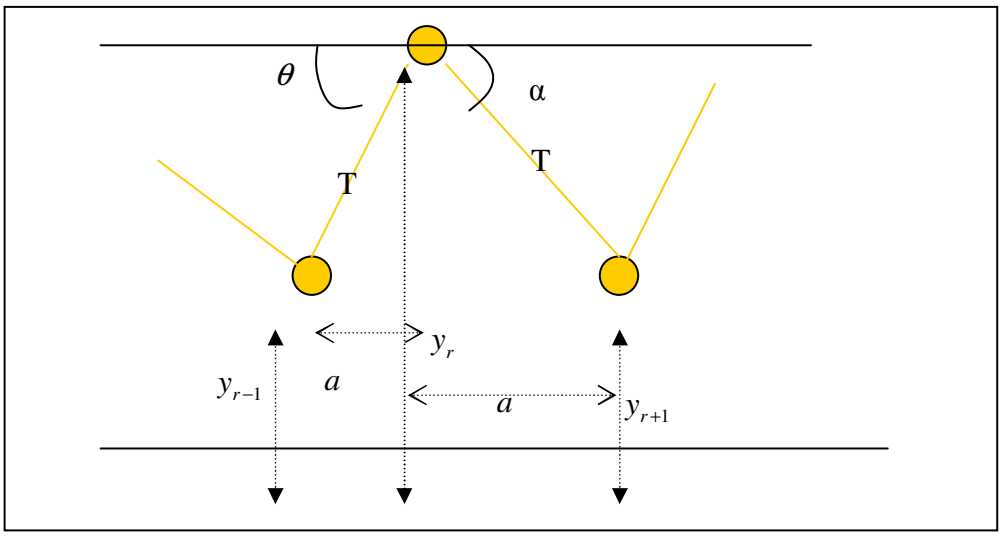
(i) For what value of '**a**' will the first minimum for red light (λ = 650 nm) fall at $\theta = 30°$? [3]
(ii) What is the ratio of the slit width to wavelength in this case? [2]

(g) Distinguish between phase velocity and group velocity of a propagating wave giving an expression for each in terms of ω and k, where all the symbols have their usual meaning. [6]

(h) Monochromatic light from a distant source is incident on a slit 0.800mm wide. On a screen 3.00m away, the distance from the central maximum of the diffraction pattern to the first minimum is measured to be 1.25mm. Calculate the wavelength of the light. [2]

SECTION B

2. (b) The figure below illustrates coupled oscillations of a loaded string.



n equal masses (*m*) are spaced at equal distances (*a*),

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

$$\left(\frac{d^2 y_r}{dt^2}\right) = \frac{T}{m_a}\left(y_{r-1} + y_{r+1} - 2y_r\right) \qquad [5]$$

(ii) By considering $y_r = Are^{i\omega t}$, show that this equation can be reduced to:

$$-Ar - 1 + \left(2 - \frac{ma\omega^2}{T}\right)Ar - Ar + 1 = 0 \qquad [5]$$

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

(iv) Show that the dimensions of ρ/T are similar to those of $\frac{1}{v^2}$. [3]

3. (a) An ideal spring with force constant k=800N/m is mounted horizontally to a fixed end. A 0.400kg mass is attached to the other end undergoes SHM with an amplitude of 0.075m. There is no friction on the mass. Compute:-

(i) The maximum speed of the mass. [2]

(ii) The speed of the mass when it is at x=0.030m [2]

(iii) The magnitude of the maximum acceleration of the mass. [2]

(iv) The acceleration of the mass at x=0.030m [2]

(v) The total mechanical energy of the mass at any point of its motion. [2]

(b) The equation of a certain transverse wave is:

$$y(x,t)=(4.00cm)\sin 2\pi\left|\frac{t}{0.0300s}-\frac{x}{50.0cm}\right|$$

Determine the waves:-

(i) Amplitude [2]

(ii) Wavelength [3]

(iii) Frequency [3]

(iv) Speed of propagation. [2]

4. (a) In the Young's double-slit interference experiment, suppose d = 0.100mm and L = 1.00m, and the incident light is monochromatic with a wavelength λ=500 nm.

(i) What is the phase difference between the two waves arriving at a point *P* on the screen when $\theta = 0.80^0$? [3]

(ii) What is the phase difference between the two waves arriving at a point *P* on the screen when y = 4.00mm? [3]

(iii) If the phase difference (φ =1/3 rad), what is the value of θ? [2]

(v) If the path difference is $\lambda/4$, what is the value of θ? [2]

(b) Sunlight reflects off the smooth surface of an unoccupied swimming pool. (n_a=1 and n_w=1.33)

(i) At what angle of reflection is the light completely polarized. [3]

(ii) What is the corresponding angle of refraction for the light that is transmitted into water? [3]

(iii) At night an underground flood light is turned on in the pool. Repeat part (i) and (ii) for the rays from the flood light that strike the smooth surface from below. [4]

5. (a) Explain what is meant by *plane polarized light*. [3]

(b) Describe how a beam of plane polarized light may be produced by:-
(i) Reflection [4]
(ii) Absorption [4]

(c) (i) Give an account of two uses of polarized light. [4]

(ii) Why is it not possible to polarize sound waves? [3]

(e) Monochromatic light of wavelength 500 nm is incident normally on a diffraction grating with 5×10^5 lines per metre in a spectrometer experiment. At what angle to the normal is the second order line seen? [2]

6. (a) Show with the aid of a diagram, the experimental arrangement by which Newton's rings pattern can be observed. [7]

(b) Light with wavelength 648nm in air is incident perpendicular from the air on a film 8.76×10^{-6}m thick that has refractive index 1.35. Part of the light is reflected from the first surface of the film, and part enters the film and is reflected back at the second surface, where the film is again in contact with air:-

(i) How many waves are contained along the path of this second part of the film? [3]

(ii) What is the phase difference between these two parts of the light as they leave the film? [3]

(c) The following two waves in a medium are superposed:

$Y_1 = A\sin(5x - 10t)$ and $Y_2 = A\sin(4x - 9t)$

Where x is in metres and t in sec:-

(i) Write an equation of combined disturbance [3]

(iii) What is its group velocity? [2]

(iv) What is the disturbance between points amplitude in the combined disturbance? [2]

END OF PAPER