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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS

2020/2021 ACADEMIC YEAR

SECOND YEAR FIRST SEMESTER REGULAR EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: PHY 211

COURSE TITLE: WAVES AND VIBRATIONS

DATE: **TIME:**

INSTRUCTION TO CANDIDATES

- **SEE INSIDE**

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REGULAR – MAIN EXAM

PHY 211: WAVES AND VIBRATIONS

STREAM: BED (Scie) **DURATION: 3 Hours**

INSTRUCTIONS TO CANDIDATES

i. *Answer questions ONE and TWO in section **A** and any other **THREE** questions in section **B**.*

SECTION A (28 MARKS)

Question One (14 Marks)

a) Distinguish between free, damped and forced vibrations, and write down differential equation of each vibration (6 Marks)

b) The equation of a transverse wave traveling a long a very long string is $y = 6.0\sin(0.02\pi x + 4.0\pi t)$, where x and y are expressed in cm and t in seconds.

Determine:

i. Amplitude (1 Mark)

ii. The wavelength (1 Mark)

iii. The frequency (1 Mark)

iv. The speed (1 Mark)

v. The direction of propagation of the wave (1 Mark)

vi. The maximum transverse speed of the particle in the string (1 Mark)

c) Two waves traveling in opposite directions produce a standing wave. The individual wave functions are: $y_1 = A\sin(kx - \omega t)$ and $y_2 = A\sin(kx + \omega t)$. Find the resultant wave function. (2 Marks)

Question Two (14 Marks)

a) What are standing waves and how are they produced? (2 Marks)

b) Distinguish between phase velocity and group velocity. (4 Marks)

c) A police car, parked by the roadside, sounds its siren, which has a frequency f of 1000 Hz. What frequency f' do you hear if (velocity of sound in air=340 ms^{-1})

i. you are driving directly toward the police car at 30 ms^{-1} (2 Marks)

ii. you are driving away from the police car at the same speed (2 Marks)

d) Briefly describe the following terms that are used in damped harmonic oscillator?

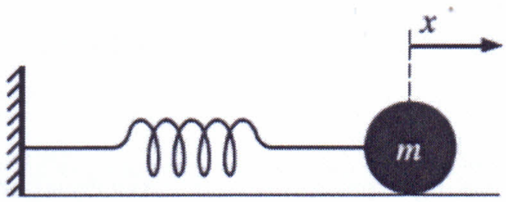
a) Logarithmic decrement (2 Marks)

b) Quality factor (2 Marks)

SECTION B (42 MARKS)

Question Three (14 Marks)

a) The mass of simple harmonic oscillator on a horizontal spring shown in the figure below *m* has a value of 0.80 kg and the spring constant *k* is 180 N m−1. At time $t = 0$ the mass is observed to be 0.04 m further from the wall than the equilibrium position and is moving away from the wall with a velocity of 0.50 m s−1.



i) Obtain an expression for the displacement of the mass in the form $x = A(\cos\omega t + \phi)$, obtaining numerical values for A, ω and φ. (6 Marks)

ii) Determine the total energy of the oscillating system. (2 Marks)

b) A vertical spring has a stiffness factor equal to 48 N/m. At $t = 0$ a force given in Newton's by $F(t) = 51 sin4t$, $t>0$ is applied to a 30 N weight which hangs in equilibrium at the end of the spring. Neglecting damping, find the position of the weight at any later time. The general solution of the forced vibration equation: $\frac{d^2z}{dt^2} + \omega^2 z = \text{f}\sin\omega t$ is $x = \text{A}\cos\omega t + \text{B}\sin\omega t - \frac{\text{f}_0 t}{2\omega}\cos\omega t$. (6 Marks)

Question Four (14 Marks)

a) A particle of mass 2 has damping force whose magnitude is numerically equal to 8 times the instantaneous speed. The particle is also attracted along the x-axis towards the origin by a force whose magnitude is numerically equal to 8x. If it is initially at rest (t=0) at x = 20 and $\frac{dx}{dt} = 0$. Given that the general solution is of the form $x = e^{-2t}(A + Bt)$. Find

i) the position of the particle at any time (4 Ma

ii) the velocity of the particle at any time (3 Marks

iii) Illustrate graphically the position of the particle as a function of time, hence describe the motion. (3 Marks)

b) A block of mass (m), on a horizontal frictionless table, is attached to a rigid support by a spring of spring constant (k). The horizontal oscillations of the system are simple harmonic in nature. Show that its time period is given by $T = 2\pi\sqrt{\frac{m}{k}}$. (2 Marks)

c) Write expressions relating damping term and stiffness term that correspond to the condition of the following damping motion

i) Heavily damped (1 Mark)

ii) Lightly damped (1 Mark)

Question Five (14 Marks)

a) Using a harmonic traveling wave employ the wave equation given by

$\mu\frac{\partial^2 z}{\partial t^2} = T\frac{\partial^2 z}{\partial x^2}$, where the symbols have their usual meaning and show that $v = \sqrt{\frac{T}{\mu}}$.

(6 Marks)

b) Show that the average power required to maintain a travelling wave of amplitude A and angular frequency ω on a long string is $P = \frac{1}{2}\mu v A^2\omega^2 = \frac{1}{2}zA^2\omega^2$,

Where μ is the mass per unit length of the string, v is the speed of transverse waves on the string and $z = \sqrt{\mu T}$ is the characteristic impedance of the string for transverse waves.

(6 Marks)

c) A sinusoidal transverse wave travels on a string. The string has length 8.00 m and mass 6.00 g. The wave speed is 30.0 m/s, and the wavelength is 0.2 m. If the wave is to have an average power of 50.0 W, what must be amplitude of the wave? (2 Marks)

Question Six (12 Marks)

a) Differentiate between longitudinal waves and transverse waves. Give examples of each. (4 Marks)

b) What is dispersion and is air a dispersive medium? Give reason for your answer. (2 Marks)

c) The resultant wave of two travelling waves is given by the equation:

$$Z(x,t) = 2Z_0 sin(Kx - \Omega t)cos\left[\left(\frac{\partial k}{2}\right)x - \left(\frac{\partial \omega}{2}\right)t\right]$$

Where $\partial k \equiv k_1 - k_2$ and $\partial \omega \equiv \omega_1 - \omega_2$

Determine the wavelength ($\frac{1}{\lambda_{beat}}$) and frequency (f_{beat}). (4 Marks)

d) Show that $y(x,t) = f(x - vt)$ represents a one-dimensional travelling wave (or progressive wave) moving with constant velocity v and without any change of shape along the positive direction of x. (4 Marks)

Question Seven (12 Marks)

a) What are shock waves? Give examples of situations in which shock waves form. (3 Marks)

b) i) When the observer is at rest and the source is in motion towards the observer show that the apparent frequency as received by the observer is

$$f_s = f\frac{\mathrm{v}}{\mathrm{v - v_s}}$$ (3 Marks)

iii) What is the apparent frequency when the source is moving away from a stationary observer? (1 Mar)

c) Given that

$$y_i = A_1 e^{i(\omega t - k_1 x)}$$

$$y_r = B_1 e^{i(\omega t + k_1 x)}$$

$$y_t = A_2 e^{i(\omega t - k_2 x)}$$

Find the expressions for reflection and transmission coefficients. (The boundary conditions stipulates that: displacement is same immediately to the left and right of $x = 0$ and there is continuity of the transverse force $T(\partial y/\partial x)$ at $x = 0$) (8 Marks)

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