MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS

2018/2019 ACADEMIC YEAR

***SECOND* YEAR *FIRST* SEMESTER**

SCHOOL OF SCIENCE

BACHELOR OF SCIENCE and BACHELOR OF EDUCATION SCIENCE

COURSE CODE: PHY 2110

COURSE TITLE: OSCILLATIONS AND WAVES

DATE: 3rd December 2018 **TIME: 1100-1300**

INSTRUCTIONS TO CANDIDATES

1. Attempt Question **ONE** and any other **TWO** questions
2. Use of sketch diagrams where necessary and brief illustrations are encouraged.
3. Read the instructions on the answer booklet keenly and adhere to them.

*This paper consists of **four** printed pages. Please turn over.*

Question One (30 marks)

a) State and briefly explain three velocities in wave motion which are quite distinct although they are connected mathematically. **3mks**

b) The general form for the energy of a simple harmonic oscillator is

$$E = \frac{1}{2}\text{mass(velocity)}^2 + \frac{1}{2}\text{stiffness(displacement)}^2$$

Set up the energy equations for a simple pendulum and use the expression $\frac{dE}{dt} = 0$ to derive the equation of motion in each case. **5mks**

c) Show that, in the Doppler effect, the change of frequency noted by a stationary observer O as a moving source S' passes him is given by $\Delta\upsilon = \frac{2\upsilon cu}{\left(c^2 - u^2\right)}$ where $c = \upsilon\lambda$, the signal velocity and u is the velocity of S. **4mks**

d) Define the term 'Quality factor' as used in damped oscillators **1mk**

e) When the E string of a guitar (frequency 330 Hz) is plucked, the sound intensity decreases by a factor of 2 after 4 s. Determine

(i) the decay time τ, **3mks**
(ii) the quality factor Q and **2mks**
(iii) the fractional energy loss per cycle. **2mks**

f) You are on a stationary ship collecting weather data from a mobile weather station in space. How will you tell if a mobile weather station is approaching or receding **2mks**

g) The sonar device on a fishing boat uses underwater sound to locate fish. Would you expect sonar to be a longitudinal or a transverse wave **2mks**

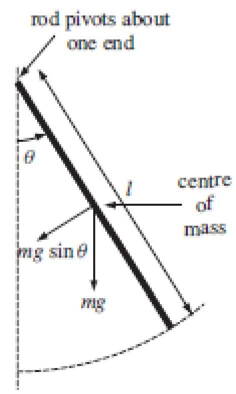
h) The equation $m\ddot{x} + kx = F_o \sin\omega t$ describes the motion of an undamped simple harmonic oscillator driven by a force of frequency ω. Show, by solving the equation in vector form, that the steady state solution is given by

$$x = \frac{F_o \sin\omega t}{m\left(\omega_o^2 - \omega^2\right)} \quad \text{where } \omega_o^2 = \frac{k}{m}$$ **5mks**

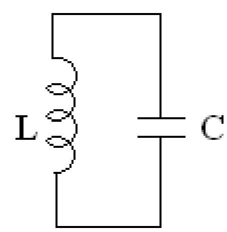
i) Distinguish between transverse and longitudinal waves **1mk**

Question Two (20 marks)

a) The figure below shows a physical pendulum when oscillating. Prove that this is SHM, obtain its angular frequency ω and period T **8mks**



b) Consider a circuit network in the figure below where an inductor L is connected across the plates of a capacitor C.

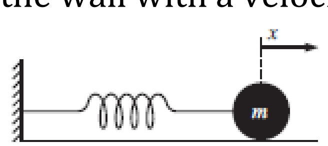


Show that the circuit executes simple harmonic motion (SHM) and hence prove that the total energy of the system is given by $E_{Total} = \frac{1}{2}L\dot{Q}^2 + \frac{Q^2}{2C}$ **8mks**

c) Two waves of equal frequencies are perpendicularly superposed. It is shown the path followed by the particle is of the form $\frac{x^2}{a_1^2} + \frac{y^2}{a_2^2} - \frac{2xy}{a_1 a_2}\cos(\phi_2 - \phi_1) = \sin^2(\phi_2 - \phi_1)^2$. Describe four different paths that could arise, indicating what conditions can lead to the said phenomena. **4mks**

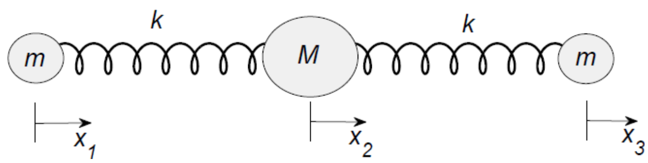
Question Three (20 marks)

a) A mass- spring system is shown in the figure below. The mass, 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}.



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. **10mks**

b) A simplistic model of a linear triatomic molecule such as carbon dioxide is shown in the figure below. For this molecule, two identical atoms of mass m are connected by two identical springs (spring constant k) to a single atom of mass M. We assume that the system is confined to move in one dimension (that is, the three atoms are always collinear). The equilibrium state of the molecule occurs when both springs are at their natural length.



(i) Write down the kinetic energy, and the potential energy for this system, using the displacement of each atom from its equilibrium position as the three generalized coordinates. **2mks**

(ii) Solve for the normal frequencies of the system, as a function of m, M, and k. **8mks**

Question Four (20 marks)

a) Show that y = f(ct + x) is a solution of the wave equation **6mks**

b) Show by the choice of appropriate values for A and B in equation $x = A\cos\omega t + B\sin\omega t$ that equally valid solutions for x is $x = a\cos(\omega t + \phi)$ **7mks**

c) Light from a star of wavelength 6×10^{-7} m is found to be shifted 10^{-11} m towards the red when compared with the same wavelength from a laboratory source. If the velocity of light is 3×10^{8} m.s^{-1} show that the earth and the star are separating at a velocity of 5 Km.s^{-1}. **7mks**