UNIVERSITY OF NAIROBI

SECOND YEAR EXAMINATIONS FOR THE DEGREE OF BACHELOR OF SCIENCE

SUPPLENTARY EXAMINATIONS 2009/2010

SPH 201: MECHANICS II

Date: **Time: 1 1/2 Hours**

- **This paper consists of five (5) Questions**
- **Attempt any THREE Questions**

Physical constants

Assume g = 10 ms^{-2}

Gravitational constant G = 6.7×10^{-11} Nm^2Kg^{-2}

Radius of Earth = 6,300Km

Mass of Earth = 5.96×10^{24} Kg

Question 1

(a) (i) Explain what is meant by Simple Harmonic motion (SHM)

(ii) A light helical spring of spring constant ***K*** hangs vertically from a fixed support and carries a mass ***m*** at its lower end. Assuming that Hook's law is obeyed and there is no damming, show that if the mass is displaced in a vertical direction from its equilibrium position and released, the subsequent motion is SHM.

(iii) Derive an expression for the period ***T*** in terms of ***m*** and ***K*** for the system in (ii) above. **[6 marks]**

(b) If ***m*** = 0.30Kg and ***K*** = 30 Nm^{-1} and the initial displacement of the mass is 0.015 m, calculate

(i) The maximum kinetic energy of the mass

(ii) The maximum and minimum values of the tension in the spring during motion

(iii) On the same axes, sketch graphs showing how the kinetic energy, potential energy and the tension in the spring vary with displacement from equilibrium positions. **[6 marks]**

(c) A body oscillates with SHM according to the equation

$$x = 6.12m\cos\left\{\left(8.38rads^{-1}\right)t + 1.92rad\right\}$$

Determine

(i) The displacement, the velocity and acceleration at time t = 1.90s

(ii) The period of the motion **[4 marks]**

(d) State with reasons whether there will be any change in the frequency of oscillation of the following systems if taken to the moon.

(i) A Torsional Pendulum

(ii) A simple pendulum

(iii) A spring-block system

(iv) A physical pendulum **[4 marks]**

Question 2

(a) Explain what you understand by the theory of **Special Relativity** and **General Relativity** respectively. On what grounds were these theories formulated. **[4 marks]**

(b) (i) State the postulates of Newtonian Theory of relativity and the Special Theory of Relativity respectively

(ii) Show that in two reference frames connected by a Galilean transform, acceleration is invariant **[8 marks]**

(c) (i) State the predictions of the special theory of relativity

(ii) A certain strain of bacteria doubles in number each 20 days. Two of these bacteria are placed on a spaceship and sent away from the earth for 1000 earth days. During this time, the speed of the ship was 0.995c. How many bacteria would be aboard when the ship lands on the earth? **[5 marks]**

(d) If L_0^3 is the rest volume of a cube, show that the volume of the same cube as viewed from a reference frame moving with uniform velocity β in a direction parallel to the edge of the cube will be given by $L_o^3\left(1-\beta^2\right)^{\frac{1}{2}}$ **[3 marks]**

Question 3

(a) Explain what you understand by the following types of harmonic oscillators

(i) Linear simple harmonic oscillator

(ii) Angular simple harmonic oscillator **[3 marks]**

(b) An object of mass 20 Kg moves with simple harmonic motion along the x-axis. Initially (at time t = 0), the particle is located at a distance 4m away from the origin, x = 0, and has a velocity of 15 ms^{-1} and an instantaneous acceleration of 100 ms^{-2} directed towards origin. Determine

(i) The position of the particle at any time t

(ii) The amplitude and frequency of the motion

(iii) The force on the object when $t = \pi/10$ seconds. **[7 marks]**

(c) Explain what is meant by geostationary orbits and show that the magnitude of the velocity in orbit of a geostationary satellite is approximately 3.1 kms^{-1}. **[4 marks]**

(d) An artificial satellite of 3500 kg made of aluminium is in circular orbit at a height of 100 km above the surface of the earth. Atmospheric friction removes energy from the satellite and causes it to spiral downwards so that it ultimately crashes into the ground.
   (i) Determine the initial orbital energy (gravitational plus kinetic) of the satellite
   (ii) Determine the final energy when the satellite comes to rest on the ground and the amount of energy change
   (iii) Suppose that all this energy is absorbed in the form of heat by the satellite, is it enough to melt or vaporize the satellite?
   [Melting point of Aluminium = 660^{o}C, Heat of Fusion = 95.3 Kcal/Kg, Heat of Vaporization = 2520 Kcal/Kg.] **[6 marks]**

Question 4

(a) State Newton's law of universal gravitation giving its formulation **[2 marks]**

(b) Based on your understanding of the law of gravitation, explain the following
   (i) Inner planets are associated with rocky interior and volcanic activities while outer planets are associated with dense gases.
   (ii) Outer planets are associated with more moons than inner planets
   (iii) Planet mercury never rotates on its axis as it revolves around the sun
   (iv) The existence of an asteroid belt between planet Jupiter and mars **[8 marks]**

(c) (i) What do you understand by lunar tides and what causes these tides? Why does the earth experience two high lunar tides and two low lunar tides per day
   (ii) Explain some of the observed effects of tides. **[6 marks]**

(d) By assuming the Earth to be spherical, show how the rotation of the earth about its axis affects the value of the acceleration due to gravity (g) as one moves from the equator to the poles. Hence sketch the variation of g on earth's surface with latitude from the equator. **[4 marks]**

Question 5

(a) Explain what you understand by the following types of harmonic oscillators
   (i) Damped harmonic oscillator
   (ii) Forced harmonic oscillator **[2 marks]**

(b) A particle P of mass 2 moves along the x-axis attracted towards the origin by a force of magnitude 8x. If the particle has a damping force

8 times the instantaneous speed and if it is initially at rest at x = 20, find

(i) The differential equation of motion
(ii) The position of the particle at any time
(iii) The velocity at any time t, the period and the amplitude of the motion
(ii) Illustrate graphically the position of the particle as function of time. **[8 marks]**

(c) The position of a particle moving along the x-axis is determined by the equation $\frac{d^2x}{dt^2} + 8x = 20\cos 2t$. If the particle starts from rest at x = 0, determine

(i) The position x as a function of time
(ii) The amplitude, period and frequency of the oscillation after a long time has elapsed. **[8 marks]**

(d) Explain the importance of damped devices in machinery **[2 marks]**
