NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1101 – MECHANICS

BSC HONOURS PART 1: JANUARY 2004 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.

Acceleration due to gravity,	$g = 9.81\ ms^{-2}$
Gravitational Constant,	$G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
Radius of the Earth,	$R_E = 6.37 \times 10^6\ m$
Mass of the Earth,	$G_E = 6.0 \times 10^{24}\ kg$
Density of water	$\rho = 1.0 \times 10^3\ kgm^{-3}$

SECTION A

1. (a) Define the concepts: inertia, rigid body, harmonic motion, kinematics, impulse. [5]

(b) What do you understand by the centre of mass for a system of n particles? Include its definition in vector notation. [5]

(c) Show that the ratio of the distances of two particles from their centre of mass is the inverse ratio of their masses. [5]

(d) A mass *m* fixed at the end of a horizontal spring rests on a frictionless plane. It is displaced by x_m from the equilibrium position and then released. Find its speed as it passes through the equilibrium position. Explain the principle of physics you use to determine the above answer. [5]

(e) Explain the law of conservation of Linear momentum. Give and explain one application of the momentum theory. [6]

(f) Prove that the escape velocity of any rocket on earth is given by $V_{esc} = \sqrt{2R_E g}$ [4]

(g) Calculate the time period of a simple pendulum of length 2m. Suppose the pendulum is taken to a planet whose acceleration due to gravity is a sixth that on earth. How will this move affect the period of oscillation of the pendulum. [5]

(h) A water tank of height 2m has a hole of 2mm at the bottom. Estimate the maximum velocity of the water jet. [5]

SECTION B

2. (a) What are the requirements for a particle to perform simple harmonic motion? [3]

(b) A circular disk is suspended by a wire attached to the centre of mass of the disk. The disk is displaced from its equilibrium position through a small angle θ and allowed to oscillate freely.

(i) What is the restoring force / torque affecting the disk? [3]

(ii) Show that the disk performs S.H.M. by deriving its equation of motion. [5]

(c) Explain the behaviour of a damped oscillator, including the effects of different degrees of damping. [6]

(d) Explain the phenomenon of resonance, especially its application in the aircraft industry. [3]

3. (a) Explain the meaning of the term torque with the aid of a diagram. [4]

(b) A non-uniform thin rod of length L lies along the x-axis with one end at the origin. It has a linear density (mass per unit length) given by:

$$\lambda = \lambda_0 \left(1 + {}^{x}\!/_{L}\right)$$

Find:

(i) the total mass of the rod [2]

(ii) the centre of mass of the rod and [2]

(iii) the moment of inertia of the rod about the less dense end. [3]

(c) A small object of mass m is attached to a light string, which passes through a hollow tube. The object is set into rotation in a circle of radius r_1 with a speed v_1. The string is then pulled down, shortening the radius of the path to r_2.

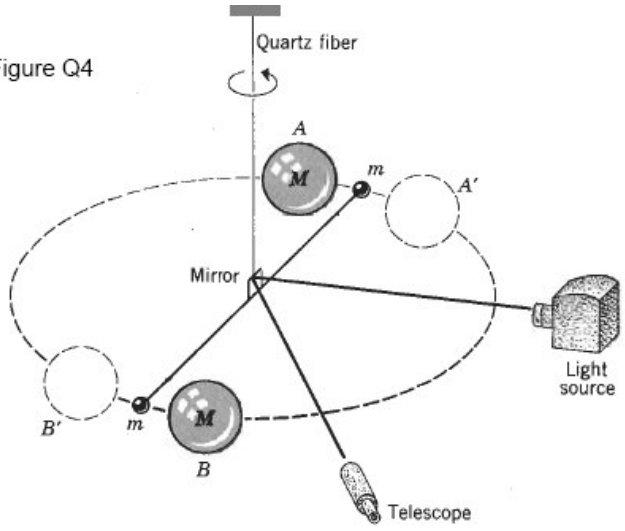
(i) Show that the angular momentum of the system is constant [3]

(ii) Find the new linear speed v_2 and the new angular speed ω_2 of the object in terms of the initial values v_1 and ω_1, and the two radii, r_1 and r_2. [6]

4. (a) State Newton's Universal Law of Gravitation, including the equation form [3]

(b)

Figure Q4



Let the small lead balls in above figure each have a mass of 10.0g and let the light rod connecting them be 50.0cm long. The period of torsional oscillation of this system is found to be 769 s. Then two large fixed lead balls each of mass 10.0kg are placed near each suspended ball so as to produce the maximum torsion. The angular deflection of the suspended rod is then 3.96×10^{-3} rad and the distance between centres of the large and small balls is 10.0cm.
Calculate the universal constant of gravitation G from these data [12]

(c) Calculate the minimum velocity of an earth satellite in its orbit if its perigee and apogee altitudes above the earth are equal to the radius and three times the radius of the earth respectively. [5]

5. (a) Derive and explain the significance of the following equation in fluid mechanics:

$$p = p_0 + \rho g h$$ [10]

(b) (i) State the Bernoulli's Equation giving three conditions for its validity. [4]

(ii) Shop how the Bernoulli's equation is applied in determining the flow speed of a gas. [6]

6. (a) State the postulates of the special theory of relativity. Write the Lorentz transformation in the four coordinate system. [10]

(b) Write the formula used for the mass variation, time variation and length variation when the observer is moving relativistically. [10]

- END OF EXAM -