NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

MECHANICS - SPH 1101

EXAMINATION

BSc HONOURS PART I : DECEMBER 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	$G = 6.67 \times 10^{-11}\ Nm^{-2}kg^{-2}$
Speed of light in vacuo	$c = 3.0 \times 10^{8}\ ms^{-1}$
Radius of Earth	$R_E = 6.37 \times 10^{6}\ m$
Electron volt	$1\ eV = 1.60 \times 10^{-19}\ J$

SECTION A

1. (a) Define the basic concepts: inertia, rigid body, dynamic pressure, free-body diagram and streamline. [5]

(b) The displacement of a particle which is confined to move along a straight line is given by $s = t^3 - 9t + 2$ where s, the displacement is measured in meters from a convenient origin and t is time in seconds. Determine:

(i) the acceleration of the particle when v = 18 m/s. [3]

(ii) the net displacement and the total distance of the particle from t = 1s and t = 4s. [4]

(c) The angular velocity ω of a rotating disc, expressed in radians per second, varies during an interval of motion according to $\omega = 20\left(1 + \frac{2t}{3} - \frac{t^2}{3}\right)$. Calculate the number of revolutions N through which the disc revolves during the fourth second. Also find the angular acceleration α when t = 3s. [5]

(d) A simple pendulum of length 1 m makes 100 complete oscillations in 204 seconds at a certain location. What is the acceleration due to gravity at this point? [3]

(e) State Kepler's Laws of planetary motion and verify the second law of the areas. [6]

(f) Calculate the height of a satellite in a stationary orbit above the Earth, such that it appears to remain above the same place on the Earth's surface. [5]

(g) Give an example of each of the following types of force:
(i) a central force,
(ii) a contact force,
(iii) a non-conservative force,
(iv) an inertial force. [4]

(h) Explain why there is a need for *special theory of relativity*? Give a short example to illustrate *Galilean transformation*. [5]

SECTION B

2. (a) A ball having a radius of 5 cm and a density of 0.4×10^3 kgm^{-3} is dropped from a height of 5.1 m into a tank of fresh water. Ignore any dissipative effects, and calculate the depth to which the ball will sink. [5]

(b) Define the following terms:
(i) apparent weight in a fluid,
(ii) steady flow,
(iii) non-viscous flow,
(iv) turbulent flow,
(v) upthrust. [5]

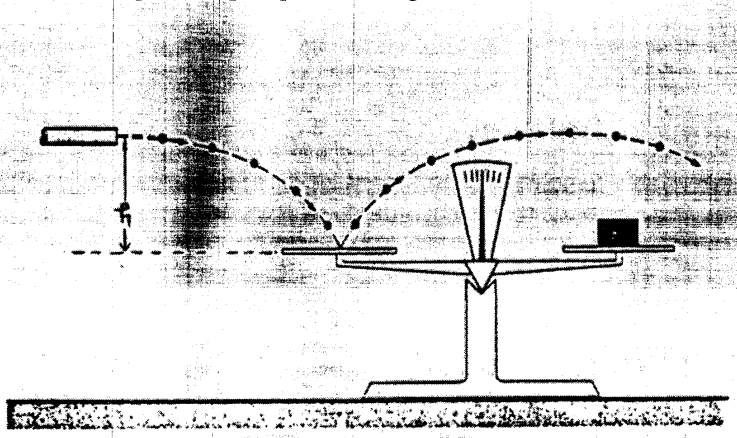
(c) State and prove Bernoulli's equation. [10]

3. (a) State the laws of energy and momentum conservation for a 1-dimensional elastic collision of two particles of mass m_1 and m_2. Prove that the velocities of the two particles after the collision are given by

$$v_1 = \frac{m_1 - m_2}{m_1 + m_2}u_1 + \frac{2m_2}{m_1 + m_2}u_2 \quad \textit{and} \quad v_2 = \frac{2m_1}{m_1 + m_2}u_1 + \frac{m_2 - m_1}{m_1 + m_2}u_2$$

where u_1 and u_2 are the initial velocities. [10]

(b) A stream of glass beads each of mass 0.5g is projected horizontally at the rate of 100 beads per second. The beads strike the pan of a beam balance, as shown in the diagram. What mass m must be placed on the other pan to keep the pointer reading zero?



[5]

(c) A neutron of mass m and energy E_1 collides with a carbon atom of mass 12m at rest. What is the kinetic energy of the neutron after the collision? [5]

4. (a) What are the requirements for a particle to perform simple harmonic motion (S. H. M.)? [3]

(b) A uniform rod of length L, suspended from one end is displaced from its equilibrium position through a small angle θ and allowed to oscillate freely about a horizontal axis.

(i) Show that the rod performs S. H. M. by deriving its equation of motion. [4]

(ii) If L = 1 m, find its period of oscillation. [3]

(iii) Show that such a physical pendulum can be used to determine the acceleration due to gravity, i.e. prove that $g = \frac{8\pi^2 L}{3T^2}$, where T is its period. [2]

[Moment of inertia of a uniform rod about one end is 1/3 ML^2]

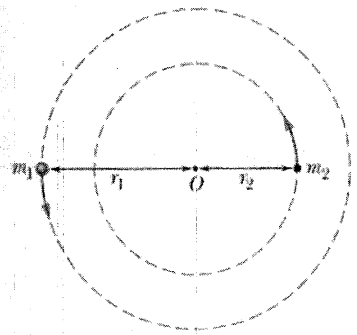
(c) (i) Explain briefly what is meant by the terms ˜ damped oscillations" and ˜ forced oscillations". [3]

(ii) A mass of 4 kg is attached to a spring of elastic constant 25 N/m and is moving on a horizontal surface after being displaced by 1.0 m and released from rest. Find how long it takes for the amplitude of the motion to become 0.1 m if the damping coefficient is 0.1 r_c, where r_c is the coefficient of critical damping. [5]

5. (a) Distinguish between ˜ conservative" and ˜ non-conservative" forces giving two examples of each. [5]

(b) Show that the gravitational potential energy of a two particle system is given by: $U = -\frac{GMm}{r}$, where G is the universal gravitational constant, M and m are the masses of the two interacting particles and r is the distance between the particles. [7]

(c) Observations of the light from a certain star indicate that it is part of a binary (two-star) system. This visible star has orbital speed v = 270 km/s, orbital period T = 1.70 days and approximate mass $m_1 = 6\ M_s$, where M_s is the Sun's mass, 1.99×10^{30} kg. Assuming that the visible star and its companion star, which is dark and unseen, are both in circular orbits as shown below, determine the approximate mass m_2 of the dark star. [8]



6. (a) Explain what is meant by *length contraction* . Apply the Lorentz transformation relations to deduce an expression for length contraction. [10]

(b) Calculate the relativistic mass of a proton when it is accelerated to a speed of 0.2c. [5]

(c) An electron is accelerated to a total energy of 1 MeV. How long will it take to pass through a tube of length 10 m? [5]

- END OF EXAMINATION -