NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1101 – MECHANICS

SUPPLEMENTARY EXAMINATION

BSC HONOURS PART I : JULY 2001 DURATION : 3 HOURS

ANSWER **ALL** PARTS OF QUESTION 1 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	$G = 6.67 \times 10^{-11}\ Nm^2\ kg^{-2}$
Atomic mass unit,	$1\ amu = 1.66 \times 10^{-27}\ kg$
Electron volt,	$1\ eV = 1.60 \times 10^{-19}\ J$
Speed of light in vacuo,	$c = 3.0 \times 10^8\ ms^{-1}$
Radius of the Earth,	$R_E = 6.37 \times 10^6\ m$
Mass of the sun,	$M_S = 1.99 \times 10^{30}\ kg$
Density of water,	$\rho_w = 1.0 \times 10^3\ kg\ m^{-3}$
Density of air,	$\rho_a = 1.2\ kg/m^3$

SECTION A

1. (a) Explain the concepts : kinematics, particle, free-body diagram and scalar product. [5]

(b) A particla is confined to move along a straight line and its displacement is given by $s = 2t^3 - 24t + 6$ where s, the displacement is measured in metres from a convenient origin and t is time in seconds. Determine :

(i) the acceleration for the particle when $v = 20$ m/s, [3]

(ii) the net displacement and the total distance of the particle from t = 1s and t = 3s. [4]

(c) The rotational velocity in revolutions per second of a radial line on a rotating gear is given by

$$\omega = -200 + 8t^2$$

where t is in seconds. Calculate the angle θ in radians through which the gear rotates

During the third second of its motion after $t = 0$.

[5]

(d) The x- and y-coordinates of a particle moving with plane curvilinear motion are given by $x = 2t^2 + 3t$ and $y = t^3/3 - 8$ where x and y are in metres and t is in seconds. Determine the magnitudes of the velocity v and acceleration **a** and the angles which the vectors make with the x-axis when $t = 3$ *s*. [7]

(e) A 60-kg man stands on a spring scale in an elevator. During the first 4 s of upward motion from rest, the tension T in the hoisting cable is 6000 N. Find the reading R of the scale during this interval and the upward velocity v of the elevator at the end of the 4 s. The total mass of the elevator, man and scale is 600 kg. [5]

(f) Express Kepler's second and third law of planetary motion mathematically and define the symbols used. [4]

(g) Define undamped and damped vibrations. [2]

(h) The end of a chain of length l and mass p per unit length which is piled on a platform is lifted vertically with a constant velocity v by a variable force P. Find P as a function of the height x of the end above the platform. [5]

SECTION B

2. (a) A missile is launched at point and follows a trajectory in a vertical plane. A tracking device stationed at O records the coordinates r and θ as functions of time, and it is found that the functions may be approximated closely by the relations

$$r = 3t - t^2/20 \text{ and}$$

$$\theta^2 = 1600 - t^2$$

where r is in kilometres, θ is in degrees, and t is in seconds. Compute the velocity and acceleration at the instant when $t = 30$ *s*. [10]

(b) Two ships A and B are at the positions shown in Figure 1. Ship A is moving at the speed of 36 km/h in a circular arc of 3 km radius. The speed of Ship B is 18 km/h in the direction shown, but is reducing speed at the rate of 4 km/min to avoid risk of collision with A.

(i) Determine the velocity which A appears to have from an observation position attached to B, and determine the values of $\dot{r}$ and $\dot{\theta}$ as seen from B. [5]

(ii) Determine the acceleration which A appears to have with respect to B. [5]

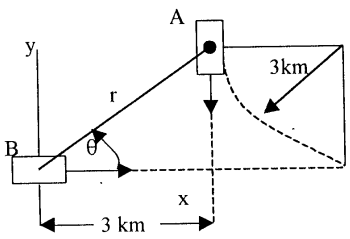

Fig. 1

3. (a) (i) Define kinetic energy T and express work-energy equation in terms of T. [3]

(ii) The 30-kg slider inclined at an angle of 60^0 is released from the higher position of 0.9 m from the spring along the same inclined plane of the slider. The slider travels with a velocity $v_o = 0.6$ m/s on the inclined rail and slides under the influence of gravity and friction. The coefficient of friction between the slider and the rail is 0.5. Calculate the velocity of the slider as it passes the position for which the spring is compressed a distance $x = 100$ *mm*. The spring offers a compressive resistance C and is known as hardening spring. The stiffness of the spring measured in newton and is given by the relation:

$$C = 0.06x^2$$

[6]

(b) (i) State the principle of conservation of linear momentum and angular momentum. [3]

(ii) A spherical particle A has a velocity $v_A = 5$ m/s in the vertical direction and collides with spherical particle B of equal mass and diameter, initially at rest. The geometry of the spheres indicates that the normal n to the enacting surfaces makes an angle of 30° with direction of v_A. If the coefficient of restitution for these conditions is 0.6, determine the resulting motion of each particle following the impact. [8]

(a) For a certain satellite with a perigee altitude of 389 km the ratio of its maximum to its minimum orbital velocity is 1.5. Compute the apogee altitude. [5]

(b) Derive the mass moment of inertia and radius of gyration of a homogeneous solid sphere. [7]

(c) The compound pendulum has a mass of 10.0 kg with centre of mass at G, 200 mm from the pivot O, has a radius of gyration about the pivot of 400 mm. If the pendulum is released from the horizontal position at rest at $\theta = 0°$, determine the total force supported by the bearing at the instant when $\theta = 45°$. Friction in the bearing is negligible. [8]

5. (a) (i) Explain simple harmonic motion for a vibrating system by drawing graphs of displacement x, velocity v and acceleration of a body as a function of time t. [6]

(ii) Find the velocity, frequency and wavelength of a propagating wave given that $x = 0.2 \sin 4t$, the tension of the string is 4 N and the mass density is 10^{-2} kg/m. [6]

(iii) Show three cases of viscous damping by graphical means. [4]

(b) Calculate the work done in deforming an aluminium rod elastically. The original dimensions are : 10 mm diameter, 250 mm length, yield stress 75 N/mm^2, 670 kN/mm^2 Young's Modulus. Find the final length. [4]

6. (a) (i) What is a non-conservative force? Give an example. [2]

(ii) A block of mass m = 4 kg slides down a surface inclined at angle 40° to the horizontal (Fig. 3). The coefficient of sliding friction is 0.25. A string attached to the block is wrapped around a flywheel on a fixed axis O. The flywheel has a mass of M = 20 kg, and outer radius R = 0.2 m, and the radius of gyration with respect to the axis $k_o = 0.1$ m. Find the acceleration of the block down the plane and the tension in the string. [8]

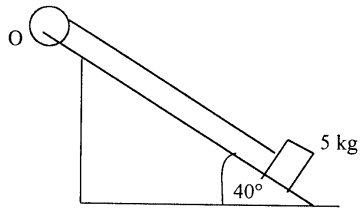

Fig. 3

(b) (i) Define viscosity and express it mathematically. [4]

(ii) Write down flow continuity equation and explain the symbols. [2]

(iii) Find the tangential stress between two adjoining layers of a fluid if they travel a distance of 1.0 m in 5 seconds given the viscosity of that fluid being 10^{-3} Pa s. [4]

END OF PAPER