NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1101 – MECHANICS

BSC HONOURS PART 1: JULY 2002 DURATION : 3 HOURS

ANSWER **ALL** PARTS OF QUESTION 1 IN SECTION A AND ANY **THREE** QUWSTIONS 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: inertial frames, dot product, torque, rigid body, angular momentum. [5]

(b) State Newton's three laws of motion and also express Newton's second law in terms of momentum. [5]

(c) A rocket of mass 15000 kg, is fired for 20 seconds and during this period, ejects gases at a rate of 180 kgs^{-1} with a speed of 300 ms^{-1} relative to the rocket. Define the term thrust and find its value during the burn. [5]

(d) State the "Work – Kinetic Energy" principle. 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. [5]

(e) A bird of mass 120g is cruising in a westerly direction at a speed of 10ms^{-1}, when a bullet of mass 10g and velocity 200 ms^{-1} also moving in a westerly direction hits it. Estimate the velocity of the bird after impact. [5]

(f) Calculate the height of a geostationary satellite over the equator of the earth using the values of the constants given above. [5]

(g) Give qualitative definitions of each of the following terms used in fluid dynamics:

- (i) Streamline
- (ii) Pathline
- (iii) Streakline
- (iv) Static pressure
- (v) Dynamic pressure [5]

(h) Under what conditions does the Bernoulli equation apply and from what theorem is it derived? [5]

SECTION B

2. (a) In discus throwing, does it matter how high you throw? What factors determine the distance of the throw? [4]

(b) Show that the trajectory of a projectile is parabolic by determining the trajectory equation in the form, $y = a + bx + cx^2$, where *a*, *b* and *c* are constants. [5]

(c) From the trajectory equation, show that the range of the projectile is given by $R = \frac{V_o^2}{g} Sin 2\theta_o$. For the above mentioned trajectory, what is the maximum range in terms of the initial velocity, V_o, and acceleration due to gravity, *g*? [5]

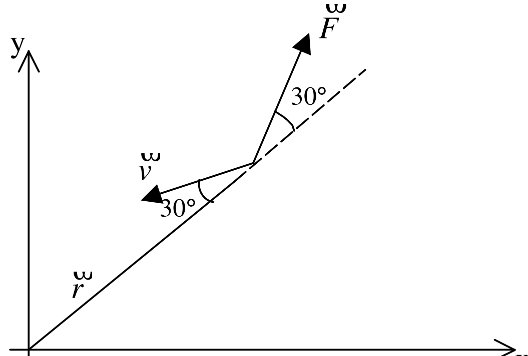
(d) An aeroplane is flying at a constant horizontal velocity of 500 km/h at an elevation of 1.0km toward a point directly above a person struggling in the water. A survival package is released and strikes very close to the person in the water.

- (i) For how long was the package in the air? [3]
- (ii) At what angle of sight was the package released? [3]

3. (a) (i) Given that $\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$ and $\vec{F} = F_x\vec{i} + F_y\vec{j} + F_z\vec{k}$, find the torque, τ. [3]

(ii) Show that if $\vec{r}$ and $\vec{F}$ lie in a given plane, then τ has no component in that plane. [2]

(iii) A particle ***P*** of mass 2.0 kg has position $\vec{r}$ and velocity $\vec{V}$ as in the figure below.



It is acted on by the force $\overset{\omega}{F}$. All three vectors lie in a common plane. Presume that, r = 3.0 m, v = 4.0 ms^{-1} and F = 2.0 N. Compute **(a)** the angular momentum of the particle and **(b)** the torque acting on the particle. What are the directions of these two vectors? [6]

(b) A uniform disk of radius R and mass M is mounted on an axle supported in a fixed frictionless bearing. A light cord is wrapped around the rim of the wheel and a steady downward pull T is exerted on the cord. Given that the mass of the disk is M = 2.5 kg, radius R = 20 cm and force T = 50 cm, find:

(i) the angular acceleration of the wheel and [5]
(ii) the tangential acceleration of a point on the rim. [4]

4. (a) Define the terms, static and dynamic equilibrium, centre of gravity and centre of mass. Under what conditions can a rid body be in equilibrium? [6]

(b) Show how one can determine the centre of gravity of an irregularly shaped plate. [6]

(c) (i) A 20 m ladder weighing 50 kg rests against a wall at a point 16 m above the ground. The centre of gravity of the ladder is one third of the way up the ladder. An 80 kg man climbs half way up the ladder. Assuming that the wall (but not the ground) is frictionless, find the forces exerted by the system on the ground and on the wall. [4]

(ii) If the coefficient of static friction between the ground and the ladder is μ_s = 0.40, how high up the ladder can the man go before it starts to slip? [4]

5. (a) Give two examples of motions that are approximately "simple harmonic". Why are motions that are exactly simple harmonic rare? [4]

(b) An object of mass *m* is supported by a vertical spring of force constant 1800Nm^{-1}. When pulled down 2.5 cm and released, it oscillates at 5.5 HZ.

(i) Calculate the mass and the equilibrium stretching of the spring. [3]

(ii) Write down expressions for the displacement *x*, the velocity *v*, and the acceleration, *a*, of the object. [5]

(iii) Draw a vector diagram to show the phase relationship between the quantities in (ii) above. [3]

(c) Suppose the spring above has a damping constant, b = 0.0070 kg^{-1}. What is the amplitude of the damped oscillations after 20 full cycles have elapsed? [5]

6. (a) State Pascal's principle for pressure variations in a fluid at rest and give brief comments on one practical application of this principle. [5]

(b) A horizontal pipe has a cross section of $0.1m^2$ in one region and $0.05m^2$ in another. The velocity of water in the first region is $5\ ms^{-1}$, and the pressure in the second is $2 \times 105\ Nm^{-2}$. Find:

(i) the velocity of water in the second region and the pressure of water in the first region [4]

(ii) the amount of water crossing per minute. [5]

(c) Raindrops are falling to the ground in the form of nearly perfect spheres of average radius r. Show that their terminal velocity v_t is given by:

$$v_t = \frac{2(\rho - \rho_f)r^2 g}{9\eta}$$

where ρ and ρ_f are the density of water and of the fluid (air) respectively, and η is the coefficient of viscosity of air. [6]

- END OF EXAM -