INSTITUTION OF ENGINEERS, SRI LANKA
PART I EXAMINATION – MARCH 2009

106 – APPLIED MECHANICS

Time allowed: Three Hours **Date:** March 2009

Before answering the question paper, read and adhere to the instructions given below,

This question paper has **two sections**, **SECETION A** and **SECTION B**. Answer only **FIVE (05)** questions selecting not more than **THREE (03)** questions from each section.

- All questions carry equal marks.
- Start answering each question from a new page. Write the relevant question No. on the starting page of the question.
- **It is extremely important that you write the question No. to which you answer appropriately in the cage appearing on the cover page**
- Pay special attention to **Units**. You should answer in SI Units only.
- Strike out any rough work and contents that you do not wish to draw the attention of the examiner.
- Wherever relevant, use free hand sketches to explain your answer.
- **Use density of water as 1,000 kg/m^3 and acceleration due to gravity as 10 m/s^2, unless otherwise specified.**
- **Marks will be deducted if the above instructions are not adhered to.**

SECTION A

Question 1

(a) A geared system shown in the Figure Q1 consists of driver gear X and Driven Gear Y. The gear ratio is G. The respective moments of inertia are I_x and I_y and the angular acceleration α_x and α_y respectively. Establish that the torque on gear X to accelerate both gears X and Y is given by

$$T_X = \alpha_X \left[I_X + G^2 I_Y\right]$$

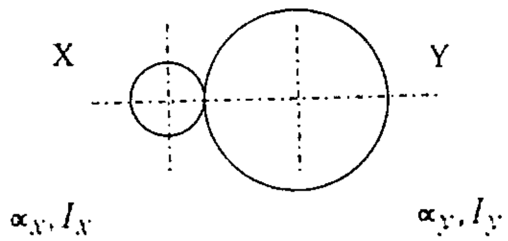

Figure Q1

(b) An electric motor drives a machine through a speed reducing gear of ratio 9:1. The motor armature with its shaft and the drive gear on it has a moment of inertia 0.5 kg-m^2. The rotating parts of the machine together with the driven gear have a moment of inertia 38 kg-m^2. The machine has a constant torque. The efficiency of the reduction gear drive is 95%.

(i) What power must the motor develop to drive the machine at a uniform speed of 160 rpm?

(ii) The torque developed on the motor armature, in starting from rest, is 27 Nm. What time will be required for the speed of the machine to increase from zero to 60 rpm?

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Question 2

(a) Explain the following Principles:

(i) Conservation of Energy

(j) Conservation of linear Momentum

(b) A tail-board of a truck weighing 300 N is 1.5 m long and 0.75 high. It is hinged along the bottom edge to the floor of the truck. Chains are attached to the top corner of the tail-board and to the sides of the truck frame, so that when the board is in horizontal position the chains are parallel and inclined at 45-deg to the horizontal. A tension spring, each having a stiffness of 62 kN/m, is inserted in each chain so as to reduce the shock and these are adjusted to prevent the board from dropping below the horizontal. This arrangement is briefly shown in Figure Q2.

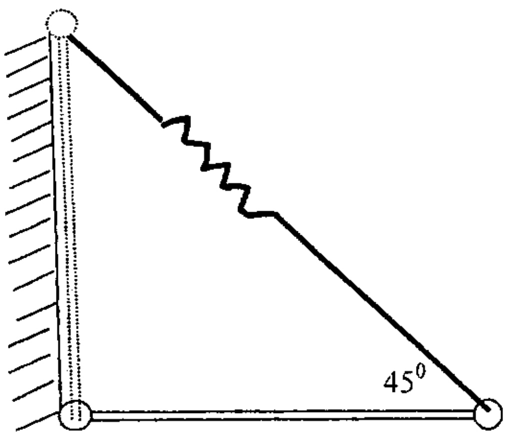

Figure Q2

Find the force in each spring and the resultant force at the hinges when the board falls freely from the vertical position and comes to rest at horizontal position. Assume the tail-board is a uniform body.

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Question 3

(a) What are advantages and disadvantages of friction clutches?

(b) Establish any formulae that can be used to determine the torques and power for a cone clutch.

(c) A cone clutch with a cone semi-angle 12^0 is to transmit 12 kW at 750 rm. The width of the face is to be one-fifth of the mean diameter and the normal pressure between the contact faces is not to exceed 70 kN/m^2. If the friction coefficient between two contact surfaces is 0.2, determine the main dimensions of the clutch and the axial force required to transmit the above power.

Question 4

(a) Explain clearly the following terms with particular reference to a flywheel fitted to power transmission system.

(i) Maximum fluctuation of energy

(ii) Maximum fluctuation of speed

(iii) Coefficient of fluctuation of energy

(b) A two-stroke internal combustion engine, which produces a torque of (900 + 200 Sin 3θ) Nm, where θ is the crank angle, drives a machine. A flywheel is coupled to the crankshaft of the engine and the rotating parts (of the engine side) have a mass of 400 kg and a radius of gyration 250 mm. The mean speed is 500 rpm.

i. Sketch the engine torque curve for two cycles.

ii. Find the mean torque.

iii. Calculate the fluctuation of energy if the resisting torque of the machine is constant

iv. Calculate the fluctuation of energy if the resisting torqu[e] machine is (900 + 100 Sin θ) Nm.

Question 5

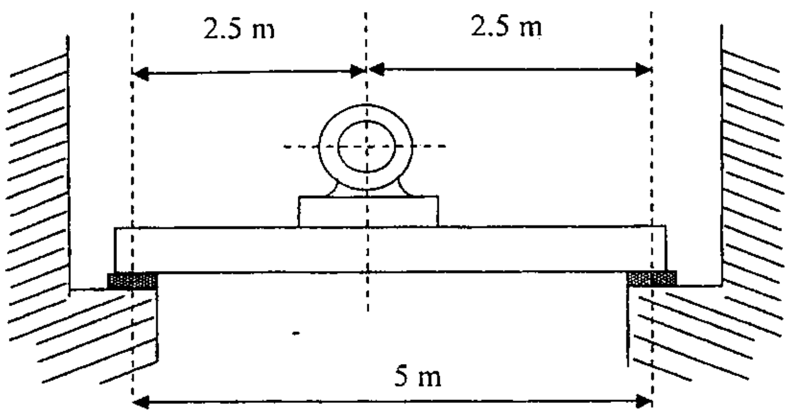
(a) Distinguish longitudinal, transverse and torsional vibration. Give an example to demonstrate each type.

(b) The diagramme in Figure Q5 shows a machine of total mass 550 kg bolted to the supporting floor at the centre. The floor consists of two parallel I-section beam each having a modulus of Elasticity (E) of 210×10^9 N/m^2, a second moment of area (I) of 0.35×10^{-4} m^4 and a mass of 25 kg/m. Each beam has a length of 5 m and is supported at each end on a thin expansion pad whose vertical stiffness is 4×10^6 N/m (each pad).

(i) Model the given system into a spring mass system.

(ii) Calculate the natural frequency of the system, assuming the machine to be a point load.

(iii)If the machine operates at a 960 rpm and has an unbalance of 0.05 kg m, calculated the force transmitted to the supporting walls. Damping is small enough to be negligible.



(Not to a scale)

Figure Q5

It is given that the deflection at the centre of the beam under a load W, $\Delta_c = \dfrac{WL^3}{48EI}$

SECTION B

Question 6

(a) State the Newton's Law of Fluid Friction.

(b) Two coaxial cylinders, inner cylinder with external diameter 0.50 m and the outer cylinder with inner diameter 0.60 m, are each 2 m long. The inner cylinder is free to rotate, while outer one is fixed. Olive oil of dynamic viscosity 0.5×10^{-2} Ns/m^2 fills the space between the cylinders. A torque of 5 N-m is applied to the inner cylinder causing it to rotate. After constant velocity is attained, calculate the following:

(i) The velocity gradient at each cylinder walls, where the oil touches.

(ii) The resulting rpm of the inner cylinder.

(iii) The power dissipated by the fluid resistance.

Ignore end effects.

Question 7

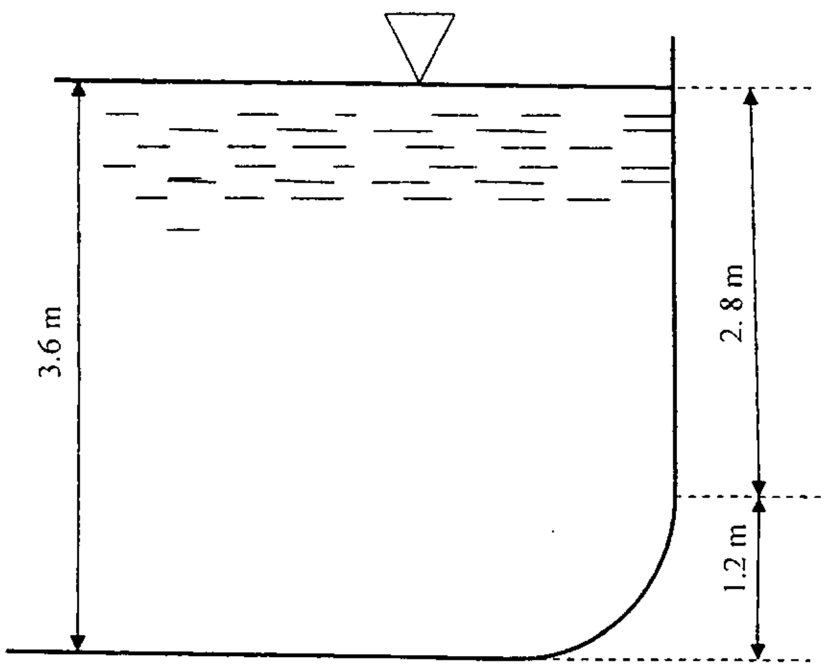


Figure Q7

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Tank shown in Figure Q7 has its bottom side surface curved as one-quarter circle having a radius of 1.2 m. It has a length (distance perpendicular to the paper) of 1.8 m. When the tank is filled with water up to a height of 3.6 m, find the horizontal and vertical components of the resulting force acting on the curved surface and their locations.

Question 8

(a) Define stream function.

(b) Write mathematical expressions when stream function satisfies two dimensional steady flow of a fluid.

(c) What is an equipotential line?

(d) A two dimensional dipole source at the origin of x-y plane produces steady incompressible flow with its stream function being

$$\psi = \frac{y}{x^2 + y^2}$$

(i) Sketch the streamlines and explain the geometry of the lines.

(ii) Find the direction of motion of a fluid particle at the point x=6 and y=9

Question 9

(a) Discuss the mechanism of each Laminar Flow and Turbulent Flow.

(b) "Most of the pipes used in engineering practice such as cement pipes, cast iron pipes, etc. cannot be regarded as hydraulically smooth." Discuss the significance of 'hydraulically roughness' in fluid flow through pipes.

(c) The pipe network shown in the Figure Q9 consists of 1,000 m of 50 mm cast iron pipe, two 45-deg and four 90-deg flanged long radius elbows, a fully flanged globe valve and a sharp exit into a reservoir. Loss coefficient for a 45-deg elbow, a 90-deg elbow, globe valve, and exit is 0.2, 0.3, 8.5 and 1 respectively. Friction factor (f) for pipe is 0.0315 (not Darcy-Coefficient of Friction).

What gauge pressure is required at point 1 to deliver 5 litres/sec[...] water at into the reservoir, whose free surface lies 100 m above the poin[...]

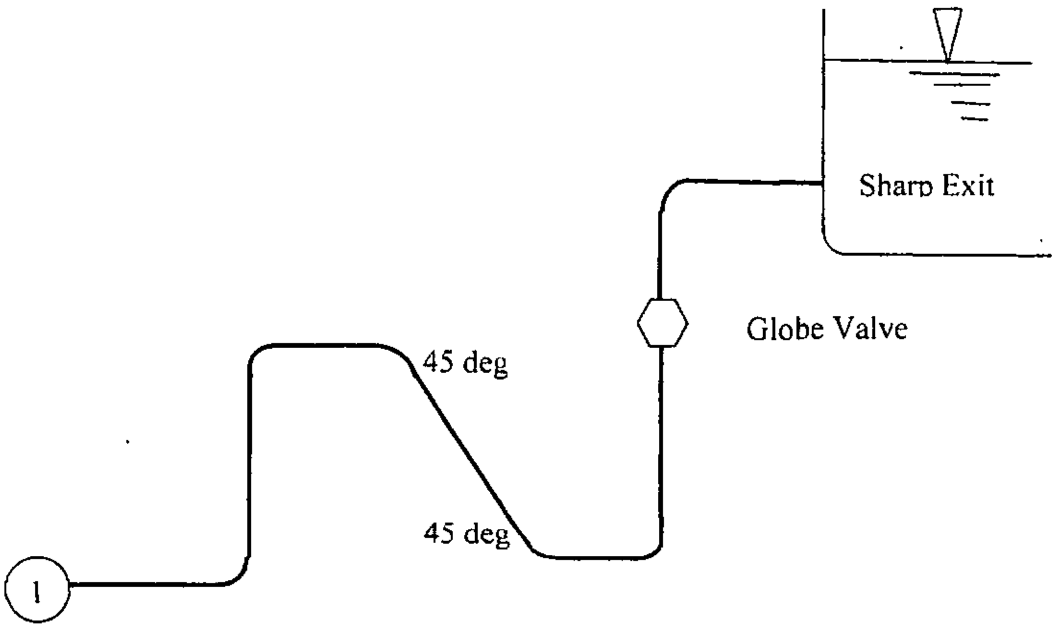

Figure Q9

Question 10

(a) Explain an experimental method, which you are familiar with, to determine the metacentric height of the vessel available in a Fluid Mechanics laboratory.

(b) Explain the meaning of Centre of Buoyancy and Metacentric Height. What is the significance of these two points on stability of floating bodies?

(c) A barge with a flat bottom and rectangular closed ends has a draft of 1.8 m when fully loaded and floating upright position as shown Figure Q10. The centre of gravity of the barge when fully loaded is on the axis symmetry and 300 mm above the water surface. The length of the barge is 12.6 m, breadth 7.5 m and depth 3.0 m.

Is the barge stable? If it is stable, what is the righting moment when the angle of heel is 12^0.

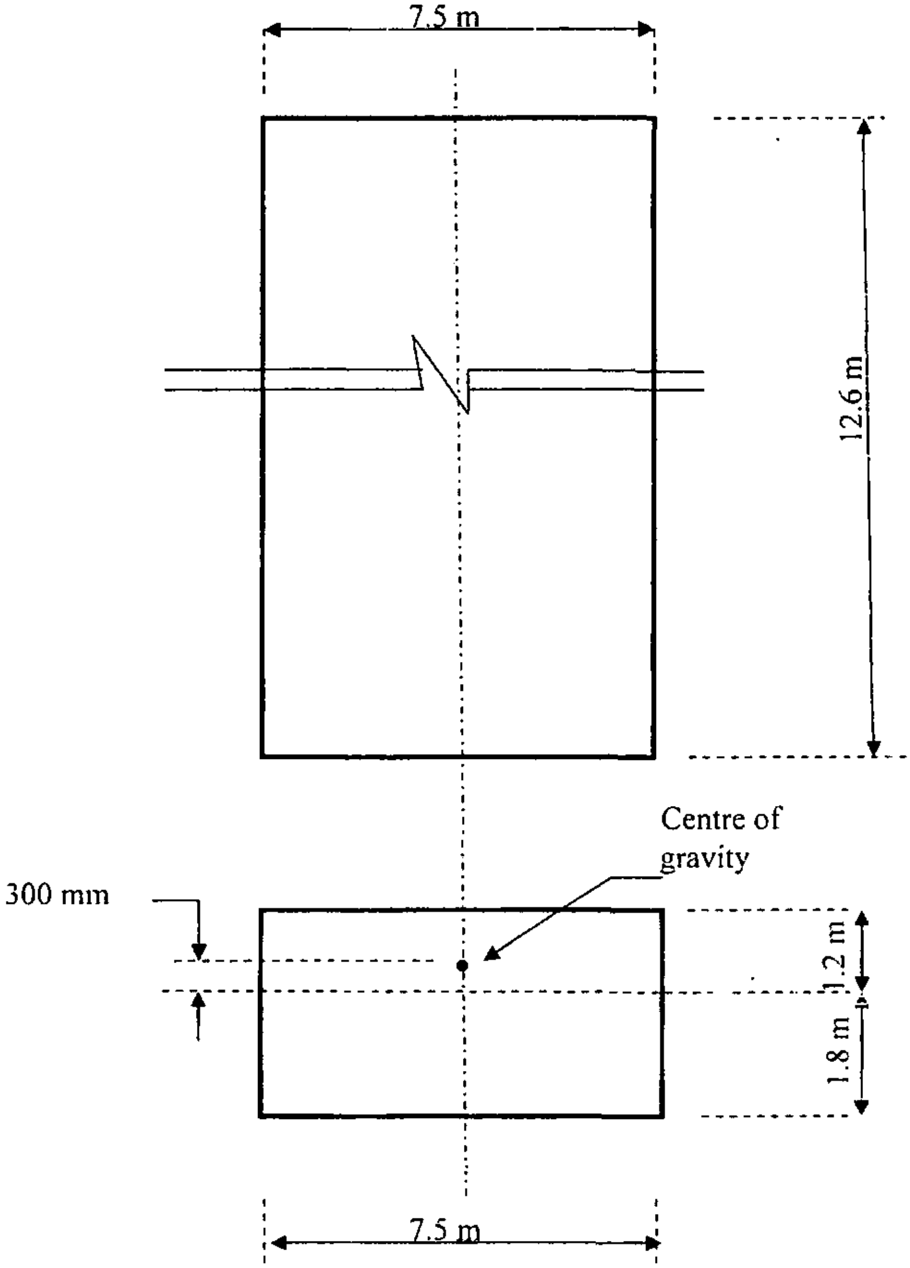

Figure Q10