INSTITUTION OF ENGINEERS, SRI L

PART I EXAMINATION – AUGUST 2007

106 - APPLIED MECHANICS

Time Allowed: Three Hours **Date: 06 August 2007**

***Read** and **follow** the instructions given below, before answering the question paper*

This question paper has two sections, **SECTION A** and **SECTION B**. Answer only six (06) questions selecting maximum (03) questions from each section.

All questions carry equal marks.

Start answering each question from a fresh page.

Strike out any rough work and contents that you do not wish to draw the attention of the examiner.

Pay special attention to the Units. You should answer in SI Units.

Write the question No. appropriately in the cage appearing on the cover page.

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.

(30)

SECTION A

Question 1

In the mechanism shown in Figure Q1 (drawn not to a scale), the crank OA rotates at a uniform angular velocity of 210 rev/minute clockwise. The slider attached to the end B of link AB moves horizontally. The link CE is **pivoted** at D so that it only rotates about pivotal point, while the slider at D moves vertically. Slider attached to the end F of the link EF too moves horizontally.

OA = 200 mm	AB = 800 mm
BC = 300 mm	CE = 700 mm
CD = 550 mm	EF = 850 mm
OX = 350 mm	Vertical heights between the two horizontal paths = 500 mm

Draw the mechanism for the given configuration shown in the figure taking the scale as 10:1. Hence draw the velocity diagramme and acceleration diagramme and determine the velocity and acceleration of the sliders connected at B, D and F.

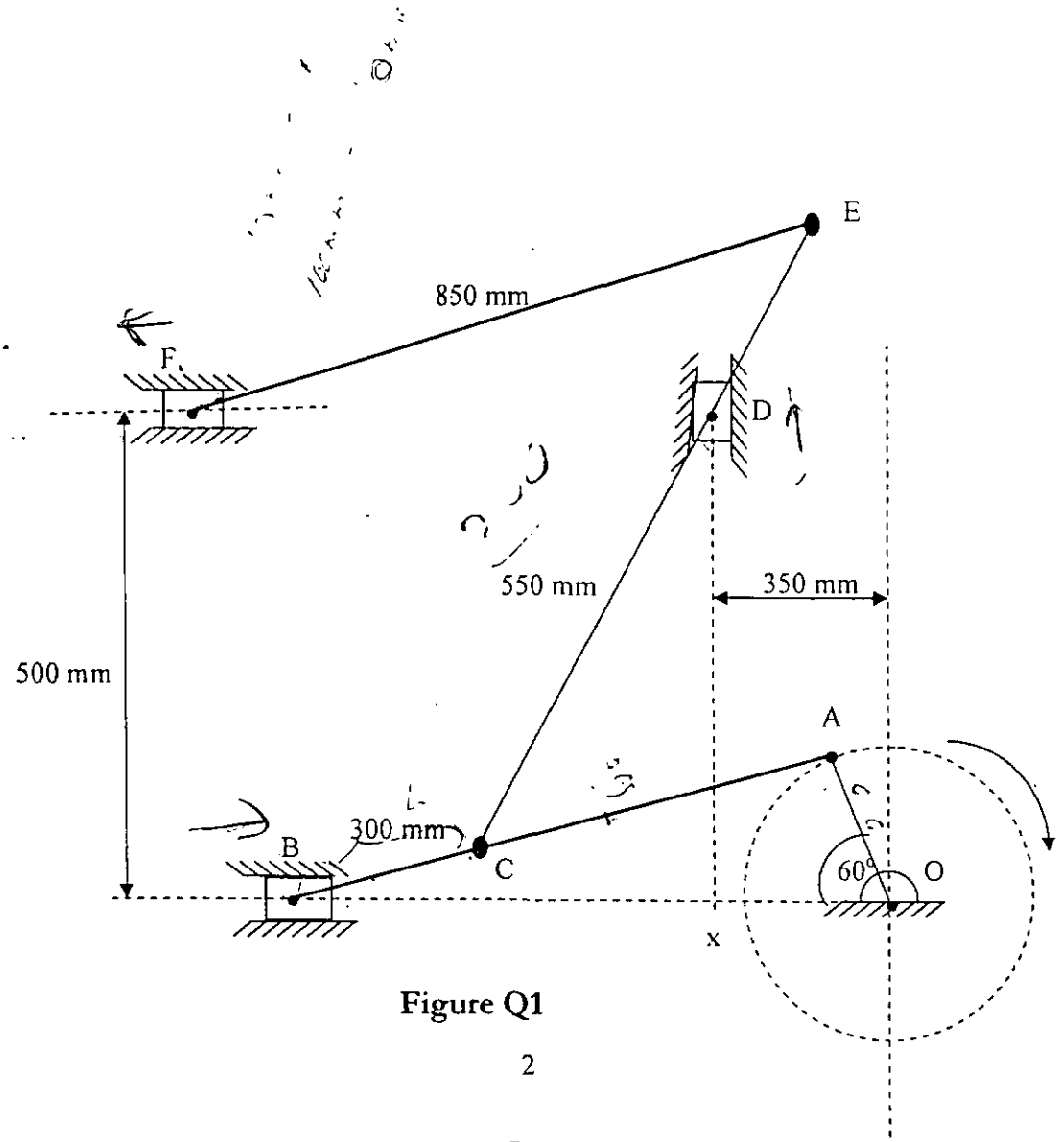


Figure Q1

Question 2

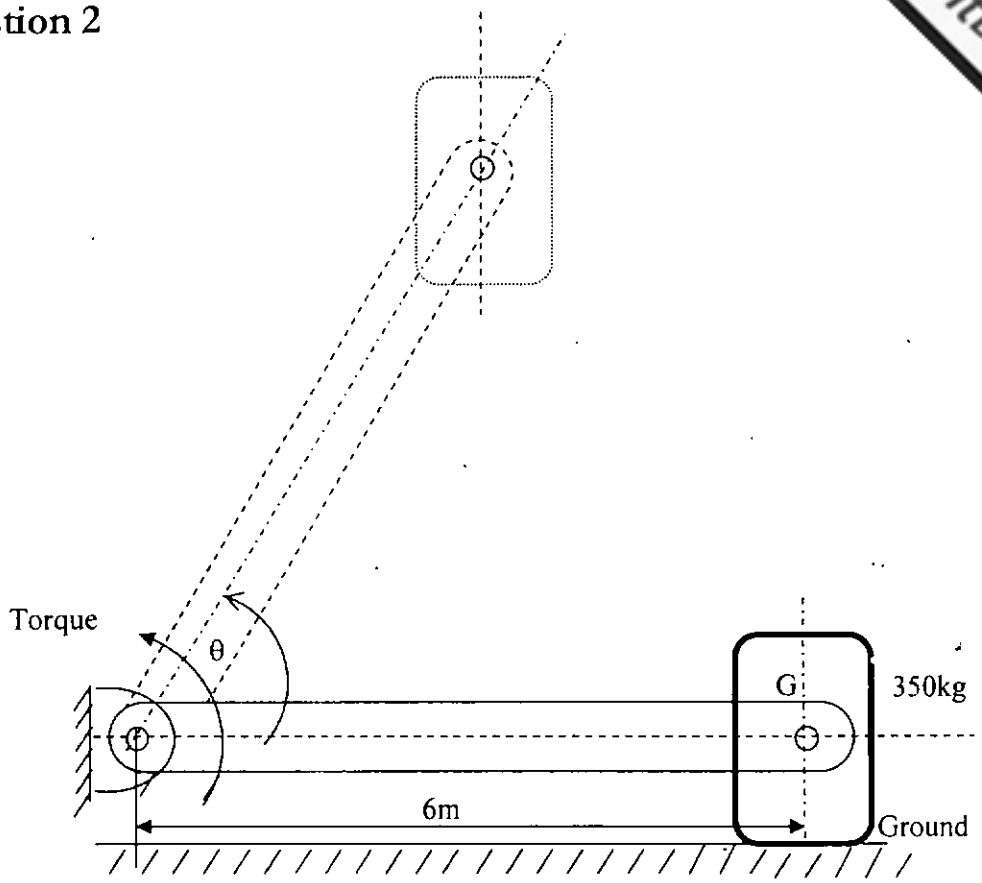


Figure Q2

(a) Define Energy and Work. How would you relate work and energy?

(b) What are the different types of mechanical energies which are important in kinetics of motion and elastic deformation of bodies?

(c) A simple elevator shown in Figure Q2 is an assembly of a uniform beam pivoted at one end and a container attached to the other end. This mechanism is used to deliver building material from the ground to a place at a higher elevation applying a torque at the pivoted end. The bucket is loaded when the beam is horizontal. The beam, which is 6 m long, has a mass of 220 kg and the container when loaded, can be considered as a concentrated mass of 350 kg at G which coincides with the point of intersection of the axis of the beam and that of the container. A constant torque of 28 kNm is applied at the pivotal end to raise the assembly.

i) Show **clearly** that when the beam is elevated at angle θ the horizontal, the angular acceleration of it can be expresse $(1.837 - 1.777 \text{ Cos } \theta)$ rad/s^2.(*Take* $g = 9.81\ m/s^2$)

ii) At what angle θ should the torque be removed in order that the beam comes to rest when it is exactly vertical?

iii) Assuming the torque to be removed as prescribed in (b), determine the maximum angular velocity and angular acceleration of the beam.

Question 3

a) Explain the following terms.

Impulse
Moment of Momentum
Angular Momentum

b) State the Newton's Second Law of Motion that applies to a rotating body and obtains a mathematical relationship for impulse.

c)

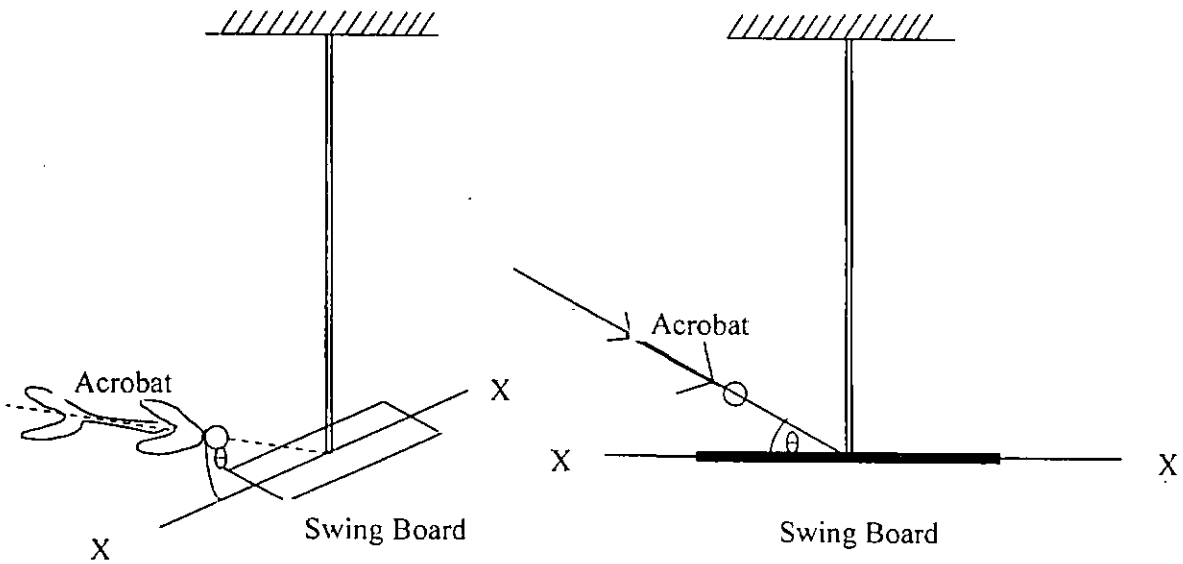


Figure Q3

A swing board of mass $5m$ kg in a circus hall hangs from [illegible]y an inextensible rope of length L m. An acrobat of mass m kg [illegible] at an angle θ to the horizontal lands on the swing board caus[illegible] impact and thereafter he is being held on to the board. Disregard t[illegible] mass of the rope and derive an expression for the impulse in the rope at the instant of impact.

If after the impact the acrobat together with the swing board is observed to swing through an angle 90^0, determine the velocity of the acrobat immediately prior to landing on the board.

Question 4

a) A single cylinder four stroke engine with a flywheel fitted on to the crankshaft drives a paddy mill. What difference would you observe if the mill is run without the flywheel being fitted?

b) On what parameters of an engine does the size of the flywheel depend?

c) In a turning moment diagramme, the areas above and below the mean torque line taken in the given order is 4400, 1150, 1300 and 4550 mm^2 respectively. The scales of the turning moment diagramme are:

Turning moment; 1mm = 100 Nm
Crank angle; 1^0 = 1 mm

Find the mass of the flywheel required to maintain the speed between 297 and 303 rev/minute if the radius of the gyration of the flywheel is 0.525 m.

Question 5

(a) In what aspect does undamped forced vibration differ from free or natural vibration? Comment on the frequencies in each case.

(b) A system previously undamped is now damped. What differences would you notice in the system?

(c) A bar of non-uniform section is pivoted at its narro
shown in the Figure Q5 and supported by two springs
stiffness 650 Nm^{-1} at a point 0.75 m away from the pivot. The
springs can be connected in two different configurations as show
in the figures (i) and (ii).

The bar in figure (i) is given a small initial angular displacement about the pivotal axis and released. If this is observed to vibrate with a period of 0.87 s, calculate the moment of inertial of the bar with respect to the transverse axis through the pivot.

Calculate what the period of oscillation would be if both springs were on the same side of the bar shown in figure (ii). *Assume that the springs are deformed axially but not sideways, the spring axes remain perpendicular to the axis of the bar and the amount of extension or compression of the springs is approximately the arc of the circular sector along which the end of the spring moves.*

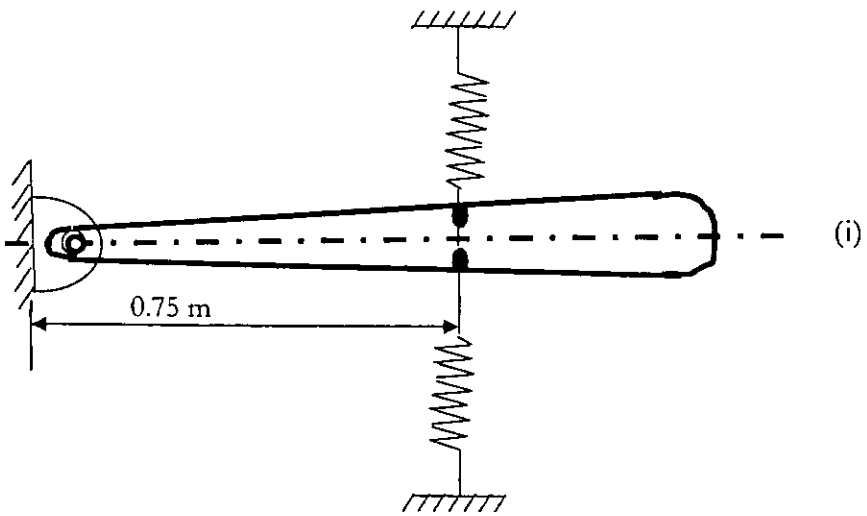
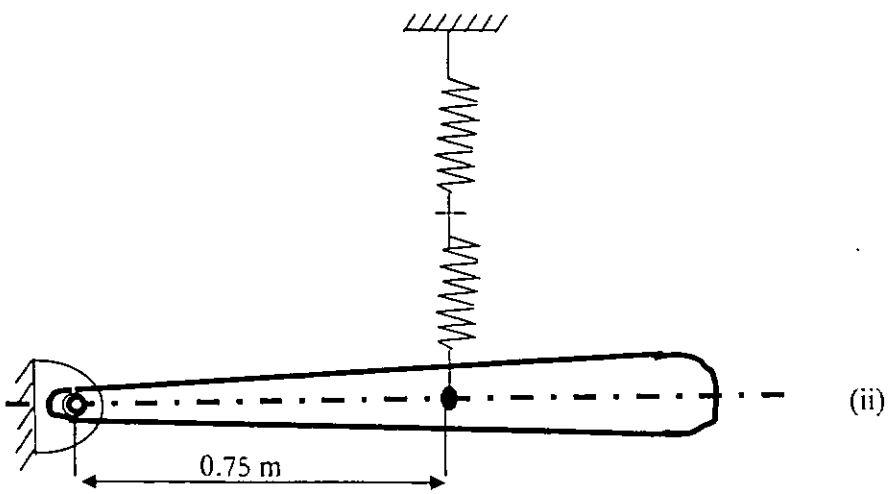


Figure Q5



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SECTION II

Question 6

A ship floats in the sea water and Figure Q6 shows a cross section of this ship at the water line.

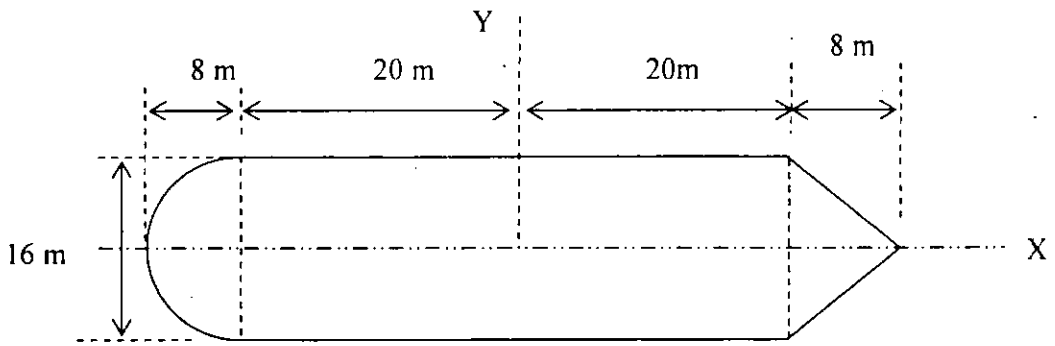

Figure Q6

a) What is the condition to be satisfied if the ship is in vertical equilibrium?

b) The ship is given a disturbance about O-X and if it is expected to restore its stable equilibrium position, what are the conditions to be satisfied?

c) The ship weighs 5,000 metric tones and its cross section at the water line has the dimensions given in the figure. It has been found that the centre of buoyancy is 1.5 m below and centre of gravity is 0.6 m above the free surface.

Using the given dimensions of the ship's cross section at the water line, compute all possible metacentirc heights.

Discuss the stability of the ship in each case.

Question 7

a) Considering the control volume ABCD shown in the Figure Q derive an expression for the rate of change of momentum in the fluid stream. Assume there is no storage of fluid within the control volume.

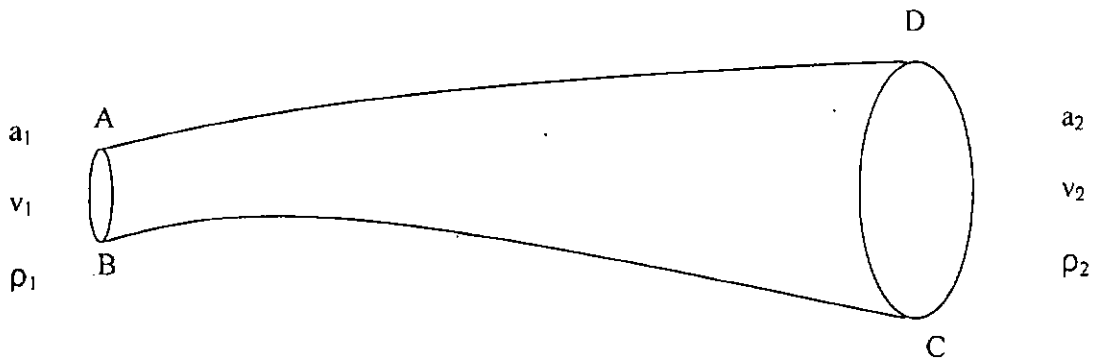

Figure Q7 (a)

b) What useful results would be obtained if the expression in (a) is considered with Newton's second and third laws.

c) The tank shown in Figure Q7(b) is kept filled by water to maintain its level of 1.5 m above the centre of orifice, while the water is being released through the orifice at 5 ms^{-1}. The orifice has 50 mm diameter.

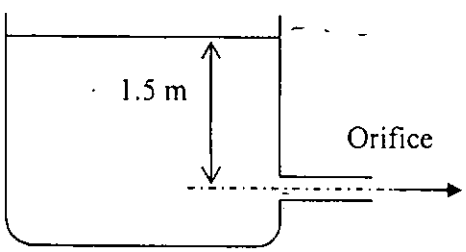

Figure Q7(b)

Calculate the reaction of the jet relative to the tank and its contents when;

i) the tank is stationery.

ii) the tank is moving with a velocity of 1.5 ms^{-1} in [illegible]osite direction to the jet, while the velocity of the jet [illegible] the tank remains unchanged.

What would be the work done per second in (ii) above?

Question 8

a) What are the different forms of mechanical energy of a flowing fluid?

b) State the Bernoulli's equation for a fluid flowing between two given points if no energy has been supplied to or taken from the fluid between the two points.

c) In between the given two points the fluid losses H units of energy and does W units of work, and the fluid is supplied with Q units of energy by a pump. Restate the Bernoulli's equation. Assume that all three quantities are measured per unit weight of fluid.

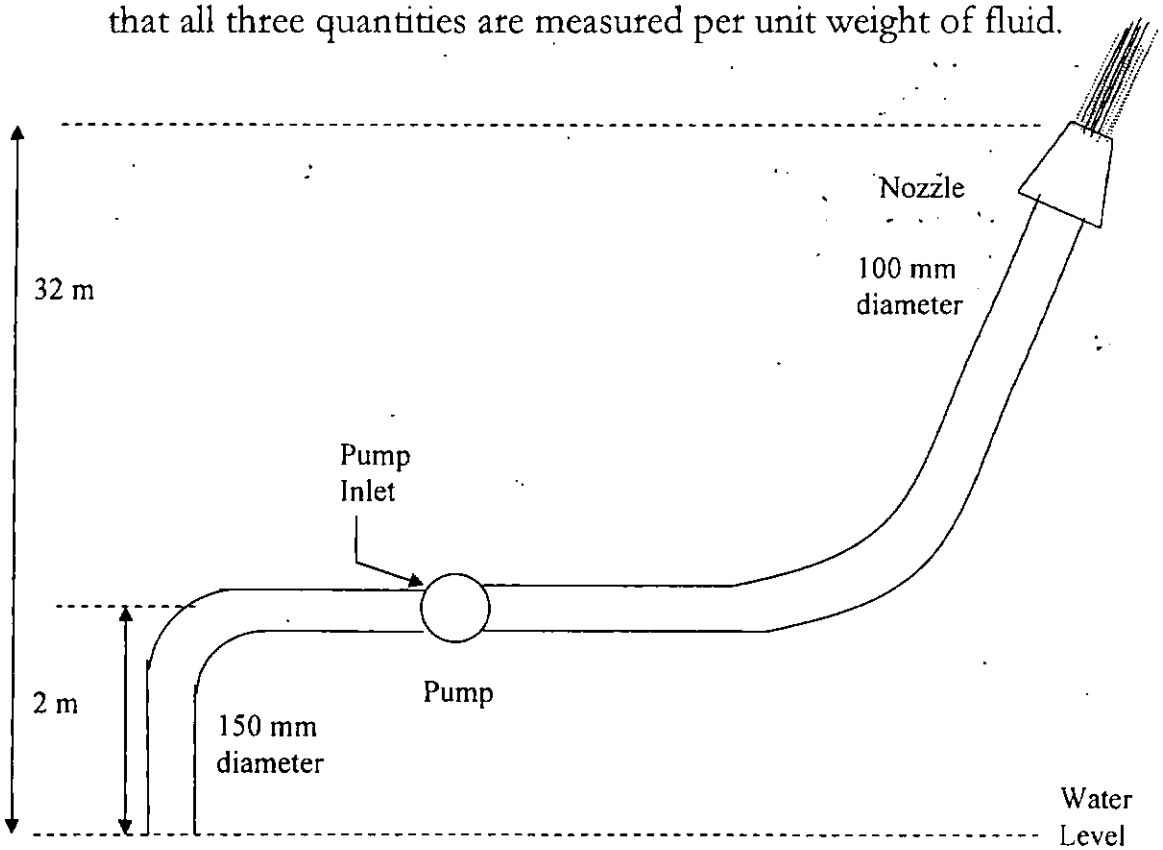

Figure Q8

d) A pump draws water from a sump and discharges ... atmosphere through a nozzle. This arrangement is sho... Figure Q8. The pump develops a head of 50 m. The suction p... of the pipe has 150 mm diameter and the delivery part of the pipe... 100 mm. The nozzle at the end of the delivery point has 75 mm diameter. The energy lost due to friction is $(5u_1^2/2g)$ m for the suction pipe and $(12u_2^2/2g)$ m for delivery pipe, where u_1 and u_2 are velocities of fluid in suction and delivery pipes respectively. Calculate the jet velocity and pressure in the suction pipe at the inlet to the pump. Assume the sump is extremely large and the sump inlet is at the free surface of the sump.

Question 9

a) Briefly state the mechanism of turbulent and laminar flows of a fluid.

b) Explain a simple experiment by which you demonstrated the laminar and turbulent flows of a liquid through a horizontal pipe.

c) Water at 20^0C flows through a 100 m long horizontal pipe at a rate of 10 litres per second. If this pipe is made of cast iron and has diameter 100 mm, determine the pressure drop over the pipe length.

If the circular cast iron pipe is replaced by a wooden pipe having a square cross section with 100 mm on a side, what would be the this pressure drop. Assume the flow is full in both cases.

Pipe Material	Roughness Factor (mm)
Cast iron	0.26
Wood	0.30

At 20^0C Density of water = 998.3 kg/m^{-3} and kinematic viscosity $\gamma = 1.00 \times 10^{-6}$ m^2/s.

Question 10

(a) From the first principles derive an equation to determine the flow rate of a liquid that flows through a pipe when using a venturimeter.

(b) A cylindrical water tank, of which the top side is open to atmosphere, has a diameter of 3 m and a height of 6 m. At the centre of the bottom has an orifice of 150 mm diameter. Water with a constant discharge of 85 litres per second is fed into the tank from an external source, while the water is being discharged from the tank through the orifice. Determine the time taken to lower the water level from 5 m to 2 m above the centre of the orifice. The coefficient of discharge for the orifice is 0.72.

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