MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

SECOND YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 204: FLUID MECHANICS I

DATE: 26/8/2022 **TIME: 2.00-4.00 PM**

INSTRUCTIONS

- This paper contains five (5) questions.
- Question one (1) carries thirty (30) marks and the remaining four questions each carries a maximum twenty (20) marks.
- Answer question one and any other two questions from the remaining four questions.

Provided:

- Where necessary take the local gravitational acceleration as 9.81 m/s^2, density of water as 1000 kg/m^3, and density of air as 1.20 kg/m^3.
- Take dynamic viscosity of water is 8.9×10^{-4} N.s/m^2 and dynamic viscosity of air is 1.682×10^{-5} N.s/m^2.

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Briefly discuss the following terms as used in fluid flow:

i) Non-slip condition (1 mark)
ii) Incompressible flow (1 mark)
iii) Newtonian fluid (1 mark)
iv) Mach number (1 mark)

b) Water flows through a long pipe of 150 mm diameter at an average velocity of 2.0 m/s. Show if the flow is laminar or turbulent by appropriate calculations. Take the kinematic viscosity of water to be, $\nu = 1.52 \times 10^{-6}$ m^2/s. (3 marks)

c) A famous solution in fluid mechanics, called Poiseuille flow, involves laminar flow in a round pipe as shown in Fig. 1. Consider the Poiseuille flow in a pipe with the velocity profile given by

$$u(r) = u_{max}(1 - \left(\frac{r}{R}\right)^2)$$

where r is radial coordinate position as measured from the centerline, u_{max}, is the maximum flow velocity, which occurs at the center, and R is the pipe radius. Water flows through the pipe.

(i) Develop a relation for the drag force applied by the fluid on a section of the pipe of length L.

(ii) Calculate the drag force if $L = 20$ m, $R = 0.1$ m, and $u_{max} = 2.0$ m/s.

(6 marks)

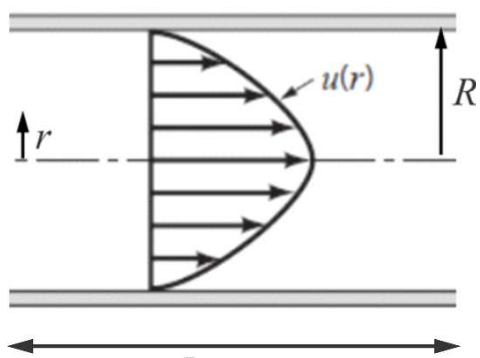


Figure 1

d) i) State Archimedes' principle. (1 mark)

ii) The homogeneous wooden block A in Fig. 2 is 1.2 m by 1.2 m by 1.8 m and weighs 2.8 kN. The concrete block B (specific weight = 25 kN/m^3) is suspended from A by means of the slender cable causing A to float in the position indicated. Determine the volume of B. (7 marks)

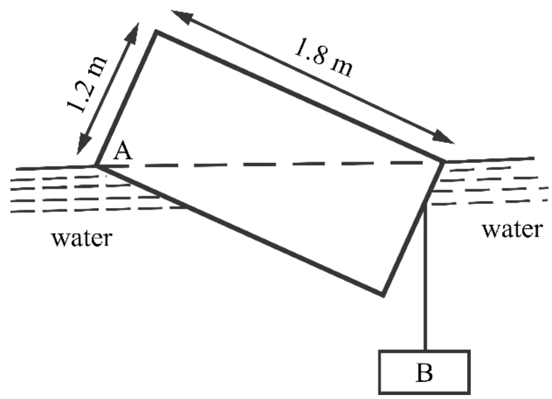


Figure 2

e) Briefly distinguish between stable- and unstable equilibrium for floating bodies using sketches, clearly showing the center of gravity *G*, center of buoyancy *B* and the metacenter *M*. (4 marks)

f) The differential mercury manometer in Fig. 3 is connected to pipe *A* containing gasoline (*SG* = 0.65), and to pipe *B* containing water. Determine the differential reading, *h*, corresponding to a pressure of *A* of 20 kPa and a vacuum of 200 mm Hg in *B*. Take the *SG* of mercury as 13.6. (5 marks)

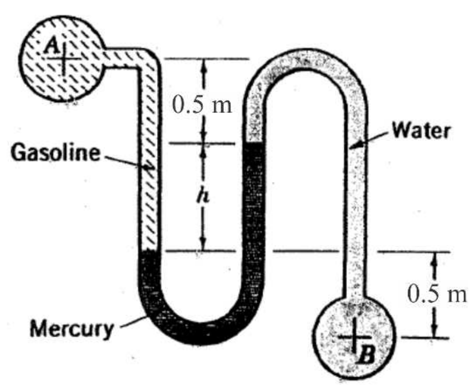


Figure 3

QUESTION TWO (20 MARKS)

a) Define the term center of pressure. (1 mark)

b) Using relevant sketches show that the buoyant force acting on a submerged body is equal to the weight of the liquid displaced by the body. (3 marks)

c) Develop from first principles a general formula/expression for the position of the center of pressure on one side of a sloping flat plate completely immersed in a liquid. Explain the meaning of all symbols used. (7 marks)

d) Consider a concrete dam as shown in Fig. 4 that weighs 24 kN/m^3 and rests on a solid foundation. Determine the minimum coefficient of friction between the dam and the foundation required to keep the dam from sliding at the water depth shown. Neglect possible uplift along the base. Perform the analysis on a unit length of the dam.

(9 marks)

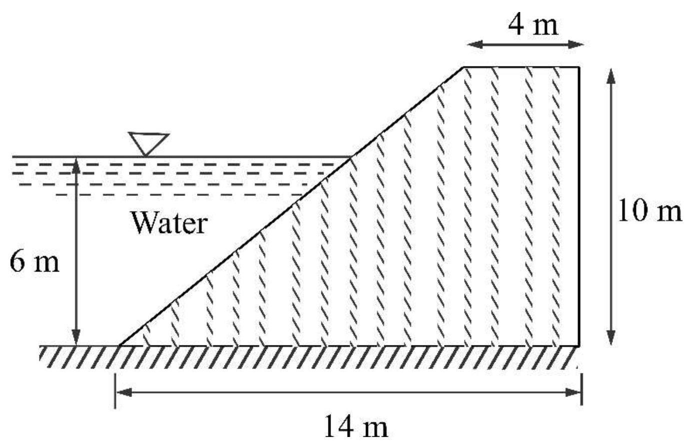


Figure 4

QUESTION THREE (20 MARKS)

a) A venturi meter having a throat area of A_2 is fitted into a pipeline with an area of A_1 at the entrance to the throat. The pressure difference between the entry and throat tappings is measured by a U-tube manometer, containing gauge liquid of density ρ_{man} and the connections are fitted with a fluid in pipeline of density ρ. The difference in level indicated by the mercury in the U-tube is h. Show that the theoretical flow rate, Q, is given as

$$\boldsymbol{Q = \left(\frac{A_1}{(m^2-1)^{\frac{1}{2}}}\right)\sqrt{2gh\left(\frac{\rho_{man}}{\rho}-1\right)}}$$

where $m = A_1/A_2$. (10 marks)

b) A venturi meter having a throat diameter d_2 of 150 mm is fitted into a pipeline which has a diameter d_1 of 250 mm through which oil of specific gravity 0.9 is flowing. The pressure difference between the entry and the throat tappings is measured by a U-tube manometer containing mercury of specific gravity 13.6, and the connections are filled with the oil flowing in the pipeline. If the difference of level indicated by the mercury in the U-tube is 0.65 m, calculate the theoretical volume flow rate through the meter.

(5 marks)

c) Air flows upward through a 6 cm diameter inclined duct at a rate of 0.065 m^3/s. The duct diameter is then reduced to 4 cm through a reducer as shown in Fig. 5. The pressure change across the reducer is measured by a water manometer. The elevation difference between the two points on the pipe where the two arms of the manometer are attached is 0.20 m. Determine the differential height h, between the fluid levels of the two arms of the manometer. (5 marks)

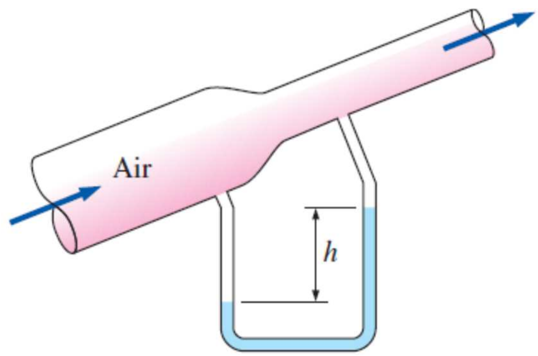


Figure 5

QUESTION FOUR (20 MARKS)

a) Briefly define what the term stagnation pressure as applied to fluid flow means. (1 mark)

b) Concisely state four limitations on the use of the Bernoulli Equation. (4 marks)

c) Figure 6 shows a necked-down section in a pipe flow, called a venturi. A low throat pressure is developed that can aspirate fluid upward from a reservoir.

i. Using Bernoulli's equation with no losses, develop an expression for the velocity V_1 (in terms of h, D_1, D_2, and g) which is just sufficient to bring reservoir fluid into the throat. Take the fluid in the tube to be stationary, such that $p_a - p_1 = \rho g h$. (7 marks)

ii. Given the diameter ratio, $\frac{D_1}{D_2} = 0.25$, $D_2 = 0.4$ m, and $h = 1.5$ m, calculate the discharge through the venturi under the conditions in (i) above. (3 marks)

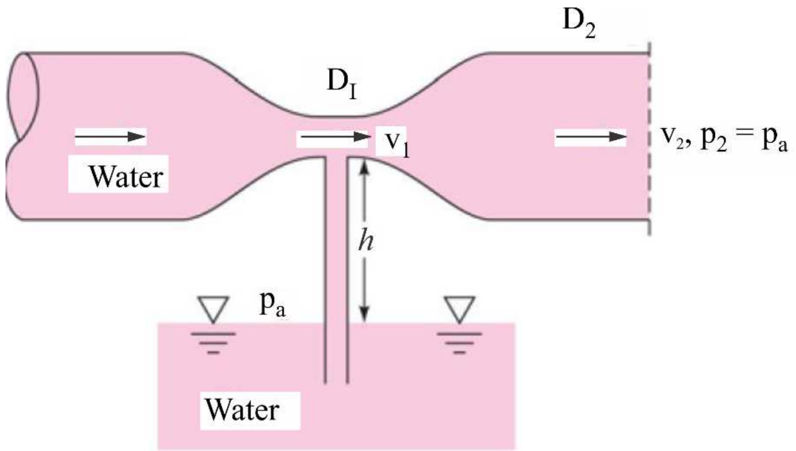


Figure 6

d) A piezometer and a Pitot tube are tapped into a 4 cm diameter horizontal water pipe and the heights of the columns are measured to be 30 cm in the piezometer and 40 cm in the Pitot tube (both measured from the pipe centerline). Determine the velocity at the center of the pipe. (5 marks)

QUESTION FIVE (20 MARKS)

a) i) Develop an expression for the quantity of liquid flowing over a sharp edged V-notch of total angle 2θ in terms of the head H above the bottom vertex of the Notch, the angle θ, the coefficient of discharge assuming the velocity of approach to be small. (6 marks)

ii) In a laboratory experiment using a 90° V-Notch total included angle, the flow is collected in a 0.9 m diameter vertical cylindrical tank. It is found that the depth of water in the tank increases by 0.685 m in 16.8 seconds when the head over the notch is 0.2 m. Determine the discharge coefficient of the Notch. (4 marks)

b) Water is siphoned from a large tank and discharges into the atmosphere through a 0.05 m diameter tube as shown in Fig. 7. The end of the tube is 0.9 m below the tank bottom, and viscous effects are negligible.

i) Determine the volume flowrate from the tank.

ii) Determine the maximum height, H, over which the water can be siphoned without cavitation occurring. Atmospheric pressure is 101.325 kPa, and the water vapour pressure is 1.8 kPa. (10 marks)

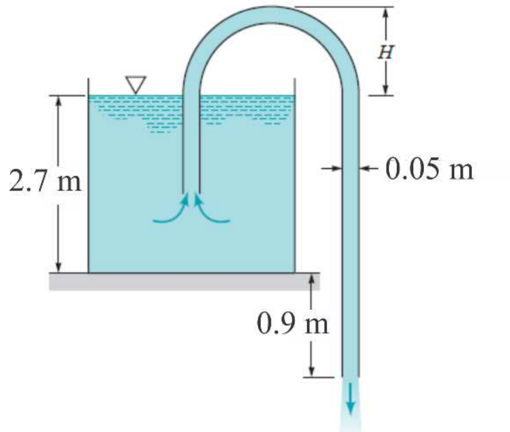
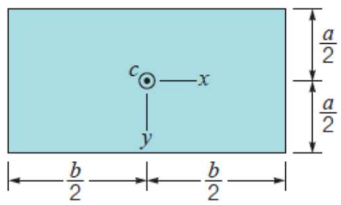


Figure 7

Geometric properties of some common shapes



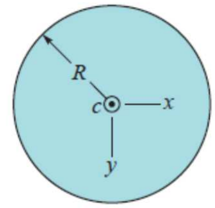
$A = ba$

$I_{xc} = \frac{1}{12} ba^3$

$I_{yc} = \frac{1}{12} ab^3$

$I_{xyc} = 0$

(*a*) Rectangle

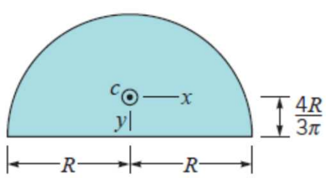


$A = \pi R^2$

$I_{xc} = I_{yc} = \frac{\pi R^4}{4}$

$I_{xyc} = 0$

(*b*) Circle



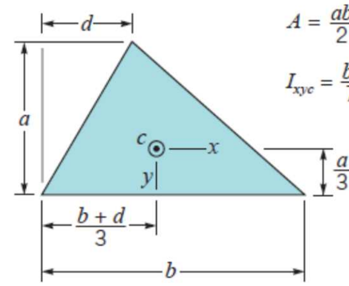
$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098R^4$

$I_{yc} = 0.3927R^4$

$I_{xyc} = 0$

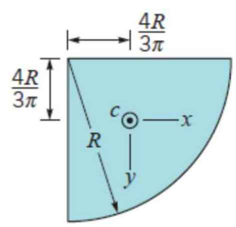
(*c*) Semicircle



$A = \frac{ab}{2}$ $\quad I_{xc} = \frac{ba^3}{36}$

$I_{xyc} = \frac{ba^2}{72}(b - 2d)$

(*d*) Triangle



$A = \frac{\pi R^2}{4}$

$I_{xc} = I_{yc} = 0.05488R^4$

$I_{xyc} = -0.01647R^4$

(*e*) Quarter circle