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BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

AEH201

Department of Engineering and Physics

Bachelor of Science (Honours) Degree in Agricultural Engineering

Hydraulics and Fluid Mechanics

3 HOURS (100 Marks)

INSTRUCTIONS

NOV 2024

This paper contains 6 questions.

Answer any **FOUR** questions. Each carries **25 marks**

Note: At the end of the exam, you will find a summary with equations and properties of some substances that will be useful for the solution of the exam.

Question 1

Both a gage and a manometer, Figure Q1, are attached to a gas tank to measure its pressure. If the reading on the pressure gage is 65 kPa . Determine the distance between the two fluid levels of the manometer if the fluid is:

i. Mercury. **[12.5 marks]**

ii. Water. **[12.5 marks]**

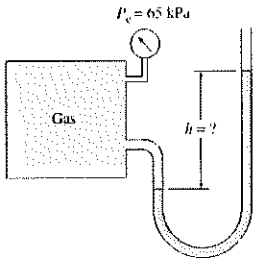

Figure Q1

Question 2

Water is pumped from a lake to a storage tank 18 m above at a rate of 70 L/s while consuming 20.4 kW of electric power. Disregarding any frictional losses in the pipes and any changes in kinetic energy, determine:

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a) The potential energy at point 2. [5 marks]

b) The mechanical energy of water. [6 marks]

c) The overall efficiency of the pump-motor unit. [7 marks]

d) The pressure difference between the inlet and the exit of the pump. [7 marks]

Question 3

Air is flowing through a venturi meter, Figure Q3, whose diameter is 6 cm at the entrance part (location 1) and 4 cm at the throat (location 2). The gage pressure is measured to be 85 kPa at the entrance and 80 kPa at the throat. Neglecting frictional effects.

Determine the flow rate of air. [25 marks]

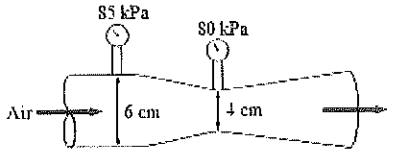

Figure Q3

Question 4

A 3 m diameter tank is initially filled with water 2 m above the center of a sharp-edged 10 cm diameter orifice. The tank water surface is open to the atmosphere, and the orifice drains to the atmosphere through a 100 m long pipe. In order to drain the tank faster, a pump is installed near the tank exit. The friction coefficient of the pipe is taken to be 0.015 and the effect of the kinetic energy correction factor can be neglected. The water temperature is 30°C and the system is located at sea level.

Determine:

a) Mass flow rate in kg/s. [5 marks]

b) The required useful pumping head. [5 marks]

c) How much pump power input is necessary to establish an average water velocity of 4 m/s when the tank is full at $z = 2$ m . [5 marks]

d) The volume of water in the tank. [5 marks]

e) The time required to drain the tank, for a constant discharge velocity. [5 marks]

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Question 5

A Venturi meter, Figure Q5, equipped with a differential pressure gage is used to measure the flow rate of water at 15 °C through a 5 cm diameter horizontal pipe. The diameter of the Venturi neck is 3 cm, and the measured pressure drop is 5 kPa . Taking the discharge coefficient to be 0.98. Determine the volume flow rate of water and the average velocity through the pipe.

a) The diameter ratio. **[5 marks]**

b) The throat area. **[6 marks]**

c) The volume flow rate. **[8 marks]**

d) The average velocity through the pipe. **[6 marks]**

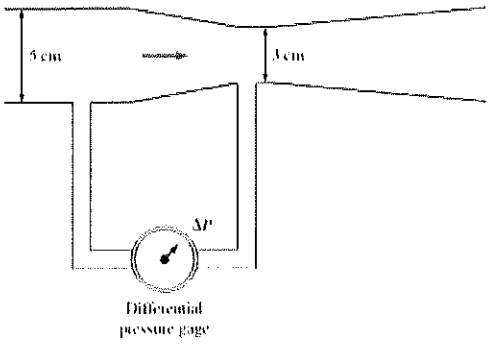

Figure Q5

Question 6

A clean-earth trapezoidal channel with a bottom width of 1.8 m and a side surface slope of 1:1 is to drain water uniformly at a rate of 8 m^3/s to a distance of 1 km. If the flow depth is not to exceed 1.2 m , determine:

a) The flow area. **[5 marks]**

b) The wetted perimeter. **[5 marks]**

c) Hydraulic radius of the channel. **[5 marks]**

d) Bottom slope of the channel. **[5 marks]**

e) The elevation drop across a pipe length. **[5 marks]**

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EQUATIONS AND PROPERTIES

Manning equation

$$C_a = \frac{a}{n} R_h^{\frac{2}{3}} \cdot S_0^{\frac{1}{2}}$$

Factor dimensional constant

$$a = 1 \frac{m^{\frac{1}{3}}}{s}$$

Mean values of the Manning coefficient n for water flow in open channels* From Chow (1959).	
Wall Material	n
A. Artificially lined channels	
Concrete, finished	0.012
Asphalt	0.016
B. Excavated earth channels	
Clean	0.022

Obstruction flowmeters:

$$\dot{V} = A_0 \cdot C_d \sqrt{\frac{2(P_1 - P_2)}{\rho(1-\beta^4)}}$$

Temperature of water (°C)	Density of water ρ (kg/m³)	Dynamic Viscosity of water μ (kg/(m·s))
4	1000.0	$1.574 \cdot 10^{-3}$
10	999.7	$1.307 \cdot 10^{-3}$
15	999.1	$1.138 \cdot 10^{-3}$
20	998.0	$1.002 \cdot 10^{-3}$
30	996.0	$0.798 \cdot 10^{-3}$

Substance	Density ρ (kg/m³)
Air	1.2040
Oil	850.00
Mercury	1,3534

Equivalent roughness values for new commercial pipes*
Roughness, ε (mm).

Material	ε (mm)
Glass, plastic	0
Concrete	0.9 to 9
Wood stave	0.5
Rubber, smoothed	0.01
Copper or brass tubing	0.0015
Cast iron	0.26
Galvanized iron	0.15
Wrought iron	0.046
Stainless steel	0.002
Commercial steel	0.045

Pipe components	KL
Well-rounded entrance	0.03
Standard flanged elbows	0.3
Gate valve, fully open	0.2
sharp-edged exit	1.0