BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ENGINEERING AND PHYSICS

NOV 2024

BACHELOR OF SCIENCE (HONOURS) DEGREE IN AGRICULTURAL ENGINEERING

AEH310 (1): PUMP TECHNOLOGY

DURATION: 3 HOURS **TOTAL MARKS: 100**

INSTRUCTIONS TO CANDIDATES

This paper contains 6 questions.

Answer any FOUR questions. Each questions carries 25 marks

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

1. A centrifugal pump is used to pump water at 25 °C from a reservoir whose surface is 6 m above the centerline of the pump inlet (Figure 1). The piping system consists of 20 m of PVC pipe with an inner diameter of 30 mm and negligible average inner roughness height. The length of pipe from the bottom of the lower reservoir to the pump inlet is 3.5 m . The sum of all the minor loss coefficients in the piping system is K_L =7.8. The Friction factor is f = 0.01736. The pump's required net positive suction head is provided by the manufacturer as a curve fit:

$$NPSH_{required} = 0.305\ m + \left(0.0319\ m \cdot \left(\frac{h}{m^3}\right)^2\right)\dot{V}^2$$

Determine if for a maximum volume flow rate 9 m³/h the pump can operate without cavitation. Explain your answer. **(25 marks)**

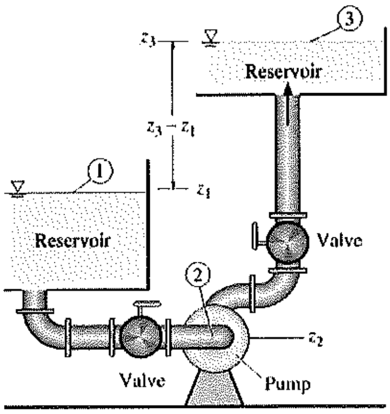

Figure 1

2. The internal and external diameters of the impeller of a centrifugal pump are 200 mm and 400 mm respectively. The pumps is running at 1200 rpm . The vane angles of the impeller at inlet and outlet are 20° and 30° respectively. The water enters the impeller radially and velocity of flow constant. Determine the work done by the impeller per unit weight of water. **(25 marks)**

3. A single-stage centrifugal pump with impeller diameter of 30 cm rotates at 2 000 rpm and lifts 3 m^3/s of water to a height of 30 m with an efficiency of 75 % . Find the number of stages and diameter of each impeller of a similar multistage pump lift 5 m^3/s of water to a height of 200 meters when rotating at 1 500 rpm . **(25 marks)**

4. The length and diameter of a suction pipe of a single-acting reciprocating pump are 5 m and 10 cm respectively. The pump has a plunger of diameter 15 cm and stroke length of 35 cm . The centre of the pump is 3 m above the water surface in the pump. The atmospheric pressure head is 10.3 m of water and pump is running at 35 rpm . Determine:

a) Pressure head due to acceleration at the beginning of the suction stroke. **(15 marks)**
b) Maximum pressure head due to acceleration. **(5 marks)**
c) Pressure head in the cylinder at the beginning and the end of the stroke. **(5 marks)**

5. Water is flowing through a horizontal pipe of diameter 200 mm at a velocity of 3 m/s . A circular solid plate of diameter 150 mm is placed in the pipe to obstruct the flow. Find the loss of head due to obstruction in the pipe if Cc = 0.62. **(25 marks)**

6. The head of water at the inlet of pipe 2000 m long and 500 mm diameter is 60 m . A nozzle of diameter 100 mm at its outlet is fitted to the pipe. Find the velocity of water at the outlet of the nozzle if f = 0.01 for the pipe. **(25 marks)**

EQUATIONS AND PROPERTIES

Question 1

$$\frac{P_1}{\rho \cdot g}+\alpha_1 \cdot \frac{V_1^2}{2 \cdot g}+z_1+h_{pump.u}=\frac{P_2}{\rho \cdot g}+\alpha_2 \cdot \frac{V_2^2}{2 \cdot g}+z_2+h_{turbine.e}+h_{L.total}$$

$$NPSH=\frac{P_{atm}-P}{\rho \cdot g}+(z_1-z_2)-h_{L.total}$$

$$h_{L.total}=\left(f \cdot \frac{L}{D}+\sum K_L\right) \cdot \frac{V^2}{2 \cdot g}$$

Question 3

$$\left(\frac{N \cdot \sqrt{\dot{V}}}{H_m^{3/4}}\right)_1=\left(\frac{N \cdot \sqrt{\dot{V}}}{H_m^{3/4}}\right)_2$$

$$\left(\frac{\sqrt{H_m}}{D \cdot N}\right)_1=\left(\frac{\sqrt{H_m}}{D \cdot N}\right)_2$$

Question 4

$$h_a=\frac{l}{g} \cdot \frac{A}{a} \cdot \omega^2 \cdot r \cdot \cos(\theta)$$

Question 5

$$h_i=0.5 \cdot \frac{V^2}{2 \cdot g}$$

$$h_l=\frac{4 \cdot f \cdot L \cdot V^2}{d \cdot 2 \cdot g}$$

$$h_e=\frac{(V_1-V_2)^2}{2 \cdot g}$$

$$h_L=\frac{V^2}{2 \cdot g} \cdot \left(\frac{A}{C_c \cdot (A-a)}-1\right)^2$$

$$\frac{P_1}{\rho \cdot g}+\frac{V_1^2}{2 \cdot g}+z_1=\frac{P_2}{\rho \cdot g}+\frac{V_2^2}{2 \cdot g}+z_2+h_i+h_{f1}+h_e+h_{f2}$$

Question 6

$$H=\frac{V^2}{2 \cdot g}+\frac{4 \cdot f \cdot L \cdot V^2}{D \cdot 2 \cdot g} \cdot \frac{a}{A}$$

$$h_i=\rho \cdot g \cdot \dot{V} \cdot \left(H-\frac{4 \cdot f \cdot L \cdot V^2}{D \cdot 2 \cdot g}\right)$$

Temperature of water (°C)	Saturation Pressure (kPa)	Density of water ρ (kg/m³)	Dynamic Viscosity of water μ (kg/(m·s))
5	0.8721	999.9	$1.792 \cdot 10^{-3}$
10	1.2276	999.7	$1.307 \cdot 10^{-3}$
15	1.7051	999.1	$1.138 \cdot 10^{-3}$
20	2.339	998.0	$1.002 \cdot 10^{-3}$
25	3.169	997.0	$0.891 \cdot 10^{-3}$
30	4.246	996.0	$0.798 \cdot 10^{-3}$

END OF PAPER