THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

Department of Mechanical Engineering

ME223 Fluid Mechanics for Mechanical Engineering

Final Examination 2nd Year Degree

Semester 2, Year 2024

Time Allowed: 2 hours

Wednesday, October 23, 2024 – 08:20

INSTRUCTION FOR STUDENTS

(1) YOU HAVE 10 MINUTES TO READ THE PAPER. DO NOT WRITE ANYTHING DURING THIS TIME.

(2) CHECK YOUR QUESTION PAPER HAS **7 PAGES**.

(3) TOTAL NUMBER OF QUESTIONS – FOUR (4). **ANSWER ALL QUESTIONS**

(4) SHOW YOUR WORK CLEARLY. FOR FULL CREDIT SHOW ALL STEPS.

(5) NOTES AND TEXT BOOKS ARE NOT ALLOWED. CALCULATORS ARE PERMITED IN THE EXAMINATION ROOM.

(6) WRITE YOUR **NAME** AND **STUDENT NUMBER** CLEARLY ON THE FRONT OF THE ANSWER BOOKLET. **DO IT NOW.**

(7) START EACH QUSTION ON A NEW PAGE AND SHOW ALL YOUR WORK IN THE ANSWER BOOK PROVIDED.

(8) TOTAL MARKS: 40

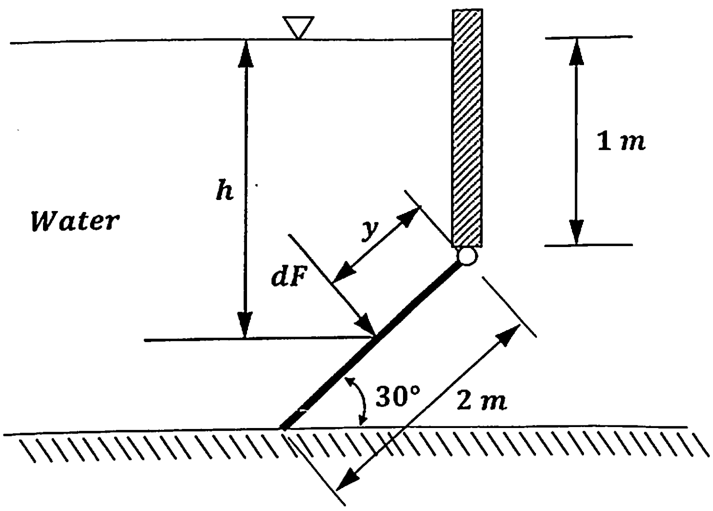
(9) MARKING SCHEME:

QUESTION 1	5 MARKS
QUESTION 2	5 MARKS
QUESTION 3	14 MARKS
QUESTION 4	16 MARKS

ALL ANSWERS MUST BE WRITTEN IN INK.

QUESTION 1

Determine the total force by **integration** due to water pressure on the inclined surface shown in the diagram below. The surface is hinge at the top and is 3 m wide.



NOTE: The total force is normal to the gate and may be found by integrating the pressure over the surface.

QUESTION 2

A spherical balloon of diameter 1.5 m and total mass 1.2 kg, is released in the atmosphere. Assuming that the balloon does not expand and that temperature lapse rate in the atmosphere is $\lambda = 0.0065\ K/m$, determine the height (Z) above sea-level to which the balloon will rise. Atmospheric temperature and pressure at sea-level are 15°C and 101 kPa respectively; for air, $R = 287$ J/kgK (gas constant). Use the information provided above to calculate the following densities;

1. Density of balloon, $\rho =$ ______ kg/m^3
2. Density of the air at 15°C and 101 kPa, $\rho_o =$ ______ kg/m^3

Now, use the above densities and the following equations provided to calculate height (Z);

- If the temperature lapse rate is constant, then $T = T_o - \lambda Z$,
- $P/P_0 = exp(-gZ/RT)$ also $ln\frac{P}{P_o} = \frac{g}{R\lambda} ln\frac{T_o - \lambda Z}{T_o}$
- Also $ln\frac{\rho}{\rho_o} = ln\frac{P}{P_o} - ln\frac{T}{T_o} = \left(\frac{g}{R\lambda} - 1\right) ln\left(\frac{T_o - \lambda Z}{T_o}\right)$

QUESTION 3

A uniform, closed cylinder buoy, 1.5 m high, 1.0 m diameter, and of mass 80 kg is to float with its axis vertical in sea water of density 1026 kg/m³. A body of mass 10 kg is attached to the centre of the top surface of the buoy as shown on the diagram below.

Show that, if the buoy floats freely, initial instability will occur.

TIPS on answering Q3 refer to the diagram and information provided below:

- Take moments of **mass** about horizontal axis through O to find OG

  $\therefore OG = \_\_\_\_\_\_ m$

- For vertical equilibrium, use buoyance = weight to find h

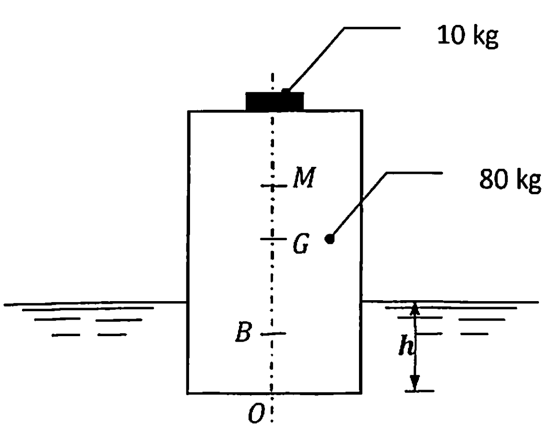
- Use Second moment of the centroidal axes or Ak^2 of a circle about a centroidal axis is given as $(Ak^2)_{CC} = \pi d^4/64$ to find BM.

  Where:

  $A = cross\ sectional\ area;\ k = radius\ of\ gyration;\ BM = \frac{Ak^2}{V};\ V = \frac{\pi d^2}{4}h\ (vol.\ submerged)$

  $\therefore BM = \_\_\_\_\_\_ m$

- Now, find GM *as per the* ***NOTES*** *below and draw your conclusion.*

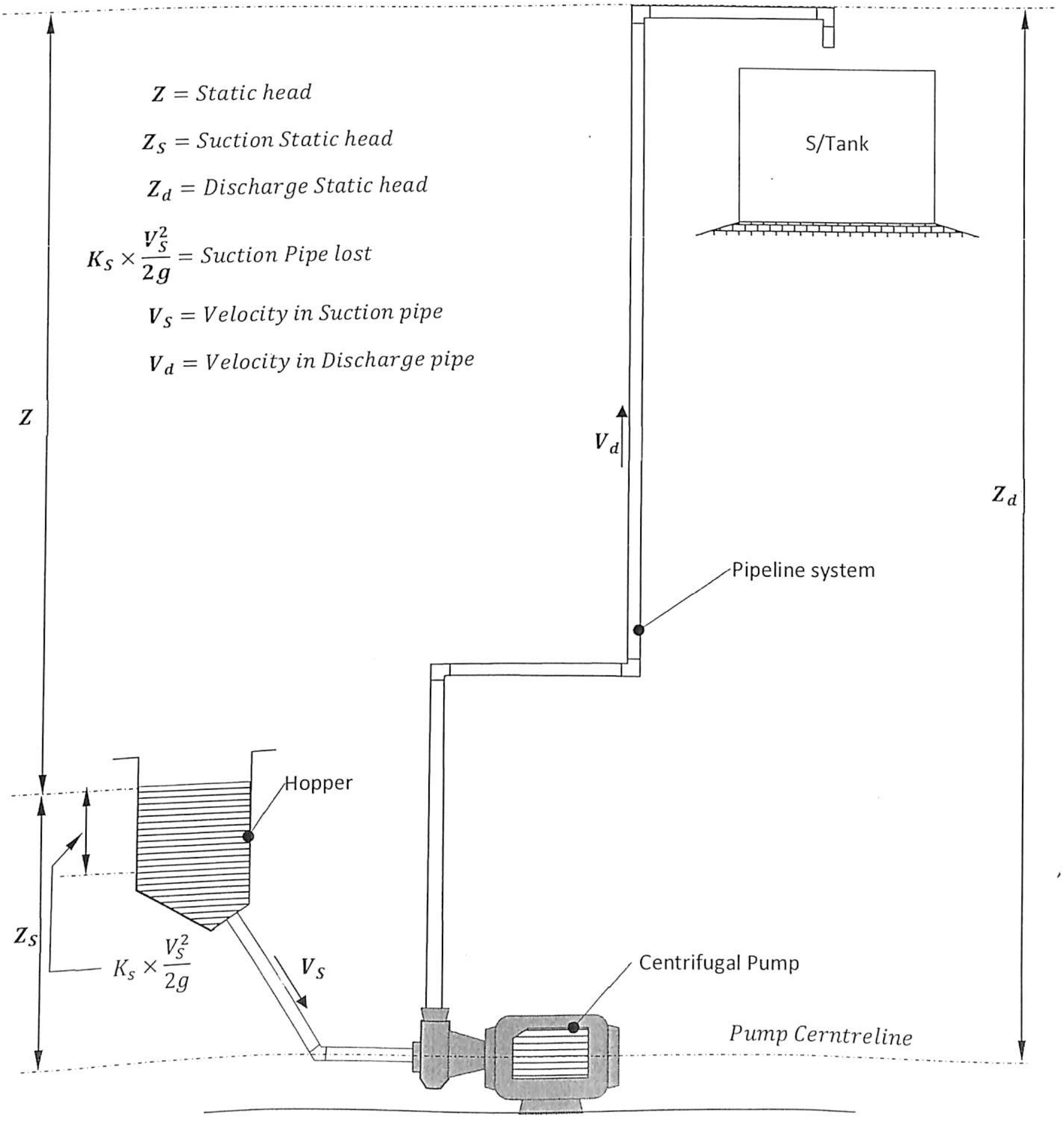


NOTES:

1. *For stability,* $GM = OB + BM - OG = positive\ for\ stability\ i.e.\ M\ has\ to\ be\ above\ G$
2. *For instability,* $GM = OB + BM - OG = negative\ for\ instability\ i.e.\ M\ is\ below\ G$

QUESTION 4

You were asked to design a pipeline system to convey process water to a storage tank. Your task is to design and select a pump from the pump performance curve that will overcome all the system resistance from the entire installations to pump process water from the hopper to the storage tank via the centrifugal pump. The pump will be gravity fed from a hopper and be arranged generally as shown on the diagram below.



You are also being told that a heavy-duty process water pump is to be selected for the following duty:

- $Static\ discharge\ head\ (Zd) = \ 20\ metres$
- $Suction\ head\ (Zs) = \ 1\ metre\ (positive)$
- $Length\ of\ pipeline = \ 100\ metres$
- $Valves\ and\ fittings = \ 5 \times 90°\gamma\ long\ radius\ bends$
- $Flowrate\ of\ process\ water, \boldsymbol{Q_p} = 176.2\ m^3/hr = 49\ L/s$
- $Pipe\ diameter, \boldsymbol{D_p} = 150\ mm$
- $Assumed, g = 9.81 m/s^2$

Calculate the total pressure drop in metre (m) head of water against the flow rate in L/s given and selected the appropriate pump and specify the model, efficiency and motor speed in rpm from the pump performance curve attached.

a) Process Water Velocity in m/s in Pipeline

A 150mm diameter steel pipe is selected for the system, what is the process water velocity V_p $(process\ water\ velocity\ in\ m/s)$?

Calculate V_p in m/s to the nearest whole number i.e. $V_p =$ ________m/s

b) Friction head H_f for the pipeline

The equivalent length of valves and fittings head losses is given as 3.35 metre each. Use this information to determine the equivalent length L of the pipeline system and calculate the friction head in metre head of water. The value $f = 0.017$ is given for the **Darcy's equation** for friction head. State the **Darcy's** equation and calculate both $L\ and\ H_f$.

c) Loss in discharge pipe enlargement

The pump discharge is found to be 100mm diameter. Therefore a pipe transition piece is required in this case to enlarge the discharge to the 150mm pipeline size. The Head loss in this case using an enlargement included angle of 30° and through interpolation, $K_e = 0.55$. You now need to calculate the velocities in the transition piece and use the correct formula to calculate the corresponding Head loss in m of water H_e:

d) Loss at pipe discharge

Under the normal open discharge conditions, the velocity head at the pump discharge must be added to the required total head. State the formula for the velocity head and calculate the head H_d in m of water.

e) Loss of head at entrance to suction pipe

The suction (inlet) pipe is similar to the discharge diameter of 150 mm. Assuming the hopper would be fitted with a flush type connection, calculate the head loss H_{et}, where $k = 0.5$.

f) Total dynamic head on the pump

Under the normal open discharge conditions, the velocity head at the pump discharge must be added to the required total head H_m.

$H_m = Z + H$, where ***Z*** is static head and ***H*** is the sum of all losses

g) Equivalent water total dynamic head

Using Correction factor (HR) as 0.89. The total head of equivalent water (H_w) is therefore calculated.

$$Hw = \frac{Hm}{HR}$$

h) Pump Selection

The pump can now be selected, using the required flow rate of 49 L/s and total head of H_W of equivalent water from the pump performance curve. Plot the pump performance curves provided and select the followings as your answer:

a) Pump Efficiency and RPM?
b) Pump Model?

Pump Performance Curve.