higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

FLUID MECHANICS N5

(8190205)

24 November 2022 (X-paper)
09:00–12:00

Nonprogrammable calculators may be used.

This question paper consists of 8 pages and a formula sheet of 2 pages.

203Q1E2224

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
FLUID MECHANICS N5
TIME: 3 HOURS
MARKS: 100

NOTE: If you answer more than the required number of questions, only the required number of questions will be marked. All work you do not want to be marked must be clearly crossed out.

INSTRUCTIONS AND INFORMATION

1. Answer ONLY FIVE questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Show all the necessary steps for every calculation. All units must be shown in the final answers.
5. Use THREE decimals after the comma for all calculations.
6. Use g = 9,81 m/s^2.
7. Start each question on a new page.
8. Use only a blue or black pen.
9. Write neatly and legibly.

QUESTION 1

1.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (1.1.1–1.1.6) in the ANSWER BOOK.

1.1.1 Gauge pressure is the intensity of pressure measured above or below atmospheric pressure.

1.1.2 A perfect vacuum is a completely empty space in which gauge pressure is measured at 101° C.

1.1.3 Absolute pressure is the sum of gauge pressure and atmospheric pressure.

1.1.4 The viscosity layer (film) of any liquid substance used in a mechanical system for lubrication purposes decreases with respect to any rise in temperature within the system.

1.1.5 There is no loss in power due to viscous resistance between a journal bearing and a moving part (e.g. a shaft) if there is layer of a lubricating agent between the two parts.

1.1.6 All fluids used in mechanical hydraulic systems are incompressible.
(6 × 1) (6)

1.2 Briefly define each of the following terms:

1.2.1 The relative density of a fluid

1.2.2 The surface tension of a fluid
(2 × 2) (4)

1.3 A 50 mm diameter solid shaft rotates inside a plain bearing with an inside diameter of 50,2 mm and a length of 100 mm. The dynamic viscosity of the fluid lubricant is 0,355 Pa.s when the shaft rotates inside the bearing with a rotational frequency of 3 000 rev/min.

Calculate the following:

1.3.1 The circumferential velocity of the rotating shaft in m/s (2)

1.3.2 The area in contact between the plain bearing and the shaft in m^2 (2)

1.3.3 The mechanical force required to overcome the viscous resistance in newtons (4)

1.3.4 The mechanical power generated by shaft to overcome the viscous resistance in watts (2)
[20]

QUESTION 2

2.1 Name any THREE basic types of press machines used in the mechanical industry. (3)

2.2 What is the function of a hydraulic actuator device? (2)

2.3 A hydraulic machine used to lift loads of material consists of a hollow master cylinder with an internal diameter of 120 mm with a stroke length of 600 mm. The modulus of elasticity for the cylinder material is 12,5 GPa.

The master cylinder is filled with an oil with a bulk modulus of 1,95 GPa. The internal cylinder is subjected to a piston force of 8 000 N.

Calculate the following:

2.3.1 The pressure generated inside the master cylinder by the piston force in kPa (2)

2.3.2 The effective bulk modulus of the hydraulic machine in GPa (3)

2.3.3 The free play on the piston of the master cylinder in mm (3)

2.4 If the master cylinder of the hydraulic machine in QUESTION 2.3 has 3,5% of air leaked into the cylinder, determine the following:

2.4.1 The bulk modulus of the air leaked into the cylinder in kPa, if the air constant is 1,4 (2)

2.4.2 The effective bulk modulus of the hydraulic machine under the new conditions in MPa (3)

2.4.3 The free play on the piston of the master cylinder under the new conditions in mm (2)

[20]

QUESTION 3

3.1 Briefly define each of the following terms:

3.1.1 The hydrostatic force acting on a plane of a submerged surface

3.1.2 The buoyancy force of a fluid

3.1.3 The draught of an object (body) submerged in fluid

(3 × 2) (6)

3.2 A balloon is completely filled with a fluid until a diameter of 200 mm is achieved. The balloon is now placed on the sea waterline (surface), where its total volume is submerged by 36% below the sea waterline. The density of the sea water is 1 025 kg/m^3 under these conditions.

Calculate the following:

3.2.1 The total volume of the sea displaced by the balloon placed on its waterline in m^3

HINT: $V_{balloon} = \frac{4\pi R^3}{3} = \frac{\pi D^3}{6}$ (3)

3.2.2 The total mass of the balloon in kilograms (2)

3.2.3 The total density of the balloon in kg/m^3 (2)

3.2.4 The percentage draught of the balloon if it is placed on the surface of the sea water (3)

3.2.5 The required mass of fluid to be added in the balloon in order to fully submerge it in sea water while maintaining the same diameter parameters of the balloon in kilograms (4)

[20]

QUESTION 4

4.1 Define each of the following terms:

4.1.1 Stream tube (tube of flow)

4.1.2 Volumetric flow rate

4.1.3 Potential energy

(3 × 2) (6)

4.2 A company pipeline network system is used to deliver diesel oil with a density of 920 kg/m^3 to four diesel oil substations. The four substation pipelines are connected and fed from a single main pipeline of 225 mm diameter, and the diesel oil was recorded as flowing at an average velocity of 2,285 m/s along the main pipeline.

Two of the four pipelines are identical in size and have unknown specifications. There is a 70 mm diameter pipeline in which the diesel oil is flowing at a velocity of 5,235 m/s, and the other pipeline is 105 mm in diameter. The flow velocity in the 70 mm diameter pipeline is 1,5 times the flow velocity in the 105 mm diameter pipeline.

Determine the following:

4.2.1 The total volumetric flow rate of the diesel oil flowing along the main pipeline in litres per second (2)

4.2.2 The mass flow rate of the diesel oil flowing along the main pipeline in tons per minute (3)

4.2.3 The volumetric flow rate of the diesel oil flowing in the 105 mm diameter section in litres per second (2)

4.2.4 The diesel oil volumetric flow rate in each of the two identical pipelines in litres per second (5)

4.2.5 The diameter of each of the two identical pipelines in mm if each pipeline has a flow velocity of 4,756 m/s (2)

[20]

QUESTION 5

5.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (5.1.1–5.1.5) in the ANSWER BOOK.

5.1.1 An orifice plate flow meter is more accurate than a venturi flow meter when measuring the volumetric flow of a fluid flowing in a pipeline.

5.1.2 The pressure head of a fluid-flowing system is measured in Pa.

5.1.3 A rotameter is a mechanical device or tool used to measure the flow of fluid.

5.1.4 The throat section of a venturi flow meter generates the highest pressure energy when determining the flow rate in a pipeline

5.1.5 The stagnation point is a point where a fluid flowing in a system comes to rest, i.e. where the fluid velocity is zero.

(5 × 1) (5)

5.2 A pitot tube is placed in a 500 mm diameter pipeline in which diesel with a density of 832 kg/m^3 is flowing The pitot tube is connected to a U-tube mercury manometer that registers a pressure head reading of 115 mm.

The pitot tube is placed centrally along the pipeline for the measuring of flow at a position where the diesel velocity of flow is at the maximum. The average velocity of flow of the diesel in the pipeline is recorded as 0,86 times the maximum velocity of flow of the diesel during the operation.

Determine the following:

5.2.1 The change in pressure head for the diesel along the pipeline in metres (3)

5.2.2 The diesel theoretical velocity of flow in m/s under the pressure head calculated in QUESTION 5.2.1 (2)

5.2.3 The diesel maximum velocity of flow along the pipeline in m/s if the coefficient of velocity is 0,96 (2)

5.2.4 The diesel average velocity of flow along the pipeline in m/s (2)

5.2.5 The average volumetric flow rate along the pipeline in litres per minute (3)

5.2.6 The actual discharge rate of flow in litres per hour for 6 hours if the pitot tube coefficient of meter is 0,92 (3)

[20]

QUESTION 6

6.1 Briefly define Bernoulli's energy theorem in any system of fluid flow. (2)

6.2 Name any TWO types of flow that can be found in a fluid-flowing system under any conditions. (2)

6. 3 An open surface storage tank in a steam boiler plant is to be drained out to a reservoir situated below it through a 65 mm diameter pipeline with a length of 35 m. The surface of the reservoir was measured as 8,5 m below the water surface in the storage tank before routine maintenance in the steam boiler plant took place.

The pipeline system is fitted with three fittings: a flow control valve with a head loss coefficient (k) of 0,66, a filter with a head loss coefficient (k) of 3,2 and a 90° elbow with a head loss coefficient (k) of 0,675.

Ignore the shock loss at the entrance to the pipeline system. The coefficient of friction (f) of the pipeline is 0,0025.

Determine the following:

6.3.1 The length to diameter ratio of the system (5)

6.3.2 The total head loss generated by the system in metres with the aid of Bernoulli's energy equation (4)

6.3.3 The flow velocity of water running through the pipeline into the reservoir in m/s (3)

6.3.4 The volumetric flow rate of the pipeline system in litres for a 24-hour routine maintenance period (4)

[20]

TOTAL: 100

FORMULA SHEET

$$\rho = \frac{m}{v}$$

$$SG = Rel = \frac{\rho_{\text{substance}}}{\rho_{water}}$$

$$Specific\omega = \frac{weight}{volume} = \rho g$$

$$P = \frac{F}{A}$$

$$P_{absolute} = P_{gauge} + P_{atmospheric}$$

$$P_{gauge} = \rho gh$$

$$F_{Surface\ tension} = \sigma 2\pi R$$

$$\Delta P = P_i - P_o = \frac{2\sigma}{R} = \frac{4\sigma}{D}$$

$$F_{viscous} = \frac{\mu Av}{t} \text{ and } \upsilon = \frac{\mu}{\rho}$$

$$W = mg$$

$$W_{\substack{perpendicular-inclined \\ plane}} = mg\cos\theta$$

$$W_{\substack{parallel-inclined \\ plane}} = mg\sin\theta$$

$$K_e = \frac{P}{\varepsilon_v}$$

$$\varepsilon_v = \frac{\Delta V}{V}$$

$$\frac{1}{K_e} = \frac{1}{K_\ell} + \frac{1}{K_c} + \frac{V_g}{V_t}\left(\frac{1}{K_g}\right)$$

$$K_g = \delta P \text{ and } K_c = \frac{E}{2{,}5}$$

$$F_{hydrostatic} = \rho g A\bar{y}$$

$$\bar{h} = \frac{I_g Sin^2\theta}{A\bar{y}} + \bar{y}$$

$$I_{g(\text{rectangular})} = \frac{bd^3}{12}$$

$$I_{g(\text{circular})} = \frac{\pi D^4}{64}$$

$$W = R = \rho g V$$

$$V_{\substack{hollow-pipe \\ with\ closed\ ends}} = \pi D L t + 2\frac{\pi}{4}D^2 t$$

$$Q \text{ or } \overset{\circ}{V} = A_1 u_1 = A_2 u_2; \quad \overset{\circ}{m} = \rho \overset{\circ}{V}; \quad \overset{\circ}{W} = g\,\overset{\circ}{m} = \rho g A u; \quad P = H\overset{\circ}{W} = \rho g Q H$$

$$\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + Z_1 + \frac{P_{pump}}{\overset{\circ}{W}} = H_{total} = \frac{P_2}{\rho g} + \frac{u_2^2}{2g} + Z_2 + \frac{P_{motor}}{\overset{\circ}{W}} + \frac{P_{turbine}}{\overset{\circ}{W}} + h_{loss}\ (J/N,\ m)$$

$$\frac{P_{turbine}}{\overset{\circ}{W}} = Turbine\ head; \quad \frac{P_{pump}}{\overset{\circ}{W}} = Pump\ head; \quad \eta = \frac{P_F}{P_m} \times 100; \quad R_e = \frac{\rho v D}{\mu}$$

$\underline{h_{loss}\ (J/N)\ or\ m:}$

$$h_s = k\frac{u^2}{2g}; \quad h_s = \left(\frac{1}{C_c} - 1\right)^2 \frac{u^2}{2g}; \quad h_a = h(1 - C^2{}_v); \quad h_f = 4f\left(\frac{L_e}{d}\right)_T \frac{u^2}{2g}$$

$$h_s = \frac{(u_1 - u_2)^2}{2g}$$

$$F_{inlet} = \overset{\circ}{m}u_1 + P_1 A_1 \quad and \quad F_{exit} = \overset{\circ}{m}u_2 + P_2 A_2$$

$$Flat\ plate: \quad Stationary\ F = \rho A u^2 \quad Moving\ F = \rho A(u - u_m)^2 \quad Angle\ F = \rho A u^2 Cos\,\theta$$

$$Curved: \quad X - Direction \quad F_x = \rho A u^2(1 + Cos\,\theta) \quad Y - Direction \quad F_y = \rho A u^2 Sin\,\theta$$

$$U_m = \frac{\pi D n}{60}; \quad P = \overset{\circ}{m} V_{w_t} u_m; \quad \eta = \frac{2 V_w u_m}{u_1^2}\ x\,100$$