higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

FLUID MECHANICS N5

(8190216)

1 December 2023 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 6 pages and a formula sheet of 3 pages.

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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 questions, only the required will be marked. All work you do not want to be marked must be clearly crossed out.

INSTRUCTIONS AND INFORMATION

1. Answer any FIVE of the SIX questions in this question paper.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Use only a black or blue pen.
5. Use g = 9,81 m/s^2.
6. All units must at least be shown in the answers.
7. Use THREE decimals after the comma with all solutions.
8. Write neatly and legibly.

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QUESTION 1

1.1 Define *kinematic viscosity* and give its unit. (2)

1.2 If an oil with a high viscosity is used to lubricate bearings, what impact will it have on the motion and the power of high-speed running machine parts? (2)

1.3 A solid shaft with a diameter of 150 mm rotates inside a sleeve with an internal diameter of 150,2 mm at a speed of 2 100 r/min. The length of the sleeve is 200 mm and it is lubricated with an SAE oil with a dynamic viscosity of 0,68 Pa-s.

Calculate the following:

1.3.1 The power loss to viscous forces in the bearing in kW (9)

1.3.2 The maximum rotational frequency in r/min of the solid shaft to limit the maximum power loss to 8,25 kW, with no changes to other variables (5)

1.3.3 The kinematic viscosity of the SAE oil if it has a mass density of 960 kg/m^3 (2)

[20]

QUESTION 2

2.1 A 100 mm diameter double-acting single-rod actuator is fed with a volumetric flow of 1,2 l/s. It is designed to exert a maximum force of 4,25 kN and so that the time for the return stroke is 6/9 the time of the forward stroke.

Calculate the following:

2.1.1 The pressure required in kPa (3)

2.1.2 The rod diameter in mm (5)

2.1.3 The time taken for the forward and return strokes in minutes, if the stroke length is 420 mm (4)

2.2 What is the function of a barometer and the purpose of the vacuum at the top surface of the fluid? (2)

2.3 A pressure vessel contains oil and water to a depth of 910 mm and 1,52 m, respectively. The bulk modulus of the two immiscible fluids is 2 060 MPa for the oil and 2 100 MPa for the water.

Determine the downward movement of the oil and water in mm as the pressure vessel is pressurised to a pressure of 1,65 MPa. (6)

[20]

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QUESTION 3

3.1 State Archimedes' principle with regard to floating objects on a fluid and explain the major influence that fluid density has on floating objects. (4)

3.2 A circular tank 6 m in diameter is filled with two immiscible fluids – water to a depth of 4,25 m and oil with a specific gravity of 0,96 to a depth of 1,75 m.

Calculate the following:

3.2.1 The total hydrostatic force acting on the vertical side of the tank in newtons (10)

3.2.2 The position of the centre of pressure from the oil-free surface in metres (6)

[20]

QUESTION 4

4.1 Distinguish between a *streamline* and a *stream tube*. (4)

4.2 A water system consists of two bends with a friction factor of 0,75 (k = 0,75), a filter with a length-to-diameter ratio of 110 and a pressure valve with a length-to-diameter ratio of 150. The pipe of the water system has a diameter and length of 32 mm and 15 m, respectively. The pipe has a friction coefficient of 0,0013. The water system entrance is 3 m above the pipe system exit. The flow rate through the system is 1,8 ℓ / s.

Calculate the following:

4.2.1 The total length-to-diameter ratio of the water system (5)

4.2.2 The total head loss of the water system using Darcy's equation (3)

4.2.3 The pressure at the exit if the inlet pressure to the water system is 500 kPa (4)

4.3 Determine whether the flow is laminar or turbulent if a fluid with a density of 900 kg/m^3 is flowing in a 50 mm diameter pipe with a velocity of 0,511 m/s.

Take the absolute coefficient of viscosity of the fluid as 0,01 Pa-s. (4)

[20]

QUESTION 5

A confined tank is fitted with a 45 mm diameter sharp-edged orifice with a coefficient of discharge of 0,8. The fluid in the tank has a relative density of 0,86 and the surface of fluid is 8,5 m above the centre of the orifice. To increase the rate of flow, it was decided to pressurise the tank to a pressure of 70 kPa.

Calculate the following:

5.1.1 The flow rate through the orifice at the pressure (5)

5.1.2 The height of the fluid to be maintained above the centre of the orifice if the surface of the fluid is to be freed while keeping the same flow rate (4)

5.2 A basin discharges a fluid with a specific gravity of 1,22 into the atmosphere through a cloggy 50 mm diameter pipe that is 18 m long and having a pipe friction coefficient (including clog in the pipe) of 1,067.

The outlet is 7 m below the surface of the fluid in the basin. A flow control valve with an L/d of 2 is fitted towards the discharge end of the pipe.

Calculate the flow rate in litres per second that would flow from the basin if there is a shock loss at the entrance to the pipe with a head loss coefficient of 0,56. (11)

[20]

QUESTION 6

A water turbine has a wheel with vanes mounted at a mean diameter of 0,5 m and is rotating at 763,944 rpm. A 45-m/s jet of water discharged through a nozzle inclines at 25º to the wheel of rotation and flows over the blade at a mass rate of 25,3 kg/s. A blade frictional loss of 12,5% is recorded for the relative velocities over the moving vanes. The blades and nozzles are designed to ensure that no axial thrust occurs in the turbine.

6.1 Draw the complete velocity diagram for this turbine.

Use a scale of 1 cm = 2 m/s for the construction of the diagram.

Marks will be deducted for an incorrect scale. (8)

6.2 From the velocity diagram, measure and determine the following:

6.2.1 The moving blade inlet and outlet angle

6.2.2 The relative velocities at the inlet and outlet of the moving blade in m/s

6.2.3 The angle and velocity of the water exiting the turbine

6.2.4 The total vortex velocity in m/s

6.2.5 The power generated by the turbine in kW

6.2.6 The turbine overall efficiency

(6 × 2) (12)
[20]

TOTAL: 100

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FORMULA SHEET

FLUID MECHANICS N5

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$F_{inlet} = \dot{m} u_1 + P_1 A_1 \ \text{ and } \ F_{exit} = \dot{m} u_2 + P_2 A_2$$

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

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

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

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$$\frac{P_{r1}}{P_{r2}} = \left(\frac{N_1}{N_2}\right)^2$$

$$\frac{kW_1}{kW_2} = \left(\frac{N_1}{N_2}\right)^3$$

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^3$$

$$\frac{P_{r1}}{P_{r2}} = \left(\frac{D_1}{D_2}\right)^2$$

$$\frac{kW_1}{kW_2} = \left(\frac{D_1}{D_2}\right)^5$$

$$\frac{P_{r1}}{P_{r2}} = \frac{\rho_1}{\rho_2}$$

$$\frac{kW_1}{kW_2} = \frac{1}{\rho}$$

$$\frac{H_1}{H_2} = \left(\frac{Q_1}{Q_2}\right)^2$$

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2 \;;\; \frac{w.g._1}{w.g._2} = \left(\frac{N_1}{N_2}\right)^2$$

$$\frac{H_1}{H_2} = \frac{L_1}{L_2}$$

$$\frac{W_1}{W_2} = \left(\frac{D_1}{D_2}\right)^2$$

$$\frac{N_1^2 D_1^2}{gh_1} = \frac{N_2^2 D_2^2}{gh_2}$$

$$P_r = \frac{kSV^2}{a}$$

$$P = \rho \times g \times Q \times w.g.$$

$$P = \rho \times Q \times u(v - u)\,[1 + n \cos(180° - y)]$$

$$\eta = \frac{u}{gh}\,(v - u)\,[1 + n \cos(180° - y)] \times 100$$

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