



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

FLUID MECHANICS N5

9 April 2020

This marking guideline consists of 14 pages.

✓ = mark

√ = ½ mark

QUESTION 1

- 1.1 1.1.1 A fluid is any substance that is capable of flowing, whether it is a liquid, which finds its own level in a container ✓ or whether it is a gas, which fills the container. ✓
- 1.1.2 The vapour pressure of water is the pressure at which water vapour is in thermodynamic equilibrium ✓ with its condensed state. At higher pressures water would condense. The water vapour pressure is the partial pressure of water vapour in any gas mixture in equilibrium with solid or liquid water. As for other substances, water vapour pressure is a function of temperature. ✓
- (2 × 2) (4)

1.2 1.2.1

$$\omega = \frac{2\pi N}{60}$$

$$= \frac{2 \times \pi \times 3500}{60}$$

$$= 366,52 \text{ Rad / sec} \quad \checkmark$$

$$\dot{x} = \omega R \quad \checkmark$$

$$= 366,52 \times \frac{0,046}{2}$$

$$= 8,4299 \text{ m / sec} \quad \checkmark$$

$$\text{Area} = \pi d l \quad \checkmark$$

$$= \pi \times 0,046 \times 0,05$$

$$= 7,225 \times 10^{-3} \text{ m}^2$$

$$C_r = \frac{D - d}{2} \quad \checkmark$$

$$= \frac{0,0463 - 0,046}{2} \quad \checkmark$$

$$= 0,00015 \text{ m} \quad \checkmark$$

$$\text{Power} = \frac{\mu \times A \times \dot{x} \times D \times \omega}{2C_r} \quad \checkmark$$

$$= \frac{0,7 \times 7,225 \times 10^{-3} \times 8,4299 \times 0,046 \times 366,52}{2 \times 0,00015} \quad \checkmark$$

$$= 2396,04 \text{ W} \quad \checkmark$$

(9)

1.2.2

$$\begin{aligned} \text{Power} &= \frac{\mu \times A \times \dot{x} \times D \times \omega}{2C_r} \\ &= \frac{0,1 \times 7,225 \times 10^{-3} \times 8,4299 \times 0,046 \times 366,52}{2 \times 0,00015} \\ &= 342,29W \\ \text{Change in power} &= 2396,03 - 342,29 \\ &= 2053,74W \end{aligned} \quad (5)$$

1.2.3

$$\begin{aligned} \mu &= \frac{\mu}{\rho} \\ &= \frac{0,1}{850} \\ &= 1,1764 \times 10^{-4} \end{aligned} \quad (2)$$

[20]

QUESTION 2

- 2.1 2.1.1 A hydraulic accumulator is a storage device in which fluid energy may be stored or kept from a fluid flowing system and fed back to the system during high demand. (1)
- 2.1.2
- Weight-loaded accumulator
 - Gas pressure accumulator
 - Bladder-type accumulator
 - Piston-type accumulator
 - Membrane accumulator
- (Any 3 × 1) (3)

2.2 Consider the rod side of the cylinder :

$$\text{where, } A_{rod} = \frac{\pi}{4} (D_p^2 - d_r^2)$$

$$= \frac{\pi}{4} (0,075^2 - 0,030^2)$$

$$= 3,71101 \times 10^{-3} m^2$$

$$\text{and, } F_{rod} = P A_{rod}$$

$$= 20 \times 10^3 \times 3,71101 \times 10^{-3}$$

$$\therefore F_{rod} = 74,22013 kN$$

Consider the piston side of the cylinder :

$$A_{piston} = \frac{\pi}{4} D_p^2$$

$$= \frac{\pi \times 0,075^2}{4}$$

$$\therefore A_{piston} = 4,41787 \times 10^{-3} m^2$$

$$F_{piston} = P A_{piston}$$

$$= 20 \times 10^3 \times 4,41787 \times 10^{-3}$$

$$\therefore F_{piston} = 88,35729 N$$

Thus, the difference in the force applied on the sides of the piston

$$\Delta F = F_{piston} - F_{rod}$$

$$= 88,35729 - 74,22013$$

$$\therefore \Delta F = 14,137 N$$

(6)

2.3 consider the impact of oil in the tank :

$$\text{From, } K = \Delta P \times \varepsilon$$

$$\text{as, } \varepsilon = \frac{V}{\Delta V}$$

$$\text{and, } \Delta V_{oil} = A \Delta h$$

$$\text{since, } V_{oil} = A \times h$$

$$= \frac{\pi \times 0,7^2 \times 0,85}{4} \quad \checkmark$$

$$\therefore V_{oil} = 327,11834 \times 10^{-3} m^3$$

$$\text{thus, } \Delta V_{oil} = \frac{\Delta P \times V}{K_{oil}} \quad \checkmark$$

$$= \frac{1 \times 10^6 \times 327,11834 \times 10^{-3}}{2060 \times 10^6}$$

$$\therefore \Delta V_{oil} = 158,79531 \times 10^{-6} m^3$$

consider the impact of water in the tank :

$$V_{water} = A \times h$$

$$= \frac{\pi \times 0,7^2 \times 1,5}{4} \quad \checkmark$$

$$\therefore V_{water} = 577,262765 \times 10^{-3} m^3$$

$$\text{thus, } \Delta V_{water} = \frac{\Delta P \times V}{K_{oil}} \quad \checkmark$$

$$= \frac{1 \times 10^6 \times 577,262765 \times 10^{-3}}{2100 \times 10^6}$$

$$\therefore \Delta V_{water} = 274,88936 \times 10^{-6} m^3 \quad \checkmark$$

consider overall change in the tank :

$$\Delta V_{total} = \Delta V_{oil} + \Delta V_{water}$$

$$= 158,79531 \times 10^{-6} + 274,88936 \times 10^{-6}$$

$$= 433,68467 \times 10^{-6} m^3 \quad \checkmark$$

$$\text{from, } \Delta V_{total} = A \times \Delta h_{total}$$

$$\text{thus, } \Delta h_{total} = \frac{4 \times 433,68467 \times 10^{-6}}{\pi \times 0,7^2}$$

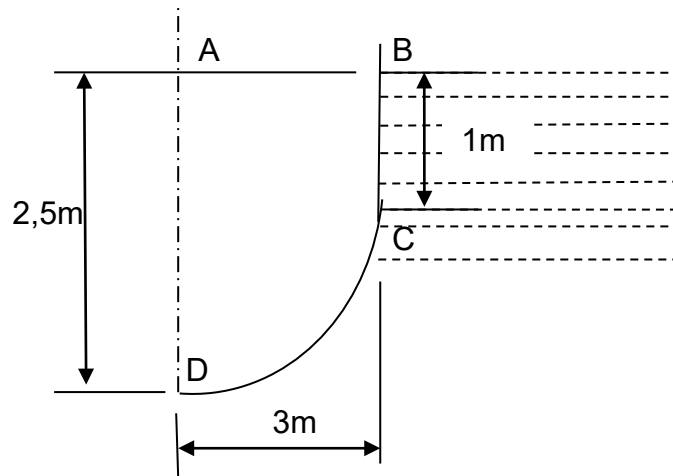
$$\therefore \Delta h_{total} = 1126,907 mm$$

(10)

[20]

QUESTION 3

3.1



FIND FORCE AND DIRECTION

$$\begin{aligned} \text{AREA}_{ABCD} &= (3 \times 3) + \left(\frac{2}{3} \times 3 \times 1,5\right) \\ &= 6\text{m}^2 \end{aligned}$$

$$\begin{aligned} \text{Volume per meter} &= \text{Area} \times \text{length} \\ &= 6 \times 1 \\ &= 6\text{m}^3 \end{aligned}$$

HORIZONTAL COMPONENT

$$\begin{aligned} H &= \rho g A \bar{y} \\ &= 1025 \times 9,81 \times (2,5 \times 1) \times \frac{2,5}{2} \\ &= 31,423\text{kN} \end{aligned}$$

VERTICAL COMPONENT

$$\begin{aligned} V &= \rho g V \\ &= 1025 \times 9,81 \times 6 \\ &= 60,332\text{kN} \end{aligned}$$

RESULTANT

$$\begin{aligned} R^2 &= H^2 + V^2 \\ \therefore R &= \sqrt{(31422,656)^2 + (60331,5)^2} \\ &= 68,024\text{kN} \end{aligned}$$

DIRECTION

$$\begin{aligned} \text{Tan } \theta &= \frac{V}{H} \\ \theta &= \text{Tan}^{-1} \frac{60,332}{31,423} \\ &= 62,488^\circ \end{aligned}$$

(10)

3.2 *Area of piston*

$$\begin{aligned} \text{Area} &= \frac{\pi}{4} \times 0,013^2 \\ &= 1,327 \times 10^{-4} \text{ m}^2 \end{aligned}$$

Volume of ball

$$\begin{aligned} \nabla_{\text{Ball}} &= \frac{4}{3} \pi r^3 \\ &= \frac{4}{3} \times \pi \times 0,06^3 \\ &= 9,0478 \times 10^{-4} \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \nabla_{\text{Submerged}} &= 9,0478 \times 10^{-4} \times \frac{1}{4} \\ &= 2,2619 \times 10^{-4} \text{ m}^3 \end{aligned}$$

$$\begin{aligned} R &= \rho g \nabla_{\text{submerged}} \\ &= 1000 \times 9,81 \times 2,2619 \times 10^{-4} \\ &= 2,2189 \text{ N} \end{aligned}$$

Take moments about pivot

$$\therefore F_{\text{piston}} \times \text{distance} = R \times \text{distance}$$

$$\begin{aligned} \therefore F_{\text{piston}} &= \frac{2,2189 \times 0,21}{0,02} \\ &= 23,2987 \text{ N} \end{aligned}$$

$$\begin{aligned} \therefore P &= \frac{F}{A} \\ &= \frac{23,2897}{1,327 \times 10^{-4}} \\ &= 175,532 \text{ kPa} \end{aligned}$$

consider the ball :

$$\text{from, } V = \frac{4\pi r^3}{3}$$

$$\text{also, } V_{\text{total}} = \frac{\pi D^3}{6}$$

$$= \frac{\pi \times 0,15^3}{6} \quad \checkmark$$

$$= 1,76715 \times 10^{-3} \text{ m}^3 \quad \checkmark$$

consider the $\frac{1}{4}$ volume of the ball during operation of the system :

$$V_{\text{quarter}} = 0,25 \times 1,76715 \times 10^{-3} \quad \checkmark$$

$$= 441,78647 \times 10^{-6} \text{ m}^3 \quad \checkmark$$

Application of Archimedes law for partially or fully submerged objects in fluids :

$$\text{where, } F_{\text{ball}} = F_{\text{bouyancy}} \quad \checkmark$$

$$= \rho g V_{\text{water displaced}} \quad \checkmark$$

$$= 9810 \times 441,78647 \times 10^{-6} \quad \checkmark$$

$$\therefore F_{\text{ball}} = 4,33393 \text{ N} \quad \checkmark$$

During the system in operation, application of moments about the pivot point :

$$F_{\text{ball}} \times 250 = F_{\text{lever}} \times 30 \quad \checkmark$$

$$F_{\text{lever}} = \frac{4,33393 \times 250}{30} \quad \checkmark$$

$$\therefore F_{\text{lever}} = 36,11608 \text{ N} \quad \checkmark$$

thus, the pressure exerted :

$$P = \frac{36,11608 \times 4}{\pi \times (16 \times 10^{-3})^2} \quad \checkmark$$

$$= 179,623 \text{ kPa} \quad \checkmark$$

(10)
 [20]

QUESTION 4

4.1 4.1.1 *from, $Q_o = \text{area} \times \text{velocity}$*

$$= \frac{\pi \times 0,04^2 \times 4,25}{4} \checkmark$$

$$= 0,005340707 \checkmark$$

$$= 5,341 \text{ l / s } \checkmark \quad (2)$$

4.1.2 *From, $\dot{m} = \text{mass} \times \text{velocity}$*
also, $\dot{m} = \rho Q$

$$= 900 \times 5,341 \times 10^{-3} \checkmark$$

$$\therefore \dot{m} = 4,807 \text{ kg / s } \checkmark \quad (2)$$

4.1.3 *from, $Q_{inlet} = Q_{outlet} \dots \text{continuity of flow principle}$:*
thus, $v_i = \frac{d_o^2}{d_i^2} \times v_o \checkmark$

$$= \frac{40^2}{70^2} \times 4,25 \checkmark$$

$$= 1,388 \text{ m / s } \checkmark \quad \text{OR}$$
alternatively, $v_i = \frac{4 \times 5,341 \times 10^{-3}}{\pi \times 0,07^2} \checkmark$

$$\therefore v_i = 1,388 \text{ m / s } \checkmark \quad (2)$$

4.1.4 *from, $Q_{inlet} = Q_{outlet} = Q_{leg-1} + Q_{leg-2} \dots \text{continuity of flow principle}$:*
as, $Q_{leg-1} = \frac{3}{5} \times Q_{inlet} \checkmark$

$$5,341 \times 10^{-3} = \frac{3 \times 5,341 \times 10^{-3}}{5} + Q_{leg-2} \checkmark$$

$$\therefore Q_{leg-2} = 2,1364 \text{ l / s } \checkmark$$
from, $Q = Av$

$$d_{leg-2} = \sqrt{\frac{2,1364 \times 10^{-3} \times 4}{\pi \times 3,25}} \checkmark$$

$$= 28,93 \text{ mm } \checkmark$$

$$Q_{leg-1} = 5,341 \times 10^{-3} - 2,1364 \times 10^{-3} = \frac{\pi \times d_{leg-1}^2}{4} \times 3,25 \checkmark$$

$$d_{leg-2} = \sqrt{\frac{(5,341 \times 10^{-3} - 2,1364 \times 10^{-3}) \times 4}{\pi \times 3,25}} \checkmark$$

$$\therefore d_{leg-2} = 35,432 \text{ mm } \checkmark \quad (6)$$

4.2 4.2.1 *from, $Q = Av$*

$$\text{thus, } v_i = \frac{4Q}{\pi d_i^2} \quad \checkmark$$
$$= \frac{4 \times 20 \times 10^{-3}}{\pi \times 0,12^2} \quad \checkmark$$
$$\therefore v_i = 1,768 \text{ m/s} \quad \checkmark$$
$$\text{and, } v_o = \frac{4 \times 20 \times 10^{-3}}{\pi \times 0,18^2} \quad \checkmark$$
$$\therefore v_o = 0,786 \text{ m/s} \quad \checkmark \quad (3)$$

4.2.2 *Application of Bernoulli's energy equation between the inlet and outlet :*

$$\frac{P_i}{\rho g} + \frac{v_i^2}{2g} + Z_i = \frac{P_o}{\rho g} + \frac{v_o^2}{2g} + Z_o + h_{\text{loss}} \dots \text{ignoring all possible losses} \quad \checkmark$$

When using inlet as the reference energy point :

$$\text{thus, } \frac{600 \times 10^3}{9810} + \frac{1,768^2}{19,62} + 0 = \frac{P_o}{\rho g} + \frac{0,786^2}{19,62} + 3,5$$

$$\therefore P_o = 58,28991 \times 9810 \quad \checkmark$$
$$= 571,824 \text{ kPa} \quad \checkmark$$

(5)
[20]

QUESTION 5

5.1 A pitot tube detects or measures the flow velocity at one point in the flow stream only while an orifice flow meter measures the full flow stream. (1 × 2) (2)

5.2

$$\text{From, } h_{sub} = h_{Hg} \left(\frac{\rho_{Hg}}{\rho_{sub}} - 1 \right)$$

$$\text{thus, } h_{oil} = 30 \left(\frac{13600}{860} - 1 \right) \checkmark$$

$$= 444,41861 \text{ mm} \checkmark$$

At the stagnation point, $v_2 = 0$

From Bernoulli's energy equation :

$$\text{thus, } \frac{P_2 - P_1}{\rho g} = \frac{v_1^2 - v_2^2}{2g} = h_{Hg} \left(\frac{\rho_{Hg}}{\rho_{sub}} - 1 \right) \checkmark$$

$$\text{now, } \frac{v_1^2}{19,62} = 444,41861 \times 10^{-3} \checkmark$$

$$v_1 = v_{central} = \sqrt{19,62 \times 444,41861 \times 10^{-3}} \checkmark$$

$$= 2,95288 \text{ m/s} \checkmark$$

also, $v_{mean} = 0,82 \times 2,95288 \checkmark$

$$= 2,42136 \text{ m/s} \checkmark$$

$$Q_{pipe} = A v_{mean}$$

$$= \frac{\pi \times 0,065^2 \times 2,42136}{4} \checkmark$$

$$= 8,03482 \text{ l/s} \checkmark$$

(7)

5.3 5.3.1

$$\text{from, } C_c = \frac{A_{vena}}{A_{orifice}} = \frac{d_v^2}{d_o^2}$$

$$0,65 = \frac{d_v^2}{50^2} \checkmark$$

$$d_v = \sqrt{0,65 \times 50^2} \checkmark$$

$$= 40,311 \text{ mm} \checkmark$$

(3)

5.3.2 from Torricelli's theorem :

where, $v = \sqrt{2gh}$

$$\text{now, } v_o = \sqrt{19,62 \times 42,5} \checkmark$$

$$= 28,87646 \text{ m/s} \checkmark$$

$$\text{from, } C_v = \frac{v_v}{v_o}$$

$$v_v = 0,98 \times 28,87646 \checkmark$$

$$= 28,299 \text{ m/s} \checkmark$$

(4)

5.3.3 *from, $Q = \text{area} \times \text{velocity}$*

$$Q_v = \frac{\pi \times 40,311 \times 10^{-3}}{4 \times 28,299} \checkmark$$

$$= 1,11878 \times 10^{-3} \checkmark$$

$$= 1,119 \text{ l/s} \checkmark$$

(2)

5.3.4 *from, $h_{\text{loss}} = h_{\text{water}} (1 - C_v^2)$*

$$= 42,5 (1 - 0,98^2)$$

$$= 1,683 \text{ m} \checkmark$$

alternatively:

$$h_{\text{loss}} = h - \frac{v_v^2}{2g}$$

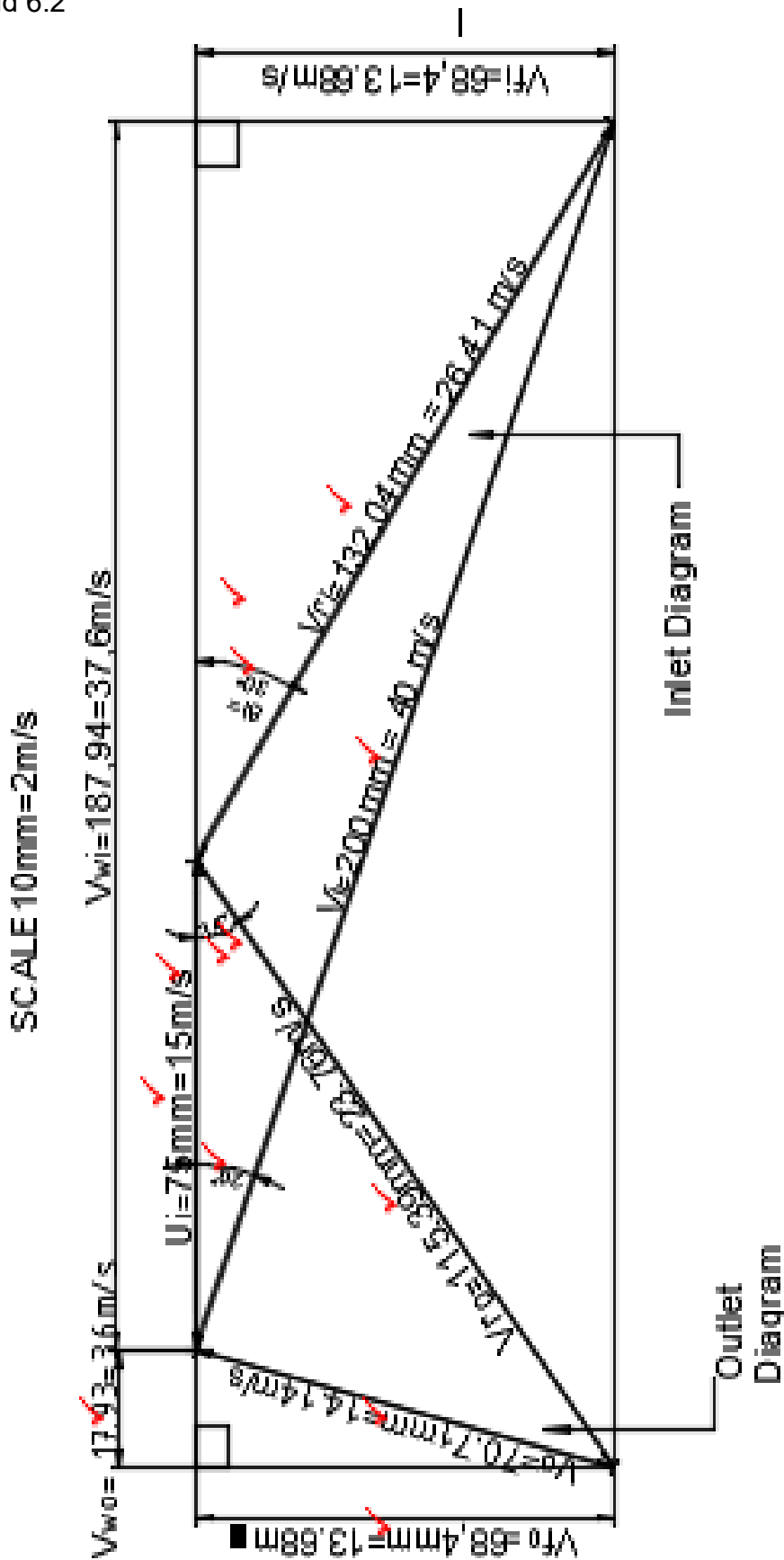
$$= 42,5 - \left(\frac{28,299^2}{19,62} \right)$$

$$= 1,683 \text{ m} \checkmark$$

(2)
[20]

QUESTION 6

6.1 and 6.2



PLEASE NOTE THAT THIS DIAGRAM IS ACCURATELY DONE AND MUST ALLOW PLUS /MINUS 1mm WHEN DONE BY HAND USING INSTRUMENTS.

6.1 VANE SPEED

$$U = \frac{\pi DN}{60} = \frac{\pi \times 0,4 \times 716,19}{60} = 15 \text{ m / s}$$

FROM INLET DIAGRAM

$$V_{wi} = 37,6 \text{ m / s}; V_{ri} = 26,4 \text{ m / s}; \theta_i = 31^\circ$$

$$\therefore V_{ro} = 0,9 \times V_{ri} = 0,9 \times 26,4 \text{ m / s}$$

Mark allocation is indicated on the diagram.

(7)

6.2 FROM OUTLET DIAGRAM

$$V_{wo} = 3,6 \text{ m / s}; V_o = 14,14 \text{ m / s}$$

Mark allocation is indicated on the diagram.

(6)

6.3 OUTLET POWER

$$\begin{aligned} P_o &= m(V_{wi} - V_{wo})U \\ &= 20[37,6 - (-3,6)]15 \\ &= 12,16 \text{ kN} \end{aligned}$$

(4)

6.4 INPUT POWER

$$\begin{aligned} P_i &= \frac{1}{2} m(V_i)^2 \\ &= \frac{1}{2} \times 20 \times 40 \\ &= 16 \text{ kN} \\ \eta &= \frac{P_o}{P_i} \times 100\% \\ &= \frac{12,16}{16} \times 100\% \\ &= 76\% \end{aligned}$$

(3)

[20]

TOTAL: 100