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

$$\omega = \frac{2\pi N}{60}$$
$$= \frac{2 \times \pi \times 3500}{60}$$
$$= 366{,}52 Rad/\sec \quad ✓$$

$$\overset{\circ}{x} = \omega R \; ✓$$
$$= 366{,}52 \times \frac{0{,}046}{2}$$
$$= 8{,}4299 m/\sec \quad √$$

$$Area = \pi d l \; √$$
$$= \pi \times 0{,}046 \times 0{,}05$$
$$= 7{,}225 \times 10^{-3} m$$

$$C_r = \frac{D-d}{2} \quad √$$
$$= \frac{0{,}0463 - 0{,}046}{2} \quad √ \quad √$$
$$= 0{,}00015 m \quad √$$

$$Power = \frac{\mu \times A \times \overset{\circ}{x} \times D \times \omega}{2C_r} \quad ✓ \quad ✓ \quad ✓$$
$$= \frac{0{,}7 \times 7{,}225 \times 10^{-3} \times 8{,}4299 \times 0{,}046 \times 366{,}52}{2 \times 0{,}00015}$$
$$= 2396{,}04 W \quad ✓$$

(9)

1.2.2

$$Power = \frac{\mu \times A \times \overset{\circ}{x} \times D \times \omega}{2C_r} \checkmark$$

$$= \frac{0,1 \times 7,225 \times 10^{-3} \times 8,4299 \times 0,046 \times 366,52}{2 \times 0,00015} \checkmark \checkmark$$

$$= 342,29W \checkmark$$

$$Change\ in power = 2396,03 - 342,29$$

$$= 2053,74W \checkmark$$

(5)

1.2.3

$$\mu = \frac{\mu}{\rho}$$

$$= \frac{0,1}{850} \checkmark$$

$$= 1,1764 \times 10^{-4} \checkmark$$

(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 $Consider\ the\ rod\ side\ of\ the\ cylinder:$

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

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

$$=3,71101\times10^{-3}m^2$$

$$and,F_{rod}=PA_{rod}$$

$$=20\times10^3\times3,71101\times10^{-3}$$

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

$Consider\ the\ piston\ side\ of\ the\ cylinder:$

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

$$=\frac{\pi\times0,075^2}{4}$$

$$\therefore A_{piston}=4,41787\times10^{-3}m^2$$

$$F_{piston}=PA_{piston}$$

$$=20\times10^3\times4,41787\times10^{-3}$$

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

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

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

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

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

(6)

2.3 $consider\ the\ impact\ of\ oil\ in\ the\ tank:$

$$From, K = \Delta P \times \varepsilon$$

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

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

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

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

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

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

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

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

$consider\ the\ impact\ of\ water\ in\ the\ tank:$

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

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

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

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

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

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

$consider\ overall\ change\ in\ the\ tank:$

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

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

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

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

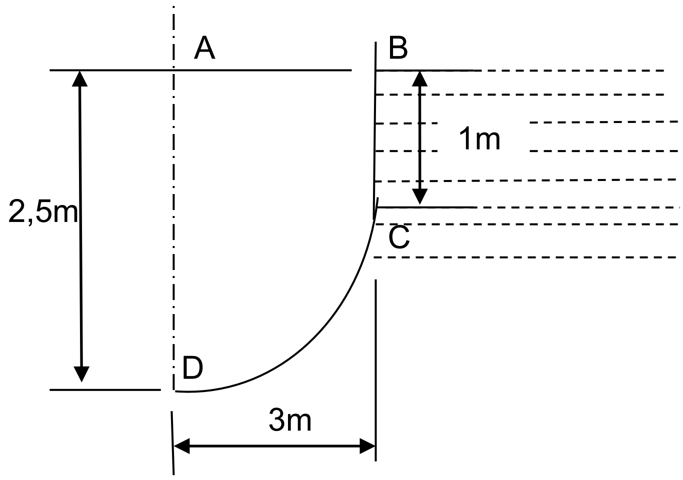
$$thus, \Delta h_{total} = \frac{4 \times 433,68467 \times 10^{-6}}{\pi \times 0,7^2}$$

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

(10)
[20]

QUESTION 3

3.1



FIND FORCE AND DIRECTION

$$AREA_{ABCD} = (3\times3) + (\frac{2}{3}\times3\times1,5)$$
$$= 6m^2$$

$$Volume\ per\ meter = Area\times length$$
$$= 6\times1$$
$$= 6m^3$$

HORIZONTAL COMPONENT

$$H = \rho g A\bar{y}$$
$$= 1025\times9,81\times(2,5\times1)\times\frac{2,5}{2}$$
$$= 31,423kN$$

VERTICAL COMPONENT

$$V = \rho g V$$
$$= 1025\times9,81\times6$$
$$= 60,332kN$$

RESULTANT

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

DIRECTION

$$Tan\theta = \frac{V}{H}$$
$$\theta = Tan^{-}\frac{60,332}{31,423}$$
$$= 62,488^0$$

(10)

3.2 $\boldsymbol{Area\,of\;\;piston}$

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

$\boldsymbol{Volume\;\;of\;\;ball}$

$$\forall_{Ball} = \frac{4}{3}\pi r^2$$
$$= \frac{4}{3} \times \pi \times 0{,}06^2$$
$$= 9{,}0478 \times 10^{-4} m^3$$

$$\forall_{Submerged} = 9{,}0478 \times 10^{-4} \times \frac{1}{4}$$
$$= 2{,}2619 \times 10^{-4} m^3$$

$$R = \rho g \forall_{submerged}$$
$$= 1000 \times 9{,}81 \times 2{,}2619 \times 10^{-4}$$
$$= 2{,}2189 N$$

$\boldsymbol{Take\;\;moments\;\;about\;\;pivot}$

$$\therefore F_{piston} \times dis\tan ce = R \times dis\tan ce$$

$$\therefore F_{piston} = \frac{2{,}2189 \times 0{,}21}{0{,}02}$$
$$= 23{,}2987 N$$

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

$$consider\ the\ ball:$$

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

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

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

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

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

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

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

$$Application\ of\ Archimedes\ law\ for\ partially\ or\ fully\ submerged\ objects\ \text{in}\ fluids:$$

$$where, F_{ball} = F_{bouyancy} \quad \surd$$

$$= \rho g V_{\substack{water\\displaced}} \quad \surd$$

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

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

$$During\ the\ system\ \text{in}\ operation, application\ of\ moments\ about\ the\ pivot\ point:$$

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

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

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

$$thus, the\ pressure\ exerted:$$

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

$$= 179,623 kPa \quad \checkmark$$

(10)
[20]

QUESTION 4

4.1 4.1.1

$$from, Q_o = area \times velocity$$
$$= \frac{\pi \times 0,04^2 \times 4,25}{4}$$
$$= 0,005340707$$
$$= 5,341\ l/s$$
(2)

4.1.2

$$From, \overset{o}{m} = mass \times velocity$$
$$also, \overset{o}{m} = \rho Q$$
$$= 900 \times 5,341 \times 10^{-3}$$
$$\therefore \overset{o}{m} = 4,807 kg/s$$
(2)

4.1.3

$$from, Q_{inlet} = Q_{outlet} ...continuity\ of\ flow\ principle:$$
$$thus, v_i = \frac{d_o^2}{d_i^2} \times v_o$$
$$= \frac{40^2}{70^2} \times 4,25$$
$$= 1,388 m/s$$
OR
$$alternatively, v_i = \frac{4 \times 5,341 \times 10^{-3}}{\pi \times 0,07^2}$$
$$\therefore v_i = 1,388 m/s$$
(2)

4.1.4

$$from, Q_{inlet} = Q_{outlet} = Q_{leg\text{-}1} + Q_{leg-2} ...continuity\ of\ flow\ principle:$$
$$as, Q_{leg-1} = \frac{3}{5} \times Q_{inlet}$$
$$5,341 \times 10^{-3} = \frac{3 \times 5,341 \times 10^{-3}}{5} + Q_{leg-2}$$
$$\therefore Q_{leg-2} = 2,1364\ l/s$$
$$from, Q = Av$$
$$d_{leg-2} = \sqrt{\frac{2,1364 \times 10^{-3} \times 4}{\pi \times 3,25}}$$
$$= 28,93 mm$$
$$Q_{leg\text{-}1} = 5,341 \times 10^{-3} - 2,1364 \times 10^{-3} = \frac{\pi \times d_{leg-1}^2}{4} \times 3,25$$
$$d_{leg-2} = \sqrt{\frac{\left(5,341 \times 10^{-3} - 2,1364 \times 10^{-3}\right) \times 4}{\pi \times 3,25}}$$
$$\therefore d_{leg-2} = 35,432 mm$$
(6)

4.2 4.2.1

$$from, Q = Av$$

$$thus, v_i = \frac{4Q}{\pi d_i^2} \quad \surd$$

$$= \frac{4 \times 20 \times 10^{-3}}{\pi \times 0{,}12^2} \quad \surd$$

$$\therefore v_i = 1{,}768 m/s \quad \surd$$

$$and, v_o = \frac{4 \times 20 \times 10^{-3}}{\pi \times 0{,}18^2} \quad \checkmark$$

$$\therefore v_o = 0{,}786 m/s \quad \surd$$

(3)

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

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

When using inlet as the reference energy point:

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

$$\therefore P_o = 58{,}28991 \times 9810 \quad \checkmark$$

$$= 571{,}824 kPa \quad \surd$$

(5)

[20]

QUESTION 5

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

5.2

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

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

$$= 444,41861mm \checkmark$$

$$At\ the\ stagnation\ point, v_2 = 0$$

$$From\ Bernoulli's\ energy\ equation:$$

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

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

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

$$= 2,95288m/s \checkmark$$

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

$$= 2,42136m/s \checkmark$$

$$Q_{pipe} = Av_{mean}$$

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

$$= 8,03482\ l/s \checkmark$$

(7)

5.3 5.3.1

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

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

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

$$= 40,311mm \checkmark$$

(3)

5.3.2

$$from, Torricelli's\ theorem:$$

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

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

$$= 28,87646m/s \checkmark$$

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

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

$$= 28,299m/s \checkmark$$

(4)

5.3.3 $from, Q = area \times velocity$

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

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

$$= 1,119\ l/s \surd$$ (2)

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

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

$$= 1,683m \checkmark$$

alternatively :

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

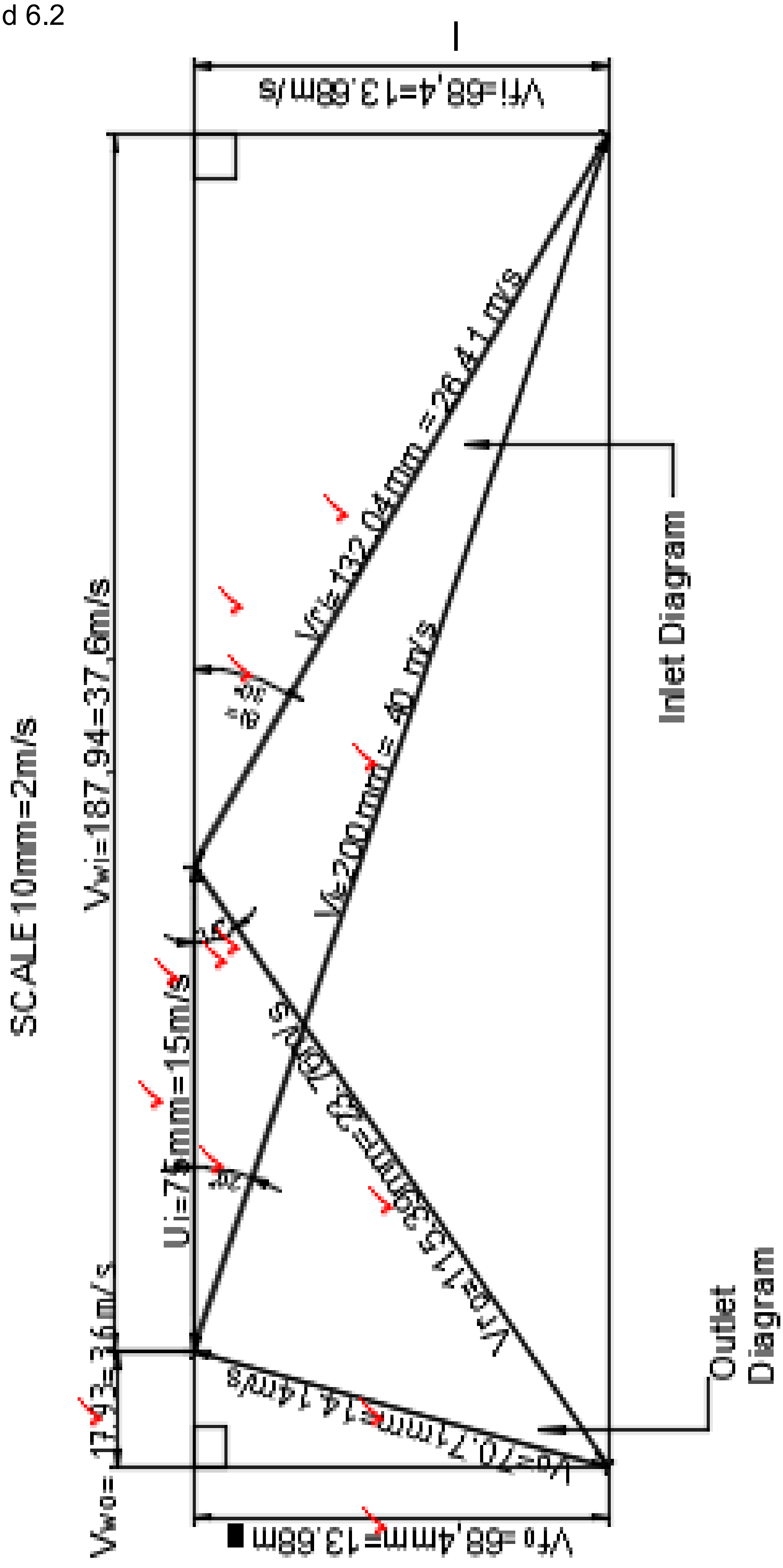
$$= 42,5 - \left(\frac{28,299^2}{19,62}\right) \surd \surd$$

$$= 1,683m \checkmark$$ (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

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

FROM INLET DIAGRAM

$$V_{wi} = 37{,}6 m/s; V_{ri} = 26{,}4 m/s; \theta_i = 31^0$$

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

Mark allocation is indicated on the diagram. (7)

6.2 FROM OUTLET DIAGRAM

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

Mark allocation is indicated on the diagram. (6)

6.3 OUTLET POWER

$$P_o = m(V_{wi} - V_{wo})U \checkmark$$

$$= 20 \checkmark [37{,}6 - (-3{,}6)]15 \checkmark$$

$$= 12{,}16 kN \checkmark$$

(4)

6.4 INPUT POWER

$$P_I = \frac{1}{2} m (V_i)^2 \quad \surd$$

$$= \frac{1}{2} \times 20 \times 40 \quad \surd$$

$$= 16 kN \quad \surd$$

$$\eta = \frac{P_i}{P_o} \times 100\% \quad \surd$$

$$= \frac{12{,}16}{16} \times 100\% \quad \surd$$

$$= 76\% \quad \surd$$

(3)

[20]

TOTAL: 100