



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

FLUID MECHANICS N5

10 April 2024

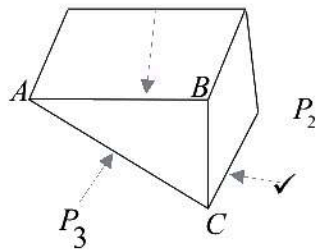
This marking guideline consists of 11 pages.

QUESTION 1

- 1.1 1.1.1 Pressure is the force exerted by a fluid on any surface✓ with which it is in contact or by one part of a fluid on the adjoining parts.✓
- 1.1.2 Atmospheric pressure is the pressure acting or exerted on the surface✓ of the earth due to the weight of the atmospheric pressure.✓
- 1.1.3 Absolute pressure is the pressure which is measured above absolute zero✓ and is the sum of the atmospheric and gauge pressure.✓
- 1.1.1 Gauge pressure is the intensity of pressure measured above or below atmospheric pressure✓ and is measured using a gauge device.✓
- (2 × 4) (8)
- 1.2 1.2.1 $SG = \frac{\rho_{ice}}{\rho_{water}}$
 $\rho_{ice} = SG \times \rho_{water}$
 $= 1,1 \times 1000 \checkmark$
 $= 1100 kg / m^3 \checkmark$ (2)
- 1.2.2 $W = mg = \rho V_{ice} g$
 $= (1100 \times 2) \times 9,81 \checkmark$
 $= 21,582 kN \checkmark$ (3)
- 1.2.3 $W_{ice} = F_{bouyancy}$
 $\rho_{ice} V_{ice} g = \rho_w V_{disp} g \checkmark$
 $21,582 \times 10^3 = 1000 \times 2 \times 2 \times h \times 9,81 \checkmark$
 $V_{disp} = 4h = \frac{21,582 \times 10^3}{9810} \checkmark$
 $h = \frac{2,2}{4} \checkmark$
 $= 0,55m \checkmark$ (5)
- 1.3 Surface tension is the tension induced due to the cohesion of forces between molecules on the surface of the fluid (liquid) which adjoins another immiscible fluid (liquid).✓ This is also the property that allows objects to float on its surface and is measured in N/m.✓ (2)
- [20]**

QUESTION 2

2.1



let force acting on place $AB = \text{Pressure} \times \text{plane} \times \text{width}$

consider a small triangular prism has a unit width of 1m

since the fluid is at rest, the forces are in equilibrium and perpendicular to the faces which they act

Resolving vertical direction :

$$P_1 \times AB \times w = P_3 \times AC \times w \cos \theta \quad \checkmark$$

using trigonometrical ratios

$$AC \cos \theta = AB \quad \checkmark$$

$$\text{thus, } P_1 = P_3 \quad \checkmark$$

Resolving horizontal direction

$$P_2 \times BC \times w = P_3 \times AC \times w \sin \theta \quad \checkmark$$

$$\text{since, } AC \sin \theta = BC \quad \checkmark$$

$$\text{thus, } P_2 = P_3 \quad \checkmark$$

therefore, $P_1 = P_2 = P_3$ and since AC is at any angle θ to AB . $\checkmark$

P_3 is the intensity of pressure in any direction

therefore the intensity of pressure at a point is the same in all direction in a fluid at rest

(7)

2.2

$$\begin{aligned} 2.2.1 \quad P_{\text{gauge}} &= \rho gh \\ &= 1030 \times 1,3 \times 9,81 \quad \checkmark \\ &= 13,136 \text{ kPa} \quad \checkmark \end{aligned}$$

(2)

$$\begin{aligned} 2.2.2 \quad P_{\text{atm}} &= \rho gh \\ &= 13600 \times 9,81 \times 0,62 \quad \checkmark \\ &= 82,718 \text{ kN} \\ P_{\text{abs}} &= P_{\text{atm}} + P_{\text{gauge}} \\ &= 82,718 + 13,136 \quad \checkmark \\ &= 69,582 \quad \checkmark \end{aligned}$$

(3)

$$\begin{aligned}
 2.3 \quad 2.3.1 \quad \frac{1}{K_{eff}} &= \frac{1}{K_{cyl}} + \frac{1}{K_{liq}} \\
 K_{eff} &= \frac{K_{cyl} \times K_{liq}}{K_{liq} + K_{cyl}} \\
 &= \frac{(1,85 \times 8)10^9}{1,85 \times 10^9 + 8 \times 10^9} \checkmark \\
 &= 1,503 GPa \checkmark
 \end{aligned} \tag{2}$$

$$\begin{aligned}
 2.3.2 \quad K_{air} &= \frac{1,4 \times 2000 \times 4}{\pi \times 0,05^2} \\
 &= 1,426 MPa \checkmark
 \end{aligned}$$

$$\begin{aligned}
 V &= A \times l \\
 &= \frac{\pi}{4} \times 0,05^2 \times 0,1 \\
 &= 196,35 \times 10^{-6} m^3 \checkmark
 \end{aligned}$$

$$\begin{aligned}
 \frac{1}{K_{eff}} &= \frac{1}{K_{cyl}} + \frac{1}{K_{liq}} + \frac{\%V_{air}}{V_{cyl}K_{air}} \\
 \%V_{air} &= 196,35 \times 10^{-6} \times 1,426 \times 10^6 \left(\frac{1}{68 \times 10^6} - \frac{1}{1,85 \times 10^9} - \frac{1}{8 \times 10^9} \right) \checkmark \\
 \%V_{air} &= \frac{k \times V_{cyl}}{100} = 3,93123 \times 10^{-6} \checkmark \\
 \therefore k &= \frac{3,93123 \times 10^{-6}}{196,35 \times 10^{-6}} \times 100\% \checkmark \\
 k &= 2\% \checkmark
 \end{aligned}$$

(6)
[20]

QUESTION 3

3.1 3.1.1

hydrostatic force

$$F_h = \rho g y A$$

$$y = \frac{2,3}{2} = 1,15m \checkmark$$

$$A = 2,3 \times 3,5$$

$$= 8,05m \checkmark$$

$$F_{hydro} = 9810 \times 8,05 \times 1,15$$

$$= 90,81608kN \checkmark$$

force on bolts

$$\sum M_{bolt} = 0$$

$$\sum M_{bolt} (CW) = \sum M_{bolt} (ACW)$$

$$F_{bolt} \times h_{bolt} = F_{hydro} \times h_{hydro} \checkmark$$

$$F_{bolt} = \frac{90,81608 \times 0,66667}{1} \checkmark$$

$$= 60,544kN \checkmark$$

$$\sum M_{hinge} = 0$$

$$\sum M_{hinge} (CW) = \sum M_{hinge} (ACW)$$

$$F_{hinge} \times h_{hinge} = F_{hydro} \times h_{hydro} \checkmark$$

$$F_{bolt} = \frac{90,81608 \times 0,3333}{1} \checkmark$$

$$= 30,272kN \checkmark$$

(8)

3.1.2

$$F_{hydro} = 9810 \times 12 \times 8,05 \checkmark$$

$$= 947,646kN \checkmark$$

(2)

3.2.1

volume of seawater displaced

$$F_{buoyancy} = F_{ship}$$

$$\rho g V_{displaced} = m_{ship} g \checkmark$$

$$V_{displaced} = \frac{50000}{1035} \checkmark$$

$$= 48,309m^3 \checkmark$$

(3)

3.2.2 *volume of fresh water displaced*

$$F_{\text{buoyancy}} = F_{\text{ship}}$$

$$\rho g V_{\text{displaced}} = m_{\text{ship}} g$$

$$V_{\text{displaced}} = \frac{50000}{1000} \checkmark$$

$$= 50 \text{ m}^3 \checkmark$$

(2)

3.2.3 *volume of seawater displaced*

$$V_{\text{displaced}} = (48,309 \times 30\%) + 48,309 = 62,8017 \text{ m}^3 \checkmark$$

$$F_{\text{buoyancy}} = F_{\text{ship}}$$

$$\rho g V_{\text{displaced}} = m_{\text{ship}} g \checkmark$$

$$= 1035 \times 62,8017 \checkmark$$

$$\therefore m = 64,1876 \text{ tons} \checkmark$$

(5)
[20]

QUESTION 4

4.1.1 Steady flow – the cross-sectional area and velocity of a stream may vary from cross-section to cross-section, however will not vary regarding time, ✓ e.g., tapering pipe. ✓

4.1.2 Unsteady flow – the cross-sectional area and velocity of a stream varies with time, ✓ e.g., wave in a channel. ✓

4.1.3 Uniform flow – the cross-sectional area and velocity of a stream are the same at successive sections, ✓ e.g., pipe of constant diameter running full. ✓

4.1.4 Non-uniform flow – the cross-sectional area and velocity of a stream are not the same at successive sections, ✓ e.g., pipe of constant diameter delivering water from reciprocating pump. ✓

(2 × 4)

(8)

$$\begin{aligned}
 4.2 \quad 4.2.1 \quad V &= \frac{m}{\rho} \\
 &= \frac{10000}{950} \checkmark \\
 &= 10,526316 m^3 \checkmark \\
 Q &= \frac{V}{t} \\
 t &= \frac{10,526316}{12 \times 10^{-3}} \checkmark \\
 &= 877,193 \text{ sec} \checkmark \\
 &= 14,62 \text{ min} \checkmark
 \end{aligned} \tag{5}$$

$$\begin{aligned}
 4.2.2 \quad P &= \rho gh \\
 &= 950 \times 9,81 \times 4 \checkmark \\
 &= 37,278 kPa \checkmark
 \end{aligned} \tag{2}$$

$$\begin{aligned}
 4.2.3 \quad &\text{applying Bernoulli's theorem :} \\
 &\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2 \checkmark \\
 &\text{since : } P_1 = P_2 \dots \text{atmospheric conditions} \\
 &v_1 \approx 0 \\
 &\text{thus, } Z_1 = \frac{v_2^2}{2g} + Z_2 \checkmark \\
 &v_2^2 = 2g(Z_1 - Z_2) \checkmark \\
 &= \sqrt{19,62 \times 6} \checkmark \\
 &\therefore v_2 = 10,85 m/s \checkmark
 \end{aligned}$$

(5)
[20]

QUESTION 5

5.1 A rota-flow meter is used to measure the flow of a fluid✓ while a pitot tube is used to measure the velocity of a fluid.✓ (2)

5.2 *mean velocity*

$$v_{mean} = \frac{4Q}{\pi d^2}$$

$$= \frac{4 \times 50 \times 10^{-3}}{\pi \times 0,15^2} \checkmark$$

$$= 4,42097 \text{ m/s} \checkmark$$

maximum velocity

$$v_{mean} = 0,75 v_{max} \checkmark$$

$$\therefore v_{max} = \frac{4,42097}{0,75} \checkmark$$

$$= 5,89463 \text{ m/s} \checkmark$$

head of air

from :

$$v_{max} = \sqrt{2gh_a}$$

$$h_a = \frac{5,89463^2}{19,62} \checkmark$$

$$\therefore h_a = 1,77098 \text{ m} \checkmark$$

manometric head of water

$$h_a = h_w \left[\frac{\rho_w}{\rho_a} - 1 \right]$$

$$h_w = \frac{h_a}{\left[\frac{\rho_w}{\rho_a} - 1 \right]} \checkmark$$

$$h_w = \frac{1,77098}{\left[\frac{1000}{1,3} - 1 \right]} \checkmark$$

$$= 2,305 \text{ m} \checkmark$$

(10)

5.3 head loss for fittings

$$\text{from : } h_l = \frac{kv^2}{2g}$$

$$\text{and : } h_f = \frac{4flv^2}{2gd}$$

$$\text{since : } \frac{l}{d} = \frac{k}{4f}$$

$$\text{thus : } h_{\text{valve}} = \frac{4fv^2}{2g} \times \frac{l}{d}$$

$$= \frac{4 \times 0,007 \times 3^2}{19,62} \times 8 \checkmark$$

$$= 102,752 \text{ mm} \checkmark$$

$$h_{\text{filter}} = \frac{4fv^2}{2g} \times \frac{l}{d}$$

$$= \frac{4 \times 0,007 \times 3^2}{19,62} \times 6 \checkmark$$

$$= 77,064 \text{ mm} \checkmark$$

$$P_{\text{valve}} = \rho gh_{\text{valve}}$$

$$= 920 \times 9,81 \times 102,752 \times 10^{-3} \checkmark$$

$$= 927,36 \text{ Pa} \checkmark$$

$$P_{\text{valve}} = \rho gh_{\text{valve}}$$

$$= 920 \times 9,81 \times 77,064 \times 10^{-3} \checkmark$$

$$= 695,518 \text{ Pa} \checkmark$$

(8)
[20]

QUESTION 6

- 6.1 Bernoulli's theorem states that the total energy per particle of a body of fluid will be the same throughout provided that no energy is supplied or removed from the system at any point in time. ✓

(2)

$$\begin{aligned}
 6.2 \quad 6.2.1 \quad h_{loss}(\text{system}) &= h_{loss}(\text{filter}) + h_{loss}(\text{pipeline}) \\
 h_{loss}(\text{filter}) &= \frac{kv^2}{2g} \\
 &= \frac{3 \times 3^2}{19,62} \\
 &= 1,376m \quad \checkmark \\
 h_{loss}(\text{pipeline}) &= \frac{4flv^2}{2gd} \\
 &= \frac{4 \times 0,001 \times 4000 \times 3^2}{19,62 \times 0,05} \\
 &= 146,789m \quad \checkmark \\
 \therefore h_{loss}(\text{system}) &= 1,376 + 146,789 \quad \checkmark \\
 &= 148,165m \quad \checkmark
 \end{aligned} \tag{4}$$

6.2.2 *for maximum power conditions :*

$$H_{inlet}(\text{energy head}) = 3h_f(\text{friction head})$$

Applying Bernoulli's theorem and equation

$$H_{inlet} = \frac{P}{\rho g} + \frac{v^2}{2g} + Z$$

under these conditions :

$$Z_i = Z_o$$

$$v_i = v_o$$

$$\therefore H_{inlet} = \frac{6 \times 10^6}{900 \times 9,81} = 679,578m \quad \checkmark$$

$$h_f = \frac{679,578}{3} = 226,526m \quad \checkmark$$

$$h_f = \frac{flQ^2}{3d^5}$$

$$Q = \sqrt{\frac{3 \times 226,526 \times 0,05^5}{0,001 \times 4000}}$$

$$\therefore Q = 7,286l/s \quad \checkmark$$

$$P_{outlet} = \rho g Q H_{outlet}$$

$$= 900 \times 9,81 \times 7,286 \times 10^{-3} (679,578 - 226,526) \quad \checkmark$$

$$\therefore P_{outlet} = 29,146kW \quad \checkmark$$

(5)

6.3 6.3.1

$$\begin{aligned}
 \overset{0}{m} &= \rho Q = \rho A_{jet} v_{jet} \\
 &= 1000 \times \frac{\pi \times 0,025^2}{4} \times 11 \\
 &= 5,3996 \text{ kg / s } \checkmark
 \end{aligned}$$

$$\begin{aligned}
 \overset{0}{F}_{jet} &= m v_{jet} \\
 &= 5,3996 \times 11 \\
 &= 59,396 \text{ N } \checkmark
 \end{aligned}$$

the turning moments theorem the hinge point is applied

$$\begin{aligned}
 F_{plate} \times y_{plate} &= F_{jet} \times y_{jet} \\
 y_{plate} &= \frac{59,396 \times 0,35}{2 \times 30} \checkmark \\
 &= 346,475 \text{ mm } \checkmark
 \end{aligned}$$

(4)

6.3.2

when the plate is 40° to the vertical

the turning moments theorem the hinge point is applied

$$\begin{aligned}
 F_{plate} \times y_{plate} &= mg \times y_{jet} \\
 59,396 \times \frac{0,35}{2} &= m \times 9,81 \times \frac{0,35}{2} \sin 40 \checkmark \\
 m &= \frac{59,396}{\sin 40 \times 9,81} \checkmark \\
 &= 9,419 \text{ kg } \checkmark \\
 \rho &= \frac{9,419}{0,35^3} \checkmark \\
 &= 76,893 \text{ kg / m}^3 \checkmark
 \end{aligned}$$

(5)
[20]

TOTAL: 100