



# higher education & training

---

Department:  
Higher Education and Training  
**REPUBLIC OF SOUTH AFRICA**

## **MARKING GUIDELINE**

**NATIONAL CERTIFICATE**

**FLUID MECHANICS N5**

**1 December 2023**

**This marking guideline consists of 10 pages.**

**QUESTION 1**

1.1 Kinematic viscosity is the ratio between the dynamic viscosity ✓ and the density of a fluid and is measured in  $m^2/s$ . ✓ (2)

1.2 The high viscosity will cause the oil to have a large shear resistance to motion, ✓ resulting in high power loss. ✓ (2)

1.3 1.3.1 *radial clearance*

$$t = \frac{D - d}{2}$$

$$= \frac{120,2 - 120}{2}$$

$$= 0,1 \text{ mm} \checkmark$$

*tan gential velocity*

$$v = \frac{\pi d N}{60}$$

$$= \frac{\pi \times 0,12 \times 1100}{60} \checkmark$$

$$= 6,9115 \text{ m/s} \checkmark$$

*shear stress*

$$\tau = \frac{\mu v}{t} = \frac{0,42 \times 6,9115}{0,1} \checkmark$$

$$= 29,028 \text{ kPa} \checkmark$$

*shear force*

$$F = \tau A$$

$$= 29,028 \times \pi \times 0,12 \times 0,1 \checkmark$$

$$= 1094,342 \text{ N} \checkmark$$

$$P = Fv$$

$$= 1094,342 \times 6,9115 \checkmark$$

$$= 7,564 \text{ kW} \checkmark$$

(9)

1.3.2 *rotaional frequency*

$$F = \frac{\mu v}{t} \times A$$

$$= \frac{0,42 \times v}{100 \times 10^{-6}} \times \pi \times 0,12 \times 0,1 \checkmark$$

$$\therefore F = 158,33627 \text{ v} \checkmark \text{ ¶}$$

$$P = Fv$$

$$3000 = 158,33627 v \times v \checkmark$$

$$\therefore v = 4,353 \text{ m/s} \checkmark$$

$$v = \pi d n$$

$$n = \frac{4,353}{\pi \times 0,12}$$

$$= 11,546 \text{ r/s} \checkmark$$

(5)

1.3.3

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

$$= \frac{0,42}{900} \checkmark$$

$$= 466,667 \times 10^{-6} \text{ m}^2/\text{s} \checkmark$$

(2)

[20]

**QUESTION 2**

2.1 2.1.1

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

$$A = \frac{\pi \times 0,08^2}{4} \checkmark$$

$$= 5,02665 \times 10^{-3} \text{ m}^2 \checkmark$$

$$\therefore P = \frac{3,5 \times 1000}{5,02665 \times 10^{-3}} \checkmark$$

$$= 696,303 \text{ kPa} \checkmark$$

(3)

2.1.2

$$Q_{\text{forward}} = Q_{\text{return}} \checkmark$$

$$\frac{\pi D^2 \times SL_f}{4t_f} = \frac{\pi(D^2 - d^2) \times SL_r}{4t_r}$$

$$\text{since } t_r = \frac{5}{8} t_f \checkmark$$

now:

$$D^2 = \frac{8(D^2 - d^2)}{5} \checkmark$$

$$d = \sqrt{D^2 - \frac{5D^2}{8}} \checkmark$$

$$= \sqrt{0,08^2 - \frac{5 \times 0,08^2}{8}} \checkmark$$

$$\therefore d = 48,99 \text{ mm} \checkmark$$

(5)

2.1.3

$$t_r = \frac{V}{Q} = \frac{A \times SL}{Q}$$

$$= \frac{\pi(0,08^2 - 0,04899^2) \times 0,3}{4 \times 0,85 \times 10^{-3}} \checkmark$$

$$= 1,109 \text{ sec } s \checkmark$$

$$t_r = \frac{V}{Q} = \frac{A \times SL}{Q}$$

$$= \frac{\pi \times 0,08^2 \times 0,3}{4 \times 0,85 \times 10^{-3}} \checkmark$$

$$= 1,774 \text{ sec } s \checkmark \quad (4)$$

2.2 A barometer is used to measure atmospheric pressure. ✓ The vacuum at the top surface of the fluid creates a lift towards the closed end of the tube. ✓ (2)

2.3 *consider oil*

$$\Delta P = K \frac{\Delta V}{V}$$

$$V = A \times h$$

$$\Delta V = A \times \Delta h$$

$$\Delta h_o = \frac{h \times \Delta P}{K} \checkmark \checkmark$$

$$= \frac{0,8 \times 1}{2060} \checkmark \checkmark$$

$$= 388,3495 \times 10^{-6} \text{ mm } \checkmark$$

*consider water*

$$\Delta P = K \frac{\Delta V}{V}$$

$$V = A \times h$$

$$\Delta V = A \times \Delta h$$

$$\Delta h_w = \frac{h \times \Delta P}{K} \checkmark \checkmark$$

$$= \frac{1,3 \times 1}{2100} \checkmark \checkmark$$

$$= 619,04762 \times 10^{-6} \text{ mm } \checkmark \checkmark$$

*downward movement*

$$\Delta h_{total} = 619,04762 \times 10^{-6} + 388,3495 \times 10^{-6} \checkmark$$

$$= 1,007 \text{ mm } \checkmark \checkmark$$

(6)  
 [20]

**QUESTION 3**

- 3.1 The principle of Archimedes states that the upward thrust or force of buoyancy acting on a body immersed or submerged in a fluid ✓ is equal to the weight of the fluid displaced. ✓ The greater the density of the fluid, ✓ the greater the effect of the upward thrust or force of buoyancy. ✓ (4)

- 3.2 3.2.1 *consider oil :*

$$P_{oil-1} = \frac{\rho g h_{oil-1}}{2}$$

$$= \frac{900 \times 9,81 \times 2}{2}$$

$$= 8829 Pa \checkmark \uparrow$$

$$F_{oil-1} = P_{oil-1} \times A_{oil-1}$$

$$= 8829 \times 3,5 \times 2 \checkmark \uparrow$$

$$= 61,803 kN \checkmark \uparrow$$

$$F_{oil2} = 900 \times 9,81 \times 2 \times 3,5 \times 3 \checkmark$$

$$= 238,383 kN \checkmark \uparrow$$

*consider water*

$$P_w = \frac{\rho g h_w}{2}$$

$$= \frac{1000 \times 9,81 \times 3}{2}$$

$$= 14715 Pa \checkmark \uparrow$$

$$F_w = P_w \times A_w$$

$$= 8829 \times 3,5 \times 2 \checkmark \uparrow$$

$$= 103,005 kN \checkmark \uparrow$$

*Total hydrostatic force*

$$F_{total} = F_{oil-1} + F_w + F_{oil2}$$

$$= 61,803 + 238,383 + 103,005 \checkmark$$

$$= 403,191 kN$$

(10)

3.2.2  $h_{oil-1} = 3 + \frac{2}{3} = 3,6667 m \checkmark$

$$h_{oil-2} = \frac{3}{2} = 1,5 m \checkmark \uparrow$$

$$h_w = \frac{3}{3} = 1 m \checkmark \uparrow$$

moments taken about the turning point :

$$(F_w \times h_w) + (F_{oil-1} \times h_{oil-1}) + (F_{oil-2} \times h_{oil-2}) = F_{total} y_{total}$$

$$(103,005 \times 1) + (61,803 \times 3,6667) + (238,383 \times 1,5) = 403,191 y_{total} \checkmark$$

$$y_{total} = 1,704 m \text{ (from bottom)} \checkmark \parallel$$

$$y_{total} = 5 - 1,704 = 3,3 m \text{ (from free surface)} \checkmark \parallel$$

(6)

#### QUESTION 4

- 4.1 If the position of the successive molecules in a fluid can be joined up by a curve that is tangential to the direction of motion, ✓ this curved is called a streamline. ✓ However, if the streamlines are drawn through every position of all the molecules on the circumference of a small area, ✓ this forms a stream tube. ✓

(4)

4.2 4.2.1 
$$\dot{W} = \frac{W}{t} = \frac{mg}{t} = \dot{m} g$$

$$\dot{m} = \rho Q$$

$$= \frac{1000 \times \pi \times 0,045^2 \times 11}{4} \checkmark$$

$$= 17,494744 \text{ kg / s } \checkmark$$

$$\dot{W} = 17,494744 \times 9,81 \checkmark$$

$$= 171,623 N$$

(5)

4.2.2 *from Bernoulli's equation*

$$E_1 = E_2 + \text{LOSS}$$

$$\frac{v_1^2}{2g} - \Delta Z = \frac{v_2^2}{2g} \checkmark$$

$$v = \sqrt{2g \left( \frac{v_1^2}{2g} - \Delta Z \right)} \checkmark$$

$$= \sqrt{19,62 \left( \frac{11^2}{19,62} - 4 \right)} \checkmark$$

$$= 6,521 \text{ m/s}$$

(3)

4.2.3  $Q = AV$ ...continuity of flow

$$Q = \frac{\pi \times 0,045^2 \times 11}{4} \checkmark$$

$$= 17,49474 \times 10^{-3} \text{ m}^3 / \text{s} \checkmark$$

at  $v = 6,521 \text{ m/s}$

$$d = \sqrt{\frac{4Q}{\pi v}}$$

$$= \sqrt{\frac{4 \times 17,49474 \times 10^{-3}}{\pi \times 6,521}} \checkmark$$

$$= 58,446 \text{ mm} \checkmark$$

(4)

(4)  
 [20]

**QUESTION 5**

5.1 5.1.1 *from Bernoulli's equation, the kinetic energy per unit weight*

$$\begin{aligned}
 E_{inlet} &= E_{exit} \\
 \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 - LOSS &= \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2 \\
 \frac{50 \times 10^3}{800 \times 9,81} + 0 + 0 - 0 &= 0 + \frac{v_2^2}{2g} - 6 \\
 v &= \sqrt{19,62(6,37105 + 6)} \checkmark \\
 &= 15,57947 \text{ m/s} \checkmark \\
 Q_t &= Av \\
 &= \frac{\pi \times 0,03^2 \times 15,57947}{4} \checkmark \\
 &= 11,015 \times 10^{-3} \text{ m}^3 / \text{s} \checkmark \\
 Q_a &= 11,015 \times 10^{-3} \times 0,7 \checkmark \\
 &= 7,711 \text{ m}^3 / \text{s} \checkmark
 \end{aligned}$$

(5)

5.1.2 *from Bernoulli's equation*

$$\begin{aligned}
 \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 - LOSS &= \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2 \\
 0 + 0 + 0 + -0 &= 0 + \frac{v_2^2}{2g} \checkmark \\
 \Delta Z &= \frac{v^2}{2g} \checkmark \\
 &= \frac{15,57947^2}{19,62} \checkmark \\
 \therefore \Delta Z &= 12,371 \text{ m} \checkmark
 \end{aligned}$$

(4)

$$5.2 \quad \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 - LOSS = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2$$

$$L/d = \frac{k}{4f}$$

$$k = 1,5 \times 4 \times 1,1 \checkmark$$

$$= 6,6 \checkmark$$

$$LOSS = \frac{4fv^2}{2gd} + \frac{0,5v^2}{2g} + \frac{kv^2}{2g} \checkmark$$

$$= \frac{4 \times 1,1 \times 15v^2}{19,62 \times 0,04} + \frac{0,5v^2}{19,62} + \frac{6v^2}{19,62} \checkmark$$

$$= 84,42915v^2 \checkmark$$

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 - LOSS = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2$$

$$0 + 0 + 0 - 84,42915v^2 = 0 + 0,050968v^2 - 5$$

$$v = \frac{5}{(84,42915 + 0,050968)} \checkmark$$

$$= 0,0592 \text{ m/s} \checkmark$$

$$Q = AV$$

$$= \frac{\pi \times 0,04^2 \times 0,0592}{4} \checkmark$$

$$= 74,442 \times 10^{-6} \text{ m}^3/\text{s} \checkmark$$

(11)

**[20]****QUESTION 6**

6.1 Refer to the attached velocity diagram.  
Up to 4 marks will be deducted for incorrect use of scale. (8)

6.2 6.2.1 Moving blade inlet and outlet angle:

$$\alpha = 36^\circ \checkmark$$

$$\phi = 42^\circ \checkmark$$

6.2.2 Relative velocities at inlet and outlet of moving blade:

$$v_{ri} = 32 \text{ m/s} \checkmark$$

$$v_{ro} = 28 \text{ m/s} \checkmark$$

6.2.3 Angle and velocity of water exiting turbine:

$$\beta = 73,5^\circ \checkmark$$

$$v_{exit} = 19 \text{ m/s} \checkmark$$

6.2.4 Total vortex velocity:

$$\begin{aligned}\Delta v_w &= v_{wi} + v_{wo} \\ &= 5,6 + 40,8 \checkmark \\ &= 46,4 \text{ m/s} \checkmark\end{aligned}$$

6.2.5 Power generated by turbine:

$$\begin{aligned}P &= m \Delta v_w u \\ &= 25,3 \times 46,4 \times 20 \checkmark \\ &= 23,478 \text{ kW} \checkmark\end{aligned}$$

6.2.6 Turbine overall efficiency:

$$\begin{aligned}\eta &= \frac{2\Delta v_w u}{v_i^2} \times 100\% \\ &= \frac{2 \times 46,4 \times 20}{45^2} \times 100\% \checkmark \\ &= 91,654\% \checkmark\end{aligned}$$

(6 × 2) (12)  
[20]

**TOTAL: 100**