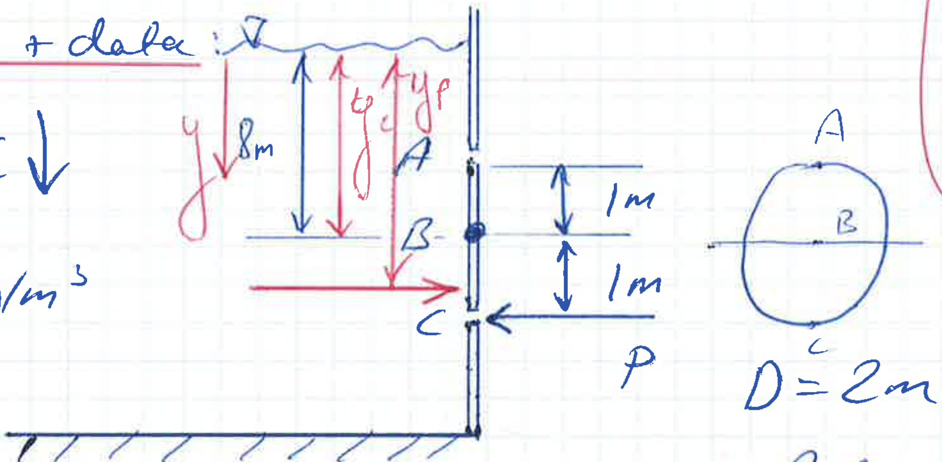
Q4 **Known:** Circular gate

Find: a) hydrostatic force b) P to keep gate closed

Schematic + data:

$g = 9.81 \frac{m}{s^2} \downarrow$

$\rho = 10^3\ kg/m^3$



2

assume: ρ const, neglect weight, neglect P_{atm}.

a) **Analysis:** $F_R = P_c \cdot A$ $\quad y_c = 8m$

$\Rightarrow$ $= \rho g y_c A$

$= 10^3 \frac{kg}{m^3} \cdot 9.81 \frac{m}{s^2} \cdot 8m \frac{\pi}{4} 2^2 m^2 = 246.6\ kN$ — 3

F_R is horizontal and acts @ $y_p = y_c + \frac{I_{xc}}{y_c A}$ — 1

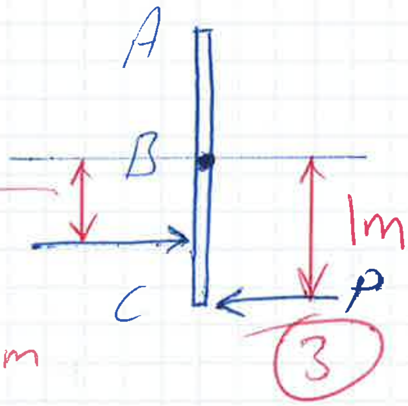
$I_{xc} = \frac{\pi}{4} R^4$

$= 8m + \frac{\frac{\pi}{4} 1^4}{8m \cdot \frac{\pi}{4} 2^2}$

$= 8 + \frac{1}{4 \cdot 8}$

$= 8.03125 m$ — 2

b) FBD



8.03215
−8 = 0.03215 m

$\sum M_B = 0$ — 2

$\Rightarrow F_R \cdot (y_p - y_c) - 1m \cdot P = 0$

$\Rightarrow P = \frac{F_R (y_p - y_c)}{1m}$

$= \frac{246.6 kN \cdot 0.03215 m}{1m}$

$= 7.69\ kN$ — 3

part b i + ii on pg 6/6

/20

THE UNIVERSITY OF ADELAIDE

ENGINEERING DESIGN CALCULATIONS

Date		Job No.	Sheet
Scale		2/6	
DRG-N BY			
Checked			

Q5

Known: Rotating cylinder in a uniform flow

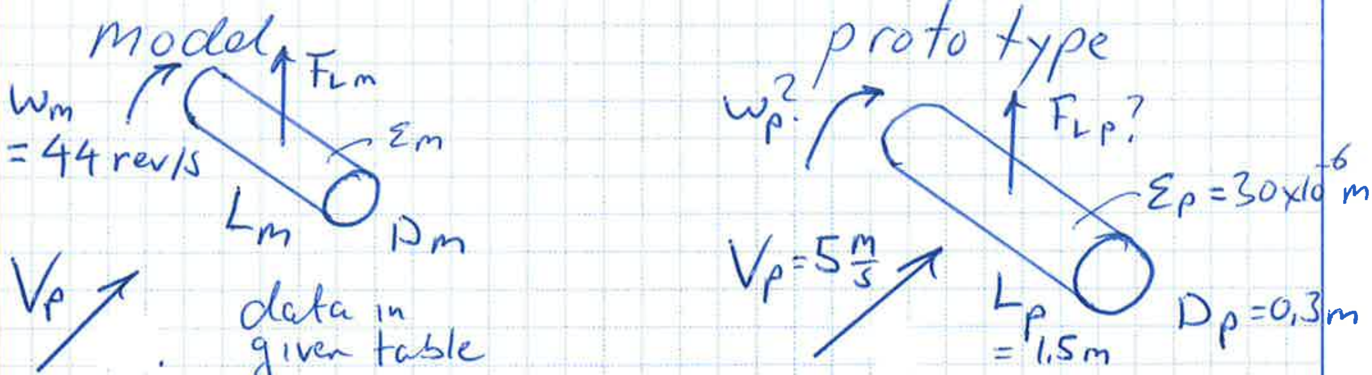
find: a) dimensionless expression for F_L

b) Compare prototype to which model?

c) ω_p

d) F_{Lp}

Schematic + data:



$\rho_m = 10^3\ kg/m^3$

$\mu_m = 1.1\times10^{-3}\ Ns/m^2$

WATER

$\rho_p = 1.2\ kg/m^3$

$\mu_p = 1.8\times10^{-5}\ Ns/m^2$

AIR

Assumptions: Steady, incompressible flow, Const properties. (-1)

Analysis: list parameters, units and dimensions.

a)

parameter	units	dimension
F_L	N	$[MLT^{-2}]$
L	m	[L]
D	m	[L]
ε	m	[L]
ω	rev/s	$[T^{-1}]$
V	m/s	$[LT^{-1}]$
ρ	kg/m^3	$[ML^{-3}]$
μ	Ns/m^2	$[ML^{-1}T^{-1}]$

n=8 parameters

m=3 dimensions

(-2)

$n = 8$ parameters, $m = 3$ dimensions $\Rightarrow$ need $8-3=5$ Π groups — (1)

Π_1: L and D both have dimensions of [L] $\Rightarrow \frac{L}{D} = \Pi_1$

Π_2: ε and D both have dimensions of [L]

$\Rightarrow \Pi_2 = \frac{\varepsilon}{D}$

Π_3: Viscous flow over body $\Rightarrow$ use Re

$\Rightarrow \Pi_3 = Re = \frac{\rho V D}{\mu}$ $\left(\text{or } \frac{\rho V \varepsilon}{\mu} \text{ or } \frac{\rho V L}{\mu}\right)$

Π_4: periodic rotation. $\Rightarrow$ use St

$\Pi_4 = St = \frac{\omega D}{V}$ $\left(\text{or } \frac{\omega \varepsilon}{V} \text{ or } \frac{\omega L}{V}\right)$

Π_5: Aerodynamic Lift force $\Rightarrow C_L$

$C_L = \frac{F_L}{\frac{1}{2}\rho V^2 (LD)}$

↑ frontal Area. Could be anything with units of m^2, but frontal area is most common.

(3)

$\Rightarrow \frac{F_L}{\frac{1}{2}\rho V^2 (LD)} = f\left(\frac{\rho V D}{\mu}, \frac{\omega D}{V}, \frac{L}{D}, \frac{\varepsilon}{D}\right)$

or $C_L = f\left(Re, St, \frac{L}{D}, \frac{\varepsilon}{D}\right)$ — (1)

b) For geometric similarity $\frac{L}{D}\Big|_m = \frac{L}{D}\Big|_p$ and $\frac{\varepsilon}{D}\Big|_m = \frac{\varepsilon}{D}\Big|_p$.

$\frac{L}{D}\Big|_p = \frac{1.5}{0.3} = 5$, $\frac{L}{D}\Big|_{mA} = \frac{0.5}{0.1} = 5$, $\frac{L}{D}\Big|_{mB} = \frac{1}{0.2} = 5$ — (1)

$\frac{\varepsilon}{D}\Big|_p = \frac{30\times10^{-6}}{0.3} = 10^{-5}$, $\frac{\varepsilon}{D}\Big|_{mA} = \frac{1.0\times10^{-5}}{0.1} = 10^{-5}$, $\frac{\varepsilon}{D}\Big|_{mB} = \frac{56\times10^{-6}}{0.2} = 28\times10^{-5}$ — (1)

$\Rightarrow$ The prototype is geometrically similar to model A. — (2) or equivalent.

c) For kinematic similarity $Re_m = Re_p$ and $St_m = St_p$. — (1)

$Re_m = Re_p \Rightarrow \frac{\rho V D}{\mu}\Big|_m = \frac{\rho V D}{\mu}\Big|_p$

$\Rightarrow V_m = \frac{\rho_p}{\rho_m} \cdot \frac{D_p}{D_m} \cdot \frac{\mu_m}{\mu_p} V_p$

$\Rightarrow \boxed{V_m = \frac{1.2}{10^3} \frac{0.3}{0.1} \cdot \frac{1.1\times10^{-3}}{1.8\times10^{-5}} 5\frac{m}{s} = 1.1\frac{m}{s}}$ — (1)

$St_m = St_p \Rightarrow \frac{\omega D}{V}\Big|_m = \frac{\omega D}{V}\Big|_p \Rightarrow \omega_p = \frac{D_m}{D_p}\frac{V_p}{V_m}\omega_m$ — (2)

$= \frac{0.1}{0.3}\frac{5}{1.1} \cdot 44\frac{rev}{s} = \boxed{66.7 \text{ rev/s}}$

d) when $V_m = 1.1 m/s$, $F_{Lm} = 12.1N$

as $L/D|_m = L/D|_p$ & $\frac{\varepsilon}{D}\Big|_m = \frac{\varepsilon}{D}\Big|_p$ & $Re_m = Re_p$ & $St_m = St_p$

$\Rightarrow C_{Lm} = C_{Lp} \Rightarrow \frac{F_L}{\frac{1}{2}\rho V^2 L D}\Big|_m = \frac{F_L}{\frac{1}{2}\rho V^2 L D}\Big|_p$ — (2)

$\Rightarrow \boxed{F_{Lp}} = \frac{\rho_p}{\rho_m}\left(\frac{V_p}{V_m}\right)^2 \cdot \frac{L_p}{L_m} \cdot \frac{D_p}{D_m} \cdot F_{Lm} = \frac{1.2}{10^3}\left(\frac{5}{1.1}\right)^2 \frac{1.5}{0.5}\frac{0.3}{0.1} \cdot 12.1N$

$= \boxed{2.7N}$ — (2)

20

THE UNIVERSITY OF ADELAIDE
ENGINEERING DESIGN CALCULATIONS

Date:		Job No.	Sheet
Scale		5/6	
DRG-N BY			
Checked			

Q6 a)

Known: Centrifugal pump

find: Power to drive pump.

sch + data: $\omega = 1200\ rev/min$

$r_1 = 60\,mm \quad r_2 = 100\,mm$

$b = b_1 = b_2 = 20\,mm$

$\beta_2 = 55°$

$V_1 = V_{f1} = 3{,}8\,m/s$

$\rho_{H_2O} = 10^3\,kg/m^3$

(2)

Assumptions: ideal, incomp., steady, radial flow, 1-D.

Analysis: $P = \dot{m} u_2 (u_2 - V_{f2} \cot \beta_2)$ — (1) (2)

$u_2 = r_2 \omega = 0.1\,m \cdot 1200 \frac{rev}{min} \cdot \frac{1}{60} \frac{min}{s} \cdot 2\pi \frac{rad}{rev} = 12{,}56\,m/s$ (3)

$\dot{m} = \rho 2\pi r_1 b_1 V_{f1} = 10^3 \frac{kg}{m^3} \cdot 2\pi\, 0{,}06\,m \cdot 0{,}02\,m \cdot 3{,}8 \frac{m}{s} = 28.65\,kg/s$ (3)

from continuity

$\dot{m}_{in} = \dot{m}_{out} \Rightarrow \rho 2\pi r_1 b_1 V_{f1} = \rho 2\pi r_2 b_2 V_{f2} \Rightarrow V_{f2} = \frac{r_1}{r_2} V_{f1}$

$= \frac{0{,}06}{0{,}1} \cdot 3{,}8 = 2{,}28 \frac{m}{s}$ (3)

eqn (1) $\Rightarrow P = \dot{m} u_2 (u_2 - V_{f2} \cot \beta_2)$

$= 28{,}65 \frac{kg}{s} \cdot 12{,}56 \frac{m}{s} \cdot \left[12{,}56 \frac{m}{s} - 2{,}28 \cot 22° \frac{m}{s}\right]$

$= 2488 \frac{kg}{s} \frac{m^2}{s^2}$

$\simeq 2{,}5\,kW$ (2)

15

THE UNIVERSITY OF ADELAIDE
ENGINEERING DESIGN CALCULATIONS

Date:		Job No.	Sheet
Scale			
DRG-N BY	6/6		
Checked			

Q6
b) All are derived from Reynolds Transport theorem. (2)

/2

c) Newtons 2nd Law of motion $\sum \vec{F} = m \cdot \vec{a}$ (2)
The N-S eqn accounts for viscous forces, the Euler eqn does not. (1)

/3

20

Q4 b) i) $y_p = y_c + \frac{I_{xc}}{y_c A}$

So as $y_c \rightarrow \infty$, $y_p \rightarrow y_c$ (2)
y_p & y_c get closer together

ii)

intensive	extensive	"not a property"
specific vol	volume	heat transfer
density	momentum	
concentration		
temp,		
viscosity		

(2)