GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – OLD PAPER – S22 TO W25 – Q&A BANK (Numerical)

Subject Name & Code:
Fluid Mechanics (3141906)

Unit 2: Fluid Kinematics & Fluid Dynamics

(As per new Syllabus For Unit- 3&4 Numerical)

Topic/Formula Group: Velocity & Acceleration Field
Marks Group: 7
Numerical Question:

1. If the velocity components are given by
$$u = 8 + 4xy + t^2, v = -(xy + 20t), w = 5x + y$$
Determine velocity and acceleration of a particle at $(2, 1, 1)$ and $t = 1$ sec.
   - **Appeared in:** 3141906(2) (Q3c, 07 marks)
   - **Frequency Tag:** Single/Unique
   - **Input Variables:** u, v, w as functions; point (2,1,1); time t = 1 s

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Answer:
Given:
$$u = 8 + 4xy + t^2, v = -(xy + 20t), w = 5x + y$$

Point $(x, y, z) = (2,1,1)$, time $t = 1$ s
To find: Velocity $\vec{V}$ and acceleration $\vec{a}$ at that point & time
Formula:
$$\vec{V} = u\hat{\imath} + v\hat{\jmath} + w\hat{k}$$

$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}$ (similarly for a_y, a_z)
Solution:
Step 1 – Velocity components at (2,1,1), t=1
$$u = 8 + 4(2)(1) + (1)^2 = 8 + 8 + 1 = 17 \text{ m/s}$$
$$v = -[(2)(1) + 20(1)] = -(2 + 20) = -22 \text{ m/s}$$
$$w = 5(2) + 1 = 10 + 1 = 11 \text{ m/s}$$
$$\vec{V} = 17\hat{\imath} - 22\hat{\jmath} + 11\hat{k} \text{ m/s}$$

Step 2 – Acceleration components
First compute partial derivatives:
For u:
$\frac{\partial u}{\partial t} = 2t = 2$ at t=1
$$\frac{\partial u}{\partial x} = 4y = 4(1) = 4$$

$$\frac{\partial u}{\partial y} = 4x = 4(2) = 8$$
$$\frac{\partial u}{\partial z} = 0$$
$$a_x = 2 + (17)(4) + (-22)(8) + (11)(0) = 2 + 68 - 176 + 0 = -106 \text{ m/s}^2$$

For v:

$v = -xy - 20t \rightarrow \frac{\partial v}{\partial t} = -20$

$$\frac{\partial v}{\partial x} = -y = -1$$
$$\frac{\partial v}{\partial y} = -x = -2$$
$$\frac{\partial v}{\partial z} = 0$$
$$a_y = -20 + (17)(-1) + (-22)(-2) + (11)(0) = -20 - 17 + 44 = 7 \text{ m/s}^2$$

For w:

$w = 5x + y \rightarrow \frac{\partial w}{\partial t} = 0$

$$\frac{\partial w}{\partial x} = 5$$
$$\frac{\partial w}{\partial y} = 1$$
$$\frac{\partial w}{\partial z} = 0$$
$$a_z = 0 + (17)(5) + (-22)(1) + (11)(0) = 85 - 22 = 63 \text{ m/s}^2$$
$$\vec{a} = -106\hat{\imath} + 7\hat{\jmath} + 63\hat{k} \text{ m/s}^2$$

Final Answer:

$$\boxed{\vec{V} = 17\hat{\imath} - 22\hat{\jmath} + 11\hat{k} \text{ m/s}}$$
$$\boxed{\vec{a} = -106\hat{\imath} + 7\hat{\jmath} + 63\hat{k} \text{ m/s}^2}$$

Topic/Formula Group: Bernoulli's Equation & Venturimeter
Marks Group: 7
Numerical Question:

1. A horizontal venturimeter with inlet diameter 200 mm and throat diameter 100 mm is employed to measure the flow of water. The reading of the differential manometer connected to the inlet is 180 mm of mercury. If the coefficient of discharge is 0.98, determine the rate of flow.
    - **Appeared in:** 3141906(4) (Q2c, 07 marks)
    - **Frequency Tag:** Single/Unique
    - **Input Variables:** D1 = 200 mm, D2 = 100 mm, manometer reading = 180 mm Hg, Cd = 0.98, fluid = water

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Answer:
Given:

Inlet diameter $D_1 = 200\text{ mm} = 0.2\text{ m}$
Throat diameter $D_2 = 100\text{ mm} = 0.1\text{ m}$
Manometer reading $x = 180\text{ mm Hg} = 0.18\text{ m Hg}$
Coefficient of discharge $C_d = 0.98$
Fluid: water ($\rho = 1000\text{ kg/m}^3$), mercury $\rho_m = 13600\text{ kg/m}^3$
To find: Rate of flow Q
Formula:
For horizontal venturimeter with manometer:

$$Q = C_d \cdot \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \cdot \sqrt{2gh}$$

where $h = x\left(\frac{\rho_m}{\rho} - 1\right)$ for water-mercury manometer.

Solution:
Step 1 – Areas

$$A_1 = \frac{\pi}{4}(0.2)^2 = 0.031416\text{ m}^2$$
$$A_2 = \frac{\pi}{4}(0.1)^2 = 0.007854\text{ m}^2$$

Step 2 – Manometer head h

$$h = 0.18 \times \left(\frac{13600}{1000} - 1\right) = 0.18 \times (13.6 - 1) = 0.18 \times 12.6 = 2.268\text{ m of water}$$

Step 3 – Theoretical discharge

$$Q_{\text{th}} = \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \cdot \sqrt{2gh}$$
$$A_1^2 = 9.87 \times 10^{-4}, A_2^2 = 6.17 \times 10^{-5}$$
$$A_1^2 - A_2^2 = 9.253 \times 10^{-4}$$
$$\sqrt{A_1^2 - A_2^2} = \sqrt{9.253 \times 10^{-4}} = 0.03042$$
$$A_1 A_2 = 0.031416 \times 0.007854 = 2.467 \times 10^{-4}$$
$$\frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} = \frac{2.467 \times 10^{-4}}{0.03042} = 0.008112$$
$$\sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.268} = \sqrt{44.50} = 6.671$$
$$Q_{\text{th}} = 0.008112 \times 6.671 = 0.05412\text{ m}^3/\text{s}$$

Step 4 – Actual discharge

$$Q = C_d \times Q_{\text{th}} = 0.98 \times 0.05412 = 0.05304\text{ m}^3/\text{s}$$

Final Answer:

$$\boxed{Q = 53.04\text{ L/s}(0.05304\text{ m}^3/\text{s})}$$

Topic/Formula Group: Impact of Jet (Moving plates & curved vanes)
Marks Group: 7
Numerical Question:

1. A jet of water of diameter 7 cm strikes a curved plate at its centre with a velocity of 15 m/s. The curved plate is moving with a velocity of 7 m/s in the direction of the

jet and it is deflected through an angle of 165°. Assuming the plate to be smooth, determine: (i) force exerted on plate in the direction of jet, (ii) power of jet, (iii) efficiency of jet.

- **Appeared in:** 3141906(1) (Q5c, 07 marks)
- **Frequency Tag:** Most Repeated
- **Input Variables:** jet diameter = 7 cm, V_j = 15 m/s, V_plate = 7 m/s, deflection = 165°

Answer:

Given:

Jet diameter $d = 7\text{ cm} = 0.07\text{ m}$

Jet velocity $V_j = 15\text{ m/s}$

Plate velocity $u = 7\text{ m/s}$ (in direction of jet)

Deflection angle $\theta = 165°$ (smooth plate → relative velocity same magnitude)

Water density $\rho = 1000\text{ kg/m}^3$

To find:

(i) Force exerted on plate in direction of jet F_x

(ii) Power of jet P

(iii) Efficiency η

Formulas:

For a moving curved vane, smooth:

Relative velocity $V_r = V_j - u$

Force in jet direction: $F_x = \rho A V_r(V_r\cos\ \phi_1 - V_r\cos\ \phi_2)$

Here $\phi_1 = 0°$ (jet strikes tangentially), $\phi_2 = 180° - \theta$

Power = $F_x \times u$

Efficiency = Power / (Kinetic energy of jet per sec)

Solution:

Step 1 – Area & relative velocity

$$A = \frac{\pi}{4}(0.07)^2 = 0.003848\text{ m}^2$$

$$V_r = V_j - u = 15 - 7 = 8\text{ m/s}$$

Mass flow rate (relative) $\dot{m}_r = \rho A V_r = 1000 \times 0.003848 \times 8 = 30.784\text{ kg/s}$

Step 2 – Force

Jet deflection $165°$ from original direction → outlet angle $180 - 165 = 15°$ from forward direction.

$$F_x = \dot{m}_r(V_r\cos\ 0° - V_r\cos\ 15°) = 30.784 \times 8 \times (1 - \cos\ 15°)$$

$$\cos\ 15° = 0.9659, 1 - 0.9659 = 0.0341$$

$$F_x = 30.784 \times 8 \times 0.0341 = 30.784 \times 0.2728 = 8.40\text{ N}$$

Step 3 – Power

$$P = F_x \times u = 8.40 \times 7 = 58.8\text{ W}$$

Step 4 – Efficiency

Kinetic energy of jet per second = $\frac{1}{2}\rho A V_j^3 = 0.5 \times 1000 \times 0.003848 \times (15)^3$

$$= 0.5 \times 1000 \times 0.003848 \times 3375 = 0.5 \times 1000 \times 12.987 = 6493.5\text{ W}$$

$$\eta = \frac{58.8}{6493.5} \times 100 = 0.905\%$$

Final Answer:

$$\boxed{F_x = 8.40\ \text{N}, P = 58.8\ \text{W}, \eta = 0.905\%}$$

2. A jet of water of diameter 8 cm strikes a flat plate normally with a velocity of 20 m/s. The plate is moving with a velocity of 12 m/s in the direction of the jet and away from the jet. Find: force exerted by the jet on the plate, work done by the jet on the plate per second.
    - **Appeared in:** 3141906(2) (OR Q4c, 07 marks)
    - **Frequency Tag:** Most Repeated
    - **Input Variables:** jet diameter = 8 cm, V_j = 20 m/s, V_plate = 12 m/s

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Answer:

Given:

Jet diameter $d = 8\ \text{cm} = 0.08\ \text{m}$

Jet velocity $V_j = 20\ \text{m/s}$

Plate velocity $u = 12\ \text{m/s}$ (away from jet, same direction)

Water $\rho = 1000\ \text{kg/m}^3$

To find: Force exerted on plate, work done per second

Solution:

For flat plate moving away from jet (normal impact):

Relative velocity $V_r = V_j - u = 20 - 12 = 8\ \text{m/s}$

Area $A = \frac{\pi}{4}(0.08)^2 = 0.005027\ \text{m}^2$

Force $F = \rho A V_r^2 = 1000 \times 0.005027 \times (8)^2 = 1000 \times 0.005027 \times 64 = 321.73\ \text{N}$

Work done per second (power) $= F \times u = 321.73 \times 12 = 3{,}860.8\ \text{W}$

Final Answer:

$$\boxed{F = 321.7\ \text{N}, P = 3.86\ \text{kW}}$$

3. A horizontal jet of water with a velocity of 30 m/s impinges on a moving curved blade having a velocity of 12 m/s. The blade moves in the direction of the jet. The jet leaves the blade at an angle of 65° with the direction of motion of the blade. Blade outlet angle is 35°. Calculate: (i) % reduction of relative velocity at outlet, (ii) force per kg in the direction of motion if jet diameter is 10 cm, (iii) work done per kg.
    - **Appeared in:** 3141906(5) (Q4c, 07 marks)
    - **Frequency Tag:** Most Repeated
    - **Input Variables:** V_j = 30 m/s, V_blade = 12 m/s, jet exit angle (to motion) = 65°, blade outlet angle = 35°, jet diameter = 10 cm

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Answer:

Given:

Jet velocity $V_j = 30\ \text{m/s}$

Blade velocity $u = 12\ \text{m/s}$ (same direction)

Jet leaves blade at 65° to direction of motion (absolute angle?)

Blade outlet angle $= 35°$ (relative angle)

Jet diameter $d = 10\ \text{cm} = 0.1\ \text{m}$

Smooth blade → relative velocity magnitude unchanged.

To find: (i) % reduction of relative velocity at outlet (for smooth blade, 0% reduction? Possibly friction included? Standard assumption: smooth → no reduction)
(ii) Force per kg in direction of motion
(iii) Work done per kg
Solution:
Step 1 – Velocities
$V_r = V_j - u = 30 - 12 = 18$ m/s (inlet relative velocity)
Outlet relative velocity $V_{r2} = V_r = 18$ m/s (smooth blade)
% reduction = 0% (if smooth). If friction given, else assume 0.
Step 2 – Force per kg
Mass flow rate (absolute) $\dot{m} = \rho A V_j$, but force per kg = force / mass flow rate = change in velocity per second per unit mass.
For moving curved vane: Force per kg of fluid = $(V_{r1}\cos\ \alpha_1 - V_{r2}\cos\ \alpha_2)$ in direction of motion, where α are angles of relative velocity with motion.
Inlet: relative velocity along motion → α_1=0° → $\cos\ = 1$
Outlet relative angle given as blade outlet angle = 35° (measured from direction of motion, presumably) → α_2=35° → $\cos\ 35° = 0.8192$
Force per kg = $18 \times 1 - 18 \times 0.8192 = 18(1 - 0.8192) = 18 \times 0.1808 = 3.2544$ N/kg
Step 3 – Work done per kg
Work per kg = Force per kg × blade velocity $u = 3.2544 \times 12 = 39.05$ J/kg

4. A jet of water moving with a velocity of $12\ \mathrm{m/s}$ impinges on a concave shaped vane to deflect the jet through $120°$ when stationary. If the vane moves at $5\ \mathrm{m/s}$, determine the angle of the jet so that there is no shock at the inlet. What is the absolute velocity of water at the exit in magnitude and direction? Also find the work done per unit mass of water. Assume the vane is smooth.
    - **Appeared in:** W25 (Q5c, 07 marks)
    - **Frequency Tag:** Most Repeated
    - **Input Variables:** V_j = 12 m/s, stationary deflection = 120°, vane speed = 5 m/s

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Answer:
Given:
Jet velocity $V_j = 12$ m/s
Vane speed $u = 5$ m/s (same direction)
Stationary deflection = $120°$ (i.e., when vane stationary, jet turns by 120°)
Smooth vane → relative velocity magnitude constant.
To find:
(i) Angle of jet at inlet for no shock (i.e., relative velocity tangential to vane at inlet)
(ii) Absolute velocity at exit (magnitude and direction)
(iii) Work done per unit mass
Solution:
Step 1 – Inlet conditions
No shock → relative velocity at inlet is along the vane inlet angle.
Relative velocity $V_r = V_j - u = 12 - 5 = 7$ m/s
For no shock, the vane inlet angle θ (from direction of motion) satisfies:

$$\tan\ \theta = \frac{V_j \sin\ \phi}{V_j \cos\ \phi - u}$$

But easier: Stationary deflection 120° means vane turns jet by 120° relative to its original direction. For moving vane, the relative velocity turns by same angle (smooth). So outlet relative velocity makes an angle of $180° - 120° = 60°$ with the direction of motion (if inlet relative is along motion). Let's assume inlet relative is along motion (θ=0). Then outlet relative velocity magnitude 7 m/s at 60° to motion.

Step 2 – Absolute velocity at exit

Exit relative velocity components:

$V_{r,x} = 7\cos\ 60° = 3.5$ m/s (forward)

$V_{r,y} = 7\sin\ 60° = 6.062$ m/s (perpendicular)

Absolute velocity = relative + blade velocity:

$$V_x = V_{r,x} + u = 3.5 + 5 = 8.5 \text{ m/s}$$
$$V_y = 6.062 \text{ m/s}$$

Magnitude $V_2 = \sqrt{8.5^2 + 6.062^2} = \sqrt{72.25 + 36.75} = \sqrt{109} = 10.44$ m/s

Direction $\beta = \tan^{-1}(6.062/8.5) = \tan^{-1}(0.713) = 35.5°$ from direction of motion.

Step 3 – Work per unit mass

Work = $u(V_{r1}\cos\ \alpha_1 - V_{r2}\cos\ \alpha_2)$ with α relative to motion.

Inlet: α_1=0°, cos=1; outlet: α_2=60°, cos=0.5

Work per kg = $5 \times (7 \times 1 - 7 \times 0.5) = 5 \times (7 - 3.5) = 5 \times 3.5 = 17.5$ J/kg

Final Answer:

$\boxed{\text{Inlet angle} = 0° \text{ (relative along motion)}, V_2 = 10.44 \text{ m/s at } 35.5°, W/m = 17.5 \text{ J/kg}}$

Assignment – 2 (Question Related to Unit 3&4)

Q-1: Continuity Equation: In a 2D incompressible flow, the fluid velocity components are given by u = 3x and v = -3y. Show whether this flow satisfies the continuity equation. Determine the stream function ψ for this flow field.

Answer:

Given: $u = 3x$, $v = -3y$, 2D incompressible flow.

Formula: $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

Solution:

$$\frac{\partial u}{\partial x} = 3, \frac{\partial v}{\partial y} = -3$$

Sum = $3 - 3 = 0 \rightarrow$ Satisfies continuity.

Stream function ψ:

$u = \frac{\partial \psi}{\partial y} = 3x \rightarrow$ Integrate: $\psi = 3xy + f(x)$

$v = -\frac{\partial \psi}{\partial x} = -3y \rightarrow$ Diff: $\frac{\partial \psi}{\partial x} = 3y + f'(x)$, but $-\frac{\partial \psi}{\partial x} = -3y \rightarrow \frac{\partial \psi}{\partial x} = 3y \rightarrow f'(x) = 0$.

Thus $\psi = 3xy + C$.

Final Answer:

$\boxed{\text{Flow satisfies continuity}, \psi = 3xy + C}$

Q-2: Bernoulli's Theorem Application: Water flows through a horizontal pipeline that tapers from a 300 mm diameter at section 1 to a 150 mm diameter at section 2. The

pressure at section 1 is 40 kPa and the velocity is 2 m/s. Assuming no energy losses, calculate the pressure at section 2.

Answer:
Given:
$D_1 = 0.3$ m, $D_2 = 0.15$ m
$P_1 = 40$ kPa, $V_1 = 2$ m/s
Horizontal pipe, no losses.
To Find: P_2
Formula:

$$A_1V_1 = A_2V_2$$
$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

Solution:
$A_1 = \pi(0.15)^2 = 0.0707\ \text{m}^2$, $A_2 = \pi(0.075)^2 = 0.01767\ \text{m}^2$

$$V_2 = V_1\frac{A_1}{A_2} = 2 \times \frac{0.0707}{0.01767} = 2 \times 4 = 8\ \text{m/s}$$
$$\frac{P_1}{\rho} + \frac{V_1^2}{2} = \frac{P_2}{\rho} + \frac{V_2^2}{2}$$
$$\frac{40000}{1000} + \frac{4}{2} = \frac{P_2}{1000} + \frac{64}{2}$$
$$40 + 2 = \frac{P_2}{1000} + 32$$
$$10 = \frac{P_2}{1000} \Rightarrow P_2 = 10000\ \text{Pa} = 10\ \text{kPa}$$

Final Answer:

$$\boxed{P_2 = 10\ \text{kPa}}$$

Q-3: Venturimeter: A horizontal venturimeter with an inlet diameter of 200 mm and a throat diameter of 100 mm is used to measure the flow of oil (Specific Gravity = 0.85). The discharge through the venturimeter is 60 lps. If the coefficient of discharge Cd is 0.97, find the reading of the oil-mercury differential manometer.

Answer:
Given:
Inlet diameter $D_1 = 200\ \text{mm} = 0.2\ \text{m}$
Throat diameter $D_2 = 100\ \text{mm} = 0.1\ \text{m}$
Oil SG = 0.85 $\rightarrow \rho_o = 850\ \text{kg/m}^3$
Discharge $Q = 60\ \text{lps} = 0.06\ \text{m}^3/\text{s}$

$$C_d = 0.97$$

Manometer fluid: Mercury ($\rho_m = 13600\ \text{kg/m}^3$)
To Find: Manometer reading h (in meters of mercury column difference)
Formula:

$$Q = C_d \cdot \frac{A_1A_2}{\sqrt{A_1^2 - A_2^2}} \cdot \sqrt{2gh\left(\frac{\rho_m}{\rho_o} - 1\right)}$$

Solution:

$$A_1 = \frac{\pi}{4}(0.2)^2 = 0.031416\,\text{m}^2, A_2 = \frac{\pi}{4}(0.1)^2 = 0.007854\,\text{m}^2$$
$$\frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} = \frac{0.031416 \times 0.007854}{\sqrt{(0.031416)^2 - (0.007854)^2}} = \frac{0.0002467}{\sqrt{0.0009868 - 0.00006168}}$$
$$= \frac{0.0002467}{\sqrt{0.0009251}} = \frac{0.0002467}{0.030415} = 0.008111$$

From venturi equation:

$$0.06 = 0.97 \times 0.008111 \times \sqrt{2 \times 9.81 \times h \times \left(\frac{13600}{850} - 1\right)}$$
$$\frac{0.06}{0.97 \times 0.008111} = \sqrt{2 \times 9.81 \times h \times (16 - 1)}$$
$$\frac{0.06}{0.007868} = 7.626 = \sqrt{294.3 \times h}$$

Square both sides:

$$58.15 = 294.3 \times h \Rightarrow h = 0.1976\,\text{m} \approx 197.6\,\text{mm}$$

Final Answer:

$$\boxed{h = 197.6\,\text{mm of mercury}}$$

Q-4: Pitot Tube: A pitot-static tube is placed in the center of a 250 mm pipe to measure the velocity of an exhaust gas flow. The stagnation pressure head is 8 mm of water, and the static pressure head is 2 mm of water. If the coefficient of the pitot tube is 0.98 and the density of the gas is 1.2 kg/m3, determine the velocity of the gas.

Answer:
Given:
Pipe diameter = 250 mm (not directly needed)
Stagnation head $h_{stag} = 8$ mm of water
Static head $h_{stat} = 2$ mm of water
Coefficient $C = 0.98$
Gas density $\rho_g = 1.2\,\text{kg/m}^3$
Water density $\rho_w = 1000\,\text{kg/m}^3$
To Find: Velocity of gas V
Formula:
Dynamic head in meters of gas = $\frac{\rho_w}{\rho_g} \times (h_{stag} - h_{stat})$ in meters of water converted to gas.

$$V = C\sqrt{2g \cdot \frac{\rho_w}{\rho_g} \cdot \Delta h}$$

where $\Delta h = 0.008 - 0.002 = 0.006$ m of water
Solution:

$$V = 0.98\sqrt{2 \times 9.81 \times \frac{1000}{1.2} \times 0.006}$$
$$\frac{1000}{1.2} \times 0.006 = 5$$

$$V = 0.98\sqrt{2 \times 9.81 \times 5} = 0.98\sqrt{98.1} = 0.98 \times 9.905 = 9.707 \text{ m/s}$$

Final Answer:

$$\boxed{V = 9.71 \text{ m/s}}$$

Q-5: Momentum Equation: A 45° reducing bend is connected in a pipeline. The diameter at the inlet and outlet of the bend are 600 mm and 300 mm respectively. Find the force exerted by water on the bend if the pressure at the inlet is 8.829 N/cm2 and the flow rate is 600 lps

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Answer:
Given:

$$\theta = 45^\circ$$
$$D_1 = 600 \text{ mm} = 0.6 \text{ m}$$
$$D_2 = 300 \text{ mm} = 0.3 \text{ m}$$
$$P_1 = 8.829 \text{ N/cm}^2 = 8.829 \times 10^4 \text{ Pa}$$
$$Q = 600 \text{ lps} = 0.6 \text{ m}^3/\text{s}$$

Water $\rightarrow \rho = 1000 \text{ kg/m}^3$
To Find: Force exerted by water on the bend (magnitude and direction)
Formula:
Momentum eqn in x and y directions:
$F_x = \rho Q(V_2 \cos\theta - V_1) + P_1A_1 + P_2A_2\cos\theta$ (with sign careful)
Better approach: Force by bend on water, then reverse.
Solution:

$$A_1 = \pi/4(0.6)^2 = 0.28274 \text{ m}^2$$
$$A_2 = \pi/4(0.3)^2 = 0.070686 \text{ m}^2$$
$$V_1 = Q/A_1 = 0.6/0.28274 = 2.122 \text{ m/s}$$
$$V_2 = Q/A_2 = 0.6/0.070686 = 8.488 \text{ m/s}$$

Find P_2 from Bernoulli (horizontal bend, neglecting losses):

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} = \frac{P_2}{\rho} + \frac{V_2^2}{2}$$
$$\frac{88290}{1000} + \frac{(2.122)^2}{2} = \frac{P_2}{1000} + \frac{(8.488)^2}{2}$$
$$88.29 + 2.251 = \frac{P_2}{1000} + 36.02$$
$$90.541 - 36.02 = \frac{P_2}{1000} \Rightarrow P_2 = 54521 \text{ Pa}$$

Force by bend on water (F_x):

$$F_x = \rho Q(V_2\cos 45^\circ - V_1) + P_1A_1 - P_2A_2\cos 45^\circ$$
$$F_x = 1000 \times 0.6 \times (8.488 \times 0.7071 - 2.122) + 88290 \times 0.28274 - 54521 \times 0.070686 \times 0.7071$$
$$= 600 \times (6.001 - 2.122) + 24960 - 2728$$
$$= 600 \times 3.879 + 22232 = 2327.4 + 22232 = 24559.4 \text{ N}$$
$$F_y = \rho Q(V_2\sin 45^\circ - 0) + 0 - P_2A_2\sin 45^\circ$$
$$= 600 \times 8.488 \times 0.7071 - 54521 \times 0.070686 \times 0.7071$$
$$= 600 \times 6.001 - 2728 = 3600.6 - 2728 = 872.6 \text{ N}$$

Magnitude:

$$F_R = \sqrt{(24559)^2 + (872.6)^2} \approx 24575\ \text{N}$$

Direction: $\phi = \tan^{-1}(872.6/24559) \approx 2^\circ$ from horizontal.
Force **by water on bend** is equal and opposite.
Final Answer:

$F_R \approx 24.58$ kN, acting at $\approx 2^\circ$ below horizontal (if bend turns upward)