Chapter 2 Fundamentals of Flow in Closed Conduits **Fundamentals of Flow in Closed**
 Conduits

2.1. From the given data: $D_1 = 0.1$ m, $D_2 = 0.15$ m, $V_1 = 2$ m/s. Using these data, the following

preliminary calculations are useful:
 $A_1 = \frac{\pi}{L} D_1^2 = \frac{\pi}{L}(0.1)^2 = 0.0$ **ndamentals of Flow in C**
 preliminary calculations are useful:
 $A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.1)^2 = 0.007854 \text{ m}^2, \qquad A_2 = \frac{\pi}{4} D_2^2 =$ $D_1 = 0.1$ m, $D_2 = 0.15$ m, $V_1 = 2$ m/s. Using these α is are useful:
 $(0.1)^2 = 0.007854 \,\text{m}^2$, $A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.15)^2 =$
 α , is given by 15 m, $V_1 = 2 \text{ m/s}$. Using these data, the

, $A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.15)^2 = 0.017671$

ing these data, the following
 $(0.15)^2 = 0.01767 \,\mathrm{m}^2$ From the given data: $D_1 = 0.1$ m, $D_2 = 0.15$ m, $V_1 = 2$ m/s. Using
preliminary calculations are useful:
 $A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.1)^2 = 0.007854 \text{ m}^2, \qquad A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.1)^2$
Volumetric flow rate, Q, is gi = 0.1 m, $D_2 = 0.15$ m, $V_1 = 2$ m/s. Using these data, the following
are useful:
.1)² = 0.007854 m², $A_2 = \frac{\pi}{4}D_2^2 = \frac{\pi}{4}(0.15)^2 = 0.01767$ m²
is given by
 $Q = A_1V_1 = (0.007854)(2) = 0.0157$ m³/s
ity equation,

Poleliminary calculations are useful:
\n
$$
A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.1)^2 = 0.007854 \text{ m}^2, \qquad A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.15)^2 = 0.01767 \text{ m}^2
$$
\n
$$
\text{Volumeetric flow rate, } Q \text{, is given by}
$$
\n
$$
Q = A_1 V_1 = (0.007854)(2) = \boxed{0.0157 \text{ m}^3/\text{s}}
$$
\nAccording to the continuity equation,
\n
$$
A_1 V_1 = A_2 V_2 = Q \qquad \rightarrow \qquad V_2 = \frac{Q}{A_2} = \frac{0.0157}{0.01767} = \boxed{0.889 \text{ m/s}}
$$
\nAt 20°C, the density of water, ρ , is 998 kg/m³, and the mass flow rate, \dot{m} , is given by

$$
Q = A_1 V_1 = (0.007854)(2) = 0.0157 \,\mathrm{m}^3/\mathrm{s}
$$

Volumetric flow rate, *Q*, is given by
\n
$$
Q = A_1 V_1 = (0.007854)(2) = \boxed{0.0157 \text{ m}^3/\text{s}}
$$
\nAccording to the continuity equation,
\n
$$
A_1 V_1 = A_2 V_2 = Q \rightarrow V_2 = \frac{Q}{A_2} = \frac{0.0157}{0.01767} = \boxed{0.889 \text{ m/s}}
$$
\nAt 20°C, the density of water, ρ , is 998 kg/m³, and the mass flow rate, \dot{m} , is given by
\n
$$
\dot{m} = \rho Q = (998)(0.0157) = \boxed{15.7 \text{ kg/s}}
$$
\nFrom the given data: $D_1 = 0.2 \text{ m}, D_2 = 0.3 \text{ m}, \text{ and } V_1 = 0.75 \text{ m/s}$. Using these data, the

$$
\dot{m} = \rho Q = (998)(0.0157) = \boxed{15.7 \,\mathrm{kg/s}}
$$

2.xx From the given data: $D_1 = 0.2$ m, $D_2 = 0.3$ m, and the mass flow rate, π , is given by
 $\dot{m} = \rho Q = (998)(0.0157) = \frac{15.7 \text{ kg/s}}{1.7 \text{ kg/s}}$

2.xx From the given data: $D_1 = 0.2$ m, $D_2 = 0.3$ m, and $V_1 = 0.75$ m/s. $A_1V_1 = A_2V_2 = Q \rightarrow V_2 = \frac{Q}{A_2} = \frac{0.0157}{0.01767} = \boxed{0.889}$

At 20°C, the density of water, ρ , is 998 kg/m³, and the mass flow rate,
 $\dot{m} = \rho Q = (998)(0.0157) = \boxed{15.7 \text{ kg/s}}$

From the given data: $D_1 = 0.2 \text{ m}$, D w rate, \dot{m} , is given by

]

m/s. Using these data, the
 $(0.3)^2 = 0.07069 \,\text{m}^2$ $\dot{m} = \rho Q = (998)(0.0157) = \boxed{15.7 \text{ kg/s}}$

(b) $\dot{m} = 0.2 \text{ m}, D_2 = 0.3 \text{ m}, \text{ and } V_1 = 0.75 \text{ m/s}$

(b) $A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.2)^2 = 0.03142 \text{ m}^2, \qquad A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.64)$

(a) According to the continuity equat $\frac{\pi}{4}D_2^2 = \frac{\pi}{4}(0.3)^2 = 0.07069 \text{ m}^2$
 $\frac{3142(0.75)}{0.07069} = 0.333 \text{ m/s}$

At 20°C, the density of water,
$$
\rho
$$
, is 998 kg/m³, and the mass flow rate, \dot{m} , is given by
\n
$$
\dot{m} = \rho Q = (998)(0.0157) = \boxed{15.7 \text{ kg/s}}
$$
\nFrom the given data: $D_1 = 0.2 \text{ m}, D_2 = 0.3 \text{ m}, \text{ and } V_1 = 0.75 \text{ m/s}$. Using these data
\nallowing preliminary calculations are useful:
\n
$$
A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.2)^2 = 0.03142 \text{ m}^2, \qquad A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.3)^2 = 0.07069 \text{ m}^2
$$
\n(a) According to the continuity equation,
\n
$$
A_1 V_1 = A_2 V_2 \qquad \rightarrow \qquad V_2 = \frac{A_1 V_1}{A_2} = \frac{(0.03142)(0.75)}{0.07069} = \boxed{0.333 \text{ m/s}}
$$
\n(b) The volume flow rate, Q , is given by
\n
$$
Q = A_1 V_1 = (0.03142)(0.75) = 0.02357 \text{ m}^3/\text{s} = \boxed{23.6 \text{ L/s}}
$$

$$
D_1 = \frac{1}{4}(0.2) = 0.03142 \text{ m}^2, \qquad A_2 = \frac{1}{4}D_2 = \frac{1}{4}(0.3) = 0.07009 \text{ m}^2
$$

to the continuity equation,

$$
A_1V_1 = A_2V_2 \quad \rightarrow \quad V_2 = \frac{A_1V_1}{A_2} = \frac{(0.03142)(0.75)}{0.07069} = \boxed{0.333 \text{ m/s}}
$$

e flow rate, *Q*, is given by

$$
Q = A_1V_1 = (0.03142)(0.75) = 0.02357 \text{ m}^3/\text{s} = \boxed{23.6 \text{ L/s}}
$$

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$$
Q = A_1 V_1 = (0.03142)(0.75) = 0.02357 \,\mathrm{m}^3/\mathrm{s} = 23.6 \,\mathrm{L/s}
$$

 $\frac{1}{4}(0.3)$ = 0.07069 m⁻

(10.3) = 0.333 m/s

(10.333 m/s)

(10.45)

(10.475)

(10.475)

(10.475)

(10.475)

(10.475)
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2.2. From the given data:
$$
D_1 = 200
$$
 mm, $D_2 = 100$ mm, $V_1 = 1$ m/s, and
\n
$$
A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.2)^2 = 0.0314 \text{ m}^2
$$
\n
$$
A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (0.1)^2 = 0.00785 \text{ m}^2
$$
\nThe flow rate, Q_1 , in the 200-mm pipe is given by
\n
$$
Q_1 = A_1 V_1 = (0.0314)(1) = 0.0314 \text{ m}^3/\text{s}
$$
\nand hence the flow rate, Q_2 , in the 100-mm pipe is
\n
$$
Q_2 = \frac{Q_1}{2} = \frac{0.0314}{2} = \boxed{0.0157 \text{ m}^3/\text{s}}
$$
\nThe average velocity, V_2 , in the 100-mm pipe is

$$
Q_1 = A_1 V_1 = (0.0314)(1) = 0.0314 \,\mathrm{m}^3/\mathrm{s}
$$

$$
A_2 = \frac{1}{4}D_2 = \frac{1}{4}(0.1)^{-1} = 0.00785 \text{ m}^{-1}
$$
\nThe flow rate, Q_1 , in the 200-mm pipe is given by
\n
$$
Q_1 = A_1V_1 = (0.0314)(1) = 0.0314 \text{ m}^3/\text{s}
$$
\nand hence the flow rate, Q_2 , in the 100-mm pipe is
\n
$$
Q_2 = \frac{Q_1}{2} = \frac{0.0314}{2} = \frac{0.0157 \text{ m}^3/\text{s}}{2}
$$
\nThe average velocity, V_2 , in the 100-mm pipe is
\n
$$
V_2 = \frac{Q_2}{A_2} = \frac{0.0157}{0.00785} = \boxed{2 \text{ m/s}}
$$
\nThe velocity distribution in the pipe is

$$
V_2 = \frac{Q_2}{A_2} = \frac{0.0157}{0.00785} = \boxed{2 \,\text{m/s}}
$$

and hence the flow rate,
$$
Q_2
$$
, in the 100-mm pipe is
\n
$$
Q_2 = \frac{Q_1}{2} = \frac{0.0314}{2} = \frac{0.0157 \text{ m}^3/\text{s}}{2}
$$
\nThe average velocity, V_2 , in the 100-mm pipe is
\n
$$
V_2 = \frac{Q_2}{A_2} = \frac{0.0157}{0.00785} = \boxed{2 \text{ m/s}}
$$
\n2.3. The velocity distribution in the pipe is
\n
$$
v(r) = V_0 \left[1 - \left(\frac{r}{R}\right)^2\right]
$$
\nand the average velocity, \bar{V} , is defined as
\n
$$
\bar{V} = \frac{1}{A} \int_A V \ dA
$$
\n(2)\nwhere
\n
$$
A = \pi R^2
$$
 and
$$
dA = 2\pi r dr
$$
\n(3)\nCombining Equations 1 to 3 yields
\n
$$
\bar{V} = \frac{1}{A} \int_A V \ dA
$$
\n(3)

$$
\bar{V} = \frac{1}{A} \int_{A} V \, dA \tag{2}
$$

where

$$
A = \pi R^2 \qquad \text{and} \qquad dA = 2\pi r dr \tag{3}
$$

$$
v(r) = V_0 \left[1 - \left(\frac{r}{R}\right) \right]
$$
\nand the average velocity, \bar{V} , is defined as

\n
$$
\bar{V} = \frac{1}{A} \int_A V \, dA
$$
\nwhere

\n
$$
A = \pi R^2 \qquad \text{and} \qquad dA = 2\pi r dr
$$
\nCombining Equations 1 to 3 yields

\n
$$
\bar{V} = \frac{1}{\pi R^2} \int_0^R V_0 \left[1 - \left(\frac{r}{R}\right)^2 \right] 2\pi r dr = \frac{2V_0}{R^2} \left[\int_0^R r dr - \int_0^R \frac{r^3}{R^2} dr \right] = \frac{2V_0}{R^2} \left[\frac{R^2}{2} - \frac{R^4}{4R^2} \right]
$$
\n
$$
= \frac{2V_0}{R^2} \frac{R^2}{4} = \boxed{\frac{V_0}{2}}
$$
\nThe flow rate, Q , is therefore given by

\n
$$
Q = A\bar{V} = \boxed{\frac{\pi R^2 V_0}{2}}
$$

$$
Q = A\bar{V} = \boxed{\frac{\pi R^2 V_0}{2}}
$$

2.4.

$$
\beta = \frac{1}{A\overline{V}^2} \int_A v^2 dA = \frac{4}{\pi R^2 V_0^2} \int_0^R V_0^2 \left[1 - \frac{2r^2}{R^2} + \frac{r^4}{R^4} \right] 2\pi r dr
$$

= $\frac{8}{R^2} \left[\int_0^R r dr - \int_0^R \frac{2r^3}{R^2} dr + \int_0^R \frac{r^5}{R^4} dr \right] = \frac{8}{R^2} \left[\frac{R^2}{2} - \frac{R^4}{2R^2} + \frac{R^6}{6R^4} \right]$
= $\left[\frac{4}{3} \right]$

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2.5.
$$
D = 0.2
$$
 m, $Q = 0.06$ m³/s, $L = 100$ m, $p_1 = 500$ kPa, $p_2 = 400$ kPa, $\gamma = 9.79$ kN/m³.
\n
$$
R = \frac{D}{4} = \frac{0.2}{4} = 0.05
$$
 m
\n
$$
\Delta h = \frac{p_1}{\gamma} - \frac{p_2}{\gamma} = \frac{500 - 400}{9.79} = 10.2
$$
 m
\n
$$
\tau_0 = \frac{\gamma R \Delta h}{L} = \frac{(9.79 \times 10^3)(0.05)(10.2)}{100} = \boxed{49.9 \text{ N/m}^2}
$$
\n
$$
A = \frac{\pi D^2}{4} = \frac{\pi (0.2)^2}{4} = 0.0314
$$
 m²
\n
$$
V = \frac{Q}{A} = \frac{0.06}{0.0314} = 1.91
$$
 m/s
\n
$$
f = \frac{8\pi_0}{\rho V^2} = \frac{8(49.9)}{(998)(1.91)^2} = \boxed{0.11}
$$
\n2.6. $T = 20$ °C, $V = 2$ m/s, $D = 0.25$ m, horizontal pipe, ductile iron. For ductile iron pipe, $k_s = 0.26$ mm, and
\n
$$
\frac{k_s}{D} = \frac{0.26}{250} = 0.00104
$$
 Re $= \frac{\rho V D}{\mu} = \frac{(998.2)(2)(0.25)}{(1.002 \times 10^{-3})} = 4.981 \times 10^5$

.

$$
I = \frac{8\tau_0}{\rho V^2} = \frac{8(49.9)}{(998)(1.91)^2} = \boxed{0.11}
$$

\n
$$
T = 20^{\circ}\text{C}, V = 2 \text{ m/s}, D = 0.25 \text{ m, horizontal pipe, ductile iron. For ductile iron pipe, } k_s = 0.26 \text{ mm, and}
$$

\n
$$
\frac{k_s}{D} = \frac{0.26}{250} = 0.00104
$$

\n
$$
\text{Re} = \frac{\rho V D}{\mu} = \frac{(998.2)(2)(0.25)}{(1.002 \times 10^{-3})} = 4.981 \times 10^5
$$

\nFrom the Moody diagram:
\n
$$
f = 0.0202 \text{ (flow is not fully turbulent)}
$$

\nUsing the Colebrook equation,
\n
$$
\frac{1}{\sqrt{f}} = -2 \log \left(\frac{k_s/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}} \right)
$$

\nSubstituting for k_s/D and Re gives

$$
f=0.0202
$$
 (flow is not fully turbulent)

$$
\frac{1}{\sqrt{f}} = -2\log\left(\frac{k_{\rm s}/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)
$$

From the Moody diagram:
\n
$$
f = 0.0202 \text{ (flow is not fully turbulent)}
$$
\nUsing the Colebrook equation,
\n
$$
\frac{1}{\sqrt{f}} = -2 \log \left(\frac{k_s/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}} \right)
$$
\nSubstituting for k_s/D and Re gives
\n
$$
\frac{1}{\sqrt{f}} = -2 \log \left(\frac{0.00104}{3.7} + \frac{2.51}{4.981 \times 10^5 \sqrt{f}} \right)
$$
\nBy trial and error leads to
\n
$$
f = 0.0204
$$
\nUsing the Swamee-Jain equation,
\n
$$
\frac{1}{\sqrt{f}} = 0.0204
$$
\n
$$
1 - 0.2264 = 0.224
$$

$$
f=0.0204
$$

Substituting for
$$
k_s/D
$$
 and Re gives
\n
$$
\frac{1}{\sqrt{f}} = -2 \log \left(\frac{0.00104}{3.7} + \frac{2.51}{4.981 \times 10^5 \sqrt{f}} \right)
$$
\nBy trial and error leads to
\n
$$
\frac{f = 0.0204}{\sqrt{f}} = -2 \log \left[\frac{k_s/D}{3.7} + \frac{5.74}{\text{Re}^{0.9}} \right] = -2 \log \left[\frac{0.00104}{3.7} + \frac{5.74}{(4.981 \times 10^5)^{0.9}} \right]
$$
\nwhich leads to
\n
$$
\frac{1}{\sqrt{f}} = -2 \log \left[\frac{k_s/D}{3.7} + \frac{5.74}{\text{Re}^{0.9}} \right] = -2 \log \left[\frac{0.00104}{3.7} + \frac{5.74}{(4.981 \times 10^5)^{0.9}} \right]
$$
\nwhich leads to
\n
$$
\frac{f = 0.0205}{\sqrt{f}} = 0.0204
$$
\n
$$
h_f = f \frac{L V^2}{D 2g} = 0.0204 \frac{100}{0.25} \frac{(2)^2}{2(9.81)} = 1.66 \text{ m}
$$
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$$
f=0.0205
$$

$$
h_{\rm f} = f \frac{L V^2}{D 2g} = 0.0204 \frac{100}{0.25} \frac{(2)^2}{2(9.81)} = 1.66 \,\mathrm{m}
$$

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Therefore the pressure drop,
$$
\Delta p
$$
, is given by

$$
\Delta p = \gamma h_{\rm f} = (9.79)(1.66) = \boxed{16.3 \,\text{kPa}}
$$

, $Δp$, is given by
 $Δp = γh$ _f = (9.79)(1.66) = $\boxed{16.3 \text{ kPa}}$

the downstream end, *f* would not change, but the pressure drop, Therefore the pressure drop, Δp , is given by
 $\Delta p = \gamma h_f = (9.79)(1.66) = \boxed{16.3 \text{ kPa}}$

If the pipe is 1 m lower at the downstream end, f would not change, but the pressure drop,
 Δp , would then be given by
 $\Delta p = \gamma (h_f -$ Therefore the pressure drop, Δp , is given by
 $\Delta p = \gamma h_f = (9.79)(1.66) = 16.5$

If the pipe is 1 m lower at the downstream end, f would no
 Δp , would then be given by
 $\Delta p = \gamma (h_f - 1.0) = 9.79(1.66 - 1) =$ drop, Δp , is given by
 $\Delta p = \gamma h_f = (9.79)(1.66) = \boxed{16.3 \text{ kPa}}$

r at the downstream end, f would not change, but the pressure drop,

en by
 $\Delta p = \gamma (h_f - 1.0) = 9.79(1.66 - 1) = \boxed{6.46 \text{ kPa}}$
 $D = 25 \text{ mm}, k_s = 0.1 \text{ mm}, \theta = 10^{\circ},$

$$
\Delta p = \gamma(h_{\rm f} - 1.0) = 9.79(1.66 - 1) = 6.46 \,\text{kPa}
$$

2.7. From the given data: $D = 25$ mm, $k_s = 0.1$ mm, $\theta = 10^\circ$, $p_1 = 550$ kPa, and $L = 100$ n $k_s = 0.1$ mm, $\theta = 0.79(1.66 - 1) = 550$ kPa, and $L = 100$ n 20° C, $\nu = 1.00 \times 10^{-6}$ m²/s, $\gamma = 9.79$ kN/m³, and 6.3 kPa
not change, but the pressure drop,
 $= 6.46 \text{ kPa}$,
 $p_1 = 550 \text{ kPa}$, and $L = 100 \text{ m}$. At $\Delta p = \gamma h_f = (9.79)(1.66) = \boxed{16.3 \text{ kPa}}$

If the pipe is 1 m lower at the downstream end, f would not change, but the pres
 Δp , would then be given by
 $\Delta p = \gamma (h_f - 1.0) = 9.79(1.66 - 1) = \boxed{6.46 \text{ kPa}}$

From the given data:

If the pipe is 1 m lower at the downstream end, *f* would not change, but the pressure drop,
\n
$$
\Delta p
$$
, would then be given by
\n
$$
\Delta p = \gamma(h_f - 1.0) = 9.79(1.66 - 1) = 6.46 \text{ kPa}
$$
\nFrom the given data: $D = 25 \text{ mm}$, $k_s = 0.1 \text{ mm}$, $\theta = 10^{\circ}$, $p_1 = 550 \text{ kPa}$, and $L = 100 \text{ m}$. At
\n 20°C , $\nu = 1.00 \times 10^{-6} \text{ m}^2/\text{s}$, $\gamma = 9.79 \text{ kN/m}^3$, and
\n
$$
\frac{k_s}{D} = \frac{0.1}{25} = 0.004
$$
\n
$$
A = \frac{\pi}{4}D^2 = \frac{\pi}{4}(0.025)^2 = 4.909 \times 10^{-4} \text{ m}^2
$$
\n
$$
h_f = f\frac{L}{D}\frac{Q^2}{2gA^2} = f\frac{100}{0.025}\frac{Q^2}{2(9.81)(4.909 \times 10^{-4})^2} = 8.46 \times 10^8 fQ^2
$$
\nThe energy equation applied over 100 m of pipe is
\n
$$
\frac{p_1}{\gamma} + \frac{V^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V^2}{2g} + z_2 + h_f
$$
\nwhich simplifies to
\n
$$
p_2 = p_1 - \gamma(z_2 - z_1) - \gamma h_f
$$
\n
$$
p_3 = 550 - 9.79(100 \sin 10^\circ) - 9.79(8.46 \times 10^8 fQ^2)
$$

$$
\frac{p_1}{\gamma} + \frac{V^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V^2}{2g} + z_2 + h_f
$$

The energy equation applied over 100 m of pipe is
\n
$$
\frac{p_1}{\gamma} + \frac{V^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V^2}{2g} + z_2 + h_f
$$
\nwhich simplifies to
\n
$$
p_2 = p_1 - \gamma(z_2 - z_1) - \gamma h_f
$$
\n
$$
p_2 = 550 - 9.79(100 \sin 10^\circ) - 9.79(8.46 \times 10^8 f Q^2)
$$
\n
$$
p_2 = 380.0 - 8.28 \times 10^9 f Q^2
$$
\n(a) For $Q = 2 \text{ L/min} = 3.333 \times 10^{-5} \text{ m}^3/\text{s}$,
\n
$$
V = \frac{Q}{A} = \frac{3.333 \times 10^{-5}}{4.909 \times 10^{-4}} = 0.06790 \text{ m/s}
$$

(a) For $Q = 2 \text{ L/min} = 3.333 \times 10^{-5} \text{ m}^3\text{/s},$

1 simplifies to
\n
$$
p_2 = p_1 - \gamma(z_2 - z_1) - \gamma h_f
$$
\n
$$
p_2 = 550 - 9.79(100 \sin 10^\circ) - 9.79(8.46 \times 10^8 f Q^2)
$$
\n
$$
p_2 = 380.0 - 8.28 \times 10^9 f Q^2
$$
\nFor $Q = 2 \text{ L/min} = 3.333 \times 10^{-5} \text{ m}^3/\text{s}$,
\n
$$
V = \frac{Q}{A} = \frac{3.333 \times 10^{-5}}{4.909 \times 10^{-4}} = 0.06790 \text{ m/s}
$$
\n
$$
\text{Re} = \frac{VD}{\nu} = \frac{(0.06790)(0.025)}{1 \times 10^{-6}} = 1698
$$
\nSince Re \lt 2000, the flow is laminar when $Q = 2 \text{ L/min}$. Hence,
\n
$$
f = \frac{64}{\text{Re}} = \frac{64}{1698} = 0.03770
$$
\n
$$
p_2 = 380.0 - 8.28 \times 10^9 (0.03770)(3.333 \times 10^{-5})^2 = 380 \text{ kPa}
$$
\nTherefore, when the flow is 2 L/min, the pressure at the downstream section is $\boxed{380 \text{ kPa}}$.
\nFor $Q = 20 \text{ L/min} = 3.333 \times 10^{-4} \text{ m}^3/\text{s}$.

$$
\text{Re} = \frac{VD}{\nu} = \frac{(0.06790)(0.025)}{1 \times 10^{-6}} = 1698
$$
\nSince Re < 2000, the flow is laminar when $Q = 2$ L/min. Hence,
\n
$$
f = \frac{64}{\text{Re}} = \frac{64}{1698} = 0.03770
$$
\n
$$
p_2 = 380.0 - 8.28 \times 10^9 (0.03770)(3.333 \times 10^{-5})^2 = 380 \text{ kPa}
$$
\nTherefore, when the flow is 2 L/min , the pressure at the downstream section is $\boxed{380 \text{ kPa}}$.
\nFor $Q = 20 \text{ L/min} = 3.333 \times 10^{-4} \text{ m}^3/\text{s}$,
\n
$$
V = \frac{Q}{A} = \frac{3.333 \times 10^{-4}}{4.909 \times 10^{-4}} = 0.6790 \text{ m/s}
$$
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1/s
8 $) ^2 = 380 \, \mathrm{kPa}$)² = 380 kPa
stream section is $\overline{\left[380 \, \mathrm{kPa} \right]}$. $/s,$

$$
V = \frac{Q}{A} = \frac{3.333 \times 10^{-4}}{4.909 \times 10^{-4}} = 0.6790 \,\mathrm{m/s}
$$

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