

CHAPTER (13)

FLOW MEASUREMENTS

HOMEWORK (5)

13.4, 13.10, 13.26, 13.40

Homework (13.4)

PROBLEM 13.4

Situation: A stagnation tube ($d = 2 \text{ mm}$) is used to measure air speed ($V = 12 \text{ m/s}$).

Find: Deflection on a water manometer: Δh

Properties: For air, $\nu = 1.4 \times 10^{-5} \text{ m}^2/\text{s}$.

Pressure drop calculation

Bernoulli equation applied to a stagnation tube

$$\Delta p = \rho V^2 / 2$$

Ideal gas law

$$\begin{aligned}\rho &= \frac{p}{RT} \\ &= \frac{98,000}{287 \times (273 + 10)} \\ &= 1.21 \text{ kg/m}^3\end{aligned}$$

Then

$$\begin{aligned}\Delta p &= 9810 \Delta h \\ &= 1.21 \times 12^2 / 2 \\ &= 8.88 \times 10^{-3} \text{ m} \\ &= 8.88 \text{ mm}\end{aligned}$$

Homework (13.10)

Note:

(y) Taken from the wall

(r) Should always be
taken from the center

y^*	$V, \text{ ft/s}$	y^*	$V, \text{ ft/s}$
0.0	0	2.0	110
0.1	72	3.0	117
0.2	79	4.0	122
0.4	88	5.0	126
0.6	93	6.0	129
1.0	100	7.0	132
1.5	106	8.0	135

*Distance from pipe wall, in.

Homework (13.10)

PROBLEM 13.10

Situation: Velocity data in a 16 inch circular air duct are given in the problem statement.

$$p = 14.3 \text{ psia}, T = 70^\circ\text{F}$$

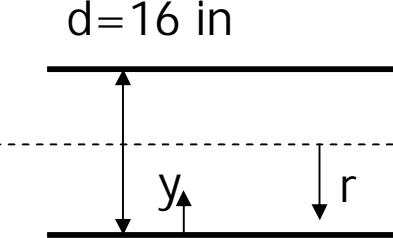
- Find:
- (a) Flow rate: Q in cfs and cfm.
 - (b) Ratio of maximum to mean velocity.
 - (c) Whether the flow is laminar or turbulent.
 - (d) Mass flow rate: \dot{m} .

APPROACH

Perform numerical integration to find flow rate (Q). Apply the ideal gas law to calculate density. Find mass flow rate using $\dot{m} = \rho Q$.

ANALYSIS

Numerical integration



y (in.)	r (in.)	V (ft/s)	$2\pi rV$ (ft ² /s)	area (ft ³ /s)
0.0	8.0	0	0	
0.1	7.9	72	297.8	1.24
0.2	7.8	79	322.6	2.58
0.4	7.6	88	350.2	5.61
0.6	7.4	93	360.3	5.92
1.0	7.0	100	366.5	12.11
1.5	6.5	106	360.8	15.15
2.0	6.0	110	345.6	14.72
3.0	5.0	117	306.3	27.16
4.0	4.0	122	255.5	23.41
5.0	3.0	126	197.9	18.89
6.0	2.0	129	135.1	13.88
7.0	1.0	132	69.4	8.51
8.0	0.0	135	0	2.88

Summing values in the last column of the above table gives $Q = 152.1 \text{ ft}^3/\text{s} = 9124 \text{ cfm}$
Flow rate equation

$$\begin{aligned}
 V_{\text{mean}} &= Q/A \\
 &= 152.1/(0.785(1.33)^2) \\
 &= 109 \text{ ft/s} \\
 V_{\text{max}}/V_{\text{mean}} &= 135/109 \\
 &= 1.24
 \end{aligned}$$

which suggests turbulent flow.

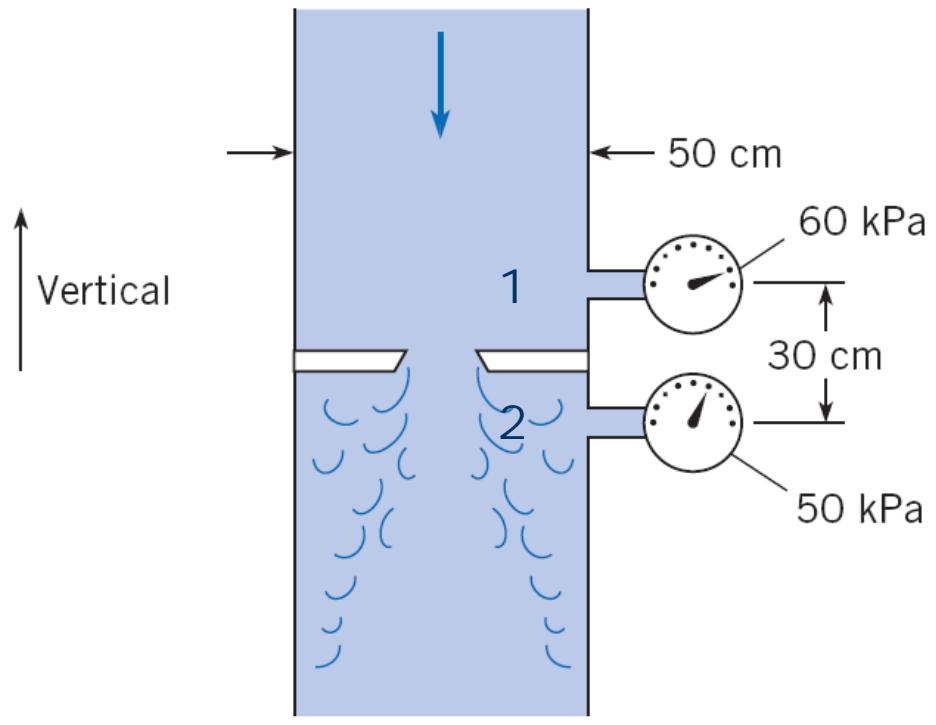
Ideal gas law

$$\begin{aligned}
 \rho &= \frac{p}{RT} \\
 &= \frac{(14.3)(144)}{(53.3)(530)} \\
 &= 0.0728 \text{ lbm/ft}^3
 \end{aligned}$$

Flow rate

$$\begin{aligned}
 \dot{m} &= \rho Q \\
 &= 0.0728(152.1) \\
 &= 11.1 \text{ lbm/s}
 \end{aligned}$$

Homework (13.26)



PROBLEM 13.26

Situation: Water flows through the orifice (vertical orientation) shown in the textbook. $D = 50 \text{ cm}$, $d = 10 \text{ cm}$, $\Delta p = 10 \text{ kPa}$, $\Delta z = 30 \text{ cm}$.

Find: Flow rate: Q

APPROACH

Find K and Δh ; then apply the orifice equation to find the discharge Q .

ANALYSIS

Piezometric head

$$\begin{aligned}\Delta h &= (p_1/\gamma + z_1) - (p_2/\gamma + z_2) \\ &= \Delta p/\gamma + \Delta z \\ &= 10,000/9,790 + 0.3 \\ &= 1.321 \text{ m of water}\end{aligned}$$

Find parameters needed to apply Fig. 13.13

$$\begin{aligned}d/D &= 10/50 = 0.20 \\ \frac{\text{Re}_d}{K} &= \sqrt{2g\Delta h} \frac{d}{\nu} \\ &= \sqrt{2 \times 9.81 \times 1.321} \frac{0.1}{10^{-6}} \\ &= 5.091 \times 10^5\end{aligned}$$

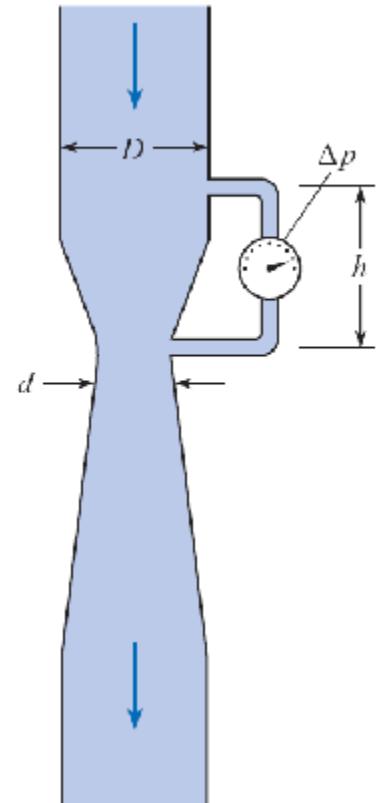
From Fig. 13.13

$$K = 0.60$$

Orifice equation

$$\begin{aligned}Q &= KA_o \sqrt{2g\Delta h} \\ &= 0.60 \times (\pi/4) \times (0.1)^2 \sqrt{2 \times 9.81 \times 1.321} \\ &= \boxed{0.0240 \text{ m}^3/\text{s}}\end{aligned}$$

Homework (13.40)



PROBLEM 13.40

Situation: Water (50°F) flows through a vertical venturi meter. $\Delta p = 6.2 \text{ psi}$, $d = 6 \text{ in.}$, $D = 12 \text{ in.}$, $\nu = 1.4 \times 10^{-5} \text{ ft}^2/\text{s}$.

Find: Discharge: Q

ANALYSIS

$$\Delta p = 6.20 \text{ psi} = 6.2 \times 144 \text{ psf}$$

Thus

$$\Delta h = 6.20 \times 144 / 62.4 = 14.3 \text{ ft}$$

Find K

$$\begin{aligned}\frac{\text{Re}_d}{K} &= \sqrt{2g\Delta h} \frac{d}{\nu} \\ &= \sqrt{2 \times 32.2 \times 14.3} \left(\frac{6/12}{1.4 \times 10^{-5}} \right) \\ &= 10.8 \times 10^5\end{aligned}$$

So $K = 1.02$.

Venturi equation

$$\begin{aligned}Q &= KA_t \sqrt{2g\Delta h} \\ &= 1.02 \times (\pi/4) \times (6/12)^2 \sqrt{2 \times 32.2 \times 14.3} \\ &\boxed{Q = 6.08 \text{ cfs}}\end{aligned}$$

THE END