

40.6 A residential gutter with a rectangular cross section transports 2gpm during peak rainfall. The channel is 6in wide and is pitched such that the height of the flowing water is 2in. Assuming 60°F rainwater, what is the friction factor for the gutter?

- A. 0.01
- B. 0.02
- C. 0.04
- D. 0.08

Often times when asked to find the friction factor is it appropriate to use the Darcy Equation, which is fairly accurate over a wide range of turbulent and laminar flow situations. However, if the flow is determined to be laminar, it may be more convenient to use the equation where f is specified directly as a function of the Reynolds number. This formula is shown on the **Moody Diagram**: $f = \frac{64}{Re}$ where $Re < 2000$.

For open channel flow, find the **hydraulic diameter** via the formula below. Note the use of the hydraulic diameter and not the equivalent diameter which is reserved for closed rectangular ducts.

$$D_h = \frac{4A}{P_{wetted}} = \frac{(4)(6in)(2in)}{[(2)(2in) + 6in]} = \frac{48in^2}{10in} = 4.8in \left(\frac{1ft}{12in} \right) = 0.4ft$$

Find the velocity of the water flow by using the volume flow rate and the cross-sectional area of the flow:

$$Q = vA \rightarrow v = \frac{Q}{A} = \frac{\left(2 \frac{\text{gallons}}{\text{min}}\right) \left(\frac{1\text{min}}{60\text{sec}}\right) \left(\frac{1\text{ft}^3}{7.48\text{gallons}}\right)}{[(6in)(2in)] \left(\frac{1\text{ft}^2}{144in^2}\right)} = .0535 \frac{\text{ft}}{\text{sec}}$$

Lookup the kinematic viscosity @60°F by searching **properties of water**:

$$\nu = 1.217 \times 10^{-5} \frac{\text{ft}^2}{\text{sec}}$$

Calculate the **Reynolds Number** and conclude the flow is laminar.

$$Re = \frac{vD}{\nu} = \frac{\left(.0535 \frac{\text{ft}}{\text{sec}}\right) (.4\text{ft})}{\left(1.217 \times 10^{-5} \frac{\text{ft}^2}{\text{sec}}\right)} = 1758 < 2000 \text{ (laminar)}$$

Calculate the friction factor for laminar flow:

$$f = \frac{64}{Re} = \frac{64}{1758} = .036$$

Answer C

40.7 A tee connection receives 4gpm of water from a 3/4 inch schedule 40 steel pipe and $3 \frac{ft}{s}$ of water from a 1 1/4in schedule 40 steel pipe. Water exits into a 1 1/2in schedule 40 steel pipe. What is the velocity in the outlet pipe? Ignore friction loss.

- A. $2.4 \frac{ft}{s}$
- B. $2.8 \frac{ft}{s}$
- C. $3.3 \frac{ft}{s}$
- D. $4.8 \frac{ft}{s}$

Make a table to organize the volume flow rate, diameter, area, and velocity at each location in the tee and populate known quantities. The volume flow rate at the exit will equal the sum of the two entering volume flow rates. Lookup **Steel Pipe Friction Tables** to gather the nominal diameters. Use diameter to find area: $A = \frac{\pi}{4}D^2$. Use $Q = VA$ to find volume flow rate and where required rearrange to $V = \frac{Q}{A}$ to find velocity.

$$Q_{3/4} = 4 \frac{gal}{min} \left(\frac{1ft^3}{7.48gal} \right) \left(\frac{1min}{60sec} \right) = 0.0089 \frac{ft^3}{s}$$

$$Q_{1 1/4} = \left(3 \frac{ft}{s} \right) (0.0104ft^2) = 0.0312 \frac{ft^3}{s}$$

$$Q_{exit} = 0.0089 \frac{ft^3}{s} + 0.0312 \frac{ft^3}{s} = 0.0401 \frac{ft^3}{s}$$

	3/4in entering	1-1/4in entering	1-1/2in exit
$Q \left[\frac{ft^3}{s} \right]$	0.0089	0.0312	0.0401
$D [in]$	—	1.38	1.61
$A [ft^2]$	—	0.0104	0.0141
$V \left[\frac{ft}{s} \right]$	—	3	$V = \frac{Q}{A} = \frac{0.0401 \frac{ft^3}{s}}{0.0141ft^2} = 2.8$

Specify the velocity at the outlet, $2.8 \frac{ft}{s}$.

Answer B