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.

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

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

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

	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	$V = \frac{Q}{A} = \frac{0.0401\frac{ft^3}{s}}{0.0141ft^2} = \mathbf{2.8}$

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

40.8 What is the kinematic viscosity of $140°F$ air at $50psia$?

A. $1 \times 10^{-5} \frac{ft^2}{s}$

B. $5 \times 10^{-5} \frac{ft^2}{s}$

C. $6 \times 10^{-5} \frac{ft^2}{s}$

D. $3 \times 10^{-3} \frac{ft^2}{s}$

Lookup Kinematic Viscosity in the reference handbook and recall the formula:

$$\nu = \frac{\mu}{\rho}$$

Dynamic Viscosity, μ, is a function of temperature only. Look up the Dynamic Viscosity in the table Properties of Air at Low Pressure. When reading the value from the table, notice the column heading is stated as Viscosity $\mu \times 10^7$. Therefore, if $\mu \times 10^7 = c$, where c is a constant, then it follows that $\mu = c \times 10^{-7}$. As a sense check, the magtitude of the viscosity is expected to be very small, not very large.

$$\mu_{@140°F \sim 600R} = 134.9 \times 10^{-7} \frac{lb_m}{sec \cdot ft}$$

The Kinematic Viscosity should not be looked up directly unless a standard temperature range associated with that table is applicable. Kinematic Viscosity changes as a function of temperature in accordance to how the density changes with temperature. Approximate the density by using the ideal gas law to determine the density of air at 600R. Lookup Properties of Ideal Gases to get the value of the gas constant for air.

$$PV = mRT \rightarrow P = \rho RT \rightarrow \rho = \frac{P}{RT}$$

$$\rho = \frac{\left(50\frac{lb_f}{in^2}\right)\left(\frac{144in}{1ft^2}\right)}{\left(53.35\frac{ft \cdot lb_f}{lb_m R}\right)(600R)} = 0.225\frac{lb_m}{ft^3}$$

Note that at more than triple atmospheric pressure, the density is substantially higher than we would typically see around standard temperature and pressure, atmospheric air.

Calculate kinematic viscosity:

$$\nu = \frac{\mu}{\rho} = \frac{134.9 \times 10^{-7} \frac{lb_m}{sec \cdot ft}}{.225\frac{lb_m}{ft^3}} = 6 \times 10^{-5} \frac{ft^2}{s}$$

Answer C