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.

$$\mu_{@140°F\sim600R} = 134.9 \times 10^{-7} \frac{lb_m}{sec \cdot ft}$$

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

40.9 **$50gpm$ of cold water at $60°F$ enters a $100ft$ tall building via $3in$ schedule 40 steel supply piping. Street pressure prior to the service entrance to the building is $85psig$. The equivalent length of piping on the longest run to the top floor is $500ft$. What pressure is available to fixtures on the top floor?**

A. $40psig$

B. $42psig$

C. $45psig$

D. $55psig$

Start by writing the Bernoulli Equation:

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_f$$

where P is static pressure, v is velocity, z is height, and h_f is friction loss. Neglecting the velocity term which makes a negligible contribution in many problems involving comparatively large static pressures and heights, and rearranging to solve for the unknown P_2 on the top floor of the building:

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + (z_1 - z_2) - h_f$$

Note the specific weight, $\gamma = \rho g$; however, at the end of the problem we will use a rule of thumb for water which saves time.

The street pressure P_1 is given and the Δz is known based on the height of the building. The main effort of the problem is finding the losses, h_f, using the Darcy Equation.

$$h_f = \frac{fLv^2}{2gD}$$

Using the Steel Pipe Friction Tables, the diameter of a nominal 3 inch pipe and the velocity of $50gpm$ through the pipe can be gathered:

$$D = \frac{3.068in}{12\frac{in}{ft}} = 0.2557ft$$

$$@50pgm : V = 2.17\frac{ft}{sec}$$