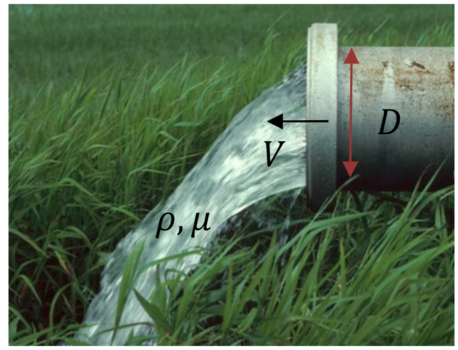
ENSC 283 Week # 2, Tutorial # 1– Dimensionless Quantities



Problem 1: A dimensionless combination of variables that is important in the study of viscous flow through pipes is called the *Reynolds number*, Re, defined as $\rho VD/\mu$ where, as indicated in the figure, ρ is the fluid density, V the mean fluid velocity, D the pipe diameter, and μ the fluid viscosity. A Newtonian fluid having a viscosity of $0.38\ N.s/m^2$ and a specific gravity of 0.91 flows through a 25-mm-diameter pipe with a velocity of $2.6\ m/s$. Determine the value of the Reynolds number using (a) SI units, and (b) BG units.

Solution

Step 1: Write out what you are required to solve for (this is so you don't forget to answer everything the question is asking for)

Find:

– Reynolds number, Re, in SI and BG units

Step 2: Prepare a data table

Data	Value	Unit
V	2.6	m/s
D	25	mm
μ	0.38	$N.s/m^2$
SG	0.91	-

Step 3: State your assumptions (you may have to add to your list of assumptions as you proceed in the problem)

Assumptions:

1) Water is considered as a Newtonian fluid.

Step 4: Calculations

(a) SI Units

The fluid density is calculated from the specific gravity as

$$\rho = SG\ \rho_{H_2O@4°C} = 0.91\ \left(1000\frac{kg}{m^3}\right) = 910\ kg/m^3 \qquad \text{(Eq1)}$$

From the definition of the Reynolds number,

$$Re = \frac{\rho V D}{\mu} = \frac{\left(910\frac{kg}{m^3}\right)\left(2.6\ \frac{m}{s}\right)(25\ mm)(10^{-3}\frac{mm}{m})}{0.38\ N.s/m^2} \qquad \text{(Eq2)}$$
$$= 156\ (kg.\frac{m}{s^2})/N$$

However, since $1N = 1\ kg.m/s^2$ it follows that the Reynolds number is unitless, therefore

$$Re = 156 \qquad \text{(Eq3)}$$

(b) BG Units

We first convert all the SI values of the variables appearing in the Reynolds number to BG values by using the conversion factors.

Since $1kW = 1kJ/s$, then the maximum electrical power generation per year become

$$\rho = \left(910\frac{kg}{m^3}\right)\left(1.940\times10^{-3}\frac{\frac{slugs}{ft^3}}{\frac{kg}{m^3}}\right) = 1.77\ slugs/ft^3 \qquad \text{(Eq4)}$$

$$V = \left(2.6\ \frac{m}{s}\right)\left(\ 3.281\frac{ft}{m}\right) = 8.53\ ft/s \qquad \text{(Eq5)}$$

$$D = (0.025\, m)\left(3.281 \frac{ft}{m}\right) = 8.20 \times 10^{-2}\, ft \qquad \text{(Eq6)}$$

$$\mu = (0.38\, N.s/m^2)\left(2.089 \frac{lb.s/ft^2}{N.s/m^2}\right) = 7.94 \times 10^{-3}\, lb.s/ft^2 \qquad \text{(Eq7)}$$

Using the definition of the Reynolds number, we get

$$Re = \frac{\rho V D}{\mu} = \frac{\left(1.77 \frac{slugs}{ft^3}\right)\left(8.53 \frac{ft}{s}\right)(8.20 \times 10^{-2}\, ft)}{7.94 \times 10^{-3}\, lb.s/ft^2} = 156 \qquad \text{(Eq8)}$$

Step 5: Concluding Statement

The value of any dimensionless quantity does not depend on the system of units used if all variables that make up the quantity are expressed in a consistent set of units.