Florida International University
Department of Civil and Environmental Engineering

CWR 3201 Fluid Mechanics
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Homework Assignment 1 Solutions

1. 1.17 (same number in 4th edition)

a) Distance has dimensions of length and time is already a dimension in itself:

$L = [C]T^2$, where [C] is a constant

Solving the equation for [C]: $[C] = \frac{L}{T^2}$

b) Force is equal to mass times acceleration so the dimensions must be $M * \frac{L}{T^2}$ and mass is already a dimension in itself:

$$M * \frac{L}{T^2} = [C]M$$

Solving the equation for [C]: $[C] = \frac{L}{T^2}$

c) Flow rate Q has dimensions of Volume per time: $\frac{L^3}{T}$,Area is length squared, and the radius is length. The slope S_0 has no units and therefore, no dimensions:

$$\frac{L^3}{T} = [C] * L^2 * L^{2/3}$$

Combining like terms: $\frac{L^3}{T} = [C] * L^{8/3}$

Solving for [C]: $[C] = L^{1/3} * T$

2. 1.25 (same number in 4th edition)
   a. Horizontal net force F=ma: $F = 10\ kg * 40\ \frac{m}{s^2} = 400\ N$
   b. Vertically, weight is acting downwards on the object and the force is acting upwards on the object: $F - W = ma$

   $$F = ma + W = 10kg * 40\ \frac{m}{s^2} + 10\ kg * 9.81\ \frac{m}{s^2} = 498.1\ N$$

   c. Sloping up at 30 degrees will make the weight acting downward on the object slope at 30 degrees. Since we are only interested in the vertical component of the weight, we make $W = W\sin 30°$

   $$F - W\sin 30° = ma$$

   $$F = ma + W\sin 30° = 10 * 40 + 10 * 9.81 * \sin 30° = 449\ N$$

3. 1.29 (same number in *Fourth edition*)
    a. $Gage\ pressure - Vacuum = Absolute\ pressure$

$$101\ kPa - 31\ kPa = 70\ kPa\ abs$$

    b. $760\ mmHg - \frac{31\ kPa}{101\ kPa} * 760\ mmHg = 527\ mmHg\ abs$
    c. $14.7\ psi - \frac{31\ kPa}{101\ kPa} * 14.7\ psi = 10.2\ psi\ abs$
    d. $34ft\ H_2O - \frac{31\ kPa}{101\ kPa} * 34ft\ H_2O = 23.6ft\ H_2O\ abs$
    e. $30\ in.of\ Hg - \frac{31\ kPa}{101\ kPa} * 30\ in.of\ Hg = 20.8\ in.of\ Hg\ abs$
4. 1.39 (same number in 4th edition)

$$Specific\ gravity, S = \frac{\rho_{liquid}}{\rho_{water}}$$

$$\rho = \frac{m}{V}$$

$$S = \frac{m/V}{\rho_{water}} = 1.2 = \frac{10\ slugs/V}{1.94\ slugs/ft^3}$$

Solving for volume: $V = 4.30\ ft^3$
5. 1.41 (same number in *Fourth edition*)
At equilibrium, the weight of the piston is balanced by the resistance in the oil due to the wall shear stress: $W_{piston} = \tau * \pi DL$, where D is the diameter of the piston and L is the piston length.

The distance between the piston and the cylinder is small, can assume linear velocity distribution, which means that the shear can be represented as:

$$\tau = \mu\frac{dv}{dr} = \mu\frac{V_{piston} - 0(no\ initial\ velocity)}{\frac{D_{cyl} - D_{piston}}{2}}$$

Combining both equations and using Weight= mass* gravity:

$$mg = \left[\mu\frac{V_{piston} - 0(no\ initial\ velocity)}{\frac{D_{cyl} - D_{piston}}{2}}\right] * \pi DL$$

Solving for velocity of the piston: $V_{piston} = \frac{0.350\ kg*9.81\frac{m}{s^2}*(0.1205m-0.120m)}{2*\left(0.025\ N\frac{s}{m^2}\right)*\pi*0.120m*0.10m} =$

$$0.91\ m/s$$

6. 1.47 (same number in *Fourth edition*)
Force applied to the belt is the viscosity due to water times the area of the surface at which the force is being applied:

$$F_{belt} = \mu\frac{dv}{dy}A = 1.31x10^{-3} * \frac{\frac{10m}{s}}{0.002\ m} * (0.6m * 4\ m) = 15.7\ N$$

$$Power = \frac{Force * Velocity}{746\ (to\ get\ in\ horsepower)} = \frac{15.7\ N * 10m/s}{746} = 0.210\ hp$$

7. 1.55 (same number in *Fourth edition*)

Applied pressure due to change in volume: $\Delta p = -\frac{B\Delta Volume}{Volume}$, where B is the bulk modulus of elasticity. At standard conditions, it is approximately 2100 MPa.

$$\Delta p = -2100\ MPa * \frac{18.7\ L - 20\ L}{20\ L} = 136.5\ MPa$$

8. 1.56 (same number in 4th edition)

   a. Speed of propagation through water: $c = \sqrt{\frac{B}{\rho}}$, use a table to find the bulk modulus of elasticity and the density of water at different temperatures: $c = \sqrt{\frac{327000psi*(144\frac{in^2}{ft^2})}{1.93\frac{slug}{ft^3}}} = 4940\frac{ft}{s}$

   b. $c = \sqrt{\frac{326000psi*(144\frac{in^2}{ft^2})}{1.93\frac{slug}{ft^3}}} = 4932\frac{ft}{s}$

   c. $c = \sqrt{\frac{308000psi*\left(144\frac{in^2}{ft^2}\right)}{1.87\frac{slug}{ft^3}}} = 4870\frac{ft}{s}$

9. 1.59 (same number in *Fourth edition*)

   $p = \frac{4\sigma}{R}$, where σ, surface tension is found using Table B.1

$$p = \frac{4 * 0.00504\ lb/ft}{\frac{\frac{1}{16}}{2} in * \frac{ft}{12\ in}} = 7.74\ psf$$

10. 1.61 (same number in *Fourth edition*)

Capillary rise: $h = \frac{4\sigma cos\beta}{\gamma D} = \frac{4\sigma cos\beta}{\rho g D} = \frac{4*0.0736\frac{kg}{m}*\cos 30}{1000\frac{kg}{m^3}*9.81\frac{m}{s^2}*0.0002m} = 0.130\ m$