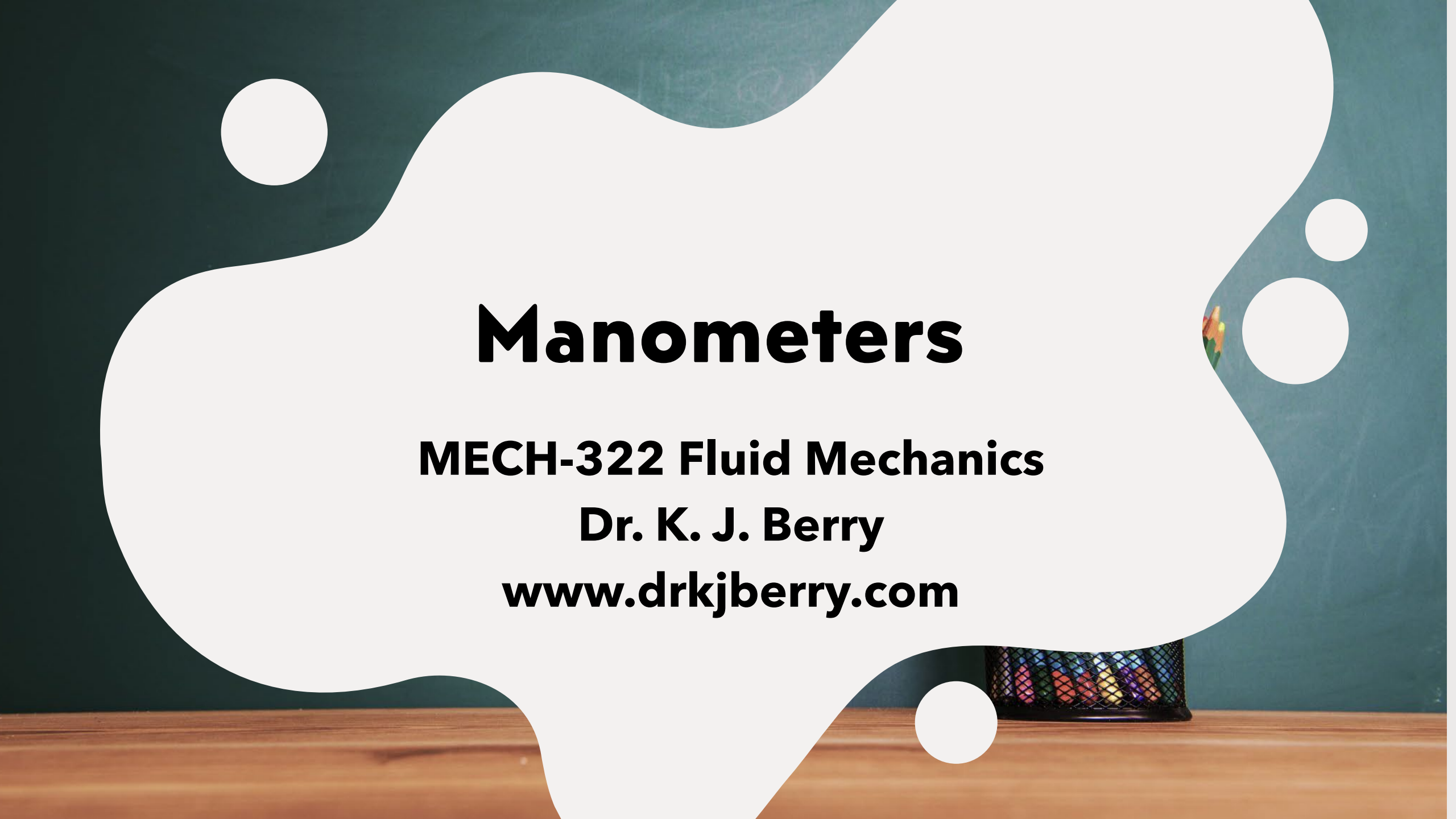


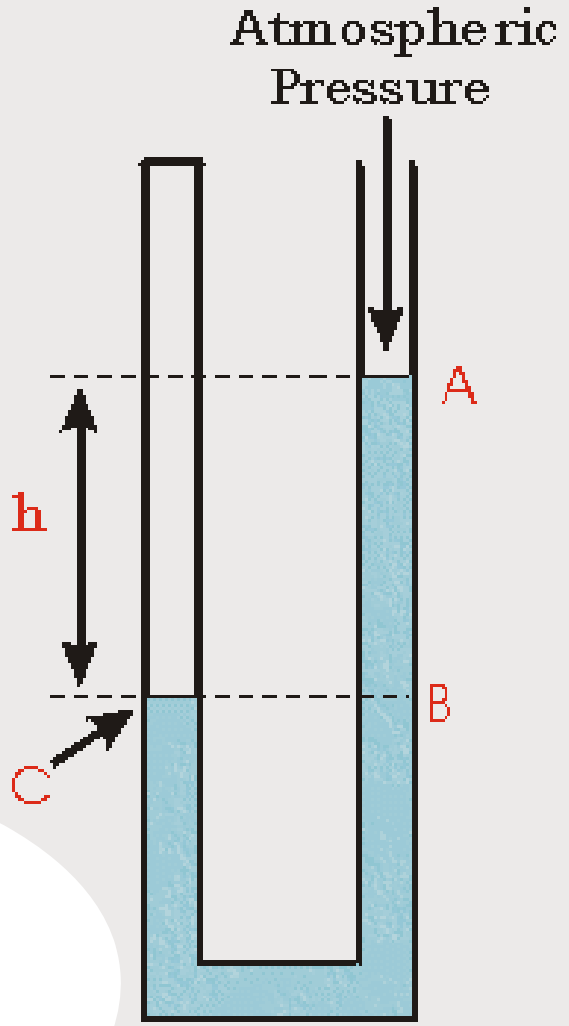
Manometers

MECH-322 Fluid Mechanics

Dr. K. J. Berry

www.drkjberry.com

A *Manometer* is a device to measure Pressure Differential. A common simple manometer consists of a *U* shaped tube of glass filled with some liquid. Typically the liquid is mercury because of its high density.



COMMON APPLICATIONS

Fluid Velocity in Pipes and Ducts
Flight Speed from Jet Aircraft to Space Shuttles

Used throughout MECH-322 Fluid Mechanics to determine pressure drops and velocity.

FLUID STATICS-LAW OF HYDROSTATICS

$$\frac{dP}{dz} = \gamma \quad g \downarrow z \downarrow$$

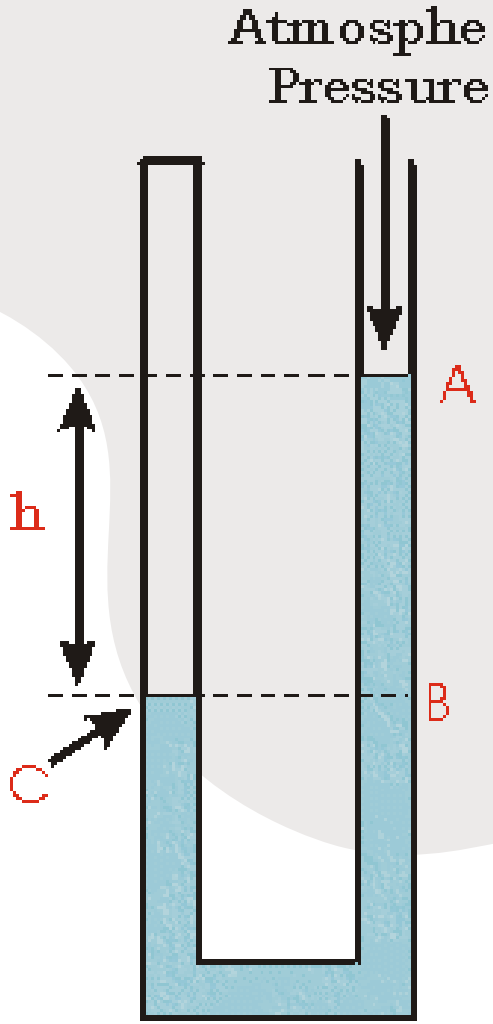
$$\frac{dP}{dz} = -\gamma \quad g \downarrow z \uparrow$$

Incompressible + No Shear Stress

POINT-TO-POINT METHOD

$$P_A + \Delta P_{A-B} = P_B$$

FOLLOW THE PATH



$$P_C - \gamma_m h = P_A; \ (P_c = P_B \rightarrow Pascals \text{ LAW})$$

$$h[ft] = \frac{P_C\left[\frac{lbf}{ft^2}\right] - P_A\left[\frac{lbf}{ft^2}\right]}{\gamma_m\left[\frac{lbf}{ft^3}\right]}$$

$$h[m] = \left\{\frac{P_C\left[\frac{N}{m^2}\right] - P_A\left[\frac{N}{m^2}\right]}{\gamma_m\left[\frac{N}{m^3}\right]}\right\}[m]$$

FIND "Δh".

ROAD MAP

Identify and label various elevation levels associated with different fluids and understanding Pascal's Law.

Identify Starting Point and Ending Point.

Identify any "MISSING" dimensions from Start Point to End Point, ΔS.

Transverse circuit from Start Point and Apply POINT-TO-POINT method for Law of Hydrostatics

Solve for Unknown.

FIND "Δh".

ROAD MAP

Identify and label various elevation levels associated with different fluids and understanding Pascal's Law.

Identify Starting Point and Ending Point.

Identify any "MISSING" dimensions from Start Point to End Point, ΔS.

Transverse circuit from Start Point and Apply POINT-TO-POINT method for Law of Hydrostatics

Solve for unknown.

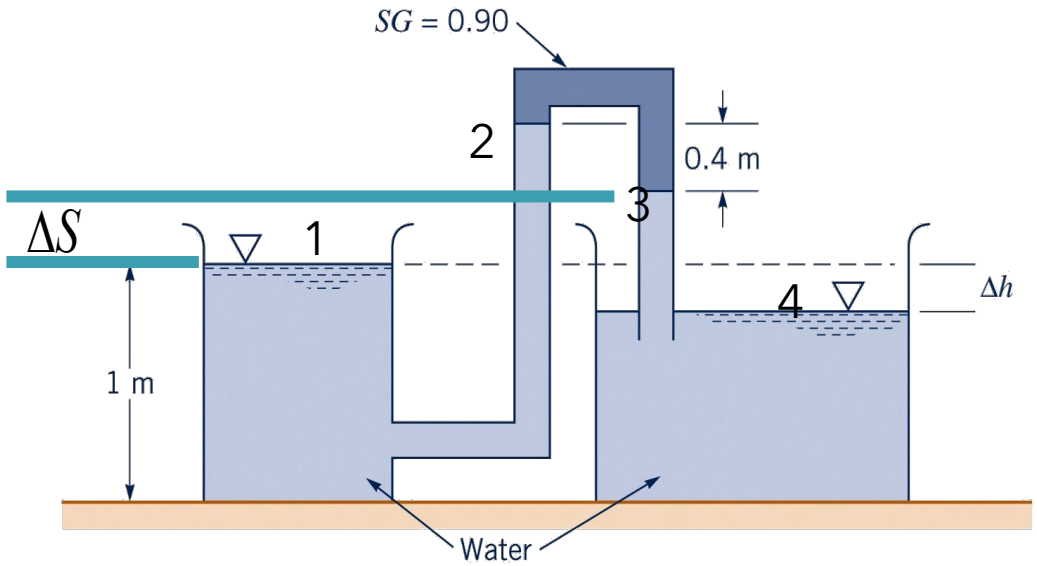


Figure P2.47

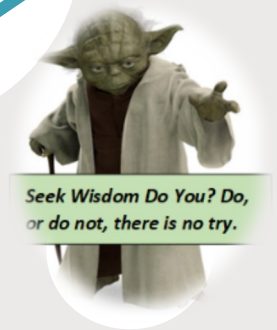
START 1, END 4

$$P_1 - \cancel{\Delta S \gamma_{H20}} - 0.4m\gamma_{H20} + 0.4\gamma_f + (\cancel{\Delta S} + \Delta h)\gamma_{H20} = P_4$$

$$P_1 = P_4 = 0 \text{gauge}$$

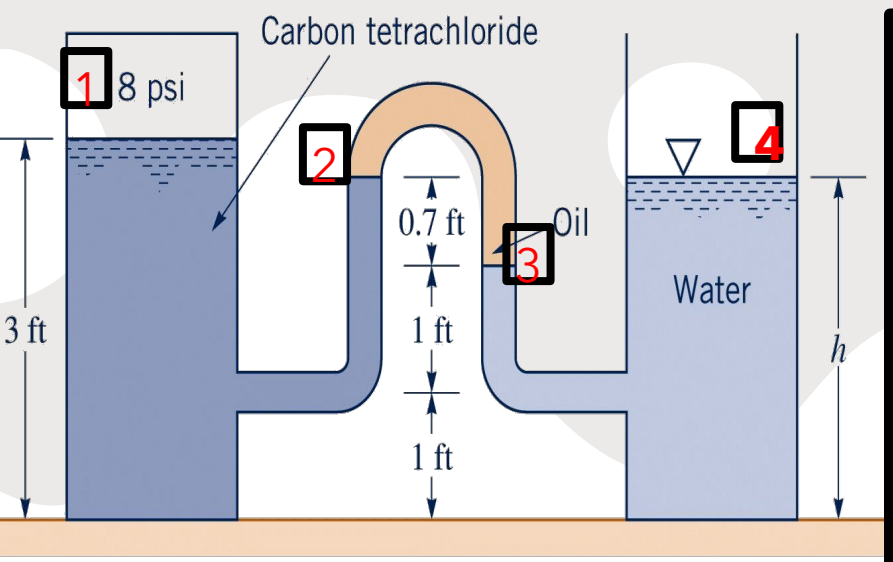
$$\Delta h = \frac{0.4m(\gamma_{H20} - \gamma_f)}{\gamma_{H20}} = 0.4m(1 - S_{g_f}) \rightarrow \text{Parametric Equation}$$

$$\Delta h = 0.4m(1 - 0.90)$$



PROBLEM 2.48

WRITE DOWN EXPLICITLY START AND END POINTS



re P2.54

FIND h Parametric Expression & Check Units

Starting: 1, Ending Point 4

$$P_1 + \gamma_{TC}(3-2.7)\,ft + \gamma_{OIL}(0.7\,ft) - \gamma_{H20}(h-2)\,ft = P_4$$

$$h = \frac{P_1 - P_4 + \gamma_{TC}(3-2.7)\,ft + \gamma_{OIL}(0.7\,ft) - \gamma_{H20}2\,ft}{\gamma_{H20}} \rightarrow \text{Parametric Expression}$$

$$P_1\left[\frac{lbf}{ft^2}\right] = 8\frac{lbs}{in^2}\bullet\frac{144in^2}{ft^2} = 1152\left[\frac{lbf}{ft^2}\right]$$

$$P_4\left[\frac{lbf}{ft^2}\right] = 0\text{gage}\left[\frac{lbf}{ft^2}\right] \rightarrow \text{OPEN to ATM}$$

$$\gamma_{TC}\left[\frac{lbf}{ft^2}\right] = 99.5\left[\frac{lbf}{ft^3}\right]$$

$$h = 16.95\,ft$$

$$h[ft] = \left\{\frac{1152\left[\frac{lbf}{ft^2}\right] - 0\left[\frac{lbf}{ft^2}\right] + 99.5\left[\frac{lbf}{ft^3}\right](0.30)\,ft + (0.8\bullet\gamma_{H20})(0.7\,ft) - \gamma_{H20}2\,ft}{62.4\left[\frac{lbf}{ft^3}\right]}\right\}[ft]$$

Question: How can one check units without the PARAMETRIC EXPRESSION?

IDENTIFY LEVELS and ANY MISSING DINENSIONS

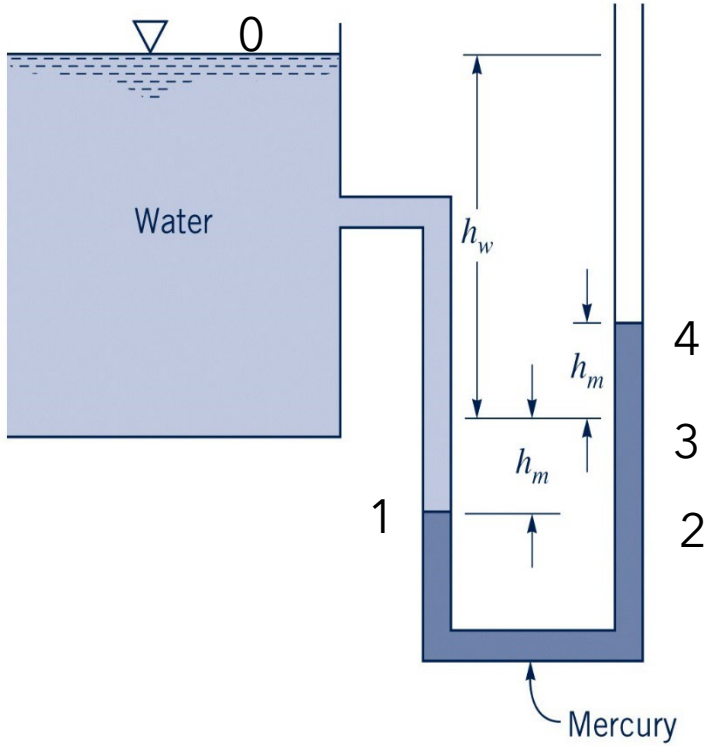


Figure P2.35

Problem 2.36

Determine $\frac{h_w}{h_m}$

Law of Hydrostatics Drives Fluid Principles

$P_1 \rightarrow$ MUST BE SAME AS P_2 (SAME FLUID/SAME ELEVATION)

Start Point 0: End Point 4

$$P_0 + \gamma_w(h_w + h_m) - \gamma_m(2h_m) = P_4$$

$$\gamma_w(h_w + h_m) - \gamma_m(2h_m) = P_4 - P_0$$

$\div h_m$

$$\frac{\gamma_w(h_w + h_m)}{h_m} - 2\gamma_m = \frac{P_4 - P_0}{h_m}$$

$\div \gamma_w$

$$\frac{h_w}{h_m} + 1 = \frac{2\gamma_m}{\gamma_w} + \frac{P_4 - P_0}{\gamma_w h_m}$$

$$\frac{h_w}{h_m} = \frac{2\gamma_m}{\gamma_w} - 1 + \frac{P_4 - P_0}{\gamma_w h_m}$$

$$\frac{h_w}{h_m} = 2(Sg)_m - 1 + \frac{(P_4 - P_0)}{\gamma_w h_m}$$

$$\frac{h_w}{h_m} = 2 \bullet 13.55 - 1 = 26.1$$

IDENTIFY LEVELS and ANY MISSING DINENSIONS

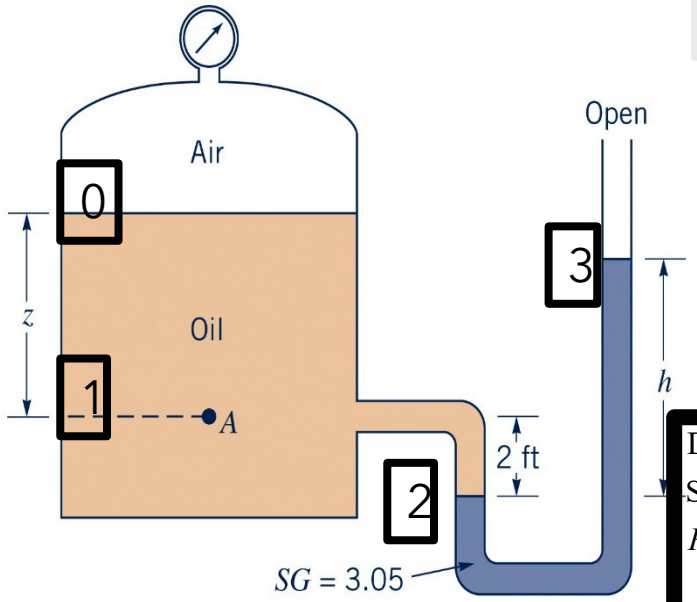


Figure P2.42

Determine Height Z

Law of Hydrostatics Drives Fluid Principles

Start Point: 0, End Point 1

$$P_0 + \gamma_{oil} z = P_A$$

$$z[ft] = \frac{(P_A - P_0)\left[\frac{lbf}{ft^2}\right]}{\gamma_{oil}\left[\frac{lbf}{ft^3}\right]}[ft]$$

$$z[ft] = \frac{(2.0 - 0.5)\frac{lbf}{in^2} \bullet \frac{144 in^2}{ft^2}}{54.0\frac{lbf}{ft^3}} = 4\,ft$$

$$\gamma_{oil}\left[\frac{lbf}{ft^3}\right] = 54.0\frac{lbf}{ft^3}$$

$$P_A\left[\frac{lbf}{ft^2}\right] = 2.0\frac{lbf}{in^2} \bullet \frac{144\,in^2}{ft^2}$$

$$P_{AIR}\left[\frac{lbf}{ft^2}\right] = 0.50\frac{lbf}{in^2} \bullet \frac{144\,in^2}{ft^2}$$

Determine Manometer Deflection "h"

Start: 0, End 3 → Apply Hydrostatics

$$P_0 + \gamma_{oil}(z+2) - \gamma_m h = P_3$$

$$h[ft] = \frac{(P_0 - P_3)\left[\frac{lbf}{ft^2}\right] + \gamma_{oil}\left[\frac{lbf}{ft^3}\right](z+2)[ft]}{\gamma_m\left[\frac{lbf}{ft^3}\right]}[ft]$$

$$h[ft] = \frac{(P_0 + \gamma_{oil} z - P_3)\left[\frac{lbf}{ft^2}\right] + 2[ft]\gamma_{oil}\left[\frac{lbf}{ft^3}\right]}{\gamma_m\left[\frac{lbf}{ft^3}\right]}$$

$$h[ft] = \frac{P_A - P_3 + 2[ft]\gamma_{oil}\left[\frac{lbf}{ft^3}\right]}{\gamma_m\left[\frac{lbf}{ft^3}\right]}[ft]$$

Problem 2.42

OR PICK OTHER POINTS

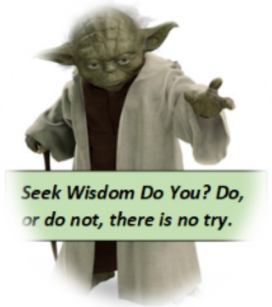
Start: A, End 3 → Apply Hydrostatics

$$P_A + 2\gamma_{oil} - \gamma_m h = P_3$$

$$h[ft] = \frac{(P_A - P_3)\left[\frac{lbf}{ft^2}\right] + 2[ft]\gamma_{oil}\left[\frac{lbf}{ft^3}\right]}{\gamma_m\left[\frac{lbf}{ft^3}\right]}[ft]$$

In the decades of teaching thermal fluids, the primary differences between those that stray from the path at the end of the course, and those that stay on the path and do extremely well are:

1. Accepting Unit Validation Before Numbers
2. Understanding and commitment to the consistent process to apply the Point-to-Point Method to determine pressure and velocity with Manometers.
3. Accepting the simplicity of Fluids, if following the PATH.



ROCKET SCIENCE,
LEARNING FLUIDS IS NOT!

Examples of Future Chapter Problems

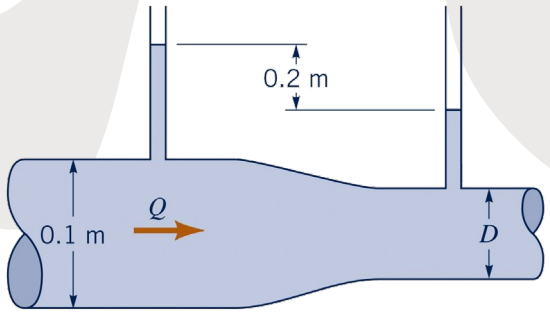


Figure P3.51

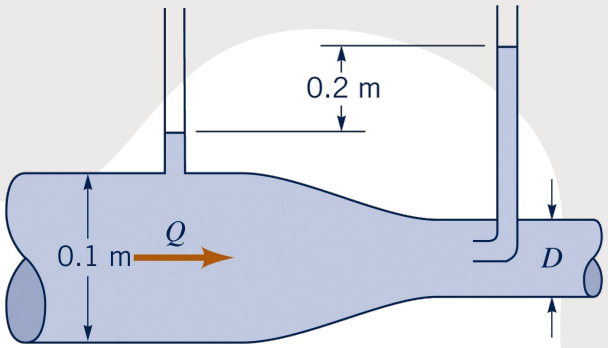


Figure P3.52

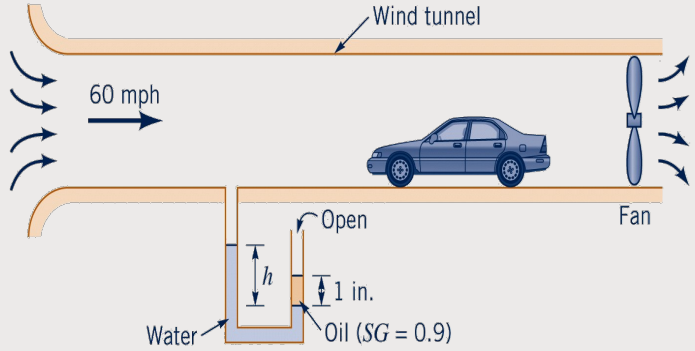


Figure P3.46

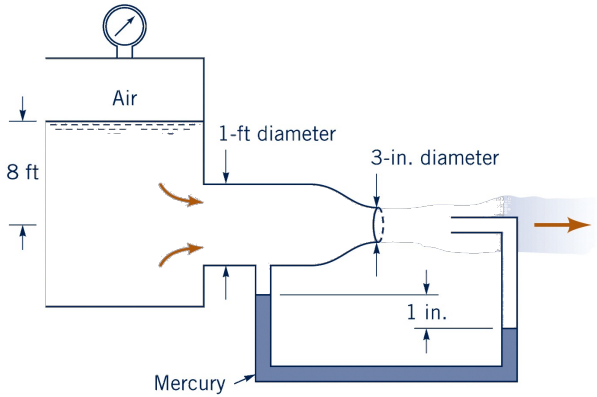


Figure P3.65

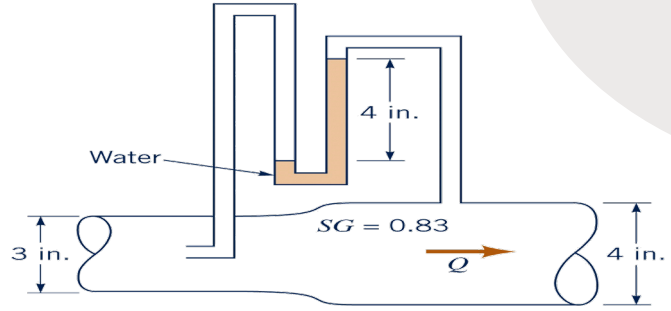


Figure P3.67

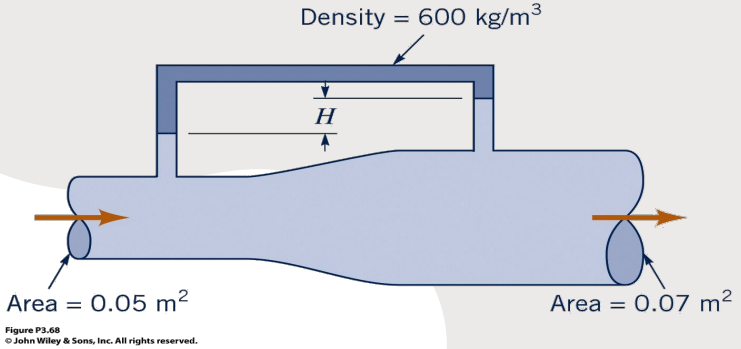


Figure P3.68

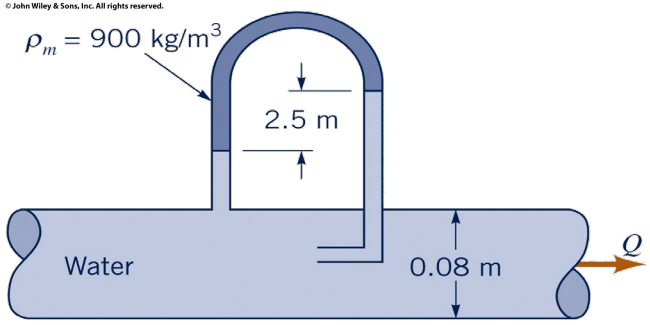


Figure P3.69

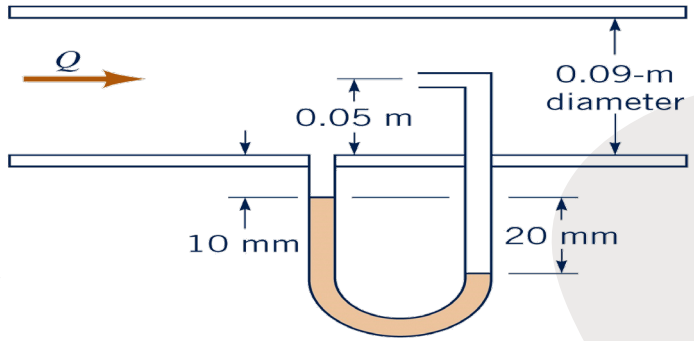


Figure P3.70

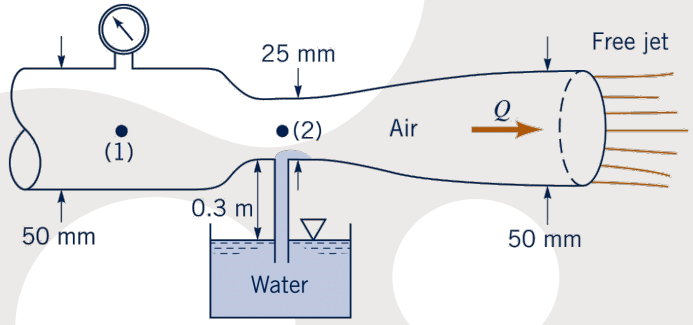


Figure P3.75

TRUST the "PATH", and Geometry Becomes Irrelevant.

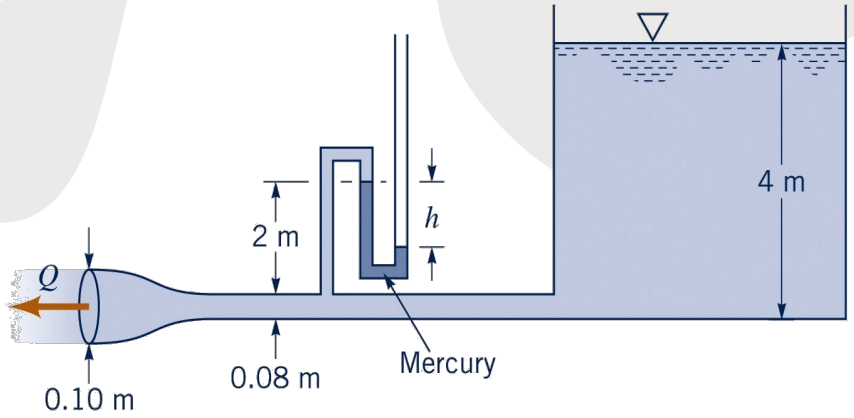


Figure P3.76
© John Wiley & Sons, Inc. All rights reserved.

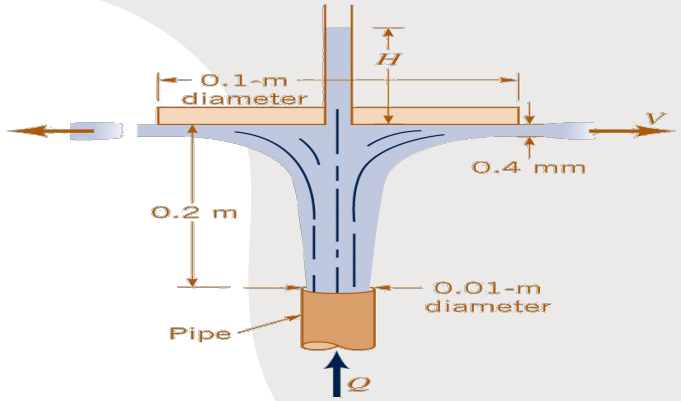


Figure P3.107
© John Wiley & Sons, Inc. All rights reserved.

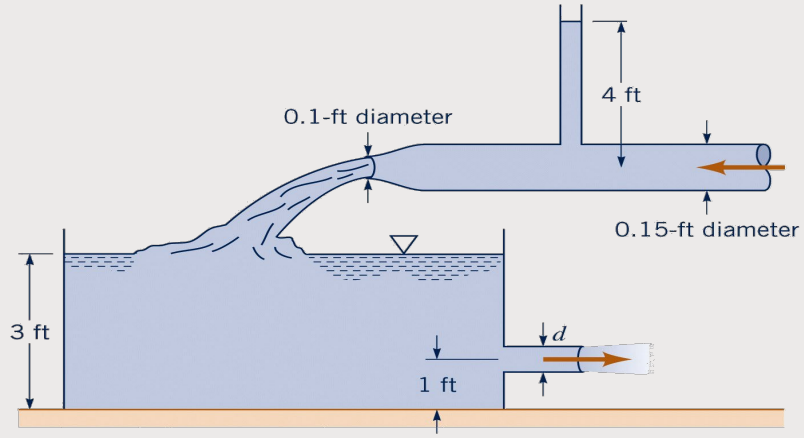


Figure P3.109
© John Wiley & Sons, Inc. All rights reserved.

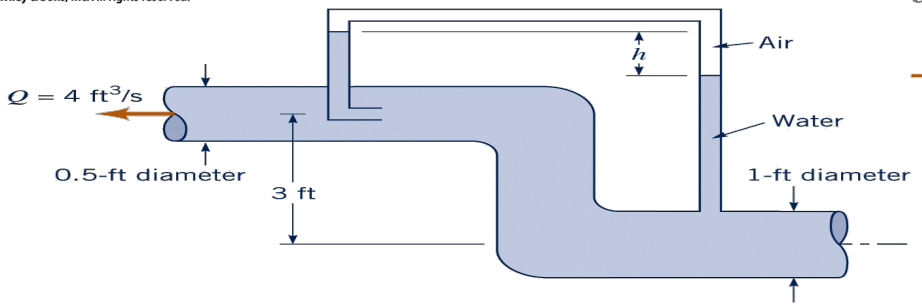


Figure P3.92
© John Wiley & Sons, Inc. All rights reserved.

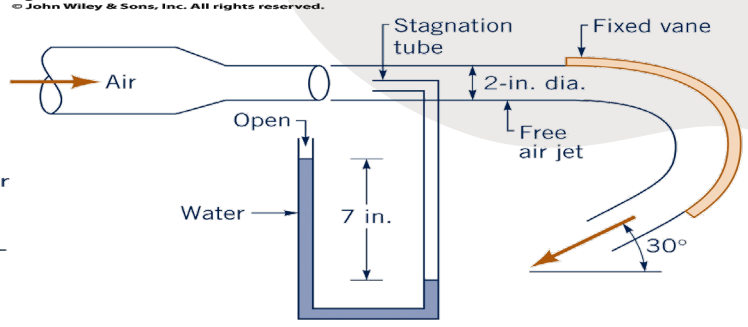


Figure P5.66
© John Wiley & Sons, Inc. All rights reserved.

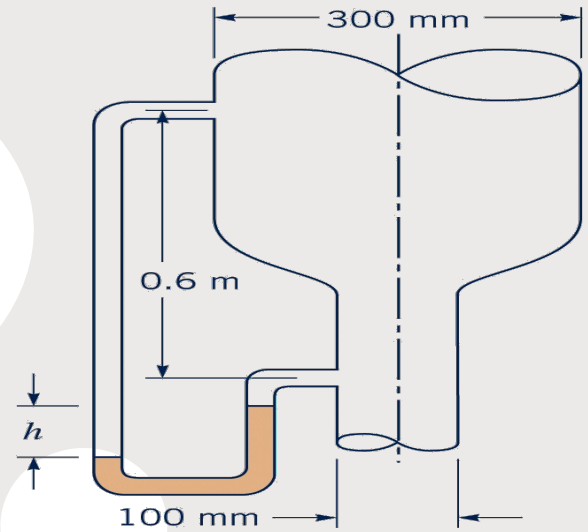


Figure P5.102
© John Wiley & Sons, Inc. All rights reserved.

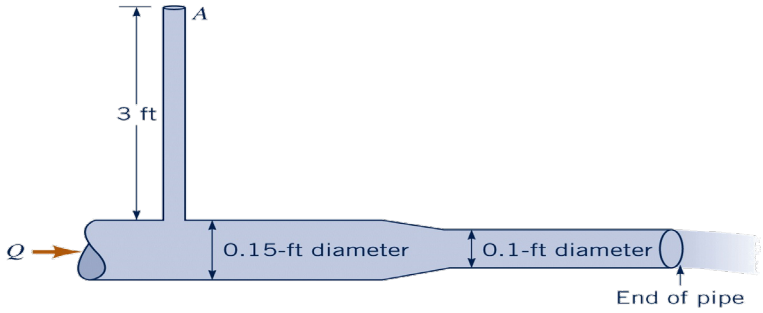


Figure P3.90
© John Wiley & Sons, Inc. All rights reserved.

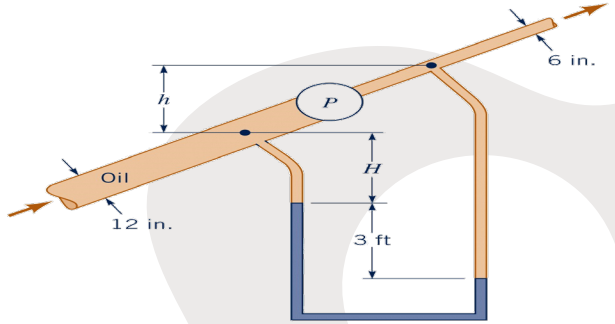


Figure P5.113
© John Wiley & Sons, Inc. All rights reserved.

Solve *EVERY* Manometer problem in the entire MECH-322 Fluid Mechanics course with the exact same process, from week #2 to FINAL EXAM, and the engineering and the problems and geometry become 2nd nature.

TRUST THE PATH