CM3215

Fundamentals of Chemical Engineering Laboratory

Prelab Preparation for

Frictional Losses in Straight Pipe

Professor Faith Morrison

Department of Chemical Engineering
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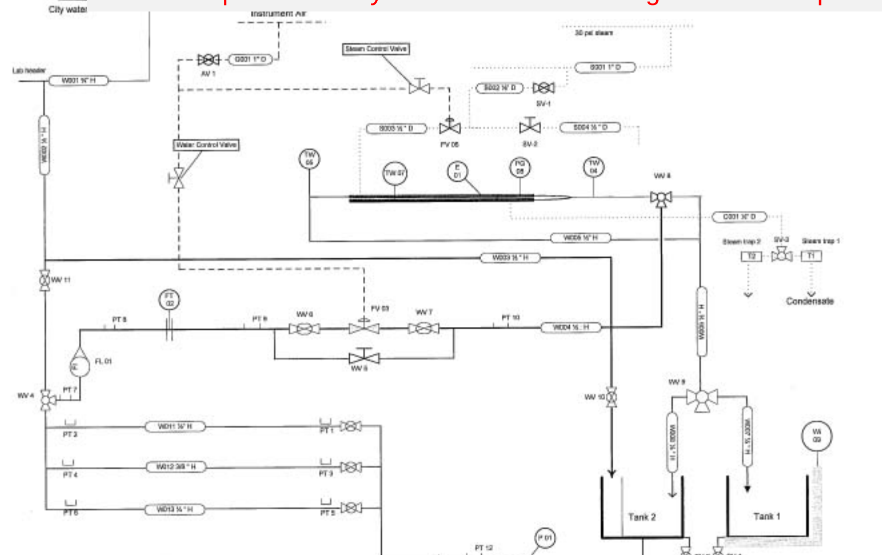
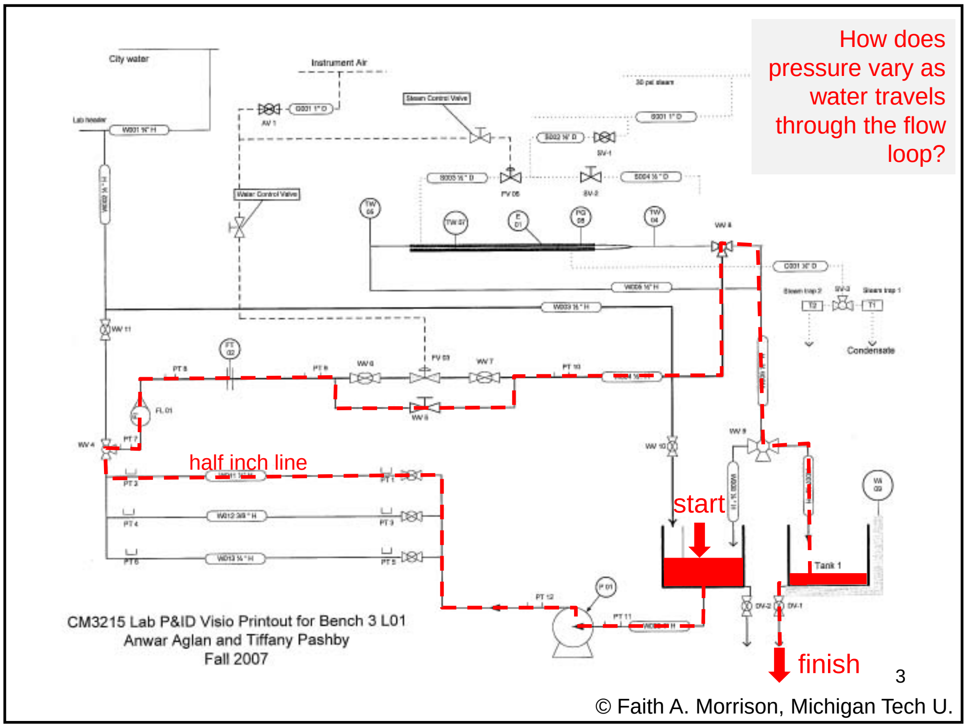
How does pressure vary as water travels through the flow loop?



CM3215 Lab P&ID Visio Printout for Bench 3 L01
Anwar Aglan and Tiffany Pashby
Fall 2007

2


How does pressure vary as water travels through the flow loop?
half inch line
start
finish
CM3215 Lab P&ID Visio Printout for Bench 3 L01
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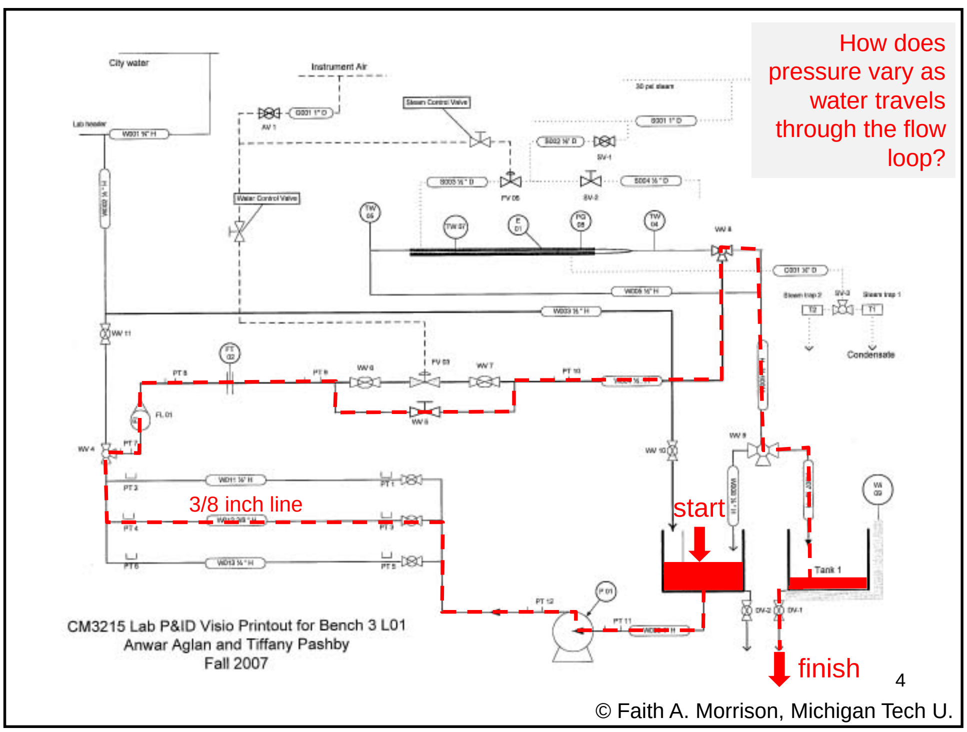
How does pressure vary as water travels through the flow loop?
3/8 inch line
start
finish
CM3215 Lab P&ID Visio Printout for Bench 3 L01
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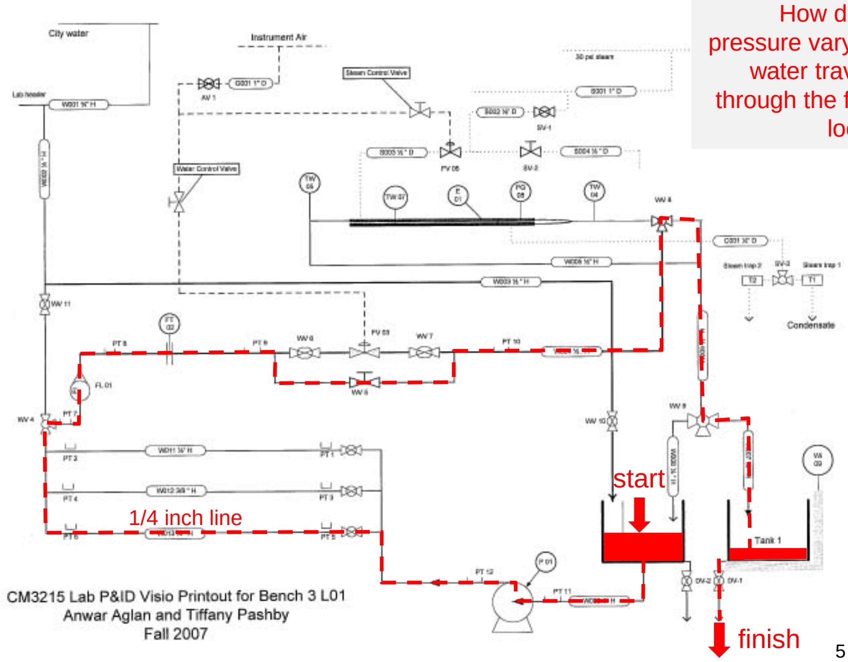

5

What do we have to do to make fluid flow in a pipe?

6

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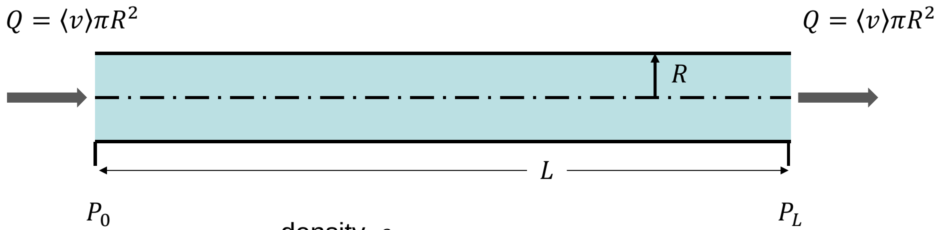

density, ρ
viscosity, μ
temperature, T

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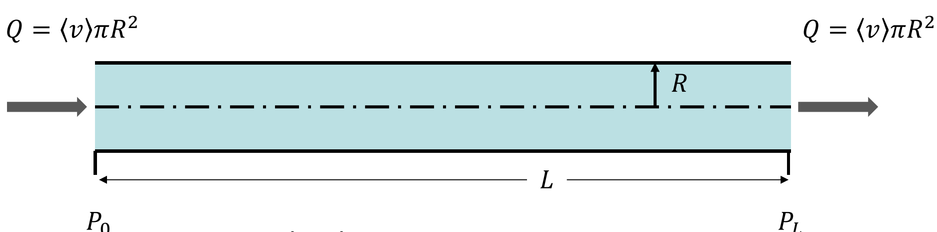
What do we have to do to make fluid flow in a pipe?



density, ρ
viscosity, μ
temperature, T

How would you <u>predict</u> the required pressure drop to obtain a desired flow rate?

$$\Delta p_{pipe} \equiv P_o - P_L$$

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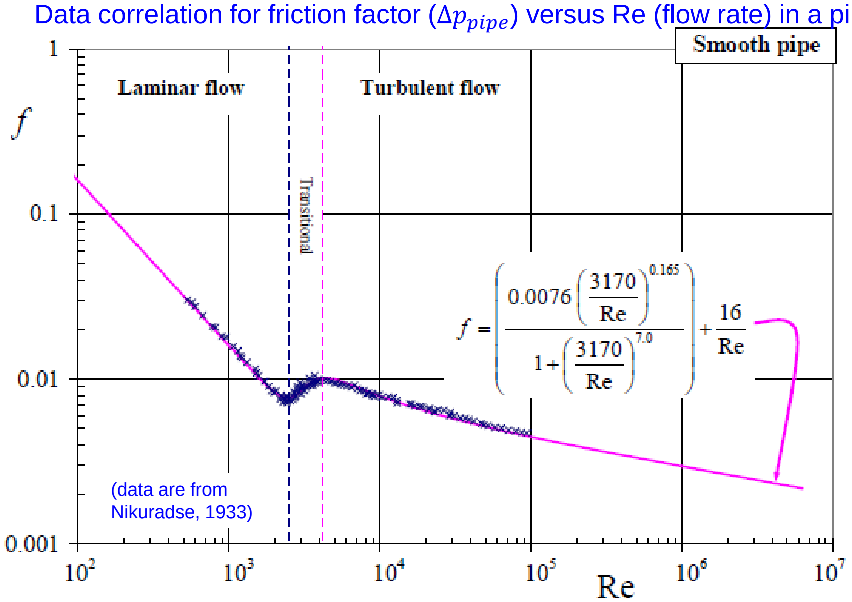
Literature

Data correlation for friction factor (Δp_{pipe}) versus Re (flow rate) in a pipe



Reference: *Morrison, Faith A, An Introduction to Fluid Mechanics, Cambridge University Press, 2013, Figure 7.18, page 532.*

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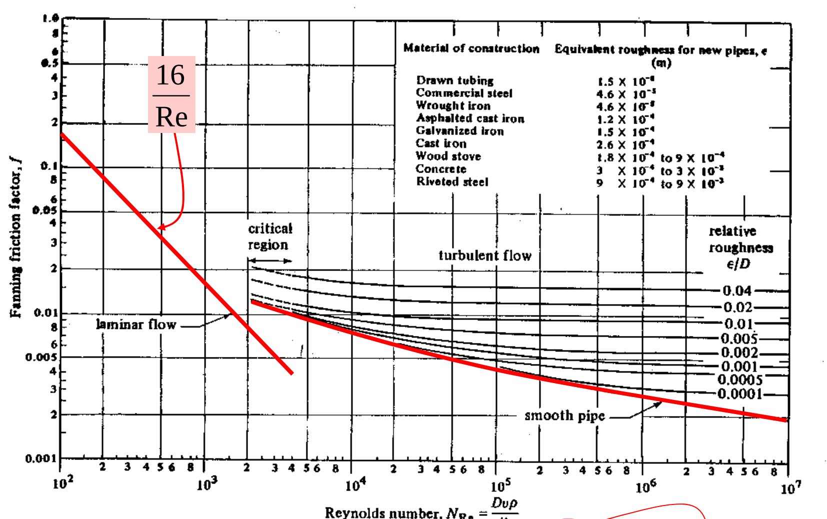

FIGURE 2.10-3. *Friction factors for fluids inside pipes. [Based on L. F. Moody, Trans. A.S.M.E., 66, 671, (1944); Mech. Eng. 69, 1005 (1947). With permission.]*

(Geankoplis, 2003)

10

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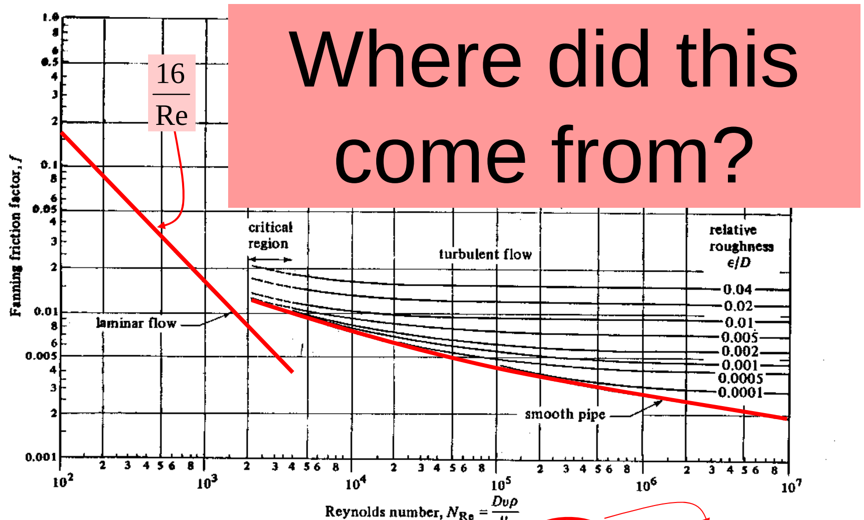

FIGURE 2.10-3. *Friction factors for fluids inside pipes.* [*Based on L. F. Moody, Trans. A.S.M.E., 66, 671, (1944); Mech. Eng. 69, 1005 (1947). With permission.*]

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Fanning Friction Factor = Dimensionless Wall Drag

$$f \equiv \frac{F_{drag} \text{ on pipe walls}}{\frac{1}{2}\rho\langle v\rangle^2(\pi DL)}$$

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$$f \equiv \frac{F_{drag} \text{ on pipe walls}}{\frac{1}{2}\rho\langle v\rangle^2(\pi D L)}$$

$$f = \frac{\left(\Delta p_{pipe}\pi\left(\frac{D^2}{4}\right)\right)}{\frac{1}{2}\rho\langle v\rangle^2(\pi D L)}$$

(comes from a macroscopic momentum balance; see CM3110)

$$\Delta p_{pipe} \equiv P_{upstream} - P_{downstream}$$

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$$\Delta p_{pipe} \equiv P_{upstream} - P_{downstream}$$

$$f = \frac{\Delta p_{pipe} D}{2L\rho\langle v\rangle^2}$$

(see Morrison, *An Intro to FM*, inside front cover)

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(comes from a macroscopic momentum balance; see CM3110)

$$\Delta p_{pipe} \equiv P_{upstream} - P_{downstream}$$

Measure: Δp_{pipe} versus $\langle v\rangle$ on straight pipe of length L and inner diameter D.

$$f = \frac{\Delta p_{pipe} D}{2L\rho\langle v\rangle^2}$$

(see Morrison, *An Intro to FM*, inside front cover)

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Fanning Friction Factor = Dimensionless Wall Drag

$$f \equiv \frac{F_{drag} \text{ on pipe walls}}{1}$$

Now, you do it.

$$f = \frac{1}{\frac{1}{2}\rho\langle v\rangle^2(\pi D L)}$$

(comes from a macroscopic momentum balance; see CM3110)

$$\Delta p_{pipe} \equiv P_{upstream} - P_{downstream}$$

Measure: Δp_{pipe} versus $\langle v\rangle$ on straight pipe of length L and inner diameter D.

$$f = \frac{\Delta p_{pipe} D}{2L\rho\langle v\rangle^2}$$

(see Morrison, *An Intro to FM*, inside front cover)

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Data may be organized in terms of two dimensionless parameters:

Flow rate

Reynolds Number

$$\text{Re} = \frac{\rho \langle v \rangle D}{\mu}$$

Pressure Drop

Fanning Friction Factor

$$f = \frac{\Delta p_{pipe} D}{2L\rho \langle v \rangle^2}$$

ρ density
$\langle v \rangle$ average velocity
D pipe inner diameter
μ viscosity
Δp_{pipe} pressure drop over pipe of length L
L pipe length

$$\Delta p_{pipe} \equiv P_o - P_L$$

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Lab: Frictional Losses in Straight Pipe

Note: For this laboratory, no procedure will be supplied.

Frictional Losses in a Straight Pipe

Pre-laboratory Assignment
Read through the section on friction losses in laminar and turbulent flow in your transport book (see syllabus). Create a plot in Excel or some other computer program of friction factor versus Re for a smooth pipe for $10^3 < \text{Re} < 10^6$; affix this plot to a page in your notebook. Design your plot to mimic the Moody diagram (log-log, even decades, log tic marks).

Calculate the Reynolds number and expected pressure drop in psi for 0.50 0.75, 1.0, 1.5, and 2.0 gpm for each of the three pipe sizes we have in the lab. Place a table of these calculations in your lab notebook (with units). Answer this question in your lab notebook:

a. *For which pipes and at what flow rates will you be able to obtain accurate pressure-drop readings?*
b. *For which pipes and at what flow rates will you be using the DP*

Overall Objectives:
Measure friction losses in pipes of three different diameters (1/4", 3/8", 1/2" nominal, type L copper tubing) and quantitatively compare the results with data reported in the literature. Address all other objectives as discussed in the **Data Analysis** section.

Experimental Procedure
(to be determined by each lab group)

Tasks:

1. *Measure friction factor versus Re on each of the three long sections of pipe in our laboratory station. Use as wide a range of flow rate as you can with the instruments available ($10 \leq R(\%) \leq 90$ or the maximum possible).*
2. *Calibrate the movement of needle valve WV-5; that is, measure the flow rate as a function of number of turns open for the valve. During this calibration, direct the water to*

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Lab: Frictional Losses in Straight Pipe

Note: For this laboratory, no procedure will be supplied.

- Run water through pipes of three sizes
- Measure pressure drop across the straight, smooth, horizontal copper pipe as a function of flow rate
- Convert your pipe pressure-drop/flow-rate measurements to friction factor versus Reynolds number
- Compare with **literature** correlations of the same quantity
- Do you obtain separate correlations of $f(\mathrm{Re})$ for different sized pipes?
- **Correctly consider the accuracy of your measurements when drawing conclusions and when presenting the results.**

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Prelab: (Friction Lab)

1. Create a plot (use Excel or equivalent) of the ***literature correlation*** of friction factor versus Re for a smooth pipe for $10^3 < \mathrm{Re} < 10^6$; affix this plot to a page in your notebook.

2. Based on the literature correlation, calculate the Reynolds number and pipe pressure drop in psi for 1.0, 2.0, 3.0, and 4.0 gpm for each of the three pipe sizes we have in the lab. The pipe length is 6.0ft. Compare with other groups.

3. Answer these questions in your lab notebook before the start of lab:
   a. *For which pipes and at what flow rates will you be able to obtain accurate pipe pressure-drop readings with our lab equipment?*
   b. *For which pipes and at what flow rates will you be using the DP meter? The Bourdon gauges?*

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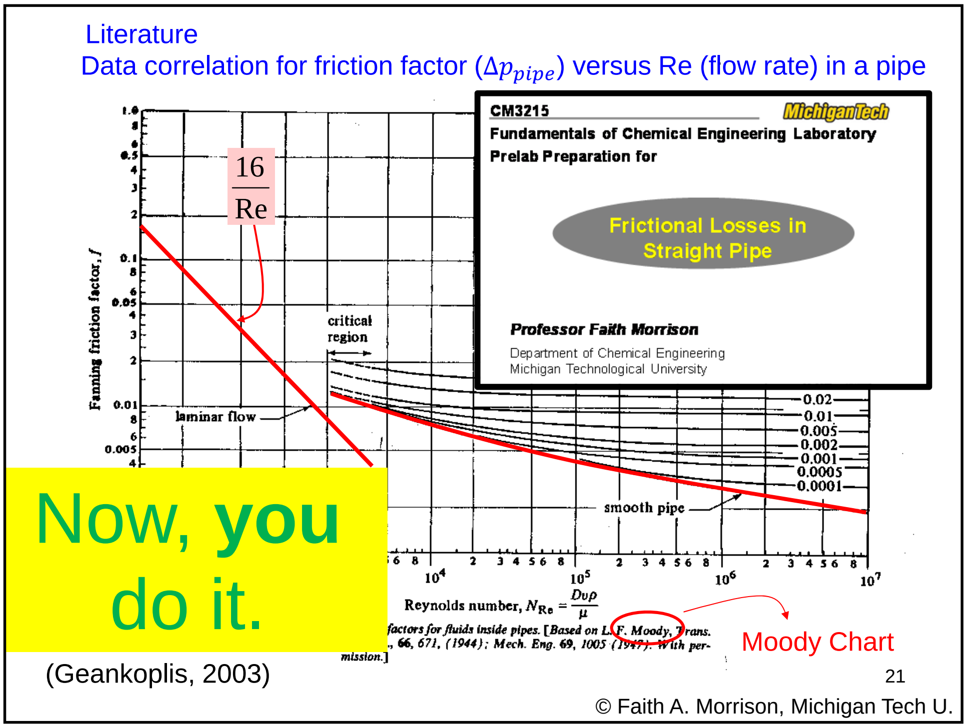
Literature
Data correlation for friction factor (Δp_{pipe}) versus Re (flow rate) in a pipe
16/Re
Fanning friction factor, f
critical region
laminar flow
smooth pipe
Reynolds number, $N_{Re} = \frac{Dv\rho}{\mu}$
Moody Chart
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Frictional Losses in Straight Pipe
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Now, you do it.
(Geankoplis, 2003)
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