UWE Bristol

Thermodynamics & Fluids

UFMEQU-20-1

FLUIDS

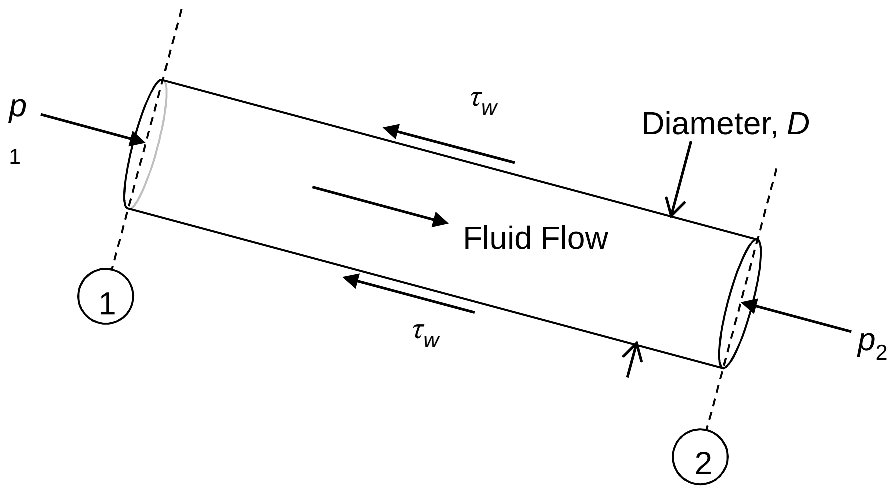
Lecture 3: Turbulent Flow & Minor Losses

Today's Lecture

- Review of Turbulent Flow
  - Pressure drop
- Determining *f* (Moody Chart)

- Minor Losses
- Example

Fluid Flow with Friction



- Bernoulli's equation:

$$p_1 + \frac{1}{2}\rho C_1^2 + \rho g z_1 = p_2 + \frac{1}{2}\rho C_2^2 + \rho g z_2 + \Delta p$$

Δp = pressure drop

Fluid Flow with Friction

- Bernoulli's equation with a pump:

$$p_1 + \frac{1}{2}\rho C_1^2 + \rho g z_1 + \boxed{\Delta p_P} = p_2 + \frac{1}{2}\rho C_2^2 + \rho g z_2 + \boxed{\Delta p_L}$$

pressure rise

(due to pump)

pressure loss

(due to friction)

Pressure Drop

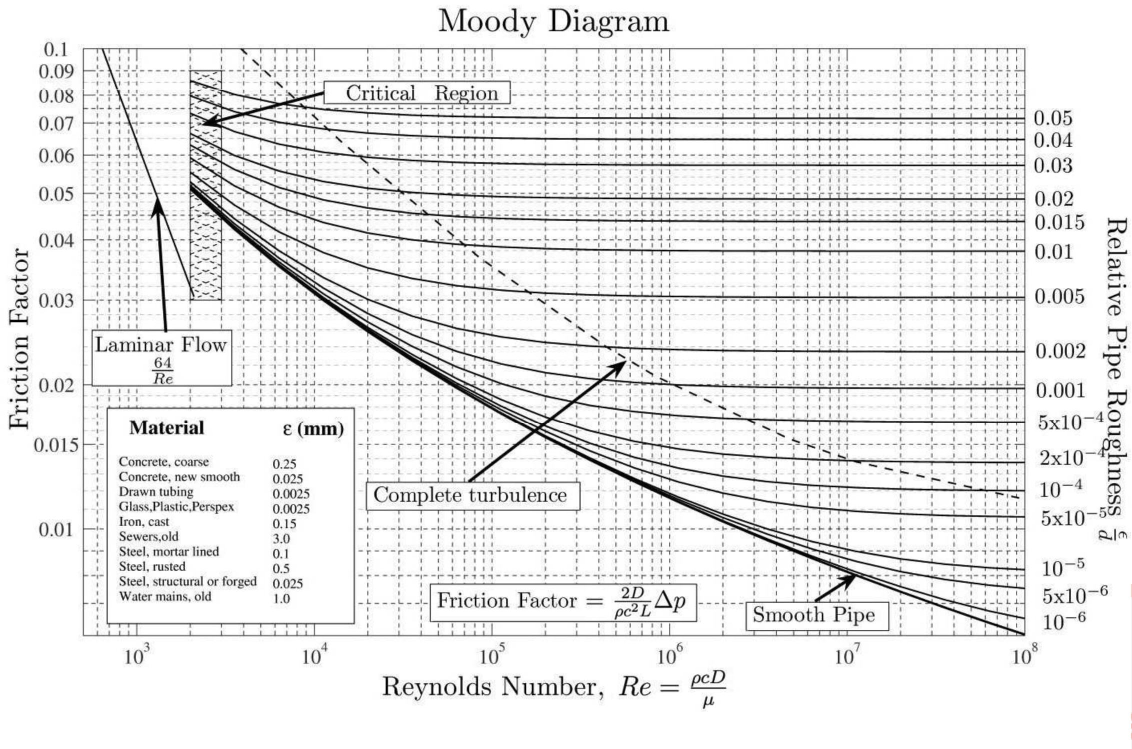
- Pressure drop is:

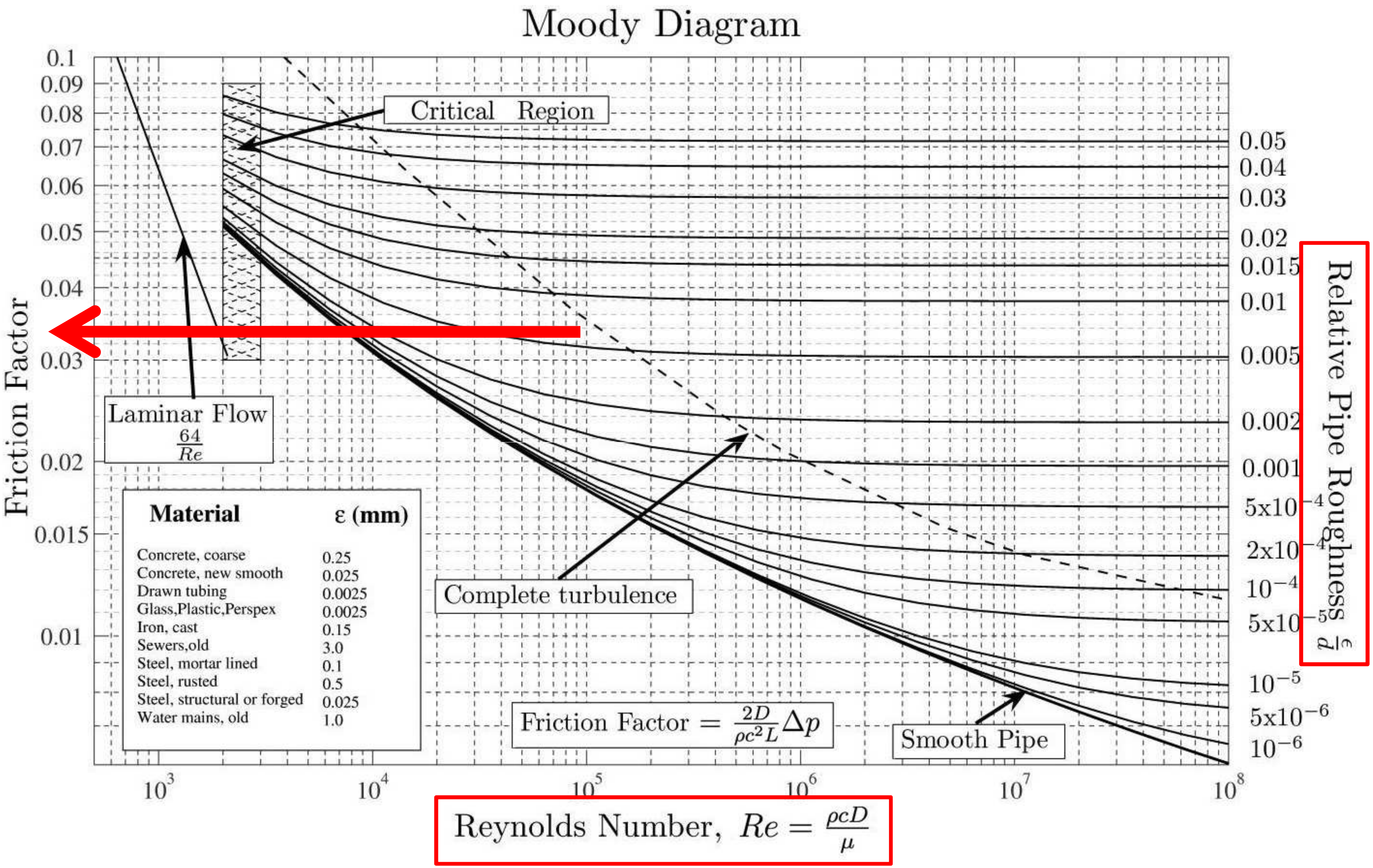
$$\Delta p = \frac{fL}{D}\frac{1}{2}\rho c^2$$

- If we have friction factor, we can calculate pressure drop to insert into Bernoulli's equation.

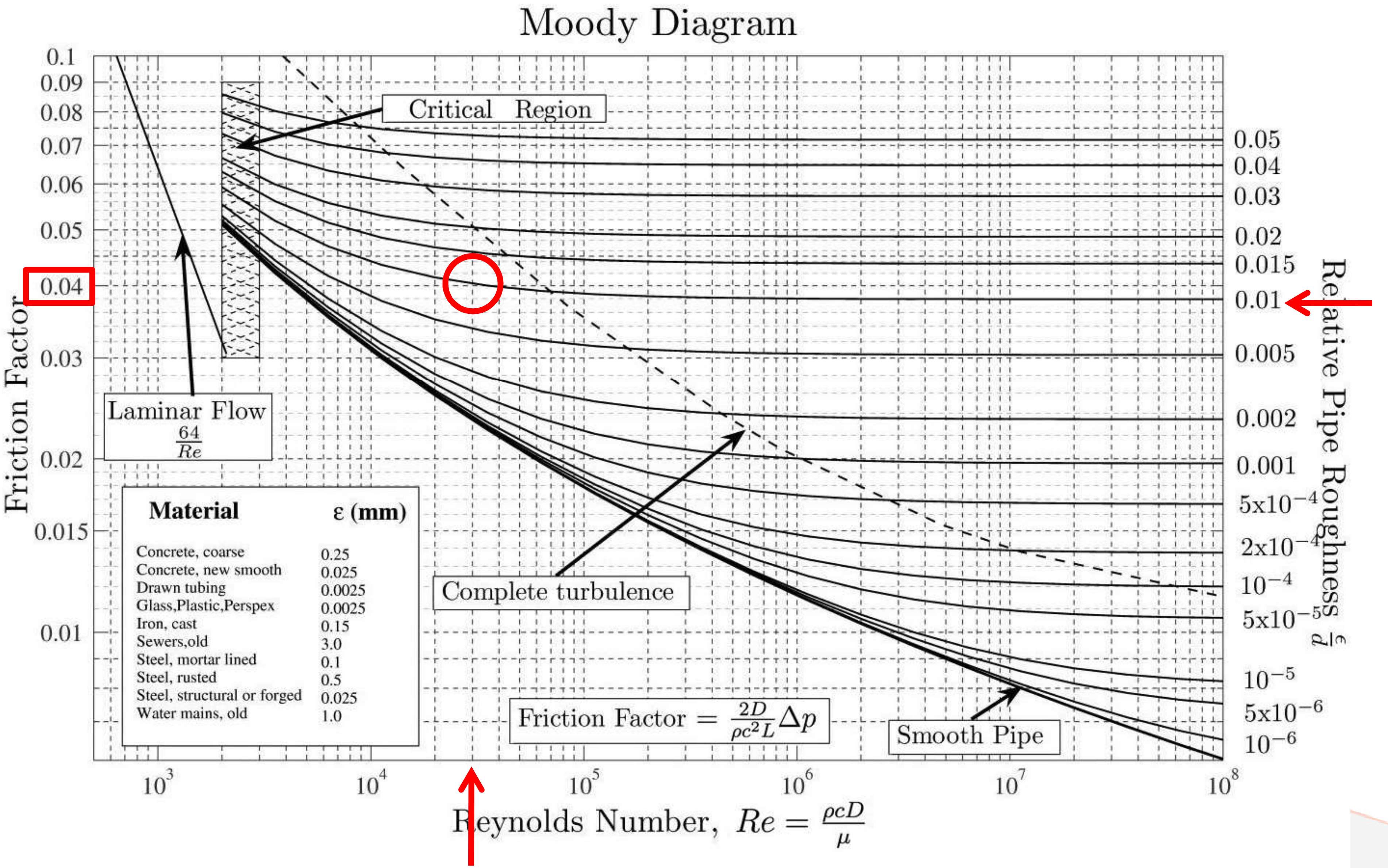
Friction Factor

- How do we determine Friction Factor?
- Moody Chart

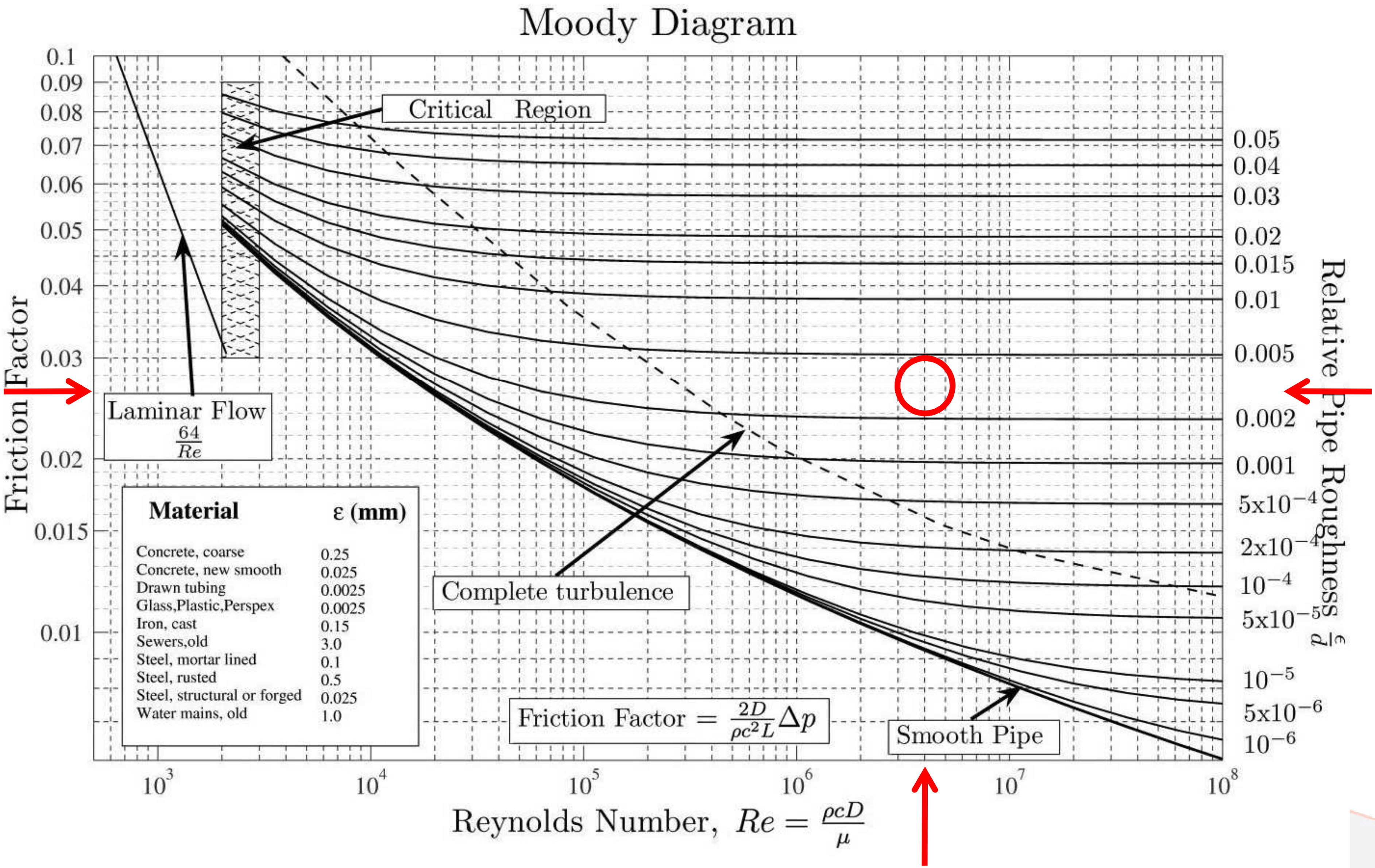



Moody Diagram
Critical Region
Laminar Flow
64/Re
Friction Factor
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.015
0.01
Relative Pipe Roughness ε/d
0.05
0.04
0.03
0.02
0.015
0.01
0.005
0.002
0.001
5x10^-4
2x10^-4
10^-4
5x10^-5
10^-5
5x10^-6
10^-6
Material ε (mm)
Concrete, coarse 0.25
Concrete, new smooth 0.025
Drawn tubing 0.0025
Glass,Plastic,Perspex 0.0025
Iron, cast 0.15
Sewers,old 3.0
Steel, mortar lined 0.1
Steel, rusted 0.5
Steel, structural or forged 0.025
Water mains, old 1.0
Complete turbulence
Friction Factor = 2D/(ρc²L) Δp
Smooth Pipe
10^3
10^4
10^5
10^6
10^7
10^8
Reynolds Number, Re = ρcD/μ

- Example: Re = 3 x 10^4 and ε/D= 0.01



- Example: Re = 4 x 10^6 and ε/D= 0.003



Find the Friction Factor!

- Try these examples:
  - Reynolds number = 5 x 10^4; ε/D= 0.05
    - f = 0.05
  - Reynolds number = 4 x 10^5; ε/D= 0.002
    - f = 0.024
  - Reynolds number = 1.5 x 10^7; ε/D= 0.01
    - f = 0.038

Problems

- 3 Types of Problems
  - Type 1 – Pressure drop
    - (Given flow rate and diameter)
    - Know everything so apply equation
  - Type 2 – Flow rate
    - (Given pressure drop and diameter)
    - Guess full turbulence, determine *c* and iterate
  - Type 3 – Pipe Diameter
    - (Given pressure drop and flow rate)
    - Guess $f = 0.03$, determine D and iterate

Minor Losses

- Pressure drop caused by
  - Frictional effects in straight pipes
  - What about other components?
    - Bends
    - Entrances
    - Exits
    - Section Changes
    - Junctions
    - Filters
    - Valves

} All contribute to pressure drop

Minor Losses

- Each loss has a **loss factor**, *k*
- Pressure drop due to minor loss

$$\Delta p = \frac{fL}{D}\frac{1}{2}\rho c^2 \quad \Rightarrow \quad \boxed{\Delta p = k\frac{1}{2}\rho c^2}$$

- Typical *k* values on p.28

Minor Losses

- Systems with more than one loss:
  - Effective *k* is sum of *k* factors

$$k_e = k_1 + k_2 + \cdots + k_n = \sum_{i=1}^{n} k_n$$

$$\Delta p = k_e \frac{1}{2} \rho c^2 = \sum_{i=1}^{n} k_n \frac{1}{2} \rho c^2$$

Minor Losses

- Total pressure drop in pipe due to minor losses *and* friction:

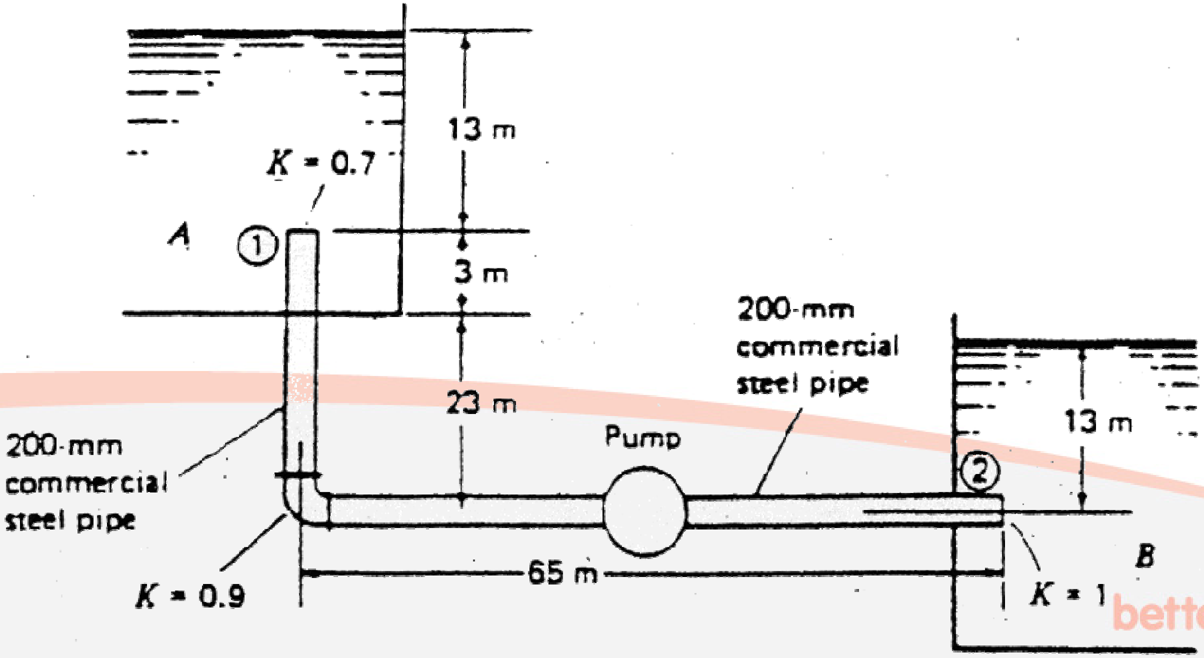
$$\Delta p = \text{drop due to losses} + \text{drop due to friction}$$

$$\Delta p = k_e \frac{1}{2}\rho c^2 + \frac{fL}{D}\frac{1}{2}\rho c^2$$

$$\Delta p = \left(k_e + \frac{fL}{D}\right)\frac{1}{2}\rho c^2$$

Example

- The flow rate from A to B is 565 litres/sec. Determine the power required from the pump. Take u to be 0.113×10^{-5} m^2/s. $\varepsilon = 0.000045$ m



bettertogether

Today's Lecture

- Review of turbulent flow
- Review of determining friction factors
- Minor losses
  - Additional losses in pipe networks
  - Can be considerable (especially valves)
- Total pressure drop:

$$\Delta p = \left(k_e + \frac{fL}{D} \right) \frac{1}{2} \rho c^2$$