5.2 Laminar Flow in Pipes

- Friction loss of laminar flow (in circular pipe)
- If the two relationships for hL are set equal to each other, we can solve for the value of the friction factor:
- The Hagen-Poiseuille and Darcy-Weisbach equations gives :

$$\frac{32\mu L v}{\gamma D^2} = \frac{f L v^2}{2gD}$$

$$f = \frac{32\mu L v}{\gamma D^2} \times \frac{2gD}{L v^2} = \frac{64\mu g}{\gamma v D}$$

$$f = \frac{64\mu g}{\gamma v D}$$

$$\rho = \frac{\gamma}{g}$$

$$\mathrm{Re} = \frac{\rho v D}{\mu}$$

$$f = \frac{64}{\mathrm{Re}}$$

5.3 Turbulent Flow in Pipes

- Friction loss in turbulent flow :
  - For turbulent flow of fluids in circular pipes it is most convenient to use Darcy’s equation to calculate the energy loss due to friction.
  - Turbulent flow is rather chaotic and is constantly varying.
  - For these reasons we must rely on experimental data to determine the value of *f*.
  - For commercially available pipe and tubing, the design value of the average wall roughness has been determined as shown in Table.
  - These are only average values for new, clean pipe. Some variation should be expected. After a pipe has been in service for a time, the roughness could change due to the formation of deposits on the wall or due to corrosion.

5.3.1 Turbulent Flow in Pipes

- Friction loss in turbulent flow :
- There are two methods to determine the friction factor f for turbulent flow.

i) Using the Colebrook – White equation

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

$$\mathrm{Re}\sqrt{f} = \frac{1}{v}\sqrt{\frac{2gh_f D}{L}}$$

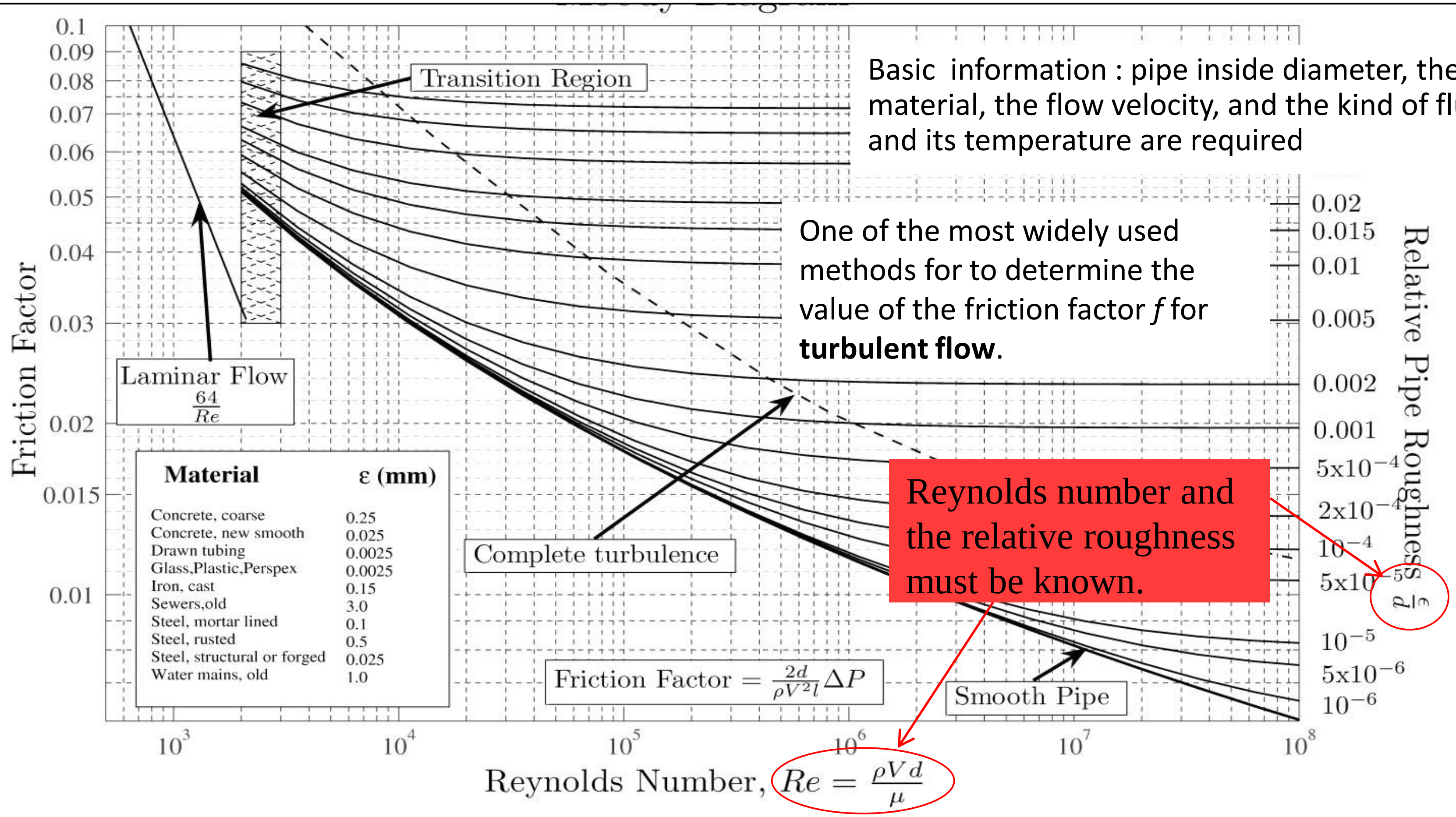
$$f = 0.001375\left[1+\left(\frac{200k_s}{d}+\frac{10^6}{\mathrm{Re}}\right)^{1/3}\right]$$

ii) Moody Diagram

Pipe material	**Pipe roughness ε (mm)**
Brass, copper, glass	0.003
Asbestos cement	0.03
Wrought iron	0.06
Galvanised iron	0.15
Plastic	0.03
Bitumen-linen iron	0.03
Spun concrete line ductile iron	0.03
Slimed concrete sewe	6.0

Moody’s Diagram

The **Moody diagram** which describes the **Darcy-Weisbach friction factor**, *f* as a function of the **Reynolds number** and relative pipe roughness.



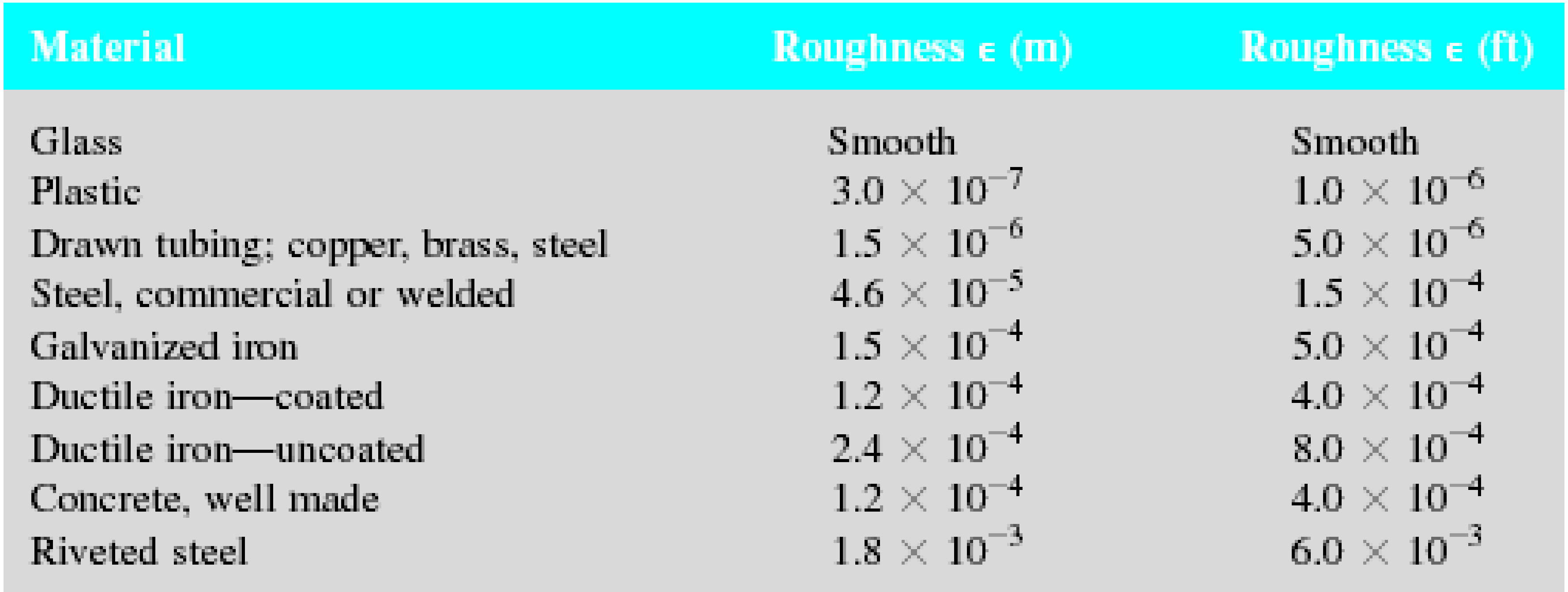
Material	**ε (mm)**
Concrete, coarse	0.25
Concrete, new smooth	0.025
Drawn tubing	0.0025
Glass,Plastic,Perspex	0.0025
Iron, cast	0.15
Sewers,old	3.0
Steel, mortar lined	0.1
Steel, rusted	0.5
Steel, structural or forged	0.025
Water mains, old	1.0

Basic information : pipe inside diameter, the pipe material, the flow velocity, and the kind of fluid and its temperature are required

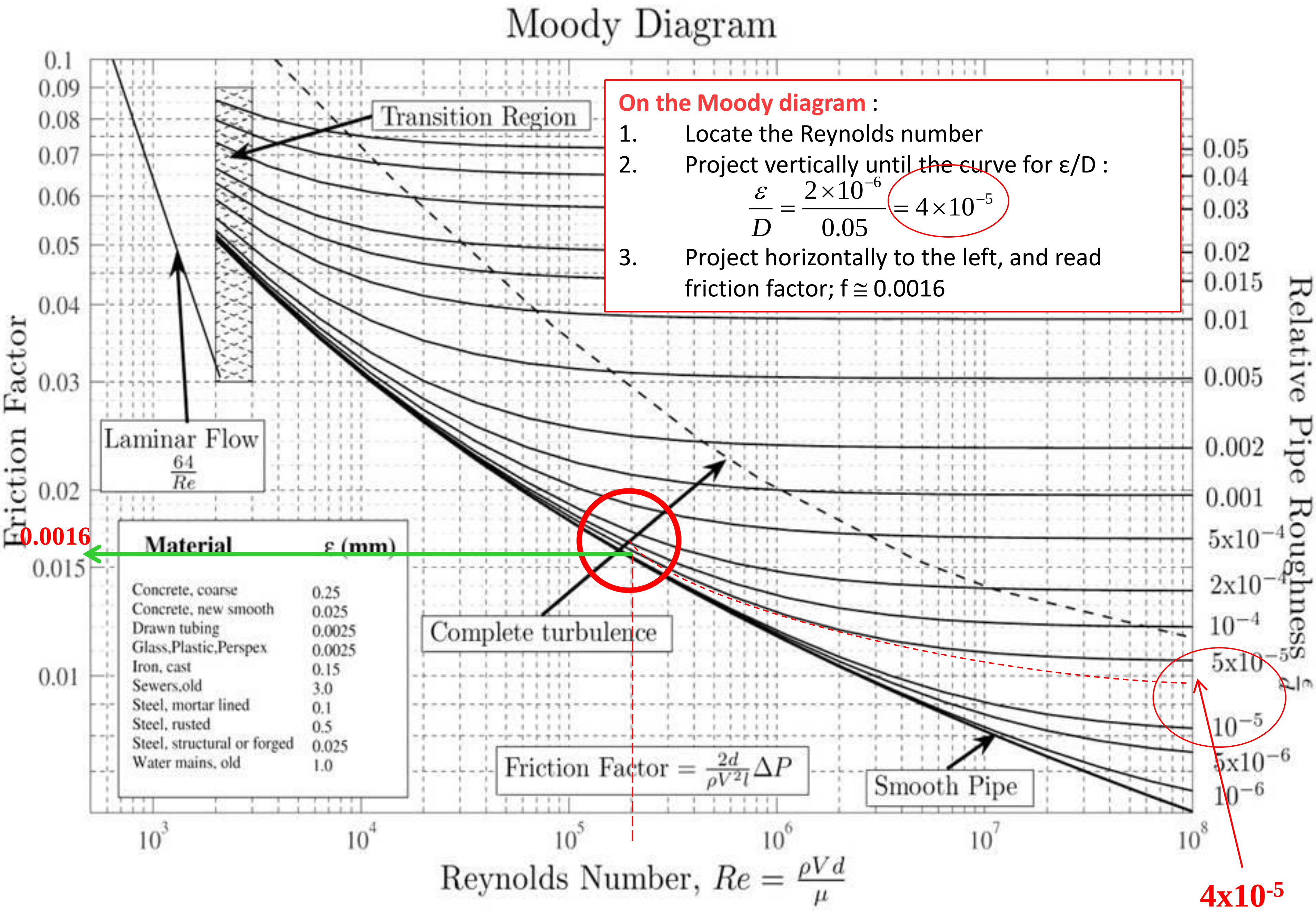
One of the most widely used methods for to determine the value of the friction factor *f* for **turbulent flow**.

Reynolds number and the relative roughness must be known.

- Friction loss in turbulent flow



Material	Roughness ϵ (m)	Roughness ϵ (ft)
Glass	Smooth	Smooth
Plastic	3.0×10^{-7}	1.0×10^{-6}
Drawn tubing; copper, brass, steel	1.5×10^{-6}	5.0×10^{-6}
Steel, commercial or welded	4.6×10^{-5}	1.5×10^{-4}
Galvanized iron	1.5×10^{-4}	5.0×10^{-4}
Ductile iron—coated	1.2×10^{-4}	4.0×10^{-4}
Ductile iron—uncoated	2.4×10^{-4}	8.0×10^{-4}
Concrete, well made	1.2×10^{-4}	4.0×10^{-4}
Riveted steel	1.8×10^{-3}	6.0×10^{-3}



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Water mains, old	1.0

On the Moody diagram :

1. Locate the Reynolds number
2. Project vertically until the curve for ε/D :

$$\frac{\varepsilon}{D} = \frac{2\times10^{-6}}{0.05} = 4\times10^{-5}$$

3. Project horizontally to the left, and read friction factor; f ≅ 0.0016

0.0016

4×10^{-5}

$201050 = 2\times10^5$