10.69 A pipeline is to be designed to carry crude oil ($S = 0.93$, $\nu = 10^{-5}$ m^2/s) with a discharge of 0.10 m^3/s and a head loss per kilometer of 30 m. What diameter of steel pipe is needed? What power output from a pump is required to maintain this flow?

Solution:

$S = 0.93$ Steel pipe

$\nu = 10^{-5}\, m^2/s$, $Q = 0.1 m^3/s$, $h_f = 30m$ per km=1000m

Find D and $P = Q\gamma h_f$ per km

$$h_f = f\frac{L}{D}\frac{V^2}{2g}$$

$$D = \frac{fL}{h_f}\frac{V^2}{2g} = \left[\frac{8LQ^2}{\pi^2 g h_f}\right]^{1/5} f^{1/5} = \left[\frac{8\times 1000\times .1^2}{\pi^2\times 9.81\times 30}\right]^{1/5} f^{1/5} = 0.4875\, f^{1/5}$$

Assume $f = 0.015$, $\Rightarrow D = 0.21m$

$$\text{Re} = \frac{VD}{\nu} = \frac{4QD}{\pi D^2 \nu} = \frac{4Q}{\pi D\nu} = 6\times 10^4$$

$k_s/D = 0.0002$, $\Rightarrow f = 0.022$

$D = 0.227m$ or $22.7cm$

Choose $D = 23cm$

$$P = Q\gamma h_f = 0.1\times 0.93\times 9810\times 30 = 27.4\, kW/km$$