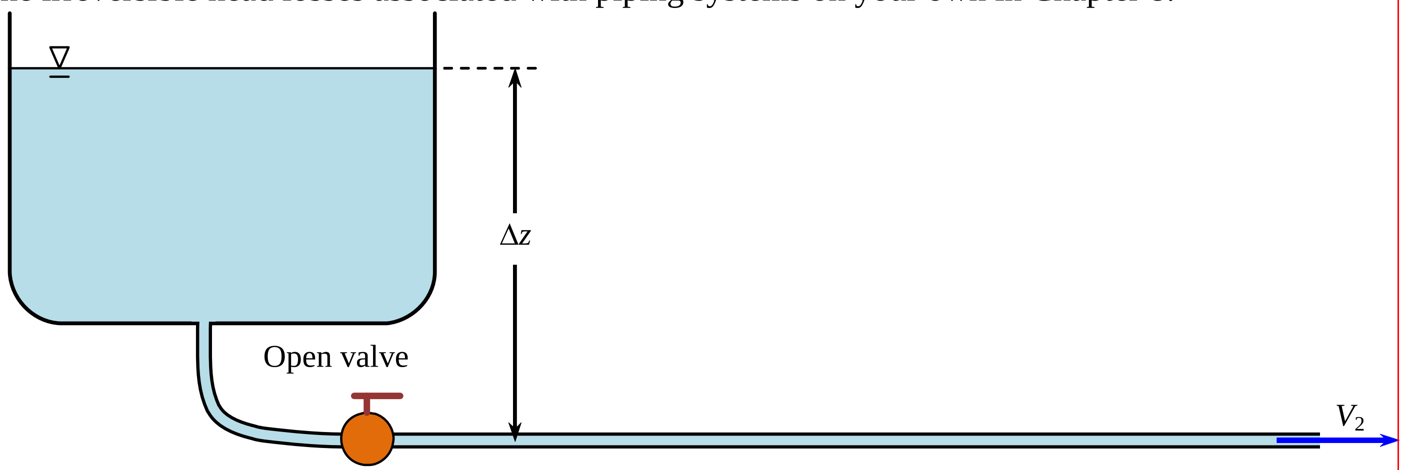
Today, we will:

- Do another example problem – head form of the energy equation
- Discuss grade lines – energy grade line and hydraulic grade line
- Derive and discuss the Bernoulli equation

5. Examples (continued)

Example – Water draining from a tank

Given: Water drains by gravity from a tank exposed to atmospheric pressure. The vertical distance from the pipe outlet to the surface of the water in the tank is Δz = 0.500 m. The irreversible head losses in the piping system (due to friction in the pipe, losses through the valve, elbow, etc.) are estimated as h_L = 0.400 m of equivalent water column height. *Note*: You will learn how to calculate the irreversible head losses associated with piping systems on your own in Chapter 8.



To do: Calculate the average velocity at the outlet, V_2.

Solution:

From previous lecture…use the head form of the conservation of energy equation:

$$\left(\frac{P_1}{\rho_1 g}+\alpha_1\frac{V_1^2}{2g}+z_1\right)+\sum h_{\text{pump,u}}=\left(\frac{P_2}{\rho_2 g}+\alpha_2\frac{V_2^2}{2g}+z_2\right)+\sum h_{\text{turbine, e}}+h_L$$

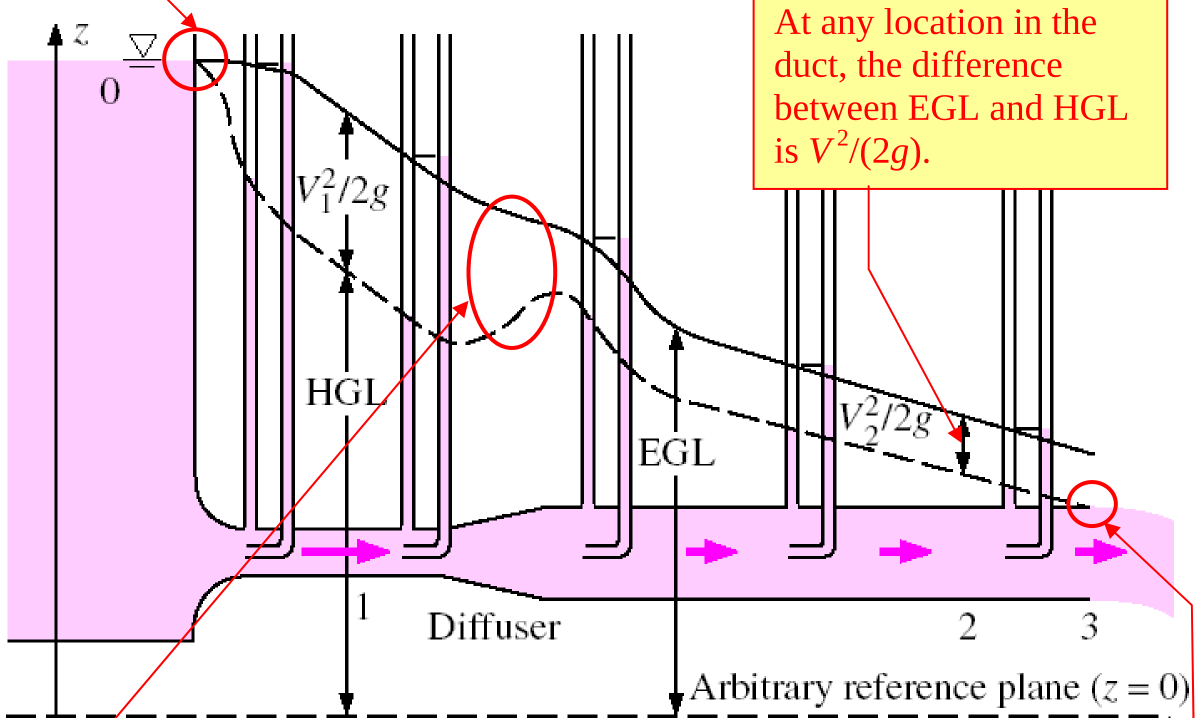
Example of Grade Lines in a Fluid Flow

At point 0, HGL = EGL inside the tank, since the fluid is at rest ($V = 0$). Neither EGL or HGL can rise above this value unless work is added to the flow (e.g., with a pump).

FIGURE 5-35

The *hydraulic grade line* (HGL) and the *energy grade line* (EGL) for free discharge from a reservoir through a horizontal pipe with a diffuser.

At any location in the duct, the difference between EGL and HGL is $V^2/(2g)$.



EGL continually falls due to irreversible losses, but HGL can rise or fall. Overall, however, HGL also must fall. In fact, HGL can *never* rise above EGL.

Since the jet exits at atmospheric pressure at the outlet of the pipe, $P_3 = P_{atm}$, and HGL is equal to the height of the free surface of the liquid.

D. The Bernoulli Equation

1. Derivation

Begin with the head form of the conservation of energy equation along a streamline:

$$\left(\frac{P_1}{\rho_1 g}+\frac{V_1^2}{2g}+z_1\right)+h_{\text{pump,u}}=\left(\frac{P_2}{\rho_2 g}+\frac{V_2^2}{2g}+z_2\right)+h_{\text{turbine, e}}+h_L$$