Name: ------------------ **Quiz 4** **Time: 20 minutes**

ME:5160 **Fall 2023**

The exam is closed book and closed notes.

When the pump in the Figure below draws 220 m^3/hr of water at 20°C (ρ = 998 kg/m^3) from the reservoir, the total friction head loss is 5 m. The flow discharges through a nozzle to the atmosphere. Estimate the pump power in kW delivered to the water.

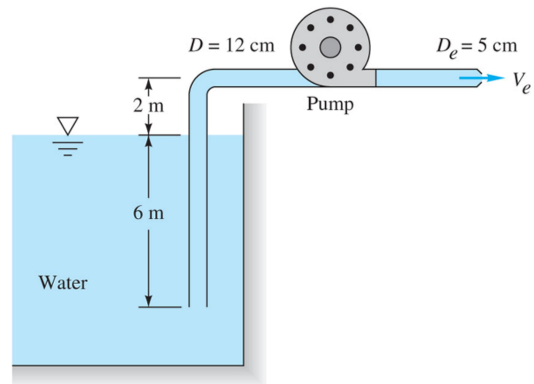
Energy Equation (for incompressible steady flow):

$$\left(\frac{p}{\rho g}+\frac{\alpha V^2}{2g}+z\right)_1=\left(\frac{p}{\rho g}+\frac{\alpha V^2}{2g}+z\right)_2+h_{turbine}-h_{pump}+h_{friction}$$

Turbulent pipe flow kinetic correction factor α = 1.11

$$P_{pump}=\rho g Q h_{pump}$$

Hint: write the energy equation between the free surface and the nozzle exit.



Solution: Format (+3)

Continuity:

$$Q = 220\ \frac{m^3}{hr} = \frac{(220)}{(3600)}\ \frac{m^3}{s} = 0.0611\ \frac{m^3}{s}$$

$$Q = A_e V_e$$

$$V_e = \frac{Q}{A_e} = \frac{Q}{\pi \frac{{D_e}^2}{4}} = \frac{(0.0611)}{\pi \frac{(0.05)^2}{4}} = 31.12\ \frac{m}{s} \qquad \textbf{(+2)}$$

Take point 1 at the free surface and 2 at the pipe exit:

$$\frac{p_1}{\rho g} + \frac{\alpha_1 V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{\alpha_2 V_2^2}{2g} + z_2 + h_{turbine} - h_{pump} + h_{friction}$$

Pressure is zero at the free surface and at the exit to atmosphere. Also assume that velocity at the free surface is almost zero:

$$0 + 0 + z_1 = 0 + \frac{\alpha_e V_e^2}{2g} + z_2 + 0 - h_{pump} + h_{friction}$$

$$h_{pump} = \frac{\alpha_e V_e^2}{2g} + (z_2 - z_1) + h_{friction}$$

$$h_{pump} = \frac{(1.11)(31.12)^2}{2(9.81)} + (2\ m) + (5\ m) = 61.79\ m$$

The pump power is:

$$P_{pump} = \rho g Q h_{pump} = (998)(9.81)(0.0611)(61.79) = 36{,}962.3\ W = 36.96\ kW \qquad \textbf{(+5)}$$