$$h_{p,f} = \frac{w_{p,f}}{g} = \frac{\dot{W}_{p,f}}{\dot{m} g} = \frac{\eta_p \cdot \dot{W}_p}{\dot{m} g} \quad ; \quad h_{t,f} = \frac{w_{t,f}}{g} = \frac{\dot{W}_{t,f}}{\dot{m} g} = \frac{\dot{W}_t}{\eta_t \cdot \dot{m} \cdot g} \quad ; \quad h_L = \frac{e_{mek,k,boruler}}{g} = \frac{\dot{E}_{mek,k,boru}}{\dot{m} g}$$

$$\dot{m}\left(\frac{P_1}{\rho} + \alpha_1 \frac{V_1^2}{2} + g z_1\right) + \dot{W}_p = \dot{m}\left(\frac{P_2}{\rho} + \alpha_2 \frac{V_2^2}{2} + g z_2\right) + \dot{W}_t + \dot{E}_{mek,kayıp} \quad ; \quad e_{mek} = \frac{P}{\rho} + \frac{V^2}{2} + g z$$

$$\dot{E}_{mek,kayıp} = \dot{E}_{mek,k,pompa} + \dot{E}_{mek,k,türbin} + \dot{E}_{mek,k,boruler} \quad ; \quad \frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_{p,f} = \frac{P_2}{\rho g} + \alpha \frac{V_2^2}{2g} + z_2 + h_{t,f} + h_L$$

$$\dot{W}_{p,faydalı} = \dot{W}_{pompa} - \dot{E}_{mek,k,pompa} = \dot{m} g . h_{p,f} = \dot{V} \rho . g \, h_{p,f}$$

$(\dot{W}_{mil} - \Delta \dot{E}_{mek})$

$$\dot{E}_{mek,k,boruler} = \dot{m} g h_L = \dot{V} \rho \, g \, h_L$$

$$\dot{W}_{t,f} = \dot{m} g h_{t,f} = \dot{V} \cdot \rho g \, h_{t,f} = \dot{E}_{mek,k,t} - \dot{W}_t$$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + g z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + g z_2$$

$$\eta_t = \frac{\dot{W}_{mil}}{\Delta \dot{E}_{mek}} = \frac{\dot{W}_t}{\dot{W}_{t,f}}$$

$$\eta_J = \frac{\dot{W}_{elek}}{\dot{W}_{mil}}$$

$$\eta_{t-J} = \frac{\dot{W}_{elek}}{\dot{W}_{t,f}} = \frac{\dot{W}_{elek}}{\Delta \dot{E}_{mek}}$$

$$\eta_{t-J} = \eta_t \eta_J$$

$$\eta_p = \frac{\Delta \dot{E}_{mek}}{\dot{W}_{mil}} = \frac{\dot{W}_{p,f}}{\dot{W}_p}$$

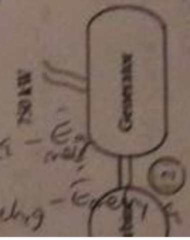
$$\eta_m = \frac{\dot{W}_{mil}}{\cancel{\Delta \dot{E}_{mek}} \; \dot{W}_{elek}} = \frac{\cancel{\dot{W}_t}}{\dot{W}_{t,f}}$$

$$\eta_{p-m} = \frac{\dot{W}_{p,f}}{\dot{W}_{elek}} = \frac{\Delta \dot{E}_{mek}}{\dot{W}_{elek}}$$

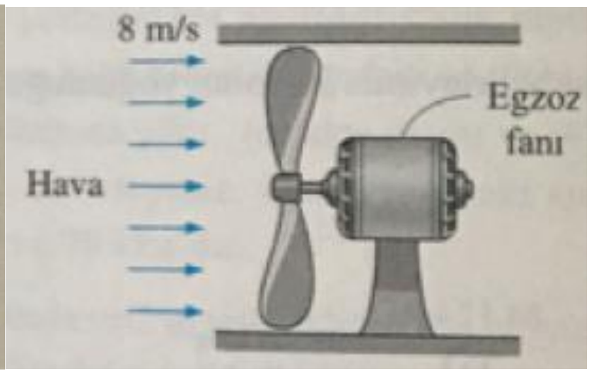
$$\eta_{p-m} = \eta_p \, \eta_m$$

$$\Delta \dot{E}_{mek,p} = \dot{E}_{mek,ç} - \dot{E}_{mek,g}$$

$$\Delta \dot{E}_{mek,t} = \dot{E}_{mek,g} - \dot{E}_{mek,ç}$$



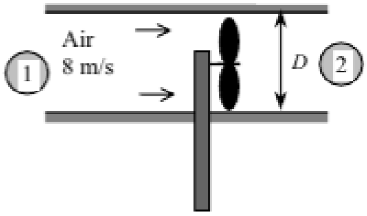
5-73 2 m × 3 m × 3 m ebatlarındaki bir banyoyu havalandırmak üzere bir fan seçilecektir. Titreşimi ve gürültüyü en aza indirgemek için hava hızının 8 m/s'yi geçmemesi isteniyor. Kullanılacak fan-motor grubunun toplam verimi yüzde 50 alınabilir. Fanın odadaki tüm havayı 10 dakika'da değiştirmesi istendiğine göre, (*a*) satın alınacak fan-motor grubunun watt biriminde gücünü, (*b*) fanın dış çapını ve (*c*) fanın giriş ve çıkışı arasındaki basınç farkını belirleyiniz. Hava yoğunluğunu 1.25 kg/m³ alınız ve kinetik enerji düzeltme faktörlerinin etkisini göz ardı ediniz.



5-73 A fan is to ventilate a bathroom by replacing the entire volume of air once every 10 minutes while air velocity remains below a specified value. The wattage of the fan-motor unit, the diameter of the fan casing, and the pressure difference across the fan are to be determined. √

Assumptions **1** The flow is steady and incompressible. **2** Frictional losses along the flow (other than those due to the fan-motor inefficiency) are negligible. **3** The fan unit is horizontal so that z = constant along the flow (or, the elevation effects are negligible because of the low density of air). **4** The effect of the kinetic energy correction factors is negligible, $\alpha = 1$.

Properties The density of air is given to be 1.25 kg/m³.



Analysis (*a*) The volume of air in the bathroom is $V = 2\text{ m} \times 3\text{ m} \times 3\text{ m} = 18\text{ m}^3$. Then the volume and mass flow rates of air through the casing must be

$$\dot{V} = \frac{V}{\Delta t} = \frac{18\text{ m}^3}{10 \times 60\text{ s}} = 0.03\text{ m}^3/\text{s}$$

$$\dot{m} = \rho\dot{V} = (1.25\text{ kg/m}^3)(0.03\text{ m}^3/\text{s}) = 0.0375\text{ kg/s}$$

We take points 1 and 2 on the inlet and exit sides of the fan, respectively. Point 1 is sufficiently far from the fan so that $P_1 = P_{atm}$ and the flow velocity is negligible ($V_1 = 0$). Also, $P_2 = P_{atm}$. Then the energy equation for this control volume between the points 1 and 2 reduces to

$$\dot{m}\left(\frac{P_1}{\rho} + \alpha_1\frac{V_1^2}{2} + gz_1\right) + \dot{W}_{pump} = \dot{m}\left(\frac{P_2}{\rho} + \alpha_2\frac{V_2^2}{2} + gz_2\right) + \dot{W}_{turbine} + \dot{E}_{mech,loss} \quad \rightarrow \quad \dot{W}_{fan,u} = \dot{m}\alpha_2\frac{V_2^2}{2}$$

since $\dot{E}_{mech,\,loss} = \dot{E}_{mech\,loss,\,pump}$ in this case and $\dot{W}_{pump,\,u} = \dot{W}_{pump} - \dot{E}_{mech\,loss,\,pump}$. Substituting,

$$\dot{W}_{fan,u} = \dot{m}\alpha_2\frac{V_2^2}{2} = (0.0375\text{ kg/s})(1.0)\frac{(8\text{ m/s})^2}{2}\left(\frac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2}\right)\left(\frac{1\text{ W}}{1\text{ N}\cdot\text{m/s}}\right) = 1.2\text{ W}$$

and $$\dot{W}_{fan,elect} = \frac{\dot{W}_{fan,u}}{\eta_{fan\text{-}motor}} = \frac{1.2\text{ W}}{0.5} = \mathbf{2.4\ W}$$

Therefore, the electric power rating of the fan/motor unit must be 2.4 W.

(*b*) For air mean velocity to remain below the specified value, the diameter of the fan casing should be

$$\dot{V} = A_2V_2 = (\pi D_2^2/4)V_2 \quad \rightarrow \quad D_2 = \sqrt{\frac{4\dot{V}}{\pi V_2}} = \sqrt{\frac{4(0.03\text{ m}^3/\text{s})}{\pi(8\text{ m/s})}} = 0.069\text{ m} = \mathbf{6.9\ cm}$$

(*c*) To determine the pressure difference across the fan unit, we take points 3 and 4 to be on the two sides of the fan on a horizontal line. Noting that $z_3 = z_4$ and $V_3 = V_4$ since the fan is a narrow cross-section and neglecting flow loses (other than the loses of the fan unit, which is accounted for by the efficiency), the energy equation for the fan section reduces to

$$\dot{m}\frac{P_3}{\rho} + \dot{W}_{fan,u} = \dot{m}\frac{P_4}{\rho} \quad \rightarrow \quad P_4 - P_3 = \frac{\dot{W}_{fan,u}}{\dot{m}/\rho} = \frac{\dot{W}_{fan,u}}{\dot{V}}$$

Substituting, $$P_4 - P_3 = \frac{1.2\text{ W}}{0.03\text{ m}^3/\text{s}}\left(\frac{1\text{ N}\cdot\text{m/s}}{1\text{ W}}\right) = 40\text{ N/m}^2 = \mathbf{40\ Pa}$$

Therefore, the fan will raise the pressure of air by 40 Pa before discharging it.

Discussion Note that only half of the electric energy consumed by the fan-motor unit is converted to the mechanical energy of air while the remaining half is converted to heat because of imperfections.

5–74 Mil gücü 10 kW olan bir pompayla, büyük bir gölden, 25 m yukarıda bulunan bir depoya, 25 L/s debide su basılmaktadır. Borulama sistemindeki tersinmez yük kayıpları 7 m olduğuna göre, pompanın mekanik verimini belirleyiniz. *Cevap:* yüzde 78.5

5-74 Water is pumped from a large lake to a higher reservoir. The head loss of the piping system is given. The mechanical efficiency of the pump is to be determined. √

Assumptions **1** The flow is steady and incompressible. **2** The elevation difference between the lake and the reservoir is constant.

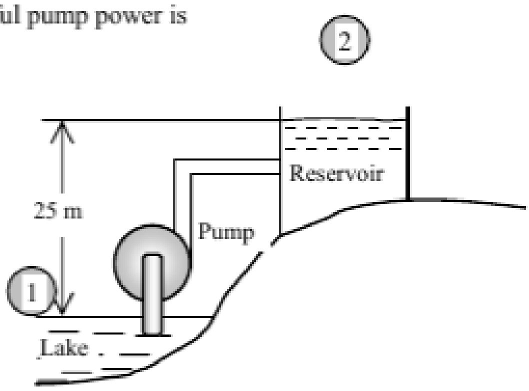
Properties We take the density of water to be $\rho = 1000$ kg/m^3.

Analysis We choose points 1 and 2 at the free surfaces of the lake and the reservoir, respectively, and take the surface of the lake as the reference level ($z_1 = 0$). Both points are open to the atmosphere ($P_1 = P_2 = P_{atm}$) and the velocities at both locations are negligible ($V_1 = V_2 = 0$). Then the energy equation for steady incompressible flow through a control volume between these two points that includes the pump and the pipes reduces to

$$\dot{m}\left(\frac{P_1}{\rho}+\alpha_1\frac{V_1^2}{2}+gz_1\right)+\dot{W}_{\text{pump}}=\dot{m}\left(\frac{P_2}{\rho}+\alpha_2\frac{V_2^2}{2}+gz_2\right)+\dot{W}_{\text{turbine}}+\dot{E}_{\text{mech,loss}} \rightarrow$$

$$\dot{W}_{\text{pump,u}} = \dot{m}gz_2 + \dot{E}_{\text{mech loss, piping}}$$

since, in the absence of a turbine, $\dot{E}_{\text{mech, loss}} = \dot{E}_{\text{mech loss, pump}} + \dot{E}_{\text{mech loss, piping}}$ and $\dot{W}_{\text{pump, u}} = \dot{W}_{\text{pump}} - \dot{E}_{\text{mech loss, pump}}$. Noting that $\dot{E}_{\text{mech loss, piping}} = \dot{m}gh_L$, the useful pump power is



$$\dot{W}_{\text{pump,u}} = \dot{m}gz_2 + \dot{m}gh_L = \rho\dot{V}g(z_2+h_L)$$

$$= (1000\ \text{kg/m}^3)(0.025\ \text{m}^3/\text{s})(9.81 m/s^2)[(25+7)\ \text{m}]\left(\frac{1\ \text{kN}}{1000\ \text{kg}\cdot\text{m/s}^2}\right)$$

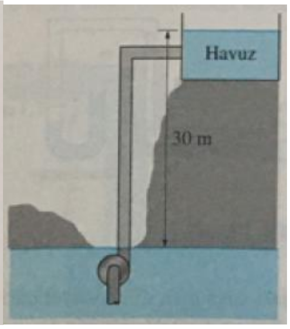
$$= 7.85\ \text{kNm/s} = 7.85\ \text{kW}$$

Then the mechanical efficiency of the pump becomes

$$\eta_{\text{pump}} = \frac{\dot{W}_{\text{pump, u}}}{\dot{W}_{\text{shaft}}} = \frac{7.85\ \text{kW}}{10\ \text{kW}} = 0.785 = \mathbf{78.5\%}$$

Discussion A more practical measure of performance of the pump is the overall efficiency, which can be obtained by multiplying the pump efficiency by the motor efficiency.

5-69 Yer altı suyu, verimi yüzde 70 olan 3 kW'lık bir dalgıç pompayla serbest yüzeyi yer altı suyunun serbest yüzeyinden 30 m yukarıda olan bir havuza basılmaktadır. Borunun emme tarafındaki çapı 7 cm ve boşaltma tarafındaki çapı ise 5 cm'dir. (*a*) suyun maksimum debisini, (*b*) pompanın giriş ve çıkışı arasındaki basınç farkını belirleyiniz. Pompanın giriş ve çıkışı arasındaki yükseklik farkının ve kinetik enerji düzeltme faktörünün ihmal edildiğini varsayınız.



5-69 Underground water is pumped to a pool at a given elevation. The maximum flow rate and the pressures at the inlet and outlet of the pump are to be determined. √

Assumptions **1** The flow is steady and incompressible. **2** The elevation difference between the inlet and the outlet of the pump is negligible. **3** We assume the frictional effects in piping to be negligible since the *maximum* flow rate is to be determined, $\dot{E}_{\text{mech loss, pipping}} = 0$. **4** The effect of the kinetic energy correction factors is negligible, $\alpha = 1$.

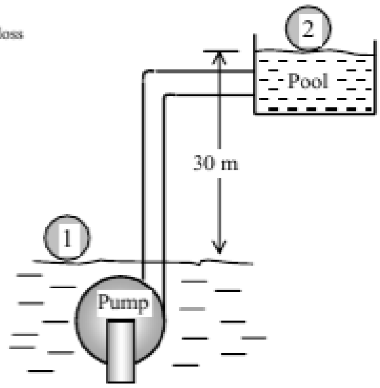
Properties We take the density of water to be 1 kg/L = 1000 kg/m³.

Analysis (*a*) The pump-motor draws 3-kW of power, and is 70% efficient. Then the useful mechanical (shaft) power it delivers to the fluid is

$$\dot{W}_{\text{pump, u}} = \eta_{\text{pump-motor}} \dot{W}_{\text{electric}} = (0.70)(3\text{ kW}) = 2.1\text{ kW}$$

We take point 1 at the free surface of underground water, which is also taken as the reference level ($z_1 = 0$), and point 2 at the free surface of the pool. Also, both 1 and 2 are open to the atmosphere ($P_1 = P_2 = P_{\text{atm}}$), the velocities are negligible at both points ($V_1 \cong V_2 \cong 0$), and frictional losses in piping are disregarded. Then the energy equation for steady incompressible flow through a control volume between these two points that includes the pump and the pipes reduces to

$$\dot{m}\left(\frac{P_1}{\rho} + \alpha_1 \frac{V_1^2}{2} + gz_1\right) + \dot{W}_{\text{pump}} = \dot{m}\left(\frac{P_2}{\rho} + \alpha_2 \frac{V_2^2}{2} + gz_2\right) + \dot{W}_{\text{turbine}} + \dot{E}_{\text{mech,loss}}$$



In the absence of a turbine, $\dot{E}_{\text{mech, loss}} = \dot{E}_{\text{mech loss, pump}} + \dot{E}_{\text{mech loss, piping}}$ and $\dot{W}_{\text{pump, u}} = \dot{W}_{\text{pump}} - \dot{E}_{\text{mech loss, pump}}$. Thus,

$$\dot{W}_{\text{pump, u}} = \dot{m} g z_2$$

Then the mass and volume flow rates of water become

$$\dot{m} = \frac{\dot{W}_{\text{pump, u}}}{gz_2} = \frac{2.1\text{ kJ/s}}{(9.81\text{ m/s}^2)(30\text{ m})}\left(\frac{1000\text{ m}^2/\text{s}^2}{1\text{ kJ}}\right) = 7.14\text{ kg/s}$$

$$\dot{V} = \frac{\dot{m}}{\rho} = \frac{7.14\text{ kg/s}}{1000\text{ kg/m}^3} = \mathbf{7.14 \times 10^{-3}\ m^3/s}$$

(*b*) We take points 3 and 4 at the inlet and the exit of the pump, respectively, where the flow velocities are

$$V_3 = \frac{\dot{V}}{A_3} = \frac{\dot{V}}{\pi D_3^2/4} = \frac{7.14\times 10^{-3}\text{ m}^3/\text{s}}{\pi(0.07\text{ m})^2/4} = 1.86\text{ m/s}, \quad V_4 = \frac{\dot{V}}{A_4} = \frac{\dot{V}}{\pi D_4^2/4} = \frac{7.14\times 10^{-3}\text{ m}^3/\text{s}}{\pi(0.05\text{ m})^2/4} = 3.64\text{ m/s}$$

We take the pump as the control volume. Noting that $z_3 = z_4$, the energy equation for this control volume reduces to

$$\dot{m}\left(\frac{P_3}{\rho} + \alpha_3 \frac{V_3^2}{2} + gz_3\right) + \dot{W}_{\text{pump}} = \dot{m}\left(\frac{P_4}{\rho} + \alpha_4 \frac{V_4^2}{2} + gz_4\right) + \dot{W}_{\text{turbine}} + \dot{E}_{\text{mech loss, pump}}$$

$$\rightarrow P_4 - P_3 = \frac{\rho\alpha(V_3^2 - V_4^2)}{2} + \frac{\dot{W}_{\text{pump,u}}}{\dot{V}}$$

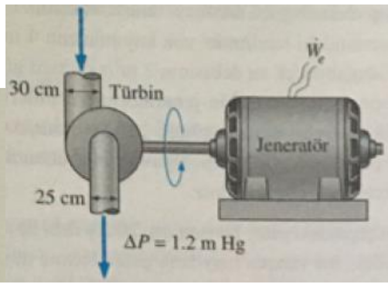
Substituting,

$$P_4 - P_3 = \frac{(1000\text{ kg/m}^3)(1.0)[(1.86\text{ m/s})^2 - (3.64\text{ m/s})^2]}{2}\left(\frac{1\text{ kN}}{1000\text{ kg}\cdot\text{m/s}^2}\right) + \frac{2.1\text{ kJ/s}}{7.14\times 10^{-3}\text{ m}^3/\text{s}}\left(\frac{1\text{ kN}\cdot\text{m}}{1\text{ kJ}}\right)$$

$$= (-4.9 + 294.1)\text{ kN/m}^2 = \mathbf{289.2\ kPa}$$

Discussion In an actual system, the flow rate of water will be less because of friction in pipes. Also, the effect of flow velocities on the pressure change across the pump is negligible in this case (under 2%) and can be ignored.

5-84 Su bir hidrolik türbine 30 cm çapındaki bir borudan 0.6 m^3/s'lik debi ile giriyor ve 25 cm çapındaki borudan dışarı çıkıyor. Türbinde meydana gelen basınç düşümü, civalı bir manometre ile 1.2 m olarak ölçülüyor. Birleşik türbin-jeneratörün verimi yüzde 83 olduğuna göre, net elektrik gücü üretimini belirleyiniz. Kinetik enerji düzeltme faktörlerini göz ardı ediniz.



5-84 Water enters a hydraulic turbine-generator system with a known flow rate, pressure drop, and efficiency. The net electric power output is to be determined. √

Assumptions **1** The flow is steady and incompressible. **2** All losses in the turbine are accounted for by turbine efficiency and thus $h_L = 0$. **3** The elevation difference across the turbine is negligible. **4** The effect of the kinetic energy correction factors is negligible, $\alpha_1 = \alpha_2 = \alpha = 1$.

Properties We take the density of water to be 1000 kg/m³ and the density of mercury to be 13,560 kg/m³.

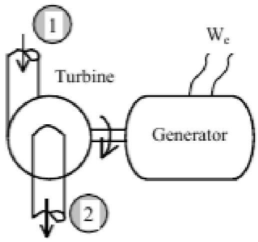
Analysis We choose points 1 and 2 at the inlet and the exit of the turbine, respectively. Noting that the elevation effects are negligible, the energy equation in terms of heads for the turbine reduces to

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_{\text{pump, u}} = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_{\text{turbine, e}} + h_L \quad \rightarrow \quad h_{\text{turbine, e}} = \frac{P_1 - P_2}{\rho_{\text{water}} g} + \frac{\alpha (V_1^2 - V_2^2)}{2g} \qquad (1)$$

where

$$V_1 = \frac{\dot{V}}{A_1} = \frac{\dot{V}}{\pi D_1^2/4} = \frac{0.6 \text{ m}^3/\text{s}}{\pi (0.30 \text{ m})^2/4} = 8.49 \text{ m/s}$$

$$V_2 = \frac{\dot{V}}{A_2} = \frac{\dot{V}}{\pi D_2^2/4} = \frac{0.6 \text{ m}^3/\text{s}}{\pi (0.25 \text{ m})^2/4} = 12.2 \text{ m/s}$$



The pressure drop corresponding to a differential height of 1.2 m in the mercury manometer is

$$P_1 - P_2 = (\rho_{\text{Hg}} - \rho_{\text{water}}) g h$$
$$= [(13{,}560 - 1000) \text{ kg/m}^3](9.81 \text{ m/s}^2)(1.2 \text{ m})\left(\frac{1 \text{ kN}}{1000 \text{ kg}\cdot\text{m/s}^2}\right)$$
$$= 148 \text{ kN/m}^2 = 148 \text{ kPa}$$

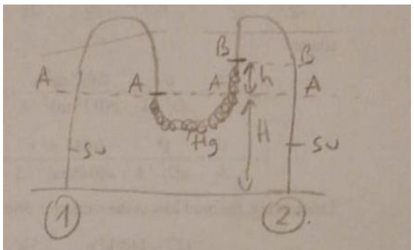
Substituting into Eq. (1), the turbine head is determined to be

$$h_{\text{turbine, e}} = \frac{148 \text{ kN/m}^2}{(1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)}\left(\frac{1000 \text{ kg}\cdot\text{m/s}^2}{1 \text{ kN}}\right) + (1.0)\frac{(8.49 \text{ m/s})^2 - (12.2 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} = 15.1 - 3.9 = 11.2 \text{ m}$$

Then the net electric power output of this hydroelectric turbine becomes

$$\dot{W}_{\text{turbine}} = \eta_{\text{turbine-gen}} \dot{m} g h_{\text{turbine, e}} = \eta_{\text{turbine-gen}} \rho \dot{V} g h_{\text{turbine, e}}$$
$$= 0.83(1000 \text{ kg/m}^3)(0.6 \text{ m}^3/\text{s})(9.81 \text{ m/s}^2)(11.2 \text{ m})\left(\frac{1 \text{ N}}{1 \text{ kg}\cdot\text{m/s}^2}\right)\left(\frac{1 \text{ kW}}{1000 \text{ N}\cdot\text{m/s}}\right) = \mathbf{55 \text{ kW}}$$

Discussion It appears that this hydroelectric turbine will generate 55 kW of electric power under given conditions. Note that almost half of the available pressure head is discarded as kinetic energy. This demonstrates the need for a larger turbine exit area and better recovery. For example, the power output can be increased to 74 kW by redesigning the turbine and making the exit diameter of the pipe equal to the inlet diameter, $D_2 = D_1$. Further, if a much larger exit diameter is used and the exit velocity is reduced to a very low level, the power generation can increase to as much as 92 kW.



$P_1 > P_2$ olmalı türbinde

$P_A + \rho_{su} g H = P_1$

$P_B + \rho_{civa} g h = P_A$

$P_B + \rho_{su} g (h+H) = P_2$

$P_1 - P_2 = P_A + \cancel{\rho_{su} g H} - P_B - \rho_{su} g (h + \cancel{H})$

$P_A - P_B = \rho_{civa} g h$

$P_1 - P_2 = (\rho_{civa} - \rho_{su}) g h$

... debisini belirleyiniz.

5-77 Su, çapı bir redüksiyon ile 15 cm'den 8 cm'ye düşürülen yatay bir boru içerisinden 0.035 m^3/s'lik debi ile akmaktadır. Borunun merkezindeki basınç, redüksiyondan önce ve sonra sırasıyla 470 kPa ve 440 kPa olarak ölçüldüğüne göre redüksiyondaki tersinmez yük kaybını belirleyiniz. Kinetik enerji düzeltme faktörünü 1.05 olarak alınız. *Cevap:* 0.68 m

5-77 Water flows at a specified rate in a horizontal pipe whose diameter is decreased by a reducer. The pressures are measured before and after the reducer. The head loss in the reducer is to be determined. √

Assumptions **1** The flow is steady and incompressible. **2** The pipe is horizontal. **3** The kinetic energy correction factors are given to be $\alpha_1 = \alpha_2 = \alpha = 1.05$.

Properties We take the density of water to be $\rho = 1000\ \text{kg/m}^3$.

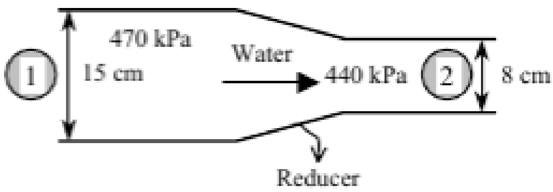
Analysis We take points 1 and 2 along the centerline of the pipe before and after the reducer, respectively. Noting that $z_1 = z_2$, the energy equation for steady incompressible flow through a control volume between these two points reduces to

$$\frac{P_1}{\rho g}+\alpha_1\frac{V_1^2}{2g}+z_1+h_{\text{pump, u}}=\frac{P_2}{\rho g}+\alpha_2\frac{V_2^2}{2g}+z_2+h_{\text{turbine, e}}+h_L \quad\rightarrow\quad h_L=\frac{P_1-P_2}{\rho g}+\frac{\alpha(V_1^2-V_2^2)}{2g}$$

where

$$V_1=\frac{\dot V}{A_1}=\frac{\dot V}{\pi D_1^2/4}=\frac{0.035\ \text{m}^3/\text{s}}{\pi(0.15\ \text{m})^2/4}=1.98\ \text{m/s}$$

$$V_2=\frac{\dot V}{A_2}=\frac{\dot V}{\pi D_2^2/4}=\frac{0.035\ \text{m}^3/\text{s}}{\pi(0.08\ \text{m})^2/4}=6.96\ \text{m/s}$$



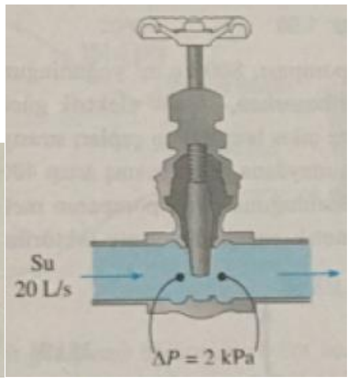
Substituting, the head loss in the reducer is determined to be

$$h_L=\frac{(470-440)\ \text{kPa}}{(1000\ \text{kg/m}^3)(9.81\ \text{m/s}^2)}\left(\frac{1\ \text{kN/m}^2}{1\ \text{kPa}}\right)\left(\frac{1000\ \text{kg}\cdot\text{m/s}^2}{1\ \text{kN}}\right)+\frac{1.05[(1.98\ \text{m/s})^2-(6.96\ \text{m/s})^2]}{2(9.81\ \text{m/s}^2)}$$
$$=3.06-2.38=\mathbf{0.68\ m}$$

Discussion Note that the 0.79 m of the head loss is due to frictional effects and 2.27 m is due to the increase in velocity. This head loss corresponds to a power potential loss of

$$\dot E_{\text{mech loss, piping}}=\rho\dot V g h_L=(1000\ \text{kg/m}^3)(0.035\ \text{m}^3/\text{s})(9.81\ \text{m/s}^2)(0.79\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{W}}{1\ \text{N}\cdot\text{m/s}}\right)=\mathbf{271\ W}$$

5-81 Su 3 cm çapındaki yatay bir borudan 20 L/s debi ile akmaktadır. Boru içerisindeki bir vanada meydana gelen basınç düşüşü 2 kPa olarak ölçülmektedir. Vananın tersinmez yük kaybını ve meydana gelen basınç düşüşünü yenmek için gereken faydalı pompa gücünü hesaplayınız *Cevaplar: 0.204 m, 40 W*



5-81 Water flows through a horizontal pipe at a specified rate. The pressure drop across a valve in the pipe is measured. The corresponding head loss and the power needed to overcome it are to be determined. √

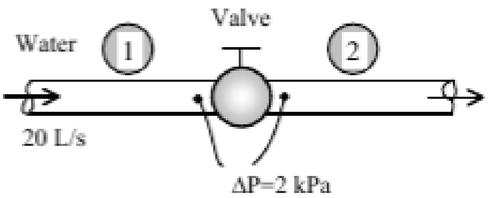
Assumptions **1** The flow is steady and incompressible. **2** The pipe is given to be horizontal (otherwise the elevation difference across the valve is negligible). **3** The mean flow velocities at the inlet and the exit of the valve are equal since the pipe diameter is constant.

Properties We take the density of water to be $\rho = 1000\ \text{kg/m}^3$.

Analysis We take the valve as the control volume, and points 1 and 2 at the inlet and exit of the valve, respectively. Noting that $z_1 = z_2$ and $V_1 = V_2$, the energy equation for steady incompressible flow through this control volume reduces to

$$\frac{P_1}{\rho g}+\alpha_1\frac{V_1^2}{2g}+z_1+h_{\text{pump, u}}=\frac{P_2}{\rho g}+\alpha_2\frac{V_2^2}{2g}+z_2+h_{\text{turbine, e}}+h_L \quad\rightarrow\quad h_L=\frac{P_1-P_2}{\rho g}$$

Substituting,



$$h_L=\frac{2\ \text{kN/m}^2}{(1000\ \text{kg/m}^3)(9.81\ \text{m/s}^2)}\left(\frac{1000\ \text{kg}\cdot\text{m/s}^2}{1\ \text{kN}}\right)=\mathbf{0.204\ m}$$

The useful pumping power needed to overcome this head loss is

$$\dot W_{\text{pump, u}}=\dot m g h_L=\rho\dot V g h_L$$

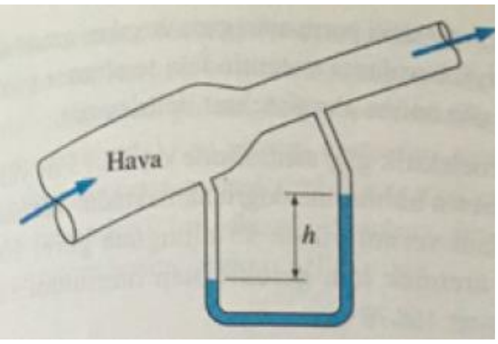
$$=(1000\ \text{kg/m}^3)(0.020\ \text{m}^3/\text{s})(9.81\ \text{m/s}^2)(0.204\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{W}}{1\ \text{N}\cdot\text{m/s}}\right)=\mathbf{40\ W}$$

Therefore, this valve would cause a head loss of 0.204 m, and it would take 40 W of useful pumping power to overcome it.

Discussion The required useful pumping power could also be determined from

$$\dot W_{\text{pump}}=\dot V\Delta P=(0.020\ \text{m}^3/\text{s})(2000\ \text{Pa})\left(\frac{1\ \text{W}}{1\ \text{Pa}\cdot\text{m}^3/\text{s}}\right)=\mathbf{40\ W}$$

5-55 11 0 kPa ve 50 °C'deki hava, 6 cm çapındaki eğimli bir kanal içerisinden 45 L/s'lik debi ile yukarı doğru akmaktadır. Kanal çapı daha sonra bir redüksiyon ile 4 cm'ye düşürülmektedir. Redüksiyonun giriş ve çıkışı arasındaki basınç değişimi bir sulu manometre ile ölçülmektedir. Manometre kollarının boruya bağlandığı iki nokta arasındaki yükseklik farkı 0.20 m'dir. Manometrenin iki kolundaki sıvı seviyeleri arasındaki yükseklik farkını belirleyiniz.



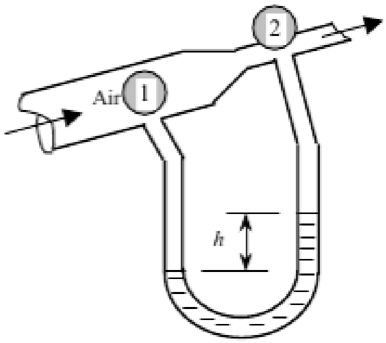
5-55 Air flows upward at a specified rate through an inclined pipe whose diameter is reduced through a reducer. The differential height between fluid levels of the two arms of a water manometer attached across the reducer is to be determined. √ Mod Feb'05.

Assumptions **1**The flow through the duct is steady, incompressible and irrotational with negligible frictional effects (so that the Bernoulli equation is applicable). **2** Air is an ideal gas. **3** The effect of air column on the pressure change is negligible because of its low density. **3** The air flow is parallel to the entrance of each arm of the manometer, and thus no dynamic effects are involved.

Properties We take the density of water to be ρ = 1000 kg/m^3. The gas constant of air is R = 0.287 kPa·m^3/kg·K.

Analysis We take points 1 and 2 at the lower and upper connection points, respectively, of the two arms of the manometer, and take the lower connection point as the reference level. Noting that the effect of elevation on the pressure change of a gas is negligible, the application of the Bernoulli equation between points 1 and 2 gives

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2 \quad\rightarrow\quad P_1-P_2=\rho_{\text{air}}\frac{V_2^2-V_1^2}{2}$$



where $\rho_{air}=\dfrac{P}{RT}=\dfrac{110\,\text{kPa}}{(0.287\,\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(50+273\,\text{K})}=1.19\,\text{kg/m}^3$

$$V_1=\frac{\dot{V}}{A_1}=\frac{\dot{V}}{\pi D_1^2/4}=\frac{0.045\,\text{m}^3/\text{s}}{\pi(0.06\,\text{m})^2/4}=15.9\,\text{m/s}$$

$$V_2=\frac{\dot{V}}{A_2}=\frac{\dot{V}}{\pi D_2^2/4}=\frac{0.045\,\text{m}^3/\text{s}}{\pi(0.04\,\text{m})^2/4}=35.8\,\text{m/s}$$

Substituting,

$$P_1-P_2=(1.19\,\text{kg/m}^3)\frac{(35.8\,\text{m/s})^2-(15.9\,\text{m/s})^2}{2}\left(\frac{1\,\text{N}}{1\,\text{kg}\cdot\text{m/s}^2}\right)=612\,\text{N/m}^2=612\,\text{Pa}$$ The

differential height of water in the manometer corresponding to this pressure change is determined from $\Delta P=\rho_{water}gh$ to be

$$h=\frac{P_1-P_2}{\rho_{water}g}=\frac{612\,\text{N/m}^2}{(1000\,\text{kg/m}^3)(9.81\,\text{m/s}^2)}\left(\frac{1\,\text{kg}\cdot\text{m/s}^2}{1\,\text{N}}\right)=0.0624\,\text{m}=\mathbf{6.24\ cm}$$

Discussion When the effect of air column on pressure change is considered, the pressure change becomes

$$\begin{aligned}P_1-P_2&=\frac{\rho_{air}(V_2^2-V_1^2)}{2}+\rho_{air}g(z_2-z_1)\\&=(1.19\,\text{kg/m}^3)\left[\frac{(35.8\,\text{m/s})^2-(15.9\,\text{m/s})^2}{2}+(9.81\,\text{m/s}^2)(0.2\,\text{m})\right]\left(\frac{1\,\text{N}}{1\,\text{kg}\cdot\text{m/s}^2}\right)\\&=(612+2)\,\text{N/m}^2=614\,\text{N/m}^2=614\,\text{Pa}\end{aligned}$$

This difference between the two results (612 and 614 Pa) is less than 1%. Therefore, the effect of air column on pressure change is, indeed, negligible as assumed. In other words, the pressure change of air in the duct is almost entirely due to velocity change, and the effect of elevation change is negligible.

Also, if we were to account for the Δz of air flow, then it would be more proper to account for the Δz of air in the manometer by using ρ_{water} - ρ_{air} instead of ρ_{water} when calculating h. The additional air column in the manometer tends to cancel out the change in pressure due to the elevation difference in the flow in this case.

5-43 Bir piyezometre ve bir Pitot tüpü 3 cm çapındaki yatay bir su borusuna takılıyor ve su sütunu yükseklikleri piyezometrede 20 cm ve Pitot tüpünde 35 cm olarak ölçülüyor (her ikisi de borunun üst yüzeyinden ölçülüyor). Borunun merkezindeki hızı belirleyiniz.

5-43 The static and stagnation pressures in a horizontal pipe are measured. The velocity at the center of the pipe is to be determined. √

Assumptions The flow is steady, incompressible, and irrotational with negligible frictional effects (so that the Bernoulli equation is applicable).

Analysis We take points 1 and 2 along the centerline of the pipe, with point 1 directly under the piezometer and point 2 at the entrance of the Pitot-static probe (the stagnation point). This is a steady flow with straight and parallel streamlines, and thus the static pressure at any point is equal to the hydrostatic pressure at that point. Noting that point 2 is a stagnation point and thus $V_2 = 0$ and $z_1 = z_2$, the application of the Bernoulli equation between points 1 and 2 gives

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2 \quad \rightarrow \quad \frac{V_1^2}{2g}=\frac{P_2-P_1}{\rho g}$$

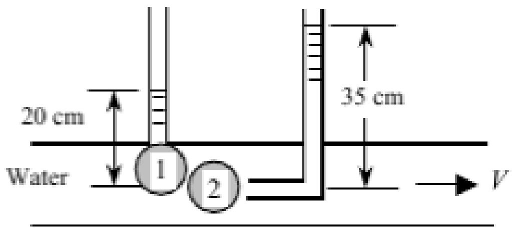
Substituting the P_1 and P_2 expressions give

$$\frac{V_1^2}{2g}=\frac{P_2-P_1}{\rho g}=\frac{\rho g(h_{\text{pitot}}+R)-\rho g(h_{\text{piezo}}+R)}{\rho g}=\frac{\rho g(h_{\text{pitot}}-h_{\text{piezo}})}{\rho g}=h_{\text{pitot}}-h_{\text{piezo}}$$

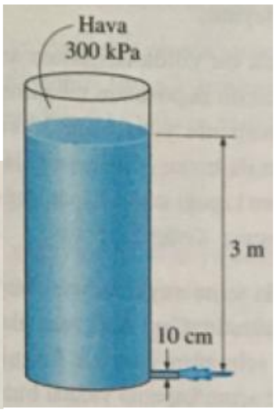
Solving for V_1 and substituting,

$$V_1=\sqrt{2g(h_{\text{pitot}}-h_{\text{piezo}})}=\sqrt{2(9.81\text{ m/s}^2)[(0.35-0.20)\text{ m}]}=\mathbf{1.72\ m/s}$$

Discussion Note that to determine the flow velocity, all we need is to measure the height of the excess fluid column in the Pitot-static probe.



5-45 Basınçlı bir su tankının tabanında suyun atmosfere boşaldığı 10 cm çapında bir delik vardır. Su seviyesi çıkıştan 3 m yüksektedir. Su yüzeyinin üzerindeki hava basıncı 300 kPa (mutlak olarak) ve atmosfer basıncı ise 100 kPa'dır. Sürtünme etkilerini ihmal ederek, tanktan boşalan suyun başlangıçtaki debisini belirleyiniz.
Cevap: 0.168 m³/s



5-45 Water discharges to the atmosphere from the orifice at the bottom of a pressurized tank. Assuming frictionless flow, the discharge rate of water from the tank is to be determined. √EES

Assumptions **1** The orifice has a smooth entrance, and thus the frictional losses are negligible. **2** The flow is steady, incompressible, and irrotational with negligible frictional effects (so that the Bernoulli equation is applicable).

Properties We take the density of water to be 1000 kg/m³.

Analysis We take point 1 at the free surface of the tank, and point 2 at the exit of orifice, which is also taken to be the reference level ($z_2 = 0$). Noting that the fluid velocity at the free surface is very low ($V_1 \cong 0$) and water discharges into the atmosphere (and thus $P_2 = P_{atm}$), the Bernoulli equation simplifies to

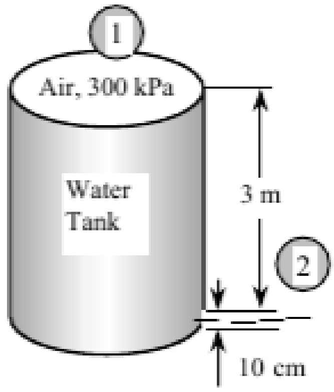
$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2 \quad \rightarrow \quad \frac{V_2^2}{2g}=\frac{P_1-P_2}{\rho g}+z_1$$

Solving for V_2 and substituting, the discharge velocity is determined to

$$V_2=\sqrt{\frac{2(P_1-P_2)}{\rho}+2gz_1}=\sqrt{\frac{2(300-100)\text{ kPa}}{1000\text{ kg/m}^3}\left(\frac{1000\text{ N/m}^2}{1\text{ kPa}}\right)\left(\frac{1\text{ kg}\cdot\text{m/s}^2}{1\text{ N}}\right)+2(9.81\text{ m/s}^2)(3\text{ m})}$$
$$=21.4\text{ m/s}$$

Then the initial rate of discharge of water becomes

$$\dot{V}=A_{\text{orifice}}V_2=\frac{\pi D^2}{4}V_2=\frac{\pi(0.10\text{ m})^2}{4}(21.4\text{ m/s})=\mathbf{0.168\ m^3/s}$$



Discussion Note that this is the maximum flow rate since the frictional effects are ignored. Also, the velocity and the flow rate will decrease as the water level in the tank decreases.