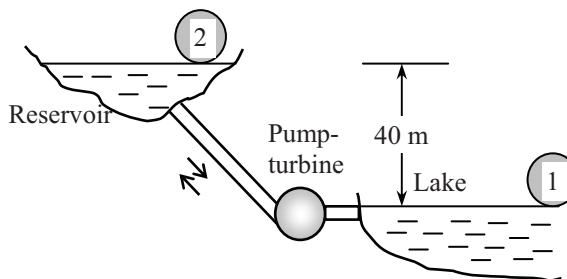


**3-106** An entrepreneur is to build a large reservoir above the lake level, and pump water from the lake to the reservoir at night using cheap power, and let the water flow from the reservoir back to the lake during the day, producing power. The potential revenue this system can generate per year is to be determined.

**Assumptions** 1 The flow in each direction is steady and incompressible. 2 The elevation difference between the lake and the reservoir can be taken to be constant, and the elevation change of reservoir during charging and discharging is disregarded. 3 Frictional losses in piping are negligible. 4 The system operates every day of the year for 10 hours in each mode.

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

**Analysis** The total mechanical energy of water in an upper reservoir relative to water in a lower reservoir is equivalent to the potential energy of water at the free surface of this reservoir relative to free surface of the lower reservoir. Therefore, the power potential of water is its potential energy, which is  $gz$  per unit mass, and  $\dot{m}gz$  for a given mass flow rate. This also represents the minimum power required to pump water from the lower reservoir to the higher reservoir.



$$\begin{aligned}\dot{W}_{\max, \text{turbine}} = \dot{W}_{\min, \text{pump}} = \dot{W}_{\text{ideal}} = \Delta \dot{E}_{\text{mech}} = \dot{m} \Delta e_{\text{mech}} = \dot{m} \Delta pe = \dot{m} g \Delta z = \rho \dot{V} g \Delta z \\ = (1000 \text{ kg/m}^3)(2 \text{ m}^3/\text{s})(9.81 \text{ m/s}^2)(40 \text{ m}) \left( \frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right) \left( \frac{1 \text{ kW}}{1000 \text{ N} \cdot \text{m/s}} \right) \\ = 784.8 \text{ kW}\end{aligned}$$

The actual pump and turbine electric powers are

$$\begin{aligned}\dot{W}_{\text{pump, elect}} = \frac{\dot{W}_{\text{ideal}}}{\eta_{\text{pump-motor}}} = \frac{784.8 \text{ kW}}{0.75} = 1046 \text{ kW} \\ \dot{W}_{\text{turbine}} = \eta_{\text{turbine-gen}} \dot{W}_{\text{ideal}} = 0.75(784.8 \text{ kW}) = 588.6 \text{ kW}\end{aligned}$$

Then the power consumption cost of the pump, the revenue generated by the turbine, and the net income (revenue minus cost) per year become

$$\text{Cost} = \dot{W}_{\text{pump, elect}} \Delta t \times \text{Unit price} = (1046 \text{ kW})(365 \times 10 \text{ h/year})(\$0.03/\text{kWh}) = \$114,500/\text{year}$$

$$\text{Revenue} = \dot{W}_{\text{turbine}} \Delta t \times \text{Unit price} = (588.6 \text{ kW})(365 \times 10 \text{ h/year})(\$0.08/\text{kWh}) = \$171,900/\text{year}$$

$$\text{Net income} = \text{Revenue} - \text{Cost} = 171,900 - 114,500 = \mathbf{\$57,400/\text{year}}$$

**Discussion** It appears that this pump-turbine system has a potential to generate net revenues of about \$57,000 per year. A decision on such a system will depend on the initial cost of the system, its life, the operating and maintenance costs, the interest rate, and the length of the contract period, among other things.