

3-40 A car is to climb a hill in 10 s. The power needed is to be determined for three different cases.

Assumptions Air drag, friction, and rolling resistance are negligible.

Analysis The total power required for each case is the sum of the rates of changes in potential and kinetic energies. That is,

$$\dot{W}_{\text{total}} = \dot{W}_a + \dot{W}_g$$

(a) $\dot{W}_a = 0$ since the velocity is constant. Also, the vertical rise is $h = (100 \text{ m})(\sin 30^\circ) = 50 \text{ m}$. Thus,

$$\dot{W}_g = mg(z_2 - z_1) / \Delta t = (2000 \text{ kg})(9.81 \text{ m/s}^2)(50 \text{ m}) \left(\frac{1 \text{ kJ}}{1000 \text{ kg} \cdot \text{m}^2/\text{s}^2} \right) / (10 \text{ s}) = 98.1 \text{ kW}$$

and $\dot{W}_{\text{total}} = \dot{W}_a + \dot{W}_g = 0 + 98.1 = \mathbf{98.1 \text{ kW}}$

(b) The power needed to accelerate is

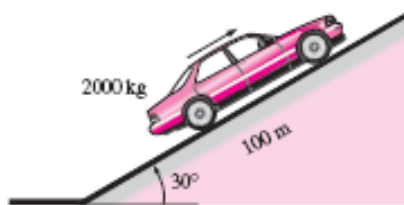
$$\dot{W}_a = \frac{1}{2} m(V_2^2 - V_1^2) / \Delta t = \frac{1}{2} (2000 \text{ kg}) [(30 \text{ m/s})^2 - 0] \left(\frac{1 \text{ kJ}}{1000 \text{ kg} \cdot \text{m}^2/\text{s}^2} \right) / (10 \text{ s}) = 90 \text{ kW}$$

and $\dot{W}_{\text{total}} = \dot{W}_a + \dot{W}_g = 90 + 98.1 = \mathbf{188.1 \text{ kW}}$

(c) The power needed to decelerate is

$$\dot{W}_a = \frac{1}{2} m(V_2^2 - V_1^2) / \Delta t = \frac{1}{2} (2000 \text{ kg}) [(5 \text{ m/s})^2 - (35 \text{ m/s})^2] \left(\frac{1 \text{ kJ}}{1000 \text{ kg} \cdot \text{m}^2/\text{s}^2} \right) / (10 \text{ s}) = -120 \text{ kW}$$

and $\dot{W}_{\text{total}} = \dot{W}_a + \dot{W}_g = -120 + 98.1 = \mathbf{-21.9 \text{ kW}}$ (braking power)



3-54 A fan is to accelerate quiescent air to a specified velocity at a specified flow rate. The minimum power that must be supplied to the fan is to be determined.

Assumptions The fan operates steadily.

Properties The density of air is given to be $\rho = 1.18 \text{ kg/m}^3$.

Analysis A fan transmits the mechanical energy of the shaft (shaft power) to mechanical energy of air (kinetic energy). For a control volume that encloses the fan, the energy balance can be written as

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{dE_{\text{system}} / dt}_{\text{Rate of change in internal, kinetic, potential, etc. energies}}^{e^0 \text{ (steady)}} = 0 \rightarrow \dot{E}_{in} = \dot{E}_{out}$$

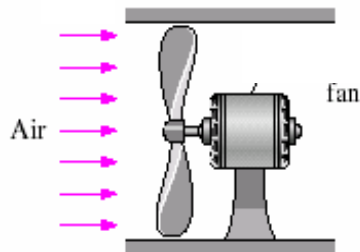
$$\dot{W}_{\text{sh, in}} = \dot{m}_{\text{air}} \text{ke}_{\text{out}} = \dot{m}_{\text{air}} \frac{V_{\text{out}}^2}{2}$$

where

$$\dot{m}_{\text{air}} = \rho \dot{V} = (1.18 \text{ kg/m}^3)(4 \text{ m}^3/\text{s}) = 4.72 \text{ kg/s}$$

Substituting, the minimum power input required is determined

$$\dot{W}_{\text{sh, in}} = \dot{m}_{\text{air}} \frac{V_{\text{out}}^2}{2} = (4.72 \text{ kg/s}) \frac{(10 \text{ m/s})^2}{2} \left(\frac{1 \text{ J/kg}}{1 \text{ m}^2/\text{s}^2} \right) = 236 \text{ J/s} = \mathbf{236 \text{ W}}$$



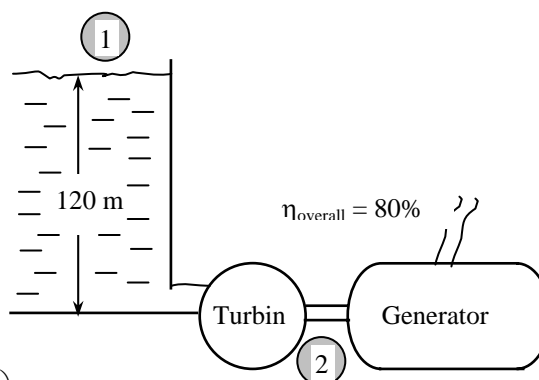
Discussion The conservation of energy principle requires the energy to be conserved as it is converted from one form to another, and it does not allow any energy to be created or destroyed during a process. In reality, the power required will be considerably higher because of the losses associated with the conversion of mechanical shaft energy to kinetic energy of air.

3-105 The available head, flow rate, and efficiency of a hydroelectric turbine are given. The electric power output is to be determined.

Assumptions **1** The flow is steady. **2** Water levels at the reservoir and the discharge site remain constant. **3** Frictional losses in piping are negligible.

Properties We take the density of water to be $\rho = 1000 \text{ kg/m}^3 = 1 \text{ kg/L}$.

Analysis The total mechanical energy the water in a dam possesses is equivalent to the potential energy of water at the free surface of the dam (relative to free surface of discharge water), and it can be converted to work entirely. 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.



$$e_{\text{mech}} = pe = gz = (9.81 \text{ m/s}^2)(120 \text{ m}) \left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2} \right) = 1.177 \text{ kJ/kg}$$

The mass flow rate is

$$\dot{m} = \rho \dot{V} = (1000 \text{ kg/m}^3)(100 \text{ m}^3/\text{s}) = 100,000 \text{ kg/s}$$

Then the maximum and actual electric power generation become

$$\dot{W}_{\text{max}} = \dot{E}_{\text{mech}} = \dot{m}e_{\text{mech}} = (100,000 \text{ kg/s})(1.177 \text{ kJ/kg}) \left(\frac{1 \text{ MW}}{1000 \text{ kJ/s}} \right) = 117.7 \text{ MW}$$

$$\dot{W}_{\text{electric}} = \eta_{\text{overall}} \dot{W}_{\text{max}} = 0.80(117.7 \text{ MW}) = \mathbf{94.2 \text{ MW}}$$

Discussion Note that the power generation would increase by more than 1 MW for each percentage point improvement in the efficiency of the turbine-generator unit.