

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

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

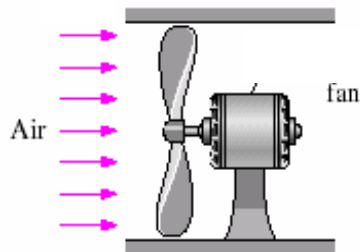
$$\dot{W}_{\text{sh, in}} = \dot{m}_{\text{air}} \text{ke}_{\text{out}} = \dot{m}_{\text{air}} \frac{V_{\text{out}}^2}{2}$$

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.