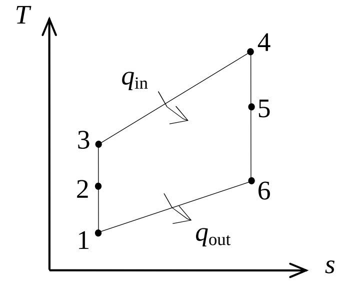
9-142 A pure jet engine operating on an ideal cycle is considered. The velocity at the nozzle exit and the thrust produced are to be determined.

Assumptions **1** Steady operating conditions exist. **2** The air standard assumptions are applicable. **3** Air is an ideal gas with constant specific heats at room temperature. **4** The turbine work output is equal to the compressor work input.

Properties The properties of air at room temperature are R = 0.287 kPa·m^3/kg·K, c_p = 1.005 kJ/kg·K and k = 1.4 (Table A-2a).

Analysis (*a*) We assume the aircraft is stationary and the air is moving towards the aircraft at a velocity of V_1 = 240 m/s. Ideally, the air will leave the diffuser with a negligible velocity ($V_2 \cong 0$).



Diffuser:

$$\dot{E}_{in} - \dot{E}_{out} = \Delta\dot{E}_{system}^{\nearrow 0 \text{ (steady)}} \longrightarrow \dot{E}_{in} = \dot{E}_{out}$$

$$h_1 + V_1^2/2 = h_2 + V_2^2/2 \longrightarrow 0 = h_2 - h_1 + \frac{V_2^{2\nearrow 0} - V_1^2}{2}$$

$$0 = c_p(T_2 - T_1) - V_1^2/2$$

$$T_2 = T_1 + \frac{V_1^2}{2c_p} = 260\text{ K} + \frac{(240\text{ m/s})^2}{(2)(1.005\text{ kJ/kg}\cdot\text{K})}\left(\frac{1\text{ kJ/kg}}{1000\text{ m}^2/\text{s}^2}\right) = 288.7\text{ K}$$

$$P_2 = P_1\left(\frac{T_2}{T_1}\right)^{k/(k-1)} = (45\text{ kPa})\left(\frac{288.7\text{ K}}{260\text{ K}}\right)^{1.4/0.4} = 64.88\text{ kPa}$$

Compressor:

$$P_3 = P_4 = (r_p)(P_2) = (13)(64.88\text{ kPa}) = 843.5\text{ kPa}$$

$$T_3 = T_2\left(\frac{P_3}{P_2}\right)^{(k-1)/k} = (288.7\text{ K})(13)^{0.4/1.4} = 600.7\text{ K}$$

Turbine:

$$w_{comp,in} = w_{turb,out} \longrightarrow h_3 - h_2 = h_4 - h_5 \longrightarrow c_p(T_3 - T_2) = c_p(T_4 - T_5)$$

or $\quad T_5 = T_4 - T_3 + T_2 = 830 - 600.7 + 288.7 = 518.0\text{ K}$

Nozzle:

$$T_6 = T_4\left(\frac{P_6}{P_4}\right)^{(k-1)/k} = (830\text{ K})\left(\frac{45\text{ kPa}}{843.5\text{ kPa}}\right)^{0.4/1.4} = 359.3\text{ K}$$

$$\dot{E}_{in} - \dot{E}_{out} = \Delta\dot{E}_{system}^{\nearrow 0 \text{ (steady)}} \longrightarrow \dot{E}_{in} = \dot{E}_{out}$$

$$h_5 + V_5^2/2 = h_6 + V_6^2/2$$

$$0 = h_6 - h_5 + \frac{V_6^2 - V_5^{2\nearrow 0}}{2} \longrightarrow 0 = c_p(T_6 - T_5) + V_6^2/2$$

or $\quad V_6 = V_{exit} = \sqrt{(2)(1.005\text{ kJ/kg}\cdot\text{K})(518.0 - 359.3)\text{K}\left(\frac{1000\text{ m}^2/\text{s}^2}{1\text{ kJ/kg}}\right)} = \mathbf{564.8\ m/s}$

The mass flow rate through the engine is

$$\boldsymbol{v}_1 = \frac{RT}{P} = \frac{(0.287\text{ kPa}\cdot\text{m}^3)(260\text{ K})}{45\text{ kPa}} = 1.658\text{ m}^3/\text{kg}$$

$$\dot{m} = \frac{AV_1}{\boldsymbol{v}_1} = \frac{\pi D^2}{4}\frac{V_1}{\boldsymbol{v}_1} = \frac{\pi(1.6\text{ m})^2}{4}\frac{240\text{ m/s}}{1.658\text{ m}^3/\text{kg}} = 291.0\text{ kg/s}$$

The thrust force generated is then

$$F = \dot{m}(V_{exit} - V_{inlet}) = (291.0\text{ kg/s})(564.8 - 240)\text{m/s}\left(\frac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2}\right) = \mathbf{94{,}520\ N}$$