1.8) The engine of a small jet aircraft develops a thrust of 18 kN when the aircraft is flying at a speed of 900 km/h at an altitude where the ambient pressure is 50 kPa. The air flow rate through the engine is 75 kg/s and the engine uses fuel at a rate of 3 kg/s. The pressure on the engine discharge plane is 55 kPa and the area of the engine exit is 0.2 m^2. Find the jet efflux velocity.

Solution:

Given:

Thrust=18 kN, fuel rate=3 kg/s

Inlet $\rightarrow V_1 = 900\,\text{km/h} = 900/3.6 = 250\,\text{m/s}$, $p_1 = 50\,\text{kPa}$, $\dot{m}_1 = 75\,\text{kg/s}$.

Outlet $\rightarrow p_2 = 55\,\text{kPa}$, $A_{\text{exit}} = 0.2\,\text{m}^2$, $V_2 = ?\,\text{m/s}$.

The schematic diagram of the problem description is shown in Fig. 1.

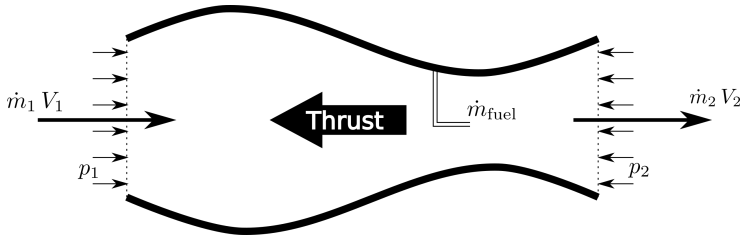

Fig. 1: Schematic diagram for problem description

Using the mass conservation equation,

$$\dot{m}_2 = \dot{m}_1 + \dot{m}_{\text{fuel}}$$

$$\dot{m}_2 = 75 + 3 = 78\,\text{kg/s}$$

Using the conservation of momentum along horizontal direction,

$$\begin{aligned}
\text{Thrust} &= \text{rate of momentum exiting} - \text{rate of momentum entering} \\
&\quad + \text{pressure force at exit} - \text{pressure force at inlet} \\
\text{Thrust} &= \dot{m}_2 V_2 - \dot{m}_1 V_1 + (p_2 - p_1)\,A_{\text{exit}} \\
18 \times 10^3 &= 78 \times V_2 - 75 \times 250 + \left(55 \times 10^3 - 50 \times 10^3\right) \times 0.2
\end{aligned}$$

$$V_2 = \frac{18 \times 10^3 + 75 \times 250 - \left(55 \times 10^3 - 50 \times 10^3\right) \times 0.2}{78}$$

$$\boxed{V_2 = 458.3333\,\text{m/s}}\,.$$