

1.10) A rocket used to study the atmosphere has a fuel consumption rate of 120 kg/s and a nozzle discharge velocity of 2300 m/s. The pressure on the nozzle discharge plane is 90 kPa. Find the thrust developed when the rocket is launched at sea level. The nozzle exit plane diameter is 0.3 m.

**Solution:**

Given:  $\dot{m}_{fuel} = 120 \text{ kg/s}$ ,  $V_e = 2300 \text{ m/s}$ ,  $p_e = 90 \text{ kPa}$ ,  $D_e = \varnothing 0.3 \text{ m}$ .

To calculate: Thrust at sea level

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

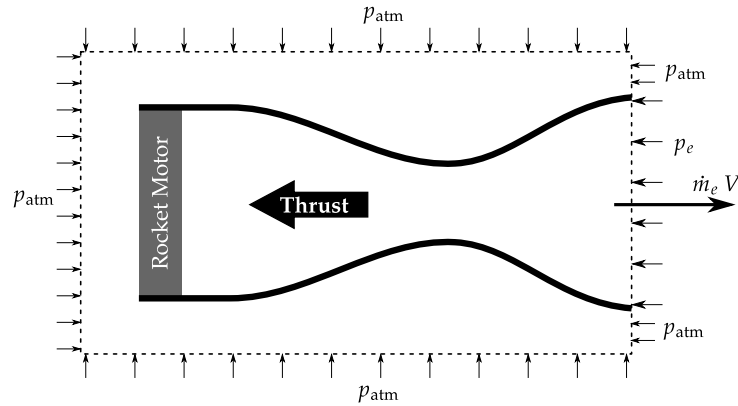


Fig. 1: Schematic diagram for problem description

Assuming the atmospheric pressure at sea level as  $p_{atm} = 1 \text{ atm} = 101325 \text{ Pa}$ .

Assuming that the oxidizer is mixed with the fuel,  $\dot{m}_e = \dot{m}_{fuel} = 120 \text{ kg/s}$ .

Applying the conservation of momentum on the control-volume around the rocket,

$$\text{Thrust} = \text{rate of momentum exiting} - \text{rate of momentum entering} \\ + \text{pressure force at exit} - \text{pressure force at inlet}$$

$$\text{Thrust} = \dot{m}_e V_e - 0 + (p_e - p_{atm}) A_{\text{exit}}$$

$$\text{Thrust} = 120 \times 2300 - 0 + \left( 90 \times 10^3 - 101325 \right) \times \frac{\pi}{4} \times 0.3^2$$

$$\boxed{\text{Thrust at sea level} = 275199.483 \text{ N}}$$