ANNOUNCED QUIZ #8 – ME 2030 –SECTION 001 – Fall 2024

NAME: SOLUTION

This is an open book quiz. You may use a four-function calculator. An unsigned honors pledge will result in a zero. Show all work.

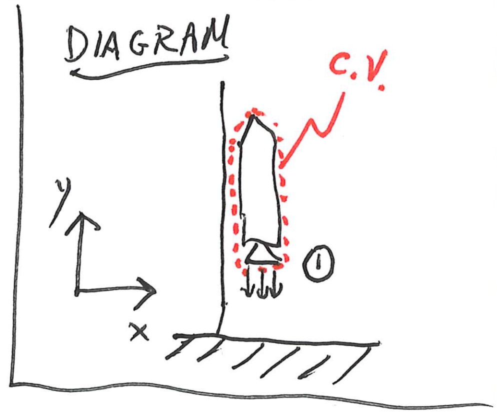
1. A vertically oriented rocket having a mass of 10,000 kg has just achieved ignition and has exhaust gasses leaving its nozzle at a mass flow rate of $\dot{m} = 49$ kg/s. If the density of the exhaust gasses is 11 kg/m^3, and the jet emanating from the rocket nozzle is not affected by the presence of the launch pad, what should the nozzle diameter be in order to just attain liftoff? Report your answer in cm.

GIVEN: Rocket mass, $\dot{m}$ and ρ of exhaust gasses

FIND: d of nozzle in cm.

ASSUME: ρ, V uniform and constant at nozzle exit; steady-state

ANALYSIS: C of Momentum for C.V.



$$\frac{\partial}{\partial t}\int_{C.V.} \vec{V}\rho\, d\forall + \int_{C.S.} \vec{V}\rho\vec{V}\cdot\hat{n}\, dA = \sum \vec{F}_{\text{contents of C.V.}}$$

0 b/c S.S.

Consider y-direction only

$$\int V_y \rho \vec{V}\cdot\hat{n}\, dA = \sum F_y$$

$$V_y \rho \vec{V}\cdot\hat{n}\int dA = \sum F_y \rightarrow V_y \rho \vec{V}\cdot\hat{n} A = \sum F_y \rightarrow (-V_y \rho V_y A)_1 = \sum F_y$$

b/c uniform

$$-\rho V_1^2 A_1 = \sum F_y \qquad \sum F_{y,\text{ contents of C.V.}} = F_{att,y} + \text{Weight}$$

($F_{att,y}$ = 0)

$$-\rho V_1^2 A = -m_r g \rightarrow +(\rho V_1 A)V_1 = +m_r g \rightarrow \dot{m} V_1 = m_r g$$

$$(49\,\tfrac{kg}{s})V_1 = (10{,}000\,kg)(9.81\,\tfrac{m}{s^2}) \rightarrow \boxed{V_1 = 2002\,\tfrac{m}{s}}$$

$$\dot{m} = \rho V_1 A_1 = (11\,\tfrac{kg}{m^3})(2002\,\tfrac{m}{s})A_1 = 49\,\tfrac{kg}{s} \rightarrow \boxed{A_1 = 0.00223\,m^2} = \frac{\pi d_1^2}{4}$$

$$d_1 = 0.0533\,m \qquad \boxed{d_1 = 5.33\,cm}$$

ANS.

I HAVE NEITHER PROVIDED OR RECEIVED HELP DURING THIS QUIZ.

SIGNATURE