Assignment -1 (AE 330)

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Ans 1) Given, Thrust = 9 kN, $\dot{m}_p = \dot{m} = 4$ kg/s, $u = 400$ m/s

Find a) Jet Velocity (V_e)
b) Propulsive efficiency of the rocket (η_p)

a) We know that,

$$T = \dot{m} V_e \quad \text{(Assuming optimum expansion condition)}$$

$$9 \times 1000 = 4 \times V_e$$

$$\boxed{V_e = 2250 \text{ m/s}}$$

b) η_p can be found as,

$$\eta_p = \frac{2(u/c)}{1 + (u/c)^2} \quad \text{, *Here } c = V_e$$

$$\therefore \eta_p = \frac{2\left(\frac{400}{2250}\right)}{1 + \left(\frac{400}{2250}\right)^2} \Rightarrow \boxed{\eta_p = 0.345}$$

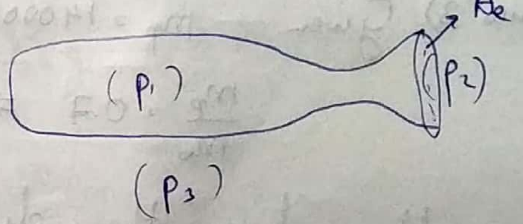
Ans 2) Given, $t_b = 40$ sec ; $M_o = 1210$ kg ; $M_b = 215$ kg $\Rightarrow M_p = 995$ kg

$T = 62.25$ kN ; $P_1 = 7$ MPa ; $P_2 = P_e = 0.07$ MPa

$A_e = \frac{\pi}{4}(0.2703)^2$; $P_{atmosphere}$ (sea level) $= 0.1013$ MPa

By definition of Thrust

$$T = \dot{m} V_e + (P_2 - P_3) A_e$$



Where $\dot{m}$ can be averaged out by

$$\boxed{\dot{m} = \frac{M_p}{t_b} = \frac{995}{40} = 24.875 \text{ kg/s}}$$

$$T = \dot{m} V_e + (p_2 - p_3) A_e$$

$$62250 = 24.875 (V_e) + (0.07 - 0.1013) \times 10^6 \times \frac{\pi}{4} (0.2703)^2$$

$$V_e = \frac{62250 + 1796.08}{24.875}$$

$$\boxed{V_e = 2574.72 \text{ m/s}}$$

Now effective exhaust velocity (c),

$$c = V_e + \frac{(P_2 - P_3) A_e}{\dot{m}} = \frac{T}{\dot{m}}$$

$$c = \frac{62.25 \times 10^3}{24.875}$$

$$\boxed{c = 2502.51 \text{ m/s}}$$

An alternative definition of Specific Impulse is given by

$$I_s = \frac{c}{g}$$

$$= \frac{2502.51}{9.81}$$

$$\boxed{I_s = 255.1 \text{ sec}}$$

Ans 3) Given, $m_p = 140000$ kg, $I_s = 270$, $T = 4800$ kN

$$\frac{m_p}{m_0} = 0.7 \Rightarrow m_0 = 200000 \text{ kg}, \; m_b = 60000$$

Now from the definition of I_s

$$I_s = \frac{T}{\dot{m} g}$$

$$\Rightarrow \dot{m} = \frac{T}{I_s g}$$

$$\dot{m} = \frac{4800 \times 10^3}{270 \times 9.81}$$

$$\boxed{\dot{m} = 1812.21 \text{ kg/s}}$$

So, $t_b = \frac{m_p}{\dot{m}} = \frac{140000}{1812.21}$

$$\Rightarrow \boxed{t_b = 77.25 \text{ sec}}$$

Initial acceleration can be given by,

$$a_i = \frac{T}{m_o} \rightarrow \text{Take off weight}$$

$$= \frac{480000}{200000}$$

$$\boxed{a_i = 2.4 \text{ m/s}^2}$$

Impulse to weight ratio can be defined as

$$\frac{I_t}{W_o} = \frac{I_s}{1 + \frac{m_b}{m_p}} = \frac{270}{1 + 3/7} = \frac{270}{10/7}$$

$$\boxed{\frac{I_t}{W_o} = 189 \text{ sec}}$$

As $I_s = \frac{c}{g} \Rightarrow c = I_s g = 270 \times 9.81$

$$\boxed{c = 2648.7 \text{ m/s}}$$

Ans 4) Given, $\dot{m} = 175\ kg/s$ $V_e = 2164\ m/s$ $P_2 = P_e = 34.5\ kPa$

$P_3 = P_{atmosphere} = 101.35\ kPa$ (sea level) $m_o = 12000\ kg$.

$t_b = 50\ s$, $A_e = 0.258\ m^2$

a) Sea-level impulse (specific)

b) Sea-level effective exhaust velocity

c) Initial thrust-to-weight ratio

d) Impulse to weight ratio.

b) $$C = V_e + \frac{(P_2 - P_3)A_e}{\dot{m}}$$

$$= 2164 + \frac{(-66.85)\times 10^3 \times 0.258}{175}$$

$$= 2164 + (-98.556)$$

$$\boxed{C_{sea} = 2065.44\ m/s}$$

a) $$I_{s(sea)} = \frac{c}{g} = \frac{2065.44}{9.81}$$

$$\boxed{I_{s(sea)} = 210.544\ s}$$

c) $$\left(T/W\right)_{initial} = \frac{\dot{m}c}{m_o g} = \frac{175}{12\times 10^3} \times \frac{210.544}{}$$

$$\boxed{\left(T/W\right)_{initial} = 3.07}$$

d) $m_p = \dot{m}t_b = 175 \times 50 = 8750\ kg$

$\Rightarrow m_b = 12000 - 8750 = 3250\ kg$

Hence, Impulse to weight ratio,

$$\frac{I_t}{W_o} = \frac{I_s}{1 + \frac{m_b}{m_p}} = \frac{210.544}{1 + \left(\frac{3250}{8750}\right)}$$

$$\boxed{\frac{I_t}{W_o} = 153.52 \text{ sec}}$$