AE-441A

NAME: ADITYA RAGHUWANSHI ROLL: 170052

Given $I_{sp} = 400$

$\therefore I_{sp} = \frac{u_{eq}}{g_e}$

$u_{eq} = I_{sp} \times g_e = 400 \times 9.81 = \boxed{3924 \text{ m/s}}$

$\because u_n = n u_{eq} \ln R - n g_e t_b$

$u_n = V_e = 11.2 \text{ km/s}$, $n = 2$, $u_{eq} = 3924 \text{ m/s}$

$n g_e t_b = g_e (n t_b) = 2000 \text{ m/s}$

$n t_b$ → total burn out time

$\Rightarrow 11200 = 2 \times 3924 \times \ln R - 2000$

$\Rightarrow \boxed{R = 5.38}$

Given, $\epsilon_1 = 0.06 = \epsilon_2 = \epsilon$, $\lambda_1 = \lambda_2 = \lambda$

$\because \frac{1+\lambda_i}{\epsilon_i + \lambda_i} = R_i$, for stage i

$\Rightarrow \frac{1+\lambda}{\epsilon+\lambda} = R \Rightarrow \frac{1+\lambda}{0.06+\lambda} = 5.38 \Rightarrow \boxed{\lambda = 0.155}$

for stage 2, $\lambda_2 = \lambda = \frac{M_e}{M_{0,2} - M_e} \Rightarrow 0.155 = \frac{10^5}{M_{0,2} - 10^5}$

$\Rightarrow \boxed{M_{0,2} = 7.47 \times 10^5 \text{ kg}}$

for stage 1, $\lambda_1 = \lambda = \frac{M_{0,2}}{M_{0,1} - M_{0,2}} \Rightarrow 0.155 = \frac{5.22 \times 10^5}{M_{0,1} - 5.22 \times 10^5}$

$\boxed{M_{0,1} = 55.77 \times 10^5 \text{ kg}}$

$\left.\frac{du}{dt}\right|_{t=0} = u_{eq}\left(1 - \frac{1}{R}\right) t_b - g_e$

for stage 1, $\left.acc\right|_{t=0} = u_{eq}\left(1 - \frac{1}{R_1}\right) - g_e$

$0.2 g_e = u_{eq}\left(1 - \frac{1}{R_1}\right)\frac{1}{t_{b_1}} - g_e \Rightarrow t_{b_1} = \frac{u_{eq}}{1.2 g_e}\left(1 - \frac{1}{R_1}\right)$

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$$t_{b_1} = \frac{3924}{(1.2)(9.81)}\left(1 - \frac{1}{5.38}\right)$$

$$\boxed{t_{b_1} = 271.375\,s}$$

$\therefore$ t_b must be less than equal to 271.375 s