Astronomy Club, IITK
Summer Projects 2021

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Space : The Final Frontier

Assignment - 1

[Deadline : 7th June, 2021 || 23:59hours]

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Question 01 :

[Ideal Rocket Equation]

Take all possible assumptions to make the "**Think Rocket Mission**" experiment an ideal scenario.
Find what fraction of original Complete loaded mass should be *Propellant*, in order to attain an orbital velocity of **~7600 m/sec** with a specific impulse of **400 seconds** and with the maximum final change in velocity of the rocket to be **9000 m/sec**."
Also, Show the calculation in order to achieve the final answer.
[Take g_o as **9.8 m.sec^{-2}**]

Question 02:

[Deviation from Ideality]

Let's consider Thrust force acting on the rocket to be -c.(dm/dt) and gravitational force also plays an important role in rocket launch. [Note: Ignore drag force but must include gravity]
Define $[n = F_{thrust}/(m_o g)]$; $[\mu = m(t)/m_o]$
Note : [Indirectly n is a measure for Thrust as well]

[1] Estimate the **velocity of the rocket** v(t) in terms of **mass fraction** (μ)
[2] Estimate the **displacement of rocket** z(t) in terms of **mass fraction** (μ)
[3] After the burn-out time (when all the propellant is consumed), rocket will coast in free-flight and would follow some trajectory (which indirectly or directly needs to satisfy Kepler's law in order to orbit around some planet or something as per the want of "Mission Controller"), So Estimate **Energy per unit mass** as function of **mass fraction(μ)**
[4] Also Continuing in Question [3], What should be energy per unit mass for a rocket, if I need a really *impulsive start*. Is it also dependent on Mass fraction(μ)?
*{ Note : Energy at impulsive start also known as **E→ ideal limit** }*
[5] Throughout the lecture it was said that Thrust really makes very important sense. So Let's check it out by Some Data collection and One simple plot.
(5.1) To estimate the losses at very **smaller 'n'** or smaller thrust, it's better if we could find **Initial Ideal Impulsive Velocity** as well as **Equivalent Real Impulsive Velocity** and

compare the (**change in Impulsive velocity with respect to ideal velocity**) with the **'n' value**
[Make sure to assume a particular propellant mass fraction(μ) any time 't' and impulsive means at the ground level without much gravitational potential.]

Fill in the boxes with **change in Impulsive velocity with respect to ideal velocity.**

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n= 1.5			
n= 3			
n=10			

Also, Plot Curves on **DESMOS** in order to see a trend of change in Impulsive velocity with respect to ideal velocity with the n values at a fixed μ
→ Find the physical significance of the plot also.

Question 03:

[SSTO Model]

In order to achieve an orbital speed of **v = 6400 m/s**, we require an ideal Δv of about **8000 m/s** where the extra velocity is needed to overcome gravity and drag. Chemical rockets produce exhaust jets at velocities of **c ≈ 2500 – 4500 m/s**. Using **highest c value**, for :
[1] Single Stage Rocket
[2] Double stage Rocket
Find the **Approximate Mass of payload** which could be present in both the contexts.
Also compare Out of the two which one has **max. Capacity** to carry payloads to space.
Note :

(1) Propellant Tank + Rocket Engine are the main contributors to the Weight of the rocket and weigh 15% of the propellant discharged.
(2) If multiple staging occurs, equal distribution of Δv's are achieved at every staging.

Question 4:

[Structural Coefficient of Rocket]

$\boxed{\frac{m_s}{m_i} = 1 - \zeta - \frac{m_{\text{pl}}}{m_i}}$ ---------> EQUATION (4.1)

$\boxed{\frac{m_s}{m_i} = \lambda \left(1 - \frac{m_{\text{pl}}}{m_i}\right)}$ ----------> EQUATION (4.2)

Given an attainable Δv of **8000 m/sec** with Specific impulses of (**350, 400 and 450 sec.**) respectively and a fixed payload mass of **2000 kg**, Plot the graph on DESMOS between **Total Initial size of Rocket** ($M_{rocket}+M_{pay}+M_{prop}$) v/s **structural coefficient** (λ) for Both SSTO's Model as well as DSTO's Model[OPTIONAL].
**Compare the steepness of the curve plotted and what could you imply from it's slope(steepness).
(Note : If multiple staging occurs, equal distribution of Δv's are achieved at every staging.)

(Submission Procedure and Details would be shared Later.)

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