1) $\Delta V = I_{sp} g_0 \ln\left(\frac{m_0}{m_f}\right)$

$m_0 = m_{prop} + m_{pay} + m_{rock}$

$m_f = m_{pay} + m_{rocket}$

$\Delta V = 7.6\ km/s = 7600\ m/s$

$I_{sp} = 400s$

$g_0 = 9.8\ m/s^2$

$\frac{19}{\cancel{7600}} = \cancel{400} \times 9.8 \ln\left(\frac{m_0}{m_f}\right)$

$\frac{19}{9.8} = \ln\left(\frac{m_0}{m_f}\right)$

$6.95 = e^{19/9.8} = \frac{m_0}{m_f} = \frac{m_{prop}}{m_f} + 1$

$\therefore m_{prop} = \left(\frac{e^{19/9.8} - 1}{e^{19/9.8}}\right) m_0$

$\left(1 - e^{-\frac{19}{9.8}}\right) m_0$

$5.95 = \frac{m_{prop}}{m_f}$

$m_0 = m_{prop} + \frac{m_{prop}}{5.95}$

$m_0 = m_{prop}\left(\frac{6.95}{5.95}\right)$

$\frac{m_{prop}}{m_0} = \left(\frac{5.95}{6.95}\right)$

≈ 0.856

2 $F_{thr} = -c\frac{dm}{dt} = c\dot{m}$ $\quad \frac{dm}{dt} = -\dot{m}$

$n = \frac{F_{thr}}{m_0 g} = \frac{c\dot{m}}{m}$

$\mu = \frac{m(t)}{m_0} = \frac{m_0 - \dot{m}t}{m_0}$

$F_{net} = c\dot{m} - mg$

$m\frac{dv}{dt} = c\dot{m} - mg$

$m\frac{dv}{dm}\frac{dm}{dt} = c\dot{m} - mg$

$-m\dot{m}\frac{dv}{dm} = c\dot{m} - mg$

$-\cancel{m}\frac{dv}{dm}\dot{m} = n(m_0 g) - mg$

(b)

$\frac{m_0 - \dot{m}t}{m_0}$

$m = m_0 - \dot{m}(t)$

$\cancel{m}\left(\frac{dv}{dt}\right) = \frac{c\dot{m} - mg}{m}$

$\frac{dz}{dt} = -gt - \frac{n m_0 g}{\dot{m}} \ln \mu$

$\frac{dv}{dt} = \frac{c\dot{m} - (m_0 - \dot{m}t)g}{m - \dot{m}t}$

$z = -\frac{gt^2}{2} + \frac{n m_0 g}{\dot{m}} t + \frac{n m_0 g (m_0 - \dot{m}t)}{\dot{m}^2} \ln \mu$

$-\frac{dv}{dm} = \left[n\left(\frac{g m_0}{m}\right) - g\right]\frac{1}{\dot{m}}$

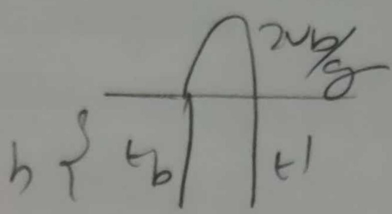
$-V = \frac{n m_0 g}{\dot{m}} \ln\left[\frac{m}{m_0}\right] - \frac{g}{\dot{m}}(m-$

$\boxed{v = -gt - \frac{m_0 n g}{\dot{m}} \ln(\mu)}$

(c) burnout time t_b (d) $n = \frac{F_{thrust}}{m_0 g}$ - exhaust speed

$t_b + \frac{2v_b}{g} + t'$

free fall



$h = v_b t' + \frac{1}{2} g (t')^2$

3. 8500

$\Delta v = v_{ex} \ln\left(\frac{m_f}{m_0}\right)$

$\overset{16}{\cancel{8000}} = \underset{9}{\cancel{4500}} \ln\left(m_0/m_f\right)$

$e^{16/9} = \frac{m_0}{m_f}$ $m_0 = 5.93 m_f$

$4.93(m_{pay} + m_r) = m_{prop}$

$4.93(m) = m_0 - m$

$m_0 = 5.93m$

4. $\Delta V = I_{sp} g_0 \ln(MR)$

propellant

rocket mass

payload

$$MR = \frac{m_i}{m_f} = \frac{m_p + m_s + m_{pl}}{m_s + m_{pl}}$$

$$\varepsilon = \frac{m_p}{m_i} = \frac{m_i - m_f}{m_i} = 1 - \frac{m_f}{m_i} = 1 - \frac{1}{MR} = \frac{MR-1}{MR}$$

$$\lambda = \frac{m_s}{m_p + m_s} = \frac{m_s}{m_i - m_{pl}} = \frac{\frac{m_s}{m_i}}{1 - \frac{m_{pl}}{m_i}} \Rightarrow \frac{m_s}{m_i} = \left(1 - \frac{m_{pl}}{m_i}\right)\lambda$$

$$\lambda - \lambda\left(\frac{m_{pl}}{m_i}\right) = \frac{m_s}{m_i}$$

$$\lambda = \frac{1}{m_i}(m_s + \lambda m_{pl})$$

$$\boxed{m_i = \frac{m_{pl}}{\left(1 - \frac{\varepsilon}{1-\lambda}\right)}}$$

$$1 = \frac{m_{pl}}{m_i} + \frac{m_p}{m_i} + \frac{m_s}{m_i}$$

$$1 = \frac{m_{pl}}{m_i} + \varepsilon + \frac{m_s}{m_i}$$

$$\left(1 - \varepsilon - \frac{m_{pl}}{m_i}\right) = \frac{m_{pl}}{m_i}$$

$$m_i = \frac{2000}{\left(1 - \frac{\varepsilon}{1-\lambda}\right)}$$

hyperbola