Houston, We Have a Problem! Lesson – Rocket Calculation Worksheet

Pick a rocket and engine to achieve a maximum height of 100 meters.
Check your values every 5 calculations with your teacher to make sure you are on track.

1. \( m_b = m_R + m_E - m_p/2 \) Note: make sure to use units of kilograms, not grams.
   \( m_b \) is the average mass of the rocket during the boost stage. (kg)
   \( m_R \) is in the rocket table (kg)
   \( m_E \) is in the engine table (initial mass with propellant) (kg)
   \( m_p \) is in the engine table (propellant mass) and the \( \frac{1}{2} \) factor in the equation is the average propellant for the boost stage. (kg)

2. \( k = \frac{1}{2} \rho C_d A \) \( k \) is the air drag constant (kg/m)
   \( C_d = 0.75 \), the drag coefficient for an average rocket (has no units)
   \( \rho = \text{air density} = 1.223 \text{ kg/m}^3 \)

   A is the cross-sectional area of the rocket \( (m^2) \).
   Use the diameter of the rocket in the rocket table to calculate the area.

3. \( T = I/\tau \) \( \tau \) = thrust duration is in the engine table \( (s) \)
   I = total impulse is in the engine table \( (Ns) \) Note: This is an average impulse.
   T = average motor thrust \( (N) \)

4. \( q = \sqrt{\frac{T-m_b*g}{k}} \)
   T, k, and \( m_b \) calculated above
   \( g \) is the acceleration of gravity at 9.81 m/s\(^2\)
   q is an intermediate value needed to solve future equations to ultimately determine the boost height. \( (m/s) \)

5. \( p = \frac{2+kq}{m_b} \)
   k, q, and \( m_b \) calculated above
   p is an intermediate value needed to solve future equations to ultimately determine the boost height. \( (s^{-1}) \)
6. \[ v_\tau = q \frac{1-e^{-p\tau}}{1+e^{-p\tau}} \] \( \tau = \) thrust duration from **engine table** (s)

\( v_\tau \) is the velocity at the **end of burnout** (m/s)

7. \[ h_b = \frac{m_b}{2k} \ln \left( \frac{q^2}{q^2-q^2_{c}} \right) \]  

\( k, q, \) and \( m_b \) and \( v_\tau \) calculated above

\( h_b \) = height during the **boost stage** (m)

8. \[ m_c = m_r + m_e - m_p \]  

\( m_c \) = mass of rocket during the **costing phase** (kg)

9. \[ q^2_c = \frac{-m_c g}{k} \]  

\( k \) and \( m_c \) calculated above, \( g = 9.81 \) m/s\(^2\)  

\( q^2_c \) is an intermediate value needed to solve a future equation to ultimately determine the coast height. (m\(^2\)/s\(^2\))  

**Note:** \( q^2_c \) is a negative value

10. \[ h_c = \frac{m_c}{2k} \ln \left( \frac{q^2_{c}-v^2_\tau}{q^2_c} \right) \]  

\( h_c \) is the **coasting height** in (m)

11. \[ h_T = h_b + h_c \]  

\( h_T \) is the **total height** in (m) (restricted to 100 m, a small soccer field, for example)

**Questions**

1. What parameters are changing over the course of the flight? Is mass constant?

2. What is the average thrust for your selected rocket? **Hint:** The table included in your Rocketry Handout has total impulse and total burn time.
3. What happens if you use maximum thrust instead of average thrust?

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4. Without a parachute, estimate the time of descent and the momentum of impact from a 100 m free fall. Note: \( \text{momentum} = \text{mass} \times \text{velocity}_{\text{at impact}} \)

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5. What forces are acting on the rocket? Draw a free body diagram for each stage. Assume a vertical flight.

**Boost**

**Coast**

**Descent**

6. Why is lift not considered in these equations?

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7. Explain how rockets are governed by Newton’s three laws in your own words (not with formulas):
   a) 1st law

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b) 2nd law
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c) 3rd law
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8. What parameters govern rocket height?
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9. List your engine size ________________.

10. List your rocket body selection ________________.

11. List your calculated height. ________________.

12. List your mission purpose (make up a pretend or not so pretend mission of your own).
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