Name: ____ **Date:** ______________________

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_{Rocket} is in the rocket table (kg)
   m_{Engine} is in the engine table (initial mass *with propellant*) (kg)
   $m_{propellant}$ is in the engine table (propellant mass) and the ½ factor in the equation is the averages the propellant for the boost stage. (kg)

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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)
   ρ = air density = 1.223 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*.

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3. $T = I / \tau$ τ = 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)

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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)

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5. $p = \frac{2 * k * q}{m_b}$ 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})

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6. $v_\tau = \ q * \frac{1-e^{-p*\tau}}{1+e^{-p*\tau}}$ τ = thrust duration from **engine table** (s)

v_τ is the velocity at the **end of burnout** (m/s)

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7. $h_b = \frac{m_b}{2k} * \ln\left(\frac{q^2}{q^2-v_\tau^2}\right)$ k, q, and m_b and v_τ calculated above

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

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8. $m_c = m_r + m_e - m_p$ m_c = mass of rocket during the **costing phase** (kg)

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9. $q_c^2 = \frac{-m_c*g}{k}$ k and m_c calculated above, **g** = 9.81 m/s^2

q_c^2 is an intermediate value needed to solve a future equation to ultimately determine the coast height. (m^2/s^2) Note: *q_c^2 is a negative value*

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10. $h_c = \frac{m_c}{2k} * \ln\left(\frac{{q_c}^2-v_\tau^2}{q_c^2}\right)$ h_c *is the* ***coasting height*** *in* (m)

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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)

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Questions

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

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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.*

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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: $momentum = mass*velocity_{at\ impact}$

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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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