

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)

$m_{\text{propellant}}$ is in the engine table (propellant mass) and the $\frac{1}{2}$ factor in the equation is the averages the 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. $T = I / \tau$ $\tau = \text{thrust duration}$ is in the engine table (s)

$I = \text{total impulse}$ is in the engine table (Ns) Note: This is an average impulse.

$T = \text{average motor thrust}$ (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. $p = \frac{2 * k * q}{m_b}$ 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})

6. $v_t = q * \frac{1-e^{-p*\tau}}{1+e^{-p*\tau}}$ τ = thrust duration from **engine table** (s)
 v_t is the velocity at the **end of burnout** (m/s)

7. $h_b = \frac{m_b}{2k} * \ln\left(\frac{q^2}{q^2-v_t^2}\right)$ k , q , and m_b and v_t 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 **coasting phase** (kg)

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

10. $h_c = \frac{m_c}{2k} * \ln\left(\frac{q_c^2-v_t^2}{q_c^2}\right)$ 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?

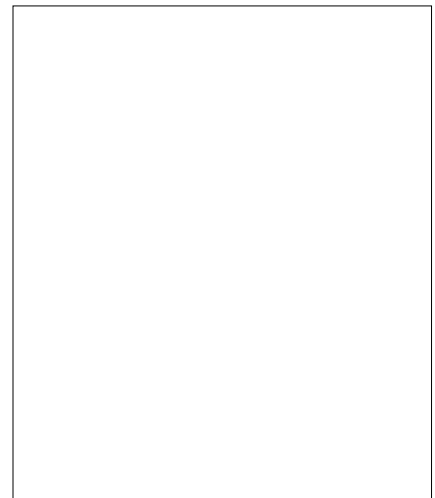
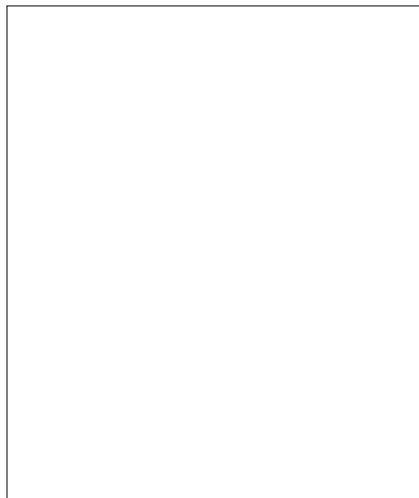
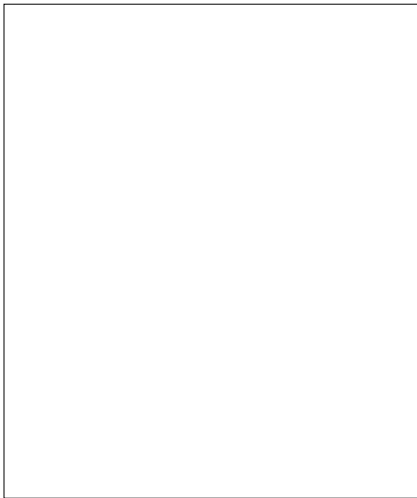
4. Without a parachute, estimate the *time of descent* and the *momentum* of impact from a 100 m free fall. Note: $momentum = mass * velocity_{at\ impact}$

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?

7. Explain how rockets are governed by Newton's three laws in your own words (not with formulas):

a) 1st law

b) 2nd law

c) 3rd law

8. What parameters govern rocket height?

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).
