# Calc II Rocket Assignment 1

Due February 7, 2025

- If you want, you can do this assignment in pairs and submit only one write-up.
- We'll start this in class today (Monday 3 Feb).
- For all problems, **please show your work**. Thanks.

A model rocket launch consists of the following steps:

1. **Powered Ascent.** The engine is firing.
2. **Coasting Flight.** The engine stops provides no force. So the rocket coasts upward and begins to fall.
3. **Parachute Deployment.** The ejection charge is fired. The parachute opens and the rocket starts to slow down.
4. **Slow Descent.** The rocket-and-parachute reach terminal velocity and fall to earth at a constant rate.

These stages are shown below in Fig. 1.

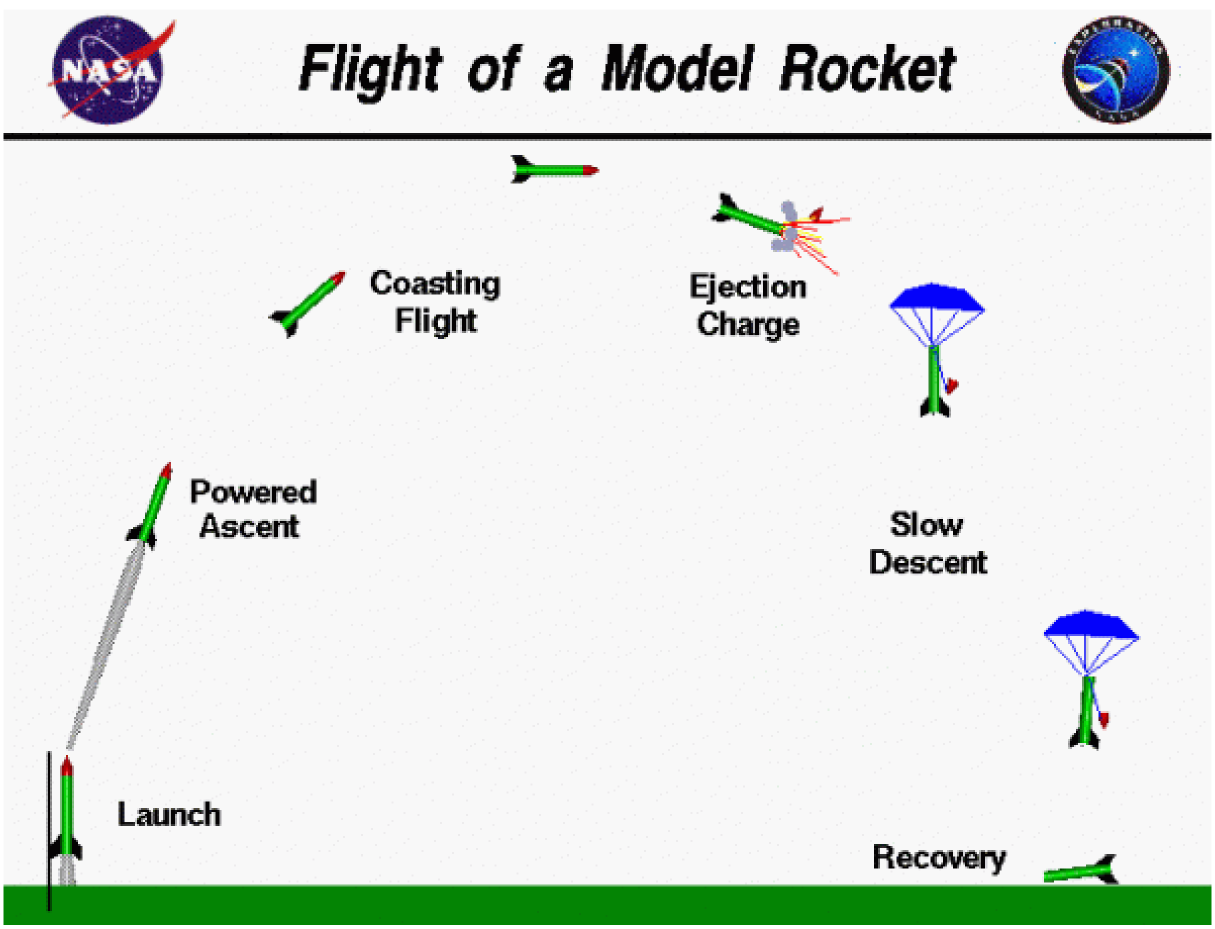


Figure 1: The stages of a model rocket launch. Image source https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/flight-of-a-model-rocket/.

In this assignment we'll explore each of the four flight stages described on the previous page. We'll ignore air resistance (drag). In subsequent assignments, we can think about how to add in air resistance if we want. The numbers below are only semi-realistic.

1. **Powered Ascent.** The rocket accelerates upward with a constant acceleration of 30 m/s$^2$ for three seconds. The initial velocity of the rocket is 0 (it starts at rest) and the initial altitude is 0 (it starts on the ground).

   (a) Determine a formula for the velocity $v(t)$ during powered ascent.

   (b) Determine a formula for the altitude $z(t)$ during powered ascent.

   (c) What is the rocket's velocity at the end of the ascent stage?

   (d) What is the rocket's altitude at the end of the ascent stage?

2. **Coasting upward.** The engine stops firing and the rocket coasts upward for 12 seconds. During this time the rocket experiences a constant downward acceleration of $-g = -9.8$ m/s$^2$.

   (a) Using your answer to question 1c, determine a formula for $v(t)$ for this stage, where $t$ is measured in seconds starting at the moment when the engine stops firing.

   (b) Using your answer to question 1d, determine a formula for $z(t)$ for this stage, where $t$ is measured in seconds starting at the moment when the engine stops firing.

   (c) What is the velocity of the rocket at the end of the coasting stage? Is the rocket going up or down?

   (d) What is the altitude of the rocket at the end of the coasting stage?

(e) What is the maximum altitude attained by the rocket. This is known as the rocket's **apogee**.

3. **Parachute Deployment.** The parachute opens and the rocket slows down. Over a time interval of 5 seconds, the rocket slows down linearly to a velocity of 3 m/s.

   (a) What is the rocket's acceleration during this stage? (Assume that the acceleration is constant.)

   (b) Using your answer to question 2c, determine a formula for $v(t)$ for this stage, where $t$ is measured in seconds starting at the moment when the parachute deploys.

   (c) Using your answer to question 2d, determine a formula for $z(t)$ for this stage, where $t$ is measured in seconds starting at the moment when the parachute deploys.

   (d) What is the velocity of the rocket at the end of the parachute deployment stage?

   (e) What is the altitude of the rocket at the end of the parachute deployment stage?

4. **Slow Descent.** The parachute is open and the rocket falls to earth at a constant speed of 3 m/s.

   (a) Using your answer to question 3d, determine a formula for $v(t)$ for this stage, where $t$ is measured in seconds starting at the moment when the rocket reaches constant velocity.

   (b) Using your answer to question 3e, determine a formula for $z(t)$ for this stage, where $t$ is measured in seconds starting at the moment when the rocket reaches constant velocity.

(c) At what time does the rocket land on earth?

(d) What is the total time of flight of the rocket, from lift-off to touch-down.

5. **Visualize it!** Make a reasonably accurate graph of $v(t)$ and $z(t)$ (on separate axes) for the entire rocket flight. Use graph paper. (Or if you're feeling ambitious, do it on a computer. But this might be more trouble than it's worth.)