

The space shuttle, at lift-off from the launch pad, has four forces acting on it, which are shown on the free-body diagram below. The combined weight of the two solid rocket boosters and external fuel tank is $W_B = 754324 \text{ kg}$. The weight of the orbiter with a full payload is $W_S = 104326 \text{ kg}$. The combined thrust of the two solid rocket boosters is $T_B = 23575574 \text{ N}$. The combined thrust of the three liquid fuel orbiter engines is $T_S = 5004249 \text{ N}$.

At liftoff, the orbiter engine thrust is directed at angle θ to make the resultant moment acting on the entire craft assembly (external tank, solid rocket boosters, and orbiter) equal to zero. With the resultant moment equal to zero, the craft will not rotate about its mass center G at liftoff. With these forces, the craft will have a resultant force with components in both the vertical and horizontal direction. The vertical resultant force component is what allows the craft to lift off from the launch pad and fly vertically.

The horizontal resultant force component causes the craft to fly horizontally. The resultant moment acting on the craft will be zero when θ is adjusted to the proper value. If this angle is not adjusted properly, and there is some resultant moment acting on the craft, the craft will tend to rotate about its mass center.

- (a) Resolve the orbiter thrust T_S into horizontal and vertical components, and then sum moments about point G, the craft mass center. Set the resulting moment equation equal to zero. This equation can now be solved for the value of θ required for liftoff.
- (b) Derive an equation for the resultant moment acting on the craft in terms of the angle θ . Plot the resultant moment as a function of the angle θ over a range of -5 radians to $+5$ radians.
- (c) Write a computer program to solve for the angle θ using Secant method to find the root of the resultant moment equation. Make an initial first guess at the root of interest using the plot. Terminate your iterations when the value of θ has better than five significant figures.
- (d) Repeat the program for the minimum payload weight of the orbiter of $W_S = 88450 \text{ kg}$.

Deliverables

Your report should include the description of the problem, how you set up the problem, assumptions, method of solution, the Matlab code that you used, the results, all relevant plots, discussion and potential weaknesses in your solution method. Hand in your work in a zip file containing all relevant files.

