Air Drop and Humanitarian Aid
Read-ahead

Introduction

Military transport airplanes are designed to deliver large payloads at relatively slow speeds, and to take off and land on short (or nonexistent) runways in the context of both war- and peace-time missions. In this application we focus on dropping cargo for purposes of humanitarian aid, and use our understanding of two-dimensional kinematics to predict when to release the cargo to ensure that it lands in the target drop zone.

Figure 1: gravity airdrop of CDS bundles from a C-17

Figure 2: Freedom packs being dropped out of an RAF C-130 Hercules

Instructions

After reading through the *Air Drop and Humanitarian Aid* context and questions below, you should complete the application reflection in Canvas. Note: *you will have a chance to talk further with your coach before answering the questions below in detail*. The point of the pre-read is to "prime the pump" for further conversations with your coaches.

Air Drop and Humanitarian Aid

When planning an airdrop there are many factors to consider. Certain staples such as rice, flour, dried peas or lentils, and sugar, can withstand a dramatic drop. Liquids such as water and vegetable oil may leak out if containers break on impact. Medicines are rarely delivered via airdrop, for the same reason. Besides the height of the drop, the speed of the airplane and the size of the drop zone must also be taken into account. Further complicating factors include wind and surface terrain.

Questions

Note: Many of the following questions refer to the *Package Drop* simulation, which can be found in the "Explore" panel of this module.

1. Run the simulation using the default parameter values, and drop the package after 3 seconds. (You can do this either by counting yourself or by using the "scheduled drop time" feature. Let t represent the time in seconds since the airplane passes over the origin, i.e., since the simulation starts, and let $x_a(t)$ and $y_a(t)$ be the horizontal and vertical components of the airplane's position vector. Without doing any calculations, i.e., just by watching the simulation, sketch graphs of $x_a(t)$ and $y_a(t)$ as functions of t, for $t \geq 0$.
2. Let s represent the time in seconds after the package is released, and let $x_p(s)$ and $y_p(s)$ be the horizontal and vertical components of the package's position vector. Again using the simulation, sketch graphs of $x_p(s)$ and $y_p(s)$ as functions of s, for $s \geq 0$.
3. (Graded for completeness only.) If you play around a bit, you will soon realize that it is not possible to hit the drop zone using the default parameter values, even if you release the package right away. Keeping all other values fixed, lower the airplane's speed to 150 meters per second, and see if you can determine experimentally when to release the package to hit the target. Describe how changing the speed of the airplane effects the trajectory of the package.
4. If the airplane's speed is 150 m/s, what are the initial horizontal and vertical components of the package's velocity vector?
5. Suppose you drop after $t = 3$ seconds. What are the horizontal and vertical components of the package's position vector at that moment?
6. Assuming no air resistance, so that the acceleration vector of the package is $\vec{a} = -9.8\hat{\jmath}$, write formulas for $x_p(s)$ and $y_p(s)$ of the package's position vector as functions of s.
7. Suppose we want to hit the exact center of the drop zone, which is at 2.5 km. If the package is dropped at time $t = c$ seconds and hits the ground after $s = d$ seconds, what must be the value of $c + d$?
8. An object with constant acceleration vector $\vec{a} = -9.8\hat{\jmath}$ falls a total of $4.9d^2$ meters in d seconds. Use this relationship to find d, and then use the result of the previous question to find the correct release time $t = c$. Check your answers using the "scheduled drop time" feature of the simulation. (Note that the simulation stops a short time *after* the package actually hits the ground.)
9. Suppose it is predetermined that the package be released at $t = 3$ seconds. Assuming the altitude of the airplane is set at the default value of 1 km and the drop zone is centered at 2.5 km, at what speed should we fly the airplane to hit the center of the target?
10. Suppose again it is predetermined that the package be released at $t = 3$ seconds. Assuming the airplane's speed is set at the default value of 200 m/s and the drop zone is centered at 2.5 km, at what altitude should we fly the airplane to hit the center of the target?
11. (Graded for completeness only.) Suppose the airplane's speed is 225 m/s, its altitude is 600 m, the drop zone is centered at 3 km and has a radius of 260 m. If the package is released after 5 seconds, will it hit the drop zone? Describe the calculations you need to perform to answer this question, then check your answer using the simulation.
12. Suppose the airplane is not moving horizontally, but is climbing at an angle of 10° so that it is easier to release the package out of the back. Returning to the default airplane speed and drop zone location, at what altitude must the airplane be at $t = 0$ so that releasing the package at $t = 2$ seconds results in a direct hit?

13. (Graded for completeness only.) In this simulation, the force of air resistance (when turned on) is assumed to be proportional to the speed of the package through the air, and also depends on the cross-sectional area of the package. The effect of air resistance on the acceleration of the package depends also on the mass of the package. Click the checkbox to turn on air resistance, and experiment with varying the area and mass of the package. Describe your observations.

Instructions, part deux

After reading and reflecting on these questions, complete the pre-read assignment on Canvas. This will give your coach some insight on your thinking in order to best help you before you are required to formally answer these questions.