MATH AND SCIENCE @ WORK

AP* PHYSICS Student Edition

SPACE SHUTTLE LANDING

Background

Since its conception in 1981, NASA has used the space shuttle for human transport, the construction of the International Space Station (ISS), and to research the effects of space on the human body. One of the keys to the success of the Space Shuttle Program is the Space Shuttle Mission Control Center (MCC). The Space Shuttle MCC at NASA Johnson Space Center uses some of the most sophisticated technology and communication equipment in the world to monitor and control the space shuttle flights.

Within the Space Shuttle MCC, teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support preflight, ascent, flight, and reentry of the space shuttle and the crew. The flight controllers provide the knowledge and expertise needed to support normal operations and any unexpected events.

Figure 1: Space Shuttle Endeavour landing

One of the flight controllers in the Space Shuttle MCC is the Mechanical, Maintenance, Arm, and Crew Systems engineer, whose call sign is MMACS (pronounced “Max”). One of the responsibilities of this position is to monitor the data associated with the landing and deceleration systems on the space shuttle. This includes monitoring the landing gear deployment functionality and timing, as well as the braking system pressures to ensure proper braking profiles. The MMACS flight controllers also verify the main and nose landing gear deployment with position sensors that detect whether the gear has moved to the down position, and finally verify drag chute deployment and jettison. It is the flight control team’s responsibility to ensure the systems on the space shuttle are operating within expected limits, or nominally. If the systems do not operate nominally, the MMACS team in mission control can call the crew to perform troubleshooting actions to put the vehicle in a safe configuration for landing.

Problem

At main gear touchdown, the space shuttle is traveling at approximately 110 meters per second. When the drag chute is deployed, the vehicle is traveling at approximately 95 meters per second. While the chute is fully deploying, the vehicle rotates downward for nose gear touchdown and continues to decrease speed. See Figure 2. Express all answers to questions in 2 significant figures.

A. The main landing gear tires each have a mass of 105 kg and are 1.2 m in diameter. At main gear touchdown, how much force does the runway exert on one tire to get it to rotate at speed? The tires have an initial rotation speed of zero at touchdown and are rotating at speed 0.50 seconds after touchdown. Assume that one tire can be approximated as a disk.

   I. Find the rotational inertia.

   II. Find the angular acceleration.

   III. Find the torque.

   IV. Find the force.

B. When the space shuttle reaches about 72 m/s ground speed, braking begins. The crew should maintain a deceleration rate of 2.5 m/s^2 by using a combination of the drag chute and the braking system until a speed of about 21 m/s is reached. How far does the space shuttle travel during this portion of the landing?

C. Assume that the chute is jettisoned at the instant the shuttle has slowed to a speed of 21 m/s. After it has reached this speed, assume that additional deceleration is only caused by braking on the main gear. After the chute is jettisoned, flight rules call for a deceleration rate of less than 1.8 m/s^2. If the crew uses the maximum braking deceleration of 1.8 m/s^2, what is the time required for the space shuttle to come to a stop from a speed of 21 m/s?

D. Using the information from questions B and C, sketch a graph of space shuttle velocity versus time, starting from when braking is initiated to the point at which the shuttle comes to a stop (assuming the drag chute is jettisoned at 21 m/s).

E. The mass of the space shuttle is approximately 90,800 kg at landing. Find the braking force after the chute is jettisoned. Use the maximum deceleration rate as defined by the flight rules.

F. How much work is done by the braking system to bring the space shuttle to a stop from 21 m/s?

G. Is the force provided by the braking system conservative or non-conservative? Justify your answer.

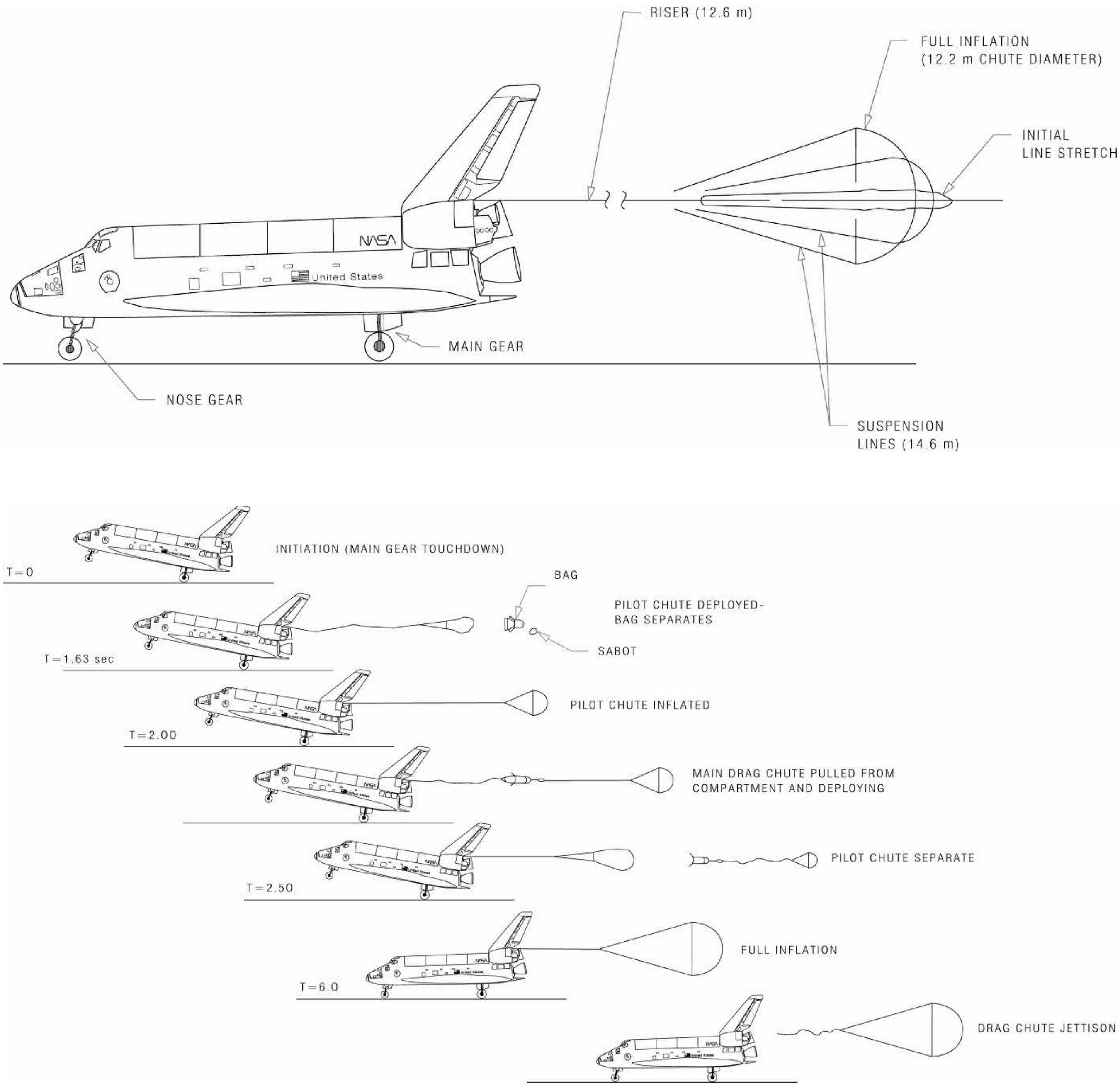

Figure 2: Space shuttle main gear touchdown through chute jettison.