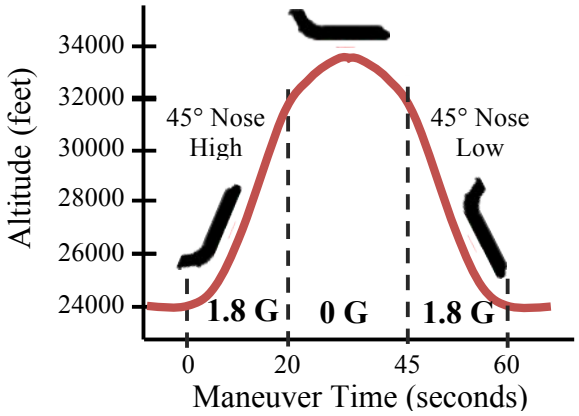
Weightlessness Training

Since 1957, the National Aeronautics and Space Administration (NASA) has used fixed wing aircraft to train astronauts for the effects of weightless sensations. The airplanes consist of an empty cabin with padding on the floors. The flight path of the plane can be described as being a collection of consecutive parabolas. Each parabola begins with a 45-degree climb. Twenty seconds into the climb, the thrust of the plane is reduced and the pilot makes an effort to gradually and steadily turn the nose of the plane downward. It is during this time that passengers experience a *zero-G* environment. This weightless experience lasts for nearly 25 seconds as the plane does its notorious *up and over the hump* maneuver. Soon after, the plane begins to pull out of its nose dive, inducing sensations of heaviness in its passengers. Each parabola lasts for approximately 65 seconds. **Figure 1** shows the path of the plane and the various sensations that are experienced.

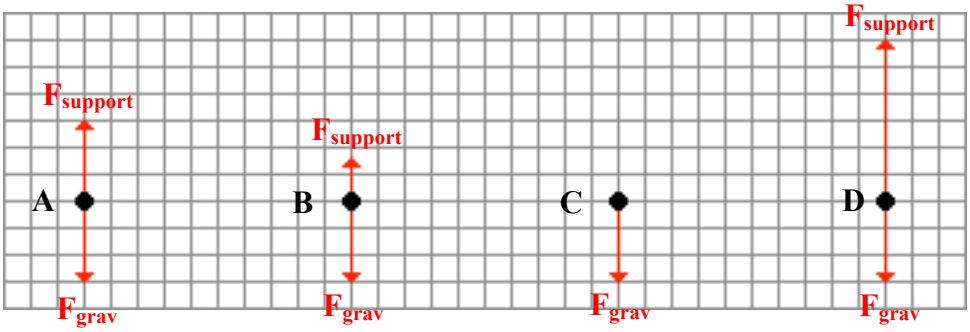
Figure 1



The sensation of weightlessness is due to the absence of support forces. Normally, an 80-kg astronaut would experience about 800 Newton of upward force. This upward force balances the downward force of gravity. It is the presence of the upward force that gives an astronaut a sensation of weight. When in a *zero-G* environment as shown in **Figure 2**, this upward force is absent and the astronaut has no sensation of having weight; they *feel weightless*. Sensations of heaviness are experienced when the support force is greater than the downward force of gravity. This sensation occurs when a downward moving astronaut is slowing down. If the support force is three times greater than the force of gravity, then the astronaut is said to be experiencing *three G's of force*. The diagrams in **Figure 3** are free-body diagrams. The arrows represent the two forces acting upon an astronaut under normal conditions (**A**), partially weightless conditions (**B**), perfectly weightless conditions (**C**), and heavier-than-normal conditions (**D**).

Figure 2

Figure 3: Sensations of Weight



Questions:

1. According to **Figure 1**, at which of the listed times during the parabolic maneuver do the astronauts begin to experience sensations of heaviness?
   a. 20 seconds
   b. 25 seconds
   c. 45 seconds
   d. 55 seconds

2. According to **Figure 1**, for what length of time does the 0-g experience last?
   a. 0 seconds
   b. 20 seconds
   c. 25 seconds
   d. 45 seconds.

3. At which of the following altitudes do the astronauts experience a sensation of feeling heavy?
   a. At 28000 feet - but only when moving upward.
   b. As the plane is at rest on the runway - before taking off.
   c. At the highest point of the maneuver - approximately 34000 feet.
   d. At 28000 feet - during both the upward and the downward movements.

4. Which one of the following explains the cause of the 0-G environment created inside the plane during the parabolic maneuver?
   a. The force of gravity is abnormally low at altitudes of around 34000 feet.
   b. The atmosphere through which the plane travels is very thin around 34000 feet.
   c. The stalling of the plane's engine causes queezy feelings in the astronaut's stomachs.
   d. As the plane moves over the *hump*, there are no forces that support the astronaut's weight.

5. Why does NASA fly their astronauts on these dramatic parabolic maneuvers?
   a. Flying at 34000 feet is about as close as they can get to flying in space.
   b. Space missions typically involve the same type of rapid zig-zag motions.
   c. The experience helps astronauts to adjust to the effects of weightlessness.
   d. It provides astronauts practice in the task of dodging space obstacles like asteroids.

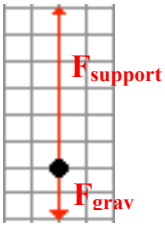
6. Which one of the following experiences would be similar to the experience that astronauts have at 34000 feet?
   a. Free falling on a ride at an amusement park.
   b. Sliding across a slip-and-slide mat on level ground.
   c. Rapidly rising upward at the start of an elevator ride.
   d. Being pressed against the car door on a left-hand turn.

7. Which free-body diagram in **Figure 3** describes the relative size of the forces that passengers on the plane experience when they are 15 seconds into the flight maneuver?
   a. Diagram A
   b. Diagram B
   c. Diagram C
   d. Diagram D

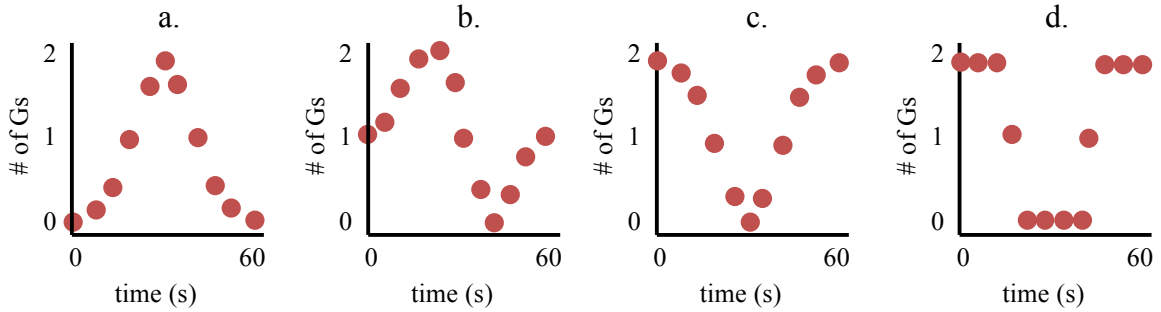
8. Which free-body diagram in **Figure 3** describes the relative size of the forces that passengers on the plane experience when they are at an elevation of about 34000 feet?
   a. Diagram A
   b. Diagram B
   c. Diagram C
   d. Diagram D

9. Consider the free-body diagram shown at the right. The size of the arrows are proportional to the size of the support forces. How many G's of force is the person experiencing?

a. 2 G's of force
b. 3 Gs of force
c. 4 Gs of force
d. 6 Gs of force



10. Which one of the following plots is an accurate representation of the number of G's of force vs. time for a single parabolic maneuver?



Credits and Sources:

1. **Figure 1** is based on a graphic provided by NASA, available from Wikimedia Commons: ttp://en.wikipedia.org/wiki/File:Zero_gravity_flight_trajectory_C9-565.jpg

2. **Figure 2** is from Wikimedia Commons: http://commons.wikimedia.org/wiki/File:Mercury_Astronauts_in_Weightless_Flight_on_C-131_Aircraft_-_GPN-2002-000039.jpg