Chapter 12

ENRICHMENT

Use with Section 2

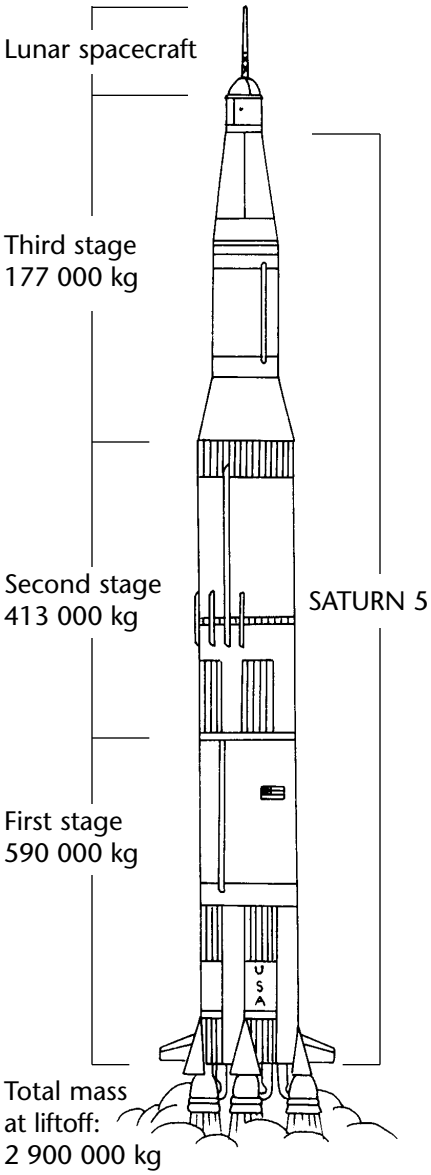
• What is momentum?

The Apollo Program

"I believe this nation should commit itself, to achieving the goal, before the decade is out, of landing a man on the moon and returning him safely to the Earth." With these words, President John Fitzgerald Kennedy, in May 1961, initiated the Apollo Space Program in the United States. In July 1969, *Apollo 11* lifted off from Cape Canaveral, Florida, with one destination in mind: the moon.

Apollo 11 included *Saturn V*—three rocket stages that thrust the lunar spacecraft (placed on top) toward the moon. Each stage, and the spacecraft, had a payload of fuel that was burned at different times during the flight in order to propel the spacecraft forward.

NASA scientists used conservation of momentum to describe *Apollo 11's* motion. By this law, the upward and downward momentums of *Apollo 11* should always be equal. The downward momentum was due primarily to the exhaust gas—with its own mass and velocity—being burned and ejected. The upward momentum was due to the total current mass of *Apollo 11* and its current velocity.



Apollo 11 Spacecraft and *Saturn 5* Launch Vehicle

1. STAGE 1: Liftoff! After *Apollo 11* lifted off, it had a mass of 2 900 000 kg. After reaching a maximum velocity of 2760 m/s, *Apollo 11* released the first stage rocket booster and ignited the second stage rocket booster. Calculate the maximum forward momentum during Stage 1.

2. STAGE 2: On our way! During Stage 2, *Apollo 11* now had a reduced mass of 2 310 000 kg. After reaching a maximum velocity of 6935 m/s, *Apollo 11* released the second stage booster and ignited the third stage booster. Calculate the maximum forward momentum during Stage 2.

3. STAGE 3: Last big push! During Stage 3 of the flight, *Apollo 11* now had a smaller mass of 1 897 000 kg. After reaching a maximum velocity of 10 835 m/s, *Apollo 11* released the third stage rocket booster and ignited the lunar spacecraft boosters. Calculate the maximum forward momentum during Stage 3.

LAST STAGE: To the moon! All that remained was the spacecraft, which continued moving toward the moon at an approximate maximum velocity of 10 835 m/s. The mission was a history-making success.