Space Motion 2:

In this quiz, you will need to continue analyzing motion in space, as in Space Motion 1. However, the examples are more complex and story driven.

For each of the following examples, answer the question provided by referring specifically to Newton's Laws.

Newton's Laws*

Newton's First Law If no force acts on an object that is not moving, it will continue not moving. If no force acts on a particular object that is already moving, the object will move at a constant velocity. To move at a constant velocity means that an object will move with a constant speed without changing direction.
Newton's Second Law $\Sigma F = ma$ Implications: If a force acts on an object that is currently stationary, that object begins accelerating in the direction of the force. If an object is moving and a force acts in the same direction the object is moving, the object will speed up. If an object is moving and a force opposes that motion, the object will slow down. If the force is perpendicular to the velocity of the object, it causes the object to change direction.
Newton's Third Law If A exerts a force on B, then B exerts a force on A in equal magnitude and opposite direction.
Newton's Law of Universal Gravitation: All masses are attracted to all other masses. The magnitude of this attraction is extremely small unless the mass is very large, such as a star or planet. - All asteroids and man-made spacecraft moving in

* Note that I've stated the laws as they apply particularly to this particular topic. In each topic on dynamics, I may slightly alter how I state Newton's Three Laws of Motion, but they are certainly the same laws!

Other concepts useful here:

Turbulent Airflow: Turbulent airflow refers to the *random motion* of the air particles. Air particles are always moving, and often randomly. Thus, on earth, all motion will include slight randomness and can't be perfectly predicted. Imagine dropping an object 5 times. It never lands in exactly the same place! Even with a PhD in physics, you can't perfectly predict its motion. In space, where there is no air, and thus no turbulent airflow, motion is perfectly predictable. By applying Newton's Laws, you can model the motion of any object through even *years* of time to perfect accuracy.
Space is Big and Empty It is important in understanding motion in space to understand that space is almost all empty, and that the planets and stars are tiny by comparison. For example, if the sun were a basketball, the earth would be smaller than a marble and several football fields away. If a spaceship, research vessel, or asteroid is aiming to strike a faraway planet, it must have perfect accuracy, hundreds of times more accurate than an Olympic archer, or it will miss it entirely.

Problems

1. Here on planet earth, most vehicles move because wheels are turning. Breaks work by applying friction to the wheels in order to make them stop turning. If a spaceship is moving at a constant speed, how can the astronaut get the spaceship to stop?

2. The Apollo 13 spacecraft was in outer space on the way to the moon when a technical failure caused an engine to fail. NASA engineers were able to figure out how to direct its motion so that it reached earth exactly as expected without using any engines.
a) Explain how it is possible to have so much certainty in the motion of the ship.
b) What forces acted on the ship when it was outside of earth's atmosphere.
c) How is it possible for a ship to fly all the way from the moon to the earth with no engines?
(In the movie, Tom Hanks says "we just put Sir Isaac Newton in the drivers seat.)

3. In one scene in the movie Apollo 13, Tom Hanks (playing Jim Lovell) and the other astronauts are counseled not to conduct any more urine dumps for the remainder of their voyage. Meaning, after going to the bathroom, leave the waste on board instead of sending it out into space, as is typical. Why? What could happen if they did?

4. A ship is flying to Mars. For the first half of the trip, it continuously blows its engines. At the halfway point, the ship turns around. It continuously blows its engines until it reaches Mars. According to Newton's Laws, the ship should reach Mars with velocity close to zero. Why?

5. When sending a satellite to far away planets, it first orbits around many closer planets to build speed. For example, if a satellite is too enter the orbit of Jupiter on a particular day, NASA engineers can calculate on precisely what day, at precisely what speed. They know exactly where Jupiter will be on that day, and they know exactly with what trajectory the satellite will leave Jupiter's orbit. And they nearly always get it 100 % correct. How?

6. Imagine a massive asteroid is heading towards earth! Oh no! Most earthlings first instinct is that the government should fire a nuclear missile at the asteroid and blow it up, but a far easier solution is possible. Many scientists and engineers believe that we can prevent an asteroid, even a giant one, from striking earth by simply hitting sending a probe up to strike it. How?

(Bonus: What Aerosmith song does everyone who was alive in the 90s immediately start singing when somebody brings up asteroids striking earth? If you don't know, Google "Aerosmith Asteroid")

Answer:

1. According to Newton's Second Law, the way for an object to *slow down* is for a force to act in the direction opposite the motion of the opposite. There are a couple ways to accomplish this. If the spaceship has thrusters, it can rotate while maintaining its velocity so that its thrusters are in the front of the ship, not the back. Then, by firing the thrusters, the ship would experience a backward force and slow down. Alternatively, the spaceship could be pre-built with thrusters on both sides, allowing it to accelerate in either direction by default.

2.
a) In space, a ship experiences much more predictable forces than here on earth. Without air turbulence (which causes randomness in motions on earth), motion can be predicted perfectly. Thus, NASA engineers were able to perfectly model the path the ship took as it returned to earth.
b) Only two forces acted on the Apollo 13 capsule as it traveled: the gravity of the moon and the gravity of the earth.
c) According to Newton's First Law, if the capsule was already in motion, in the absence of any force, it would continue moving at a constant speed in the same direction. Thus, as long as the capsule was directed towards earth, without engines it would continue to travel towards earth at a constant speed.

3. If the astronauts dumped anything, including urine, out of the ship, then according to Newton's Third Law, there would be a very small reaction force pushing backwards on the ship. Because the engines were off and no other force acted on the ship, a tiny force could redirect the motion of the spaceship and send it off course from striking the earth.

4. In the first half of the trip, the ship blows engines behind it, providing a force in the direction the ship is moving. According to Newton's Second Law, the ship would accelerate. In the middle of the motion towards Mars, the ship turns around. When it fires the thrusters again, they are in the direction *opposite* the velocity of the ship. Because the ship has so much velocity built up from its journey, the ship would then decelerate while continuing to travel towards Mars. As it reaches Mars, having accelerated for the first half of its motion and decelerated for the second half, the ship would be moving slowly.

5. In outer space, in which objects do not experience turbulent airflow, the motion of an object can be predicted precisely, even years into the future. Thus, a research vessel sent to reach several planets can be expected to follow the predictions of the engineers perfectly.

6. A small force in the direction perpendicular the motion of an object would cause it to slightly change direction. Even if the force is small, because space is so big, a tiny deflection in the direction of the asteroid will cause it to miss earth completely. Bruce Willis can stay at home and won't have to miss a thing.