Space Motion 1

Here, we are going to discuss objects moving in *outer space*.
Everything moving in *outer space* follows EXACTLY the same laws of physics as everything here on earth! (This is the single most important facts about physics there is. In fact, it is one of the greatest discoveries in human history. For more information, see *The Clockwork Universe* by Edward Dolnick.)

However, there are forces that are nearly constantly present here on earth that are absent in outer space. These forces are *gravity*, *friction*, and *air resistance*.
Gravity, of course, causes everything on earth to fall down. Friction and air resistance cause objects to stop moving, if they are not continuously pushed.
Because these forces are so omnipresent on earth, our minds tend to think that their existence is a basic fact of nature. But it is not, and the dynamics of space show that.

In space, the laws of physics are immediately apparent. We don't need to process them by drawing free-body diagrams that include friction and air resistance and make conclusions. For this reason, a careful study of space motion greatly helps us understand the laws of physics!

Newton's Laws of Motion*

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.

* 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!

Space vs. Earth

Space	Earth
1. An object thrown in space will continue to move forward at a constant speed forever. (Unless another force acts on it, which is extremely unlikely).	1. An object thrown will be slowed down by air resistance and fall due to gravity.
2. An object that continuously experiences a force in space in the same direction as its velocity (such as a spaceship that leaves its engine running), will continuously accelerate.	2. A fast moving object on earth experiences high air resistance needs a continuous force in order to maintain a constant velocity.
3. An object that continuously experiences a force in space in the opposite direction of its velocity (such as a spaceship whose engine is running the wrong way) will continuously decelerate.	3. This is also true on earth! But it is harder to notice because moving objects *always* experience forces opposite the direction of their motion (friction and air resistance)
4. If an object in space experiences a tiny force in one direction, it can completely change the motion of that object.	4. There are lots and lots of forces acting on every object, so a tiny one will likely make no difference.
5. Small objects in space will steadily attract each other due to the force of gravity. (Remember that gravity is a force that attracts all masses to all other masses.)	5. All objects on earth are attracted to each other due to gravity, but this force is not even close to strong enough to overcome friction and cause any motion

Qualitative Analysis of Forces and Motion Name ___________________

The Laws of Physics are the *same* in space and on earth. But, because of the *constant presence* of friction, air resistance, and downward gravity (weight) on earth, the laws of physics *seem* to be different on earth than they are in space.

Is there gravity in space?
YES.
(but it does different things than gravity here on earth!) Gravity is a force that attracts all mass to all other masses.
On earth, gravity attracts you to the center of the earth (the direction we call "down").
Gravity in space causes planets to orbit the sun, and causes small masses to accumulate into larger masses.

Problems:
For each situation illustrated, place indicate
a) What would happen if this were to occur on earth? Describe what will happen by referring to air resistance, friction, and downward gravity (weight).

b) What would happen if this were to occur in outer space? Defend your answer by referring to one of Newton's Laws. Note that the inter-galactic space is where there is nothing, absolutely nothing, no planets, no stars, no black holes, nothing.

1. An athlete on earth throws a baseball vs. A astronaut in the inter-galactic space throws a baseball.
What happens to the baseball?

2. An athlete on earth throws a baseball vs. an astronaut in space throws a baseball.
What happens to the person who threw it?

3. A driver on earth driving a car takes his foot off the accelerator vs. An astronaut operating a spacecraft turns off his thrusters after the craft is moving. The astronaut has no tether, means of propulsion, or friends.

4. A dog is sleeping and is stationary when a not very nice person comes up and pokes it. vs. A space dog is sleeping and is stationary in the inter-galactic space in outer space when a not very nice astronaut pokes it.

5. A car on earth is moving down a highway, and the driver notices her speed is slightly decreasing, so she very lightly presses the accelerator vs.
An astronaut's ship is moving forward at a constant speed towards Mars and she turns on her thrusters. [The thrusters are in the back of the ship and create a forward force.]

6. A person on a bike on planet earth presses their break vs.
ET is riding a bike in space that is moving towards Mars and he presses his break.

7. A kangaroo is jumping across the outback, and a daredevil walks up and slightly taps the kangaroo with a long pole in a direction perpendicular to that it was already moving.
vs.
A space kangaroo is moving at a constant speed towards the moon and a space daredevil slightly taps the kangaroo with a long pole in a direction perpendicular to that it was already moving.

8. A teacher leaves two pencils lying on a desk a few centimeters apart vs. An astronaut leaves two pencils a two centimeters apart in the inter-galactic space.
Describe the effect of gravity.

Answers:

1.
On earth: The ball will move in a parabolic arc and fall to the ground due to downward gravity. While moving in the air, it will lose some speed due to air resistance. After striking the ground, it will probably roll but due to friction it will eventually stop moving.

In space: After leaving the astronaut's hand, no force acts on the baseball. According to Newton's First Law, it will continue to move with the direction and speed it had immediately after losing contact with the person's hand forever.

2.
On earth: According the Newton's Third Law, when the athlete exerts a force on the baseball the baseball exerts a backward force of equal magnitude on the athlete. However, this force likely has too small a magnitude to overcome the friction between the athlete's feet and the ground, so it will have no effect.

In space: According to Newton's Third Law, when the astronaut exerts a force on the baseball the baseball exerts a backward force of equal magnitude on the astronaut. In the absence of any friction, this force will cause the astronaut to begin moving with an extremely small velocity in the direction opposite the baseball. However, because there are no other forces that may act on the astronaut, according to Newton's First Law, the astronaut will move in that direction with that velocity indefinitely.
If the astronaut had a tether to hold him to a spaceship, a jet pack to propel him forward, or friends to grab him, he may have a different fate.
(Note that the act of throwing the ball may also cause the astronaut to begin spinning, which he will also do indefinitely.)

3.
On earth: When the driver takes his foot off the accelerator, the car no longer experiences any forward thrust. Significant air resistance acts on the car in the direction opposite its motion, and according to Newton's Second Law that will cause the car to slow down.

In space: When the astronaut turns off his thrusters, no force is acting on the spaceship. According to Newton's First Law, it will continue moving indefinitely at a constant velocity.

4.
On earth: The poke by the unfriendly person is a force acting on the dog but is unlikely to overcome the friction acting on the dog. Thus, the net force acting on the dog is still zero and the dog will remain at rest.

In space: The poke on the dog will cause the dog to begin moving slowly in the direction of the poke. As no other force acts on the dog, according to Newton's First Law it will continue moving at the same speed in that direction indefinitely

5.
On earth: A car on the highly experiences significant air resistance, which will cause the car to slow down if the driver does not create a forward thrust force by slightly touching the gas pedal. If the driver touches the gas pedal just right, the opposing air resistance and forward thrust will cancel and the driver will move forward at a constant velocity.

In space:
If an astronaut turns her thrusters on, it will create a force in the direction the ship is already moving and the ship will speed up while moving towards Mars.

6.
On earth: The bicycle break will grab onto the wheel, exerting a strong force of friction that will quickly make the wheel stop moving. The person will stop.

In space: ET's motion towards Mars has nothing to do with the wheels of the bike! If the break makes the wheels of the bike stop moving, the bike will continue to move towards Mars at a constant velocity!
[Extra more advanced information:
The break is an *internal force* on the bike, which does not affect the motion of the bike. In the absence of any *external force*, the bike will continue moving at a constant velocity according to Newton's First Law.]

7.
On earth: The poke provided by the daredevil is a very small force on the kangaroo. The kangaroo can easily adjust its jumps so that it continues doing whatever it was doing.

In space: The poke causes a very slight change in the direction of the kangaroo's velocity. The kangaroo can't do anything to adjust. There is no ground to jump off of! Given the extremely large distances of space, this tiny change will likely cause the kangaroo to end up nowhere near the moon.

8.
On earth: According to the Law of Universal Gravitation, the two pencils, because they both have mass, are slightly attracted. However, this attraction has an extremely small magnitude and is nowhere near strong enough to make the pencils move even a little. (Note that the pencils are attracted to everything else in the room for the same reason!)

In space: According to the Law of Universal Gravitation, the two pencils, because they both have mass, are slightly attracted. In the inter-galactic space. this is the *only* force acting on the two pencils! As such, they will begin slowly *accelerating* towards each other. (If you work out the math, if the pencils are 2-3 centimeters apart they will touch each other in a matter of hours.)