X: Inertia Stories
Level 2

On this quiz, you will respond to short prompts related to inertia and inertial mass. Make sure you are able to use the term *inertial mass* correctly, to contrast inertial mass with gravitational mass, and to relate the concept of inertia to Newton's Second Law.

Newton's First Law is often called the law of inertia, but it is Newton's Second Law that mathematically describes what inertial mass is! Make sure you understand this mathematical definition.

Inertial Mass

The total amount of resistance to motion an object has.

It can be thought of as how much matter is in an object, because more matter provides protons, neutrons, and electrons that each contribute to the inertia of an object.

Newton's Second Law

Newton's Second Law is frequently written $\Sigma F = ma$.
However, it could also be written

Acceleration = net force / inertial mass

The acceleration is inversely proportional to inertial mass.
The more inertial mass, the lower acceleration that same net force would provide.

1. The acceleration is _____ proportional to inertial mass.

2. If an object is under a consistent net force, but the inertial mass of the object is increased, it will experience a _____ acceleration.

Situations related to inertial mass:

3. True story!
One day, Mr. Kuncik was driving with a huge empty tank in the passenger seat. It was so big it wouldn't fit in the trunk! The tank was constantly moving around as he drove, mostly falling forward.
Mr. Kuncik drove to a chemical supply store and filled the tank with liquid nitrogen. It would really be bad if the tank was falling over everywhere and liquid nitrogen was splashing around. Fortunately, it didn't. Once the tank was full, it rested in its seat and barely moved at all. It stayed very stable.
What was going on?

4. If you drop a ream (500 pages) of copy paper, it falls straight down at 9.8 m/s^2. If you remove a single piece from the top of the paper and let it fall, it falls gently to the ground at a slow constant velocity due to air resistance.
a) What's going on? Why would 500 pieces of paper do something different than one?
b) Which experiences a greater magnitude of air resistance, the single paper or the ream of paper?

5. If you try to pull a tablecloth out from underneath an empty glass, it frequently falls over. But if you try to pull a tablecloth out from underneath a full glass, it usually does not fall over. Why?

Inertial Mass vs. Gravitational Mass

Mass, or matter, provides both inertial mass and gravitational mass.
The two can be considered equal.

Inertial Mass All mass resists change in motion. The more inertial mass an object has, the more difficult it is to change the velocity of an object.
Gravitational Mass All mass attracts all other mass. The more mass an object has, the more it attracts the objects around it. On earth, our main experience of gravitational mass is that we are attracted to the earth itself because both us and the earth have mass. However, any mass attracts *all* other masses.

For each phenomenon regarding mass, state whether it refers to inertial mass or gravitational mass:

6. All mass attracts all other masses
7. All mass resists changes to its velocity.
8. It is difficult to pick a large metal bar.
9. If a large metal bar is hanging from a rope, it is difficult to spin the bar around.
10. A large mass on a spring moves more slowly than a heavy mass on a spring.
11. Once a spaceship is in space, it takes more fuel to accelerate a ship that has more mass on board.
12. It is very very difficult to get a spaceship outside of the earth's atmosphere.
13. The earth orbits the sun (creating the seasons)
14. The earth continues to rotate (spin around its own axis), creating days and nights, even though nothing is pushing it to do so.

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Answers

1. inversely

2. lesser

3. When the tank was empty, it was large but had a low inertia. It could very easily be moved around.
When the tank was full, it had a very high inertia. It was resistant to changes in motion**.

** Some physicists might argue that my car, during turns or change speed or direction is non-inertial, meaning that objects with high inertia should move *more* because it takes more force for their acceleration to match that of the car. That is a reasoned argument, but this actually happened, and the tank definitely moved less, not more. In science, there's no arguing with the observed result.

4. a) The single piece of paper has very low inertia, and the force of air resistance has a very strong affect on its motion. The full ream of paper has a much higher inertia and is less strongly affected by the force of air resistance.
b) The single piece of paper actually experiences a *much lower* magnitude of air resistance than the ream because it moving much slower. However, according to Newton's Second Law, the effects of forces on an object are in inverse proportion to the mass (inertia) of the object. Because the ream of paper has more inertia, a stronger magnitude force affects its motion much less.
The ream of paper also has more weight (the downward force of gravity), counteracting the upward force of air resistance.

5. The full glass has more inertia, so it is less likely to begin moving. When the tablecloth is pulled out, it causes a small frictional force, which is enough to knock down an empty glass but not enough to knock down a full glass.

6. gravitational mass
7. inertial mass
8. gravitational mass
9. inertial mass
10. inertial mass
11. inertial mass
12. gravitational mass
13. gravitational mass
14. inertial mass
(yes, inertia literally makes the world go round!)