Questions on Motion and Newton's laws*.

Motion

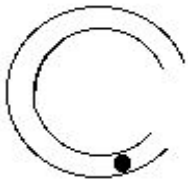
1. Why are units (such as meters or seconds or miles) important in science?
2. What is different about numbers in a science course as compared to numbers in a math course?
3. What is the difference between speed and velocity?
4. What is the difference between velocity and acceleration?
5. Does a car speedometer measure speed or velocity? Explain.
6. If you go around a curve at constant speed, do you have an acceleration? Explain.
7. Can a rapidly moving object have the same acceleration as a slowly moving one? Explain.
8. Can an object have an instantaneous velocity of zero and have a non-zero acceleration? Give an example.
9. At the end of its arc, the velocity of a pendulum is zero. Is its acceleration also zero at this point? Why or why not?
10. Assuming air resistance can be ignored, which gets to the ground first, a bowling ball or a tennis ball if they are dropped from the same height at the same time? Explain.
11. What is the difference in saying something is moving at a constant velocity and saying it is moving with zero acceleration?
12. Explain the difference between mass and weight.
13. Consult the table for the speed of sound in various substances. If you have one ear in the water and one ear out while swimming in a pool and a bell is rung that is half way in the water, which ear hears the sound first?
14. At 20 C the speed of sound is 344 m/s. How far does sound travel in 1s? How far does sound travel in 60 s?
15. Compare the last two answers with the distance traveled by light which has a speed of 3.0×10^8 m/s. Why do you see something happen before you hear it?
16. The speed of sound in water is 1482 m/s. How far does sound travel under water in 1 s? How far does sound travel under water in 60 s?
17. What would an orchestra sound like to someone in the audience if different instruments produced sounds that traveled at different speeds?
18. For the previous question, would it make a difference if you sat further away from the orchestra?

Newton's first law

1. If you are sitting at a stop sign and get hit from the rear, your head seems to fly back and hit the headrest. Explain, using Newton's law of inertia, what really happens.
2. If you are standing in a bus and it suddenly stops, you feel like you are being thrown forward. Using Newton's law of inertia, explain what is really happening.
3. Using Newton's law of inertia, explain why a headrest prevents whiplash.
4. Using Newton's law of inertia, explain why using a seatbelt in a car, plane, rollercoaster, etc. is a good idea.
5. Once a satellite is in orbit it doesn't need to fire any rockets to stay there. Why not? What keeps it going?
6. What keeps the earth going around the sun?
7. An old magician's trick is to pull the tablecloth out from under some dishes on a table by giving the tablecloth a very quick jerk. Explain why the dishes stay put (using Newton's first law of course).
8. Bowling balls slow down slightly as they roll down the lane. Does this violate Newton's law of inertia?
9. If you quit pushing a lawn mower it stops. Explain how this does not violate Newton's law of inertia.
10. The earth is rotating such that objects on the surface are traveling at close to 1000 km per hour (this is slightly different depending on latitude). Using Newton's law, explain why you don't get slammed by the wall if you jump straight up into the air.
11. When you are traveling in an airplane at cruising altitude, why does an object that is dropped not fly to the back of the plane?
12. A person drops a wrench from the top of the mast of a sailboat that is moving forward at constant velocity. Where does the wrench land relative to the mast if the boat has a speed of 10 m/s and the mast is 20 m high?
13. A driver heading towards a left curve encounters some ice on the road. Describe the motion of the car

(drawing a picture will help) assuming the ice prevents any friction force from acting on the car. Which of Newton's laws tells you what will happen?

14. A small ball rolls in a frictionless tube that is flat on a table shown from above in the drawing. Draw the trajectory of the ball when it leaves the tube and justify your answer.



Newton's second law

1. Does a book at rest on the table have no forces acting on it? Explain.
2. A car traveling North down the road at constant velocity has zero acceleration. The net force has to be zero since F = ma. Why then do you need to keep the engine running and the gas pedal pushed down?
3. Can you have an object traveling forward with a net force acting on it in the opposite direction? Explain and give an example.
4. You exert 600 N of force to push a box across the floor at a constant speed (zero acceleration). Is the friction force larger, smaller or exactly equal to 600 N? How do you know?
5. Can you make an object go around a curve without applying any force? Explain.
6. You jump out of an airplane (don't do it!!) and open your parachute. With the parachute open you travel at constant speed. How does the upward force of the parachute compare with the downward force of gravity?
7. A load of lumber in the back of a pickup truck accelerates at the same rate the truck does. What applies the force to make this happen? What happens if this force isn't large enough?
8. You throw a ball upward. Once it leaves your hand, what force acts on it on the way up? On the way down? What is the effect of this force on the way up? What is the effect of the force on the way down?
9. Explain why Newton's first law is really a special case of Newton's second law.
10. A car is traveling at a constant 60 mph in a straight line. What is the net force acting on the car?
11. An astronaut is in a spaceship far from the effects of gravity. She pushes with the same force on a baseball and a bowling ball. Indicate which of the following is true and explain why: a) they both accelerate with the same speed because they are weightless; b) they accelerate differently since their mass is different but they end up with the same terminal velocity; c) they have different accelerations.
12. The maximum tension on a guitar string is about 900 N (202 pounds of force). Suppose the peg holding the string weighs 0.002 kg and comes loose so that the 900 N causes the peg to accelerate. What will be the acceleration of the peg (in m/s^2)?
13. Is the acceleration in the previous problem dangerous? Hint: If the force acts over half the length of the guitar, say 0.20 m the final velocity will be $v = \sqrt{2ax}$ where a is the acceleration and x is the distance traveled.
14. Redo the previous two questions for the case of a piano string with 700 N of tension and a distance of 50 cm traveled. Assume the peg has the same mass.

Newton's third law

1. Can you push on you left hand with a larger force using your right hand? Explain.
2. You tie a rope to a box in order to pull it across the floor. According to Newton's second law, the box pulls back on the rope with the same force that you pull on the rope. Explain how you can move the box if these forces are exactly equal and in opposite directions.
3. Carefully explain the action and reaction forces when you push against the ground with your foot in order to take a step forward.
4. What are the action and reaction forces in these cases: a) a bat hits a ball; b) while walking, your foot pushes off from a curb; c) you push down on the pedal of a bicycle; d) during the windup of a baseball

pitcher, up until he releases the ball?

5. For each case in the previous question, state which force is the larger force.
6. A force F pushes towards the left on a box. A friction force, f, between the floor and the box resists the movement of the box. These are the only forces acting in the horizontal direction. For the following three cases state which is bigger (or the same size), F or f and why.
    a) The box does not move.
    b) The box moves to the left with constant velocity.
    c) The box moves to the left and accelerates.
    d) The box moves to the left and decelerates.
7. A bowling ball collides with a tennis ball. Which object has the larger impact force on the other? Which has the greater acceleration? Explain.
8. Before space travel some people thought rockets would not work in space because there was no atmosphere for the rocket exhaust to push against. Explain the error in this thinking using Newton's third law.
9. You are in a railroad car but the tracks are very smooth and the windows closed so you cannot tell if you are moving or not. You drop a pencil and it falls straight down and lands directly below your hand. What can you conclude about the motion of the car from this observation?
10. When you hit a xylophone bar with a mallet the mallet will bounce back. Which of Newton's three laws explains where the force comes from which causes the mallet to bounce back into the air?
11. A guitar string pulls on the peg mechanism with a tension of 600 N (134 lbs of force). What minimum force must the mechanism be able to pull back with to avoid having the string change tension (which also changes the pitch)?
12. What force must a piano frame be able to withstand if the tension in the tightest string is 900 N?

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* Many of these ideas came from *Conceptual Physics* 11th Ed. by Paul Hewitt (Addison Wesley, 2011).