Unit Two - Chapter Three - Forces

Learning Goal: By the end of today, I will be familiar with the term inertia as it applies to objects at rest and in motion, and I will understand Newton's First Law of motion.

Section 3.2 - Inertia and Newton's First Law of Motion

In the early 1600's, Galileo concluded that once an object starts moving, it will continue moving at a constant velocity if there is no friction present. Galileo used the concept of inertia to help explain his conclusion. Inertia is the property of matter that causes it to resist changes in motion. The inertia of an object depends on the mass of the object. An object with more mass has more inertia, whereas an object with less mass has less inertia. In other words, inertia is directly proportional to the mass of the object.

> Inertia the property of matter that causes it to resist changes in motion; inertia is directly proportional to the mass of the object

Newton was born in 1642, the year that Galileo died. Newton published Principia Mathematica, a set of three books which included much of his own work about physics, as well as a description of Galileo's law of inertia. The law of inertia is now called Newton's first law of motion because it was included with Newton's other laws of motion.

growth of ideas

First Law of Motion

If the net external force on an object is zero, the object will remain at rest or continue to move at a constant velocity.

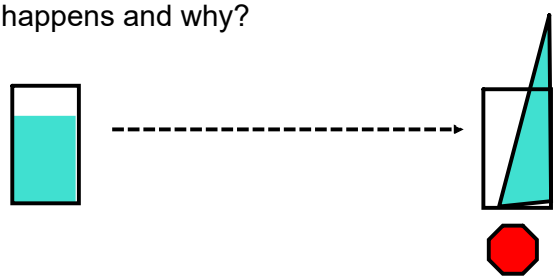
"Objects at rest, want to stay at rest, objects in motion want to stay in motion."

HUGE IDEAS - WOW!

Implications of the First Law of Motion

- A non-zero net force will change the velocity of an object. The velocity can change in magnitude, direction, or both.
- A net force is not required to maintain the velocity of an object.
- External forces are required to change the motion of an object. Internal forces have no effect on the motion of an object.

If I slide a glass full of water along the counter, then stop it quickly, what happens and why?



What do inertia and concussions have in common?

Hint: your brain is floating in your skull, with a very thin layer of fluid keeping it from touching anything too hard.

If I place a stack of coins on top of a piece of paper on the desk, can I remove the paper without upsetting the coins? (give it a try at home)

Video - inertia challenges (too lazy to try, watch these)

Video - Egg Drop challenge (Steve Spengler)

Discussion (pause and think)

1. Why is standing up on a moving bus an unsafe and dangerous idea?

2. When your car hits black ice (near frictionless), why is it difficult to stop?

3. You have snow stuck on your shovel. How could you use Newton's first law to get the snow off the shovel?

Sample Problem 2: Newton's First Law Applied to Headrests

Older cars did not have headrests, but all new cars do. How do headrests help prevent injuries during a rear-end collision? Use Newton's first law to explain your answer.

Solution

Consider the forces acting on a person's body during a collision. During a rear-end collision, the car will suddenly accelerate forward and so will your body because the seat exerts a force directed forward on your torso. In a vintage car with no headrest (**Figure 6(a)**), there is no force applied to the head. According to Newton's first law, your head will continue to remain at rest. Your head will initially appear to snap backwards relative to your body as your body accelerates forward, possibly resulting in a neck injury known as whiplash. The headrest in a modern car helps push the head forward with the rest of the body (**Figure 6(b)**). This helps to prevent whiplash since your neck does not bend backwards as far during a rear-end collision.

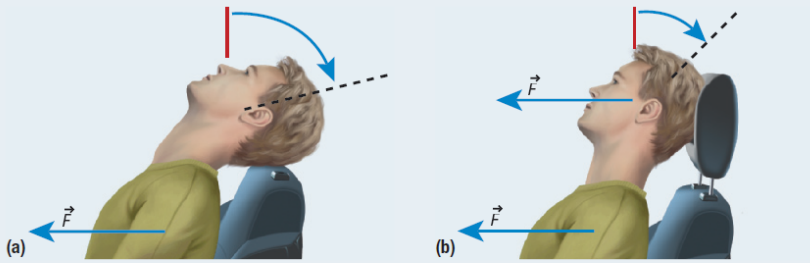


Figure 6 (a) No headrest (b) Headrest present

Video (seat belts save lives)

Active Head Restraints

Please watch these, as potential new drivers.

Sample Problem 3: Determining the Missing Force

What is the missing force on each FBD shown in **Figure 7**?

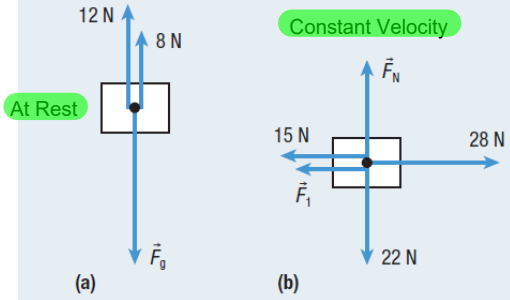


Figure 7 (a) FBD for an object at rest (b) FBD for an object moving left at a constant velocity

(pause and try)

F_g = 20N down F_N = 22N up

F_1 = 13N left

More Physics in the Car

Consider the physics of a typical seat belt. What will happen if you are not wearing a seat belt and the car suddenly stops? According to Newton's first law, you will continue to move forward at a constant velocity until an object exerts a net force on you. This could be the dashboard or the windshield. If you are wearing a seat belt, the seat belt will exert a net force on you to slow you down.

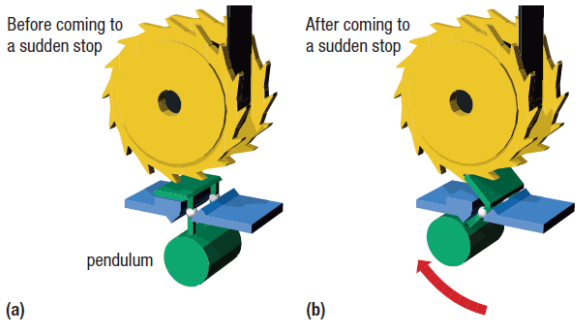


Figure 9 (a) When the vehicle is moving at constant velocity the seat belt pendulum (shown in green) hangs straight down. (b) After a sudden stop, the pendulum swings, causing the metal stop to lock into the seat belt gear.

3.2 Questions

1. Explain how modern technology can help demonstrate Galileo's thought experiments.
2. Which has the most inertia, a truck, a desk, or a feather? Which has the least inertia? How do you know?
3. Skater 1 has a mass of 45 kg and is at rest. Skater 2 has a mass of 50 kg and is moving slowly at a constant velocity of 3.2 m/s [E]. Skater 3 has a mass of 75 kg and is moving quickly at a constant velocity of 9.6 m/s [E]. Which skater experiences the greater net force? Explain your reasoning.
4. Explain each statement using inertia or Newton's first law.
   (a) You should not sit in the back (bed) of a pickup truck when it is moving.
   (b) It is hard to get a car moving on very slippery ice.
   (c) You should not put objects on the ledge of a car between the rear windshield and the rear seat.
   (d) During liftoff, astronauts are placed horizontally in the capsule rather than vertically.
5. Headrests and seat belts are two important pieces of safety equipment used in automobiles.
   (a) Will both technologies significantly improve safety if the car suddenly slows down but keeps moving in a straight line? Explain your reasoning.
   (b) Will both technologies significantly improve safety if the car suddenly speeds up but keeps moving in a straight line? Explain your reasoning.
6. Many people buy a coffee or other hot beverage on their way to work. For safety, the cup usually has a lid and is placed in a cup holder. Using Newton's first law, explain why both of these precautions are necessary.
7. **Figure 10** shows a string tied to a spike at one end and a puck at the other. The puck is moving around in a circle on the ice. Describe what the puck will do if the string is suddenly cut at the red line. Explain your reasoning using a diagram.

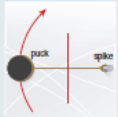


Figure 10

8. Use Newton's first law to explain why the normal force must be equal in magnitude to the force of gravity for an object to remain at rest on a horizontal surface when no other forces are acting on the object.
9. You are inside a car moving fast along a sharp turn in the road. Use Newton's first law to describe what happens to you as you safely make it around the curve.
10. Use Newton's first law to explain why you should slow down when going around a curve on an icy highway.
11. **Figure 11** shows some simple equipment used to test Newton's first law. In the experiment, the ring is suddenly pulled horizontally.
    (a) Predict what will happen to the piece of chalk. Explain your reasoning.
    (b) Why does it help to put some water in the container?

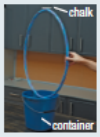


Figure 11

12. While on the bus, you throw an apple straight up into the air. What will happen if the bus
    (a) moves at a constant velocity?
    (b) slows down?
    Explain your reasoning using diagrams.
13. Determine the indicated forces on each FBD shown in **Figure 12.**
    (a) statue at rest on a shelf
    (b) sled pulled right at a constant velocity

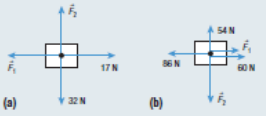


Figure 12

14. Your physics teacher challenges the class to the following puzzle. Place eight quarters into a single stack on a desk. Your task is to take the stack apart one quarter at a time using only a thin ruler. You cannot make any contact with the quarters but the ruler can. Only quarters at the bottom of the pile may be removed.
    (a) Describe how you would complete the task. Carry out your plan to test whether it works.
    (b) Explain why it works.
15. Studies reveal that many people do not use their headrest properly. Research what most people do wrong and how it can be fixed. Prepare a small pamphlet that can be used to make people aware of the problem and how to fix it. Include any useful statistics that might encourage people to make the necessary changes.

GO TO NELSON SCIENCE

Section 3.2

2,3,4,6,12,13