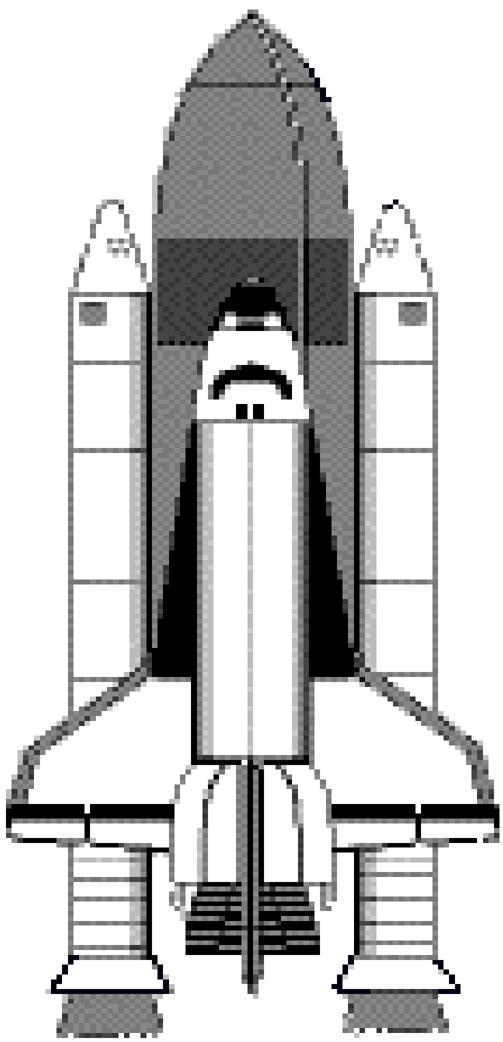
Forces and Newton's Laws



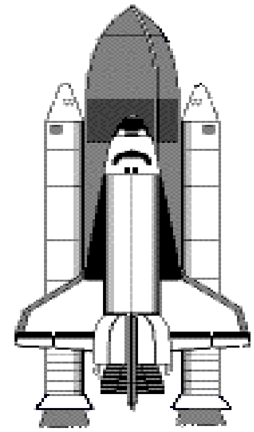
Teacher's Guide
Grades 5-9

Produced by:
Brian A. Jerome, Ph.D.
Stephanie Zak Jerome

Narrated by:
Nina Keck

Production Assistants:
Matt Wimmer
Heidi Berry
Jessica Kassis
Fred Thodal

Visual Learning Company
Brandon, Vermont
1-800-453-8481
www.visuallearningco.com



Contributors and Reviewers:

Producers:
Brian A. Jerome, Ph.D.
Stephanie Zak Jerome, MPA

Narrator:
Nina Keck

Graphics:
Meredith Patch
Matt Wimmer

Reviewers:
Jeremy Burnett
Summit View School
Winston-Salem, NC

Susan Hurstecalderone, M.S.
Blessed Sacrament School
Washington, DC

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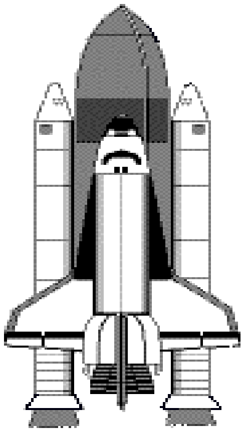

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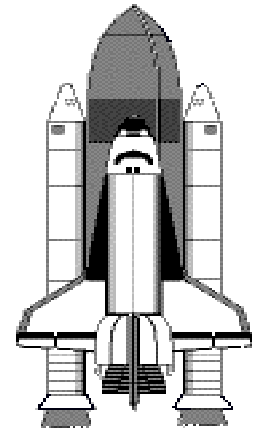

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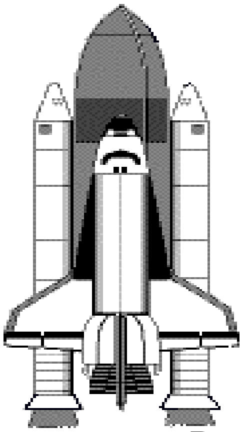


A Message from our Company . . .

Dear Educator:

Thank you for your interest in the educational videos produced by the *Visual Learning Company*. We are a Vermont-based, family owned and operated business specializing in the production of quality educational science videos and materials.

We have a long family tradition of education. Our grandmothers graduated from normal school in the 1920's to become teachers. Brian's mother was an elementary teacher and guidance counselor, and his father was a high school teacher and superintendent. This family tradition inspired Brian to become a science teacher, and to earn a Ph.D. in education, and lead Stephanie to work on science education programs at NASA.

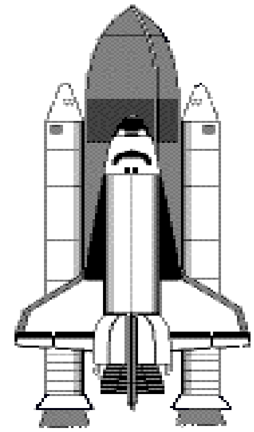
In developing this video, accompanying teacher's guide and student activities, our goal is to provide educators with the highest quality materials, thus enabling students to be successful. In this era of more demanding standards and assessment requirements, supplementary materials need to be curricular and standards based - this is what we do!

Our videos and accompanying materials focus on the key concepts and vocabulary required by national and state standards and goals. It is our mission to help students meet these goals and standards, while experiencing the joy and thrill of science.

Sincerely,

Brian and Stephanie Jerome

National Standards Correlations



National Science Education Standards

(Content Standards: 5-8, National Academy of Sciences, c. 1996)

Science as Inquiry - Content Standard A:

As a result of activities in grades 5-8, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science - Content Standard B:

As a result of their activities in grades 5-8, all students should develop an understanding of:

- Motion and Forces

Benchmarks for Science Literacy

(Project 2061 - AAAS, c. 1993)

The Physical Setting - Motion (4F)

By the end of the eighth grade, students should know that:

- In the absence of retarding forces such as friction, an object will keep its direction of motion and its speed. Whenever an object is seen to speed up, slow down, or change direction, it can be assumed that an unbalanced force is acting on it.

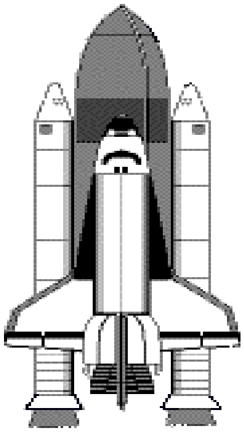
By the end of the 12th grade, students should know that:

- The change in motion of an object is proportional to the applied force and inversely proportional to the mass.

The Physical Setting - Forces of Nature (4G)

By the end of eighth grade, students should know that:

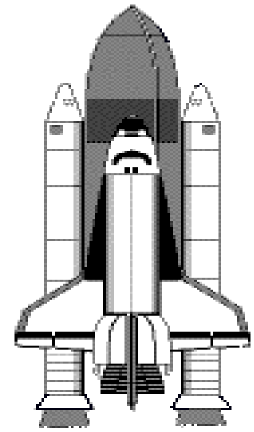
- Every object exerts gravitational force on every other object.



Student Learning Objectives

Upon viewing the video and completing the enclosed student activities, students should be able to do the following:

- Define force;
- Define friction and understand how it works against the direction of motion of an object;
- Identify Newton's first law of motion and understand the concept of inertia;
- Identify Newton's second law of motion;
- Be able to calculate force using Newton's equation:
  Force = Mass x Acceleration;
- Identify Newton's third law of motion;
- Define gravity;
- Discuss Newton's law of universal gravitation;
- Differentiate between weight and mass; and
- Understand that mass does not affect the rate of falling.



Assessment

Preliminary Test:

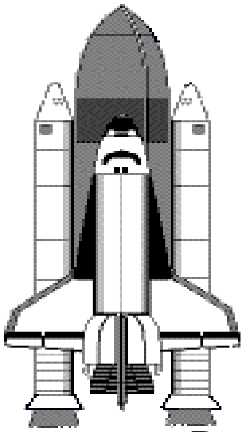
The Preliminary Test, provided in the Student Master section, is an assessment tool designed to gain an understanding of student preexisting knowledge. It can also be used as a benchmark upon which to assess student progress on the objectives stated on the previous pages.

Video Review:

The Video Review, provided in the Student Masters section, can be used as an assessment tool or as a student activity. There are two main parts. The first part contains questions titled "You Decide" that can be answered during the video. The second series of ten questions consists of video review questions to be answered at the conclusion of the video.

Post-Test:

The Post-Test, provided in the Student Masters section, can be utilized as an assessment tool following student completion of the video and student activities. The results of the Post-Test can be compared against the results of the Preliminary Test to assess student progress.



Introducing the Video

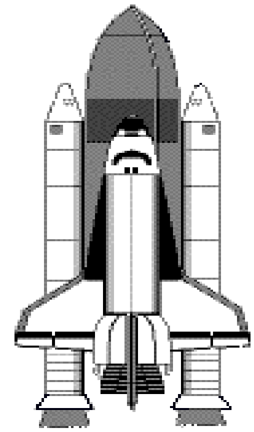
Begin by asking students to define *force*. Discuss the different types of forces that occur in everyday life. Ask students to identify different areas of work in which forces become very important. Next, split the class into groups and ask each group to define, as best they can, terms such as *mass, acceleration*, and *inertia*. Ask one representative from each group to write their definitions on the board. Discuss the definitions as a class. Allow the definitions to remain on the board throughout the video. Following the conclusion of the program, ask students to share any new information that they have learned from the video.

Video Viewing Suggestions

The Student Master "Video Review" is provided for distribution to students. You may choose to have your students complete this Master while viewing the program or to do so upon its conclusion.

The program is approximately 20-minutes in length and includes a ten-question video quiz. Answers are not provided to the Video Quiz on the video, but are included in this teacher's guide. You may choose to grade student quizzes as an assessment tool or to review the answers in class.

The video is content-rich with numerous vocabulary words. For this reason you may want to periodically stop the video to review and discuss new terminology and concepts.



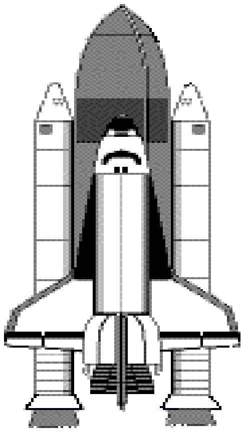
Student Assessments and Activities

Assessment Masters:

- Preliminary Test
- Video Review
- Post-Test

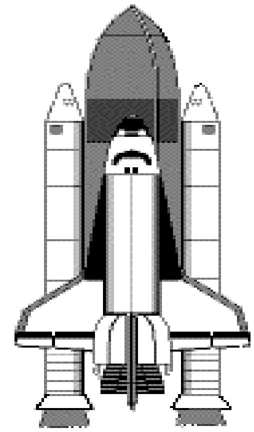
Student Activity Masters:

- The Force of Friction
- Constructing a Balloon Rocket
- Spinning Soda Can
- Calculating Force, Mass, and Acceleration
- Mass and Fall Rate
- Resisting Gravity
- Vocabulary of *Forces*



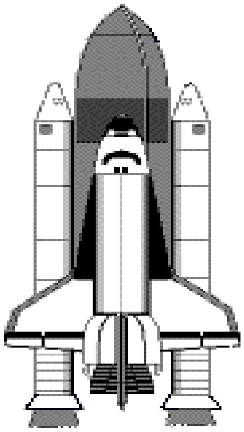
Video Script - *Forces and Newton's Laws*

1. These waves exhibit a tremendous pounding force on this beach.
2. This strong wind exhibits such a great force that it has the ability...
3. ...to blow down large trees like this one.
4. And this big dump truck has the force or strength to carry huge, heavy loads of rock.
5. What is force - how does it affect motion and how can it be computed? During the next few minutes we'll try to answer these questions and others.
6. So stick around as we consider force.
7. **Graphic Transition - Identifying Forces**
8. This golf club hit or pushed this ball 200 meters down range.
9. These oxen are pulling over a 1000 kilogram weight over 10 meters.
10. And our sun exerts a pull on the planets in the solar system.
11. All these examples involve force. A force is a push or a pull.
12. In the examples just mentioned, force gives energy to objects, causing them to start moving.
13. But force can also stop moving objects, just as this linebacker can stop this running back by tackling him,...
14. ...or this baseball player can stop the ball by catching it in his mitt.
15. Force can also change the direction of moving objects, just as this tennis racquet can change the direction of this tennis ball by hitting it.
16. All these are examples of forces. If you think about it for a few minutes, you quickly realize that you use forces everyday.
17. **Graphic Transition -Direction of forces**
18. **You Decide!**
19. Why are two horses needed to pull this wagon instead of one?
20. Two horses add more force, or pull, to the wagon. The horses are combining forces, both pulling in the same direction.
21. Just as this girl and her grandfather are combining forces in pushing this bale of hay.
22. What happened here in terms of force? The cow is pulling in one direction and the boy is pulling in the opposite direction. The forces are unbalanced and the cow won.
23. **Graphic Transition - The Force of Friction**
24. **You Decide!**
25. What force prevents this truck from skidding off the road?
26. Friction. Friction exists whenever two objects come in contact with each other.
27. Friction causes moving objects like this ball to slow down and eventually stop.
28. The texture of a surface has a big effect on the amount of friction on an object.
29. Lack of friction on the highway can be a big problem.
30. For example, wet roads cause cars to lose friction, making driving dangerous.
31. Centuries ago it was found that wheels could help reduce friction.
32. Dragging or sliding objects along the ground creates a great deal of friction.
33. But wheels create very small points of contact with the ground, thus reducing friction and making the load easier to pull.
34. One of the results of friction is heat. Try rubbing your hands together quickly for ten seconds. Feel the heat. This is the result of friction.
35. In some cases, tremendous amounts of heat are produced as a result of friction.
36. This is why lubricants such as oil and grease are used to reduce the amount of friction between moving parts, thus reducing heat and engine wear.
37. **Graphic Transition - Newton's First Law of Motion**
38. Over three hundred years ago, a scientist by the name of Isaac Newton developed the laws of motion that are still of great importance today.



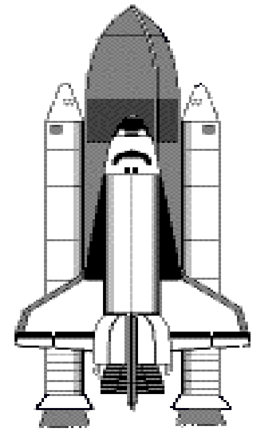
Script

39. Newton made a number of observations about the motion of matter that are now referred to as Newton's laws of motion.
40. These laws of motion describe all the states of motion including...
41. ....objects at rest,. . .
42. ....moving objects,. . .
43. ....and accelerated objects. Let's talk about Newton's first law of motion.
44. Imagine throwing a ball and not having it stop...
45. ...or coasting on a skateboard for a long distance with a single push.
46. According to Newton, these things are possible - except for one small problem - friction. Let's take a look at the effects of friction.
47. Isaac Newton's first law of motion states that objects in motion will remain in motion at a constant velocity unless acted upon by an outside force. The outside force most often at work is friction.
48. Only in space where there is very little air to create friction can an object remain in motion at a constant velocity.
49. The second part of Newton's first law of motion states that objects at rest will remain at rest until acted upon by an outside force.
50. In other words, this glass will remain in place until an outside force causes it to move.
51. Newton referred to the tendency of an object to continue its state of motion as inertia.
52. Inertia refers to an object's ability to resist change in motion.
53. The more mass an object has, the more difficult it is to change its motion and the more inertia it possesses.
54. The reason we wear safety belts is related to inertia. When a car stops suddenly, your body keeps moving and the seat belt holds you in place.
55. **Graphic Transition - Newton's Second Law of Motion**
56. **You Decide!**
57. What would you rather be hit by - a piece of paper accelerating 10 meters per second or a baseball accelerating 10 meters per second?
58. This is an easy one. Of course the paper would deliver a softer blow than the baseball.
59. This is fundamental to understanding Newton's second law of motion -the relationship between acceleration, force and mass.
60. This relationship can be summarized by the mathematical equation: Force = Mass x Acceleration.
61. With the piece of paper, force = .02 kilograms x 10 meters per second per second = .2 kilograms meters per second per second.
62. And the force of the baseball = .250 kilograms x 10 meters per second per second = 2.5 kilograms meters per second per second — over ten times greater force than the moving paper.
63. What would happen to the force of the moving baseball if the ball had a faster acceleration of let's say 20 meters per second per second?
64. Looking at the formula, we see that the force equals .25 kilograms times 20 meters per second per second which equals 5 kilograms meters per second per second.
65. As you can see the faster accelerating baseball produces an even greater amount of force.
66. **Graphic Transition - Newton's Third Law of Motion**
67. **You Decide!**
68. What causes this model rocket to be thrust skyward over 150 feet?
69. The model rocket goes up due to a strong opposite downward force,...
70. ...the same principle that is responsible for causing planes to take off...
71. ...and for large rockets to launch into space.
72. These vehicles are propelled skyward as a result of an oppositely applied force.
73. Newton's third law of motion explains this principle. It states that for every action there is an equal and opposite reaction.



Script

74. We are affected by Newton's third law of motion everyday. When we walk, we exert a force on the ground and the ground exerts a force upward against our feet.
75. Birds fly using this law as well. When a bird flaps its wings downward,...
76. ...the air pushes upward or produces resistance, allowing the bird to push off of the air under it.
77. In review, Newton's first law of motion states an object in motion will remain in motion at a constant velocity unless acted upon by an outside force.
78. Newton's second law of motion demonstrates the relationship between force, mass, and acceleration.
79. And Newton's third law of motion states that for every action there is an equal and opposite reaction.
80. **Graphic Transition - Gravity**
81. An apple falling from an apple tree, giving rise to Newton's theory of gravity, was an important discovery in helping us better understand our world.
82. You are experiencing the force of gravity at this very moment. It is the force that holds you and all the other objects around you in place.
83. Gravity is the force of attraction between two objects.
84. Objects on earth are pulled toward the center of the earth, and Newton concluded that objects in the universe are attracted to earth by the force of gravity.
85. This is summarized by the law of universal gravitation, which states that all objects in the universe are attracted to each other by the force of gravity.
86. **Graphic Transition - Weight and Mass**
87. Gravity is an important force as related to weight. Weight is a measure of the force of gravity on an object.
88. Weight is measured in Newton units.
89. This car weighs about 8000 Newtons. But weight varies with the amount of gravity placed on an object.
90. **You Decide!**
91. Do you think the car would weigh more, less or the same on the moon?
92. The force of gravity on the moon is 1/6th the force of gravity on earth. This causes the car on the moon to weigh less than on earth.
93. Even though the weight of the car can be different, its mass stays the same. Mass is the amount of matter in an object.
94. **Graphic Transition - Gravity and Falling Objects**
95. In the late 1500's, the Italian scientist Galileo elaborated on the principle of gravity by applying it to falling objects.
96. In a famous experiment, Galileo dropped two cannonballs off the Leaning Tower of Pisa.
97. One cannonball had ten times the mass of the other.
98. Let's do the same from the top of this building with two rocks of different size.
99. **You Decide!** Which rock will hit the ground first?
100. As you can see, both rocks hit the ground at the same time.
101. Galileo also found the same thing with the cannonballs.
102. Galileo stated that objects of different masses fall at equal rates of acceleration.
103. The acceleration due to gravity is 9.8 meters per second per second, regardless of the size and mass of the object.
104. This means that every second that an object falls, its velocity increases at a rate of 9.8 m/sec.
105. Let's see how this works by dropping this baseball a distance of 9.8 meters.
106. At 9.8 meters above the ground, the object has zero velocity.
107. After the object has fallen 1 second it is going 9.8 meters per second.
108. Therefore, you can see that objects continue to accelerate and gain velocity as they fall.
109. This is true until an object reaches its terminal velocity - a point where it no longer accelerates.
110. **Graphic Transition - Summing Up**
111. During the past few minutes we have explored forces and Newton's laws of motion.

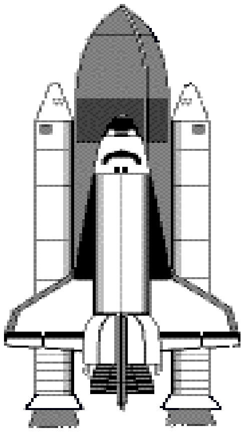


Script

112. We have observed that a force is a push or a pull, and that force can change the direction of moving objects.
113. Forces can combine with each other to make a greater force,...
114. ...or they can oppose each other.
115. We also observed that friction is a powerful force which occurs when objects come in contact with each other.
116. Sir Isaac Newton developed several laws of motion which apply to different states of motion.
117. Newton's first law of motion states that an object in motion will remain in motion at a constant velocity unless another force interferes.
118. Newton's second law of motion describes how mass and acceleration affect force...
119. ...and Newton's third law of motion states that for every action there is an equal and opposite reaction.
120. Finally, we learned how Galileo determined that falling objects with different masses have equal rates of acceleration.
121. Next time you observe moving objects, try to remember some of the things we've discussed during the past few minutes. You just might look at the world a little differently.

Video Quiz: Fill in the correct response when you hear this beep.

1. A _____________ is a push or pull
2. _______________ exists when moving objects come into contact.
3. One of the effects of friction is __________.
4. Objects remaining at rest or continually in motion have ___________.
5. Newton's Second Law of Motion describes the relationship of force, mass, and __________________.
6. Force equals ____________ times acceleration.
7. For every action there is an equal and opposite ______________.
8. The force of _____________ is an attraction between objects.
9. __________ is a measure of the force of gravity on an object.
10. Objects with different masses fall at _________ rates of acceleration.



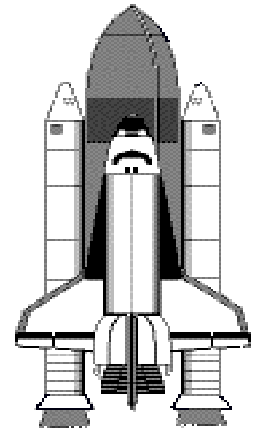
Answers to Student Assessments

Preliminary Test
1. force
2. direction
3. friction
4. Isaac Newton
5. inertia
6. acceleration
7. mass
8. gravity
9. weight
10. newtons
11. False
12. False
13. True
14. True
15. False
16. False
17. True
18. False
19. True
20. False

Video Review
You Decide:
A. Two horses add more force, or pull, to the wagon.
B. friction
C. The paper would deliver a softer blow than the baseball.
D. The model rocket goes up due to a strong opposite downward force.
E. The car would weight less on the moon.
F. Both rocks hit the ground at the same time.

Video Quiz:
1. force
2. friction
3. heat
4. inertia
5. acceleration
6. mass
7. reaction
8. gravity
9. weight
10. equal

Post Test
1. False
2. False
3. False
4. True
5. False
6. False
7. True
8. False
9. True
10. True
11. gravity
12. direction
13. Isaac Newton
14. newtons
15. acceleration
16. friction
17. mass
18. force
19. inertia
20. weight



Answers to Student Activities

The Force of Friction

Conclusions: It takes the most force to pull the wooden block across the sandpaper, demonstrating that the sandpaper exerts the most friction. The differences in friction occur because some surfaces are rougher than others. The rough, jagged edges of the sandpaper are bigger than those of the ice and therefore get easily caught on the edges of the block, creating friction.

Constructing a Balloon Rocket:

Conclusions: The balloon rocket travels across the string because it is subject to unbalanced forces. The force of the air escaping the balloon is greater than the force of gravity and the can's mass, demonstrating Newton's first law. The force of the balloon traveling across the string is equal and opposite to the force of the air escaping the balloon, demonstrating Newton's third law. The amount of force produced by the balloon is equivalent to the mass of the escaping air multiplied by the acceleration of its escape, demonstrating Newton's second law. The balloon behaves as the thrusters on a rocket. A larger balloon will generate more thrust because it can hold more air.

Spinning Soda Can

Conclusions: The can begins to spin when filled with water because of Newton's third law of motion. The water flows out of the can and in response, the can spins in the opposite direction. Therefore, the water and the can is the action-reaction pair. Bigger holes will allow more water to flow through the can, creating a larger force and causing the can to spin faster. Differences in the slants of the holes will cause differences in the direction of the can's motion.

Calculating Force, Mass, and Acceleration

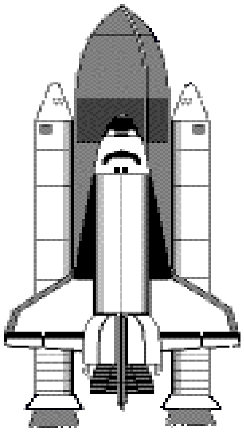
1. 105 N
2. 5400 N
3. 3200 N
4. 12.5 kg
5. 1.67 m/s^2

Mass and Fall Rate

Observations:

1. Yes
2. No, the wooden block should land first.
3. No, the crumpled paper hits first because it has a smaller surface area, generating less air resistance.

Conclusions: Data collected should support Galileo's hypothesis. The fall rate of all objects is slowed by air resistance. The large surface area and shape of the paper make it more susceptible to air resistance. Therefore, its fall rate is slowed more than that of the block or foam pad. By crumpling the paper, the surface area is reduced, decreasing air resistance.



Answers to Student Activities

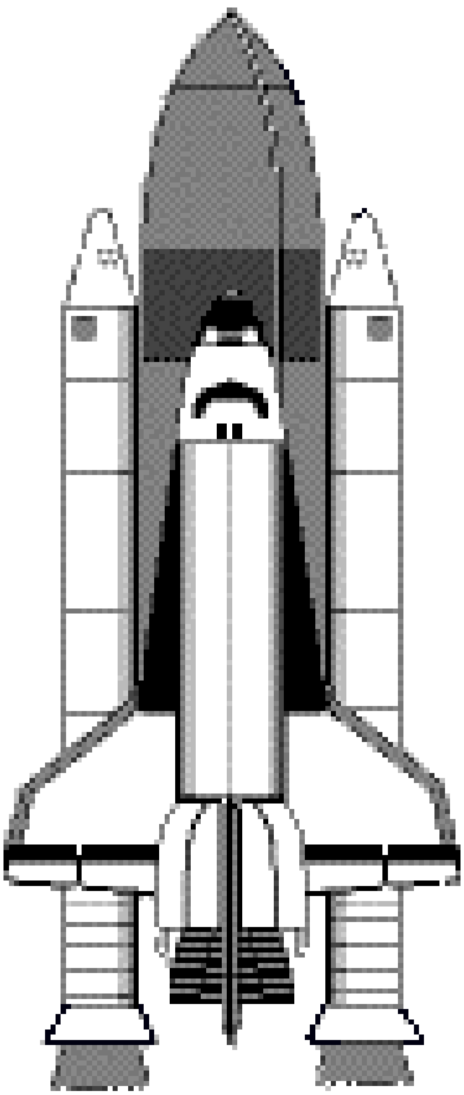
Resisting Gravity

The smallest piece will always hit the ground first, while the largest will hit last. This is because air resistance is related to surface area, such that the smaller the surface area, the less air resistance. This demonstrates that mass does not affect acceleration. You can alter the fall rate of the paper by decreasing its surface area, such as by crumpling or folding it.

Vocabulary of Forces

1. friction, e
2. Newton's second law, h
3. law of universal gravitation, c
4. weight, b
5. Galileo, l
6. gravity, n
7. force, a
8. inertia, i
9. mass, f
10. acceleration, k
11. Newton's first law, m
12. newtons, d
13. Newton's third law, g
14. Isaac Newton, j

Assessment and Student Activities Masters



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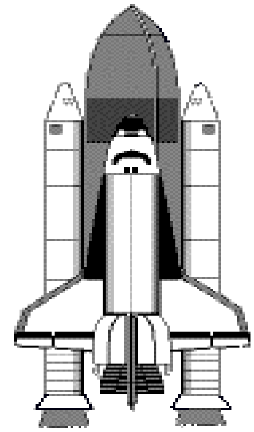


Preliminary Test

Directions: Fill in the blank with the correct word. Choose from the list of possible answers at the bottom of the page.

1. A ________ can cause an object to start or stop moving.

2. Force can change the ____________ of moving objects.

3. A force that causes the speed of objects to decrease is called __________.

4. The laws of motion were developed by ________ _________.

5. ____________ is an object's ability to resist a change in motion.

6. Newton's second law of motion forms a relationship between force, mass, and ______________.

7. Even though we weigh more on Earth than we do on the moon, our _______ remains the same.

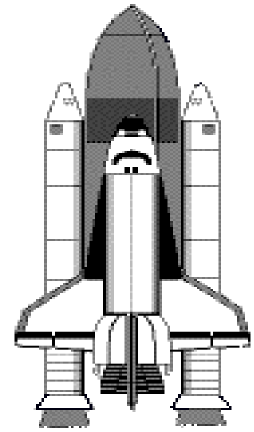
8. An apple falling from a tree is an example of the force of __________.

9. ___________ is the measure of the force of gravity on an object.

10. Force is measured in ___________.

velocity	acceleration
newtons	weight
mass	inertia
friction	Isaac Newton
spring	gravity
force	direction

Name________________



Preliminary Test

Directions: Decide whether the answer is True (T) or False (F).

11. A force always stops a moving object. T F

12. Friction causes the speed of moving objects to increase. T F

13. It was discovered centuries ago that wheels reduce friction. T F

14. The more mass an object has, the greater its inertia. T F

15. The amount of force exerted on an object can be computed by multiplying its mass by its weight. T F

16. Planes and rockets are thrust upward due to a strong opposite upward force. T F

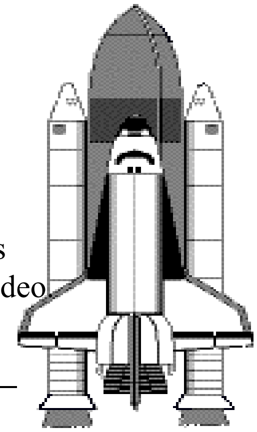
17. Newton's third law states that for every action there is an equal and opposite reaction. T F

18. Weight is the same force as gravity. T F

19. The law of universal gravitation states that all objects are attracted to each other by the force of gravity. T F

20. Acceleration due to gravity is 11.4 meters per second per second. T F

Name________________



Video Review

Directions: During the course of the program answer the "You Decide" questions as they are presented in the video. Answer the Video Quiz questions at the end of the video.

You Decide:

A. Why are two horses needed to pull this wagon instead of one? Answer:______________

B. What force prevented this truck from skidding off the road? Answer:______________

C. What would you rather be hit by, a piece of paper accelerating at 10 meters per second, or a baseball accelerating 10 meters per second? Answer:______________

D. What causes this model rocket to be thrust skyward over 150 feet? Answer:______________

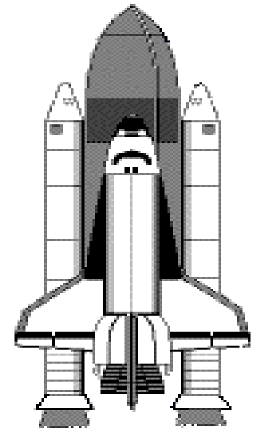
E. Do you think the car would weigh more, less, or the same on the Moon? Answer:______________

F. Which rock will hit the ground first? Answer:______________

Video Quiz:

1. A _______ is a push or pull.
2. ________ exists when moving objects come into contact.
3. One of the effects of friction is ______.
4. Objects remaining at rest or continually in motion have ________.
5. Newton's second law of motion describes the relationship of force, mass, and ________________.
6. Force equals __________ times acceleration.
7. For every action there is an equal and opposite __________.
8. The force of ___________ is the attraction between objects.
9. _________ is the measure of the force of gravity on an object.
10. Objects with different masses fall at ________ rates of acceleration.

Name________________



Post Test

Directions: Decide whether the answer is True (T) or False (F).

1. Weight is the same force as gravity. T F

2. Acceleration due to gravity is 11.4 meters per second per second. T F

3. Friction causes the speed of moving objects to increase. T F

4. The law of universal gravitation states that all objects are attracted to each other by the force of gravity. T F

5. The amount of force exerted on an object can be computed by multiplying its mass by its weight. T F

6. Planes and rockets are thrust upward due to a strong opposite upward force. T F

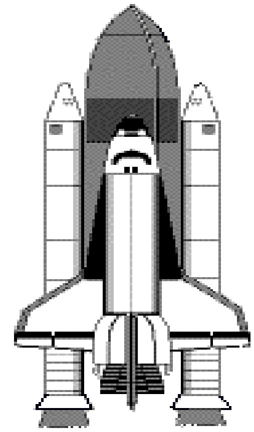
7. The more mass an object has, the greater its inertia. T F

8. A force always stops a moving object. T F

9. It was discovered centuries ago that wheels reduce friction. T F

10. Newton's third law states that for every action there is an equal and opposite reaction. T F

Name________________



Post Test

Directions: Fill in the blank with the correct word. Chose from the list of possible answers at the bottom of the page.

11. An apple falling from a tree is an example of the force of __________.

12. Force can change the ____________ of moving objects.

13. The laws of motion were developed by ________ _________.

14. Force is measured in _________.

15. Newton's second law of motion forms a relationship between force, mass, and ____________.

16. A force that causes the speed of objects to decrease is called __________.

17. Even though we weigh more on Earth than we do on the moon, our _______ remains the same.

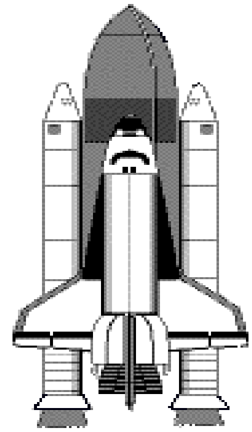
18. A ________ can cause an object to start or stop moving.

19. ___________ is an object's ability to resist a change in motion.

20. __________ is the measure of the force of gravity on an object.

newtons	inertia
mass	Isaac Newton
friction	gravity
force	direction
acceleration	velocity
weight	spring

Name________________



The Force of Friction

Objective:
In this lab activity you will observe how different amounts of friction affect the force required to move an object.

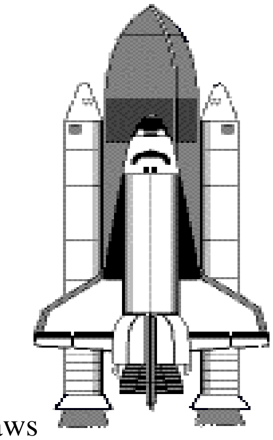
Background:
Have you ever noticed how difficult it can be to push a heavy object, such as a couch, across a floor? The difficulty you experience results from the contact between the couch and the floor, creating a force called **friction**. Friction is the force that acts against the motion of the moving object. While attempting to move a stationary object, you must always exert a force larger than the force of friction in order to achieve motion. Friction is the force that causes a moving object to slow down and eventually stop. So why does friction exist? Friction exists because objects and their surfaces are not as smooth as they may appear. If you look at most surfaces under a microscope, you will see rough, jagged edges. When two objects come in contact with one another, these edges rub against each other, slowing the moving object. The amount of friction that exists between two objects depends on the texture of their surfaces. Some surfaces are smoother than others and therefore experience less friction. For example, it would be hard to push a heavy couch across a wooden floor. However, it would be even harder to push it across a carpeted floor because the carpet has a rougher surface than the wooden floor.

Materials:
Spring scale
Thick string (12 inches)
Wooden block
Sand paper
Piece of notebook paper
Sheet of ice (in cookie sheet)
Mouse pad
Heavy tape

Procedure:
1. Your teacher will divide you into small work groups.
2. Attach a 12-inch piece of string to the spring scale and tape the other end to the wooden block.
3. Use the spring scale to drag the block across the sand paper. Take note of the reading on the spring scale as it measures the amount of force required to move the block.
4. Repeat step 3 using the notebook paper, ice, and mouse pad.
5. Experiment with other surfaces around your classroom.
6. Create a data table in which you can record your findings. Use your data to make a bar graph.

Conclusions:
Which surface exerts the most friction on the block? Why do the sand paper, notebook paper, ice, and mousepad exert different amounts of friction? Did you find any surprising results when experimenting with other surfaces?

Name________________



Constructing a Balloon Rocket

Objective:
In this activity you will construct your own balloon rocket and observe Newton's laws of motion at work.

Background:
Almost everyone has witnessed a rocket launch. Many of you have probably even launched your own model rocket. Did you realize that a rocket launch illustrates the principles of Newton's laws of motion? A rocket is able to lift off because the thrusters propelling it upward produce a greater force than the opposing force of gravity. The forces are unbalanced, with the upward force winning the battle. This illustrates **Newton's first law of motion.** The upward force of the rocket is equal and opposite the downward force of the escaping air and heat. This is an example of **Newton's third law of motion** which states that for every action there is an equal and opposite reaction. Finally, the amount of force produced by the escaping air and heat is equivalent to the mass of the air and heat multiplied by the rocket's acceleration, demonstrating **Newton's second law of motion.**

Materials:

1 soda can	1 straw
3 balloons (various sizes)	Tape
String (medium thickness)	Scissors

Procedure:
1. Your teacher will divide you into small groups.
2. Tape the straw (horizontally) to one side of the soda can.
3. Blow up the balloon and tie a knot to hold the air.
4. Tape the balloon to the side of the soda can opposite the straw.
5. Cut a 5-7 ft. piece of string. Using the tape, attach one end of the string to an object that stands above ground.
6. Run the string through the straw on the soda can and attach the other end of the string to a second object. (String may be attached to a wall if space is available).
7. Pull your balloon rocket to one end of the string. Cut the knot off the balloon and watch it launch. Experiment with different size balloons.

Conclusions:
Discuss how the balloon rocket mimics the physics of an actual space launch. What part of an actual rocket does the balloon behave as? How does the size of the balloons affect the motion of the rocket?

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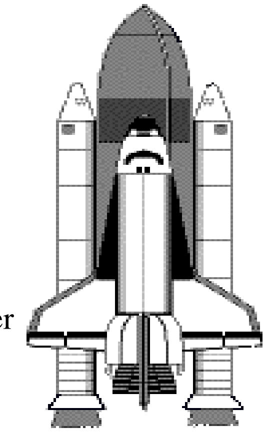

Spinning Soda Can

Objective:
In this lab activity you will observe Newton's third law of motion when falling water causes a soda can to spin.

Background:
Newton's third law states that for every action there is an equal and opposite reaction. Even though this explanation sounds quite technical, we experience Newton's third law everyday. Skateboarders experience this law of motion frequently. Imagine a skateboarder is at rest, or not moving, on his skateboard. If he jumps off the skateboard, the skateboard moves some distance in the opposite direction. The jumping is the action, while the skateboard's opposite motion is the reaction. This makes the skateboard and its rider an action-reaction pair. Newton's third law also plays a large role in launching rockets. A rocket takes off by expelling gas from its engine. The rocket pushes this gas out and in response, the gas pushes on the rocket, forcing it upward. The rocket and the gas serve as the action-reaction pair in this example. Newton's third law is even at work with simple tasks such as driving. The car pushes against the road and the road pushes against the car, another action-reaction pair. If you look closely, you will realize that Newton's third law of motion is at work all the time!

Materials:
Empty soda can
Common nail
Bucket of water
Meter stick
Nylon fishing line (light weight)
Scissors

Procedure:
1. Divide into groups of two or three.
2. Using the nail provided, punch four equally spaced holes near the bottom of the can. Before removing the nail, push it to one side to bend the metal so that the hole slants in that direction. All four holes should slant in the same direction. **Caution: Be careful when using the nail!**
3. Cut a 40-50 centimeter piece of fishing line.
4. Bend the can's opening lever up and attach the fishing line to it.
5. Dip the can in the bucket of water until it is filled. Pull it out by holding on to the fishing line and observe its motion.
6. Experiment to see how the size and slant of the holes affect the can's motion.

Conclusions: Why did the can start spinning when filled with water? What is the action-reaction pair in this example? Use class data to determine how the size and slant of the holes affect the can's motion.

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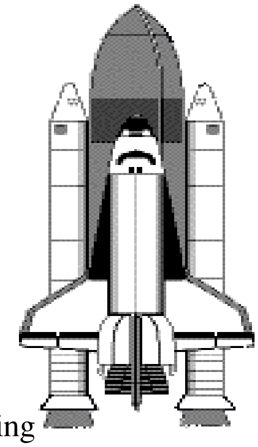

Calculating Force, Mass and Acceleration

Background:

Imagine that you are trying to push a shopping cart. The force you produce by pushing causes the cart to accelerate. As more food is put into the cart, its mass increases and it moves more slowly even though you are pushing with the same force. The relationship between force, mass, and acceleration is made clear by Newton's second law. This law of motion states that the force (F) exerted on an object is the product of its mass (M) and its acceleration (A), F = M x A. This equation can be rearranged in two ways:

1. $\frac{\text{force}}{\text{acceleration}} = \text{mass}$
2. $\frac{\text{force}}{\text{mass}} = \text{acceleration}$

Sample Calculation:

A woman has a mass of 50 kilograms. If the woman is pushed across the ice with a force of 100 Newtons (N), what is her acceleration?

1. Plan : Use Newton's second law to calculate acceleration.
2. Data : force = 100 N mass = 50 kg
3. Equation - force/ mass = acceleration > 100 N / 50 kg = 2 N/kg
4. Acceleration is measured in meters per second per second. 1 m/s^2 = 1 N/kg. So the woman is accelerating at 2 m/s^2.

Directions:

Use the equations and sample problem provided above to solve the following calculations.

Practice Problems:

1. Suppose a young boy pushes a supermarket cart with a mass of 30 kg. How much force does he use if the cart accelerates at 3.5 m/s^2?

2. How much force is needed to accelerate a 1800 kg car 3m/s^2 ?

3. It takes 3000 N to accelerate an empty 1500 kg car at 2 m/s^2. If a 100 kg swimmer gets into the car, how much force will be needed to produce the same acceleration?

4. A large rock is pushed down a hill with a force of 25 N. This push causes it to accelerate at 2 m/s^2. What is the mass of the rock?

5. A bike and its rider have a combined mass of 60 kg. If the rider and his bike are pushed down the street with a force of 100 N, what is their acceleration?

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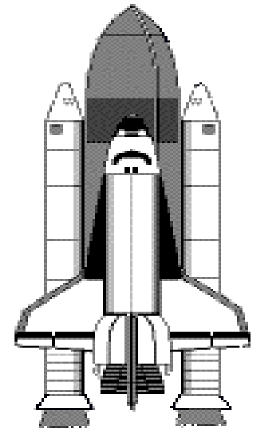


Mass and Fall Rate

Objective:
In this lab you will observe the relationship between mass and fall rate.

Materials:
Wooden block (10cm x 15 cm x 2.5 cm)
Sheet of notebook paper
Styrofoam pad (10 cm x 15 cm x 2.5 cm)
Triple beam balance

Procedure:
1. Your teacher will place you in small groups.
2. Use the balance to find the masses of the block, styrofoam, and paper.
3. Hold the block in one hand and the styrofoam in the other. Hold them at arms length with the largest surface area facing the floor.
4. Release both objects at the same time and observe when each hits the ground. Repeat this step two more times, collect data, and record.
5. Repeat steps 2, 3, and 4 using the foam pad and the paper.
6. Crumple the paper into a tight ball.
7. Compare fall rates of the crumpled paper and the wooden block. Repeat steps 3 and 4 with these objects.
8. Repeat steps 3 and 4 with the crumpled paper and the foam pad.
9. Create a data table consisting of the mass of the object and comparative falling rates.

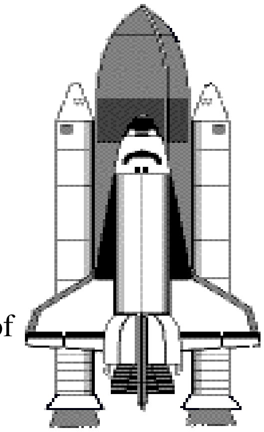
Observations:
1. Do the wooden block and the foam pad hit the ground at the same time?

2. Do the wooden block and the uncrumpled paper hit the ground at the same time? If not, which hits first?

3. Do the foam pad and the crumpled paper hit the ground at the same time? If not, which hits first?

Conclusions:
Galileo states that objects with different masses exhibit the same fall rate. Does your data support this law? Assuming that Galileo's law is true, what causes the foam pad and the wooden block to hit the ground before the uncrumpled paper? How does crumpling the paper affect its fall rate?

Name________________



Resisting Gravity

Objective: In this lab you will learn about the effect of air resistance on the force of gravity.

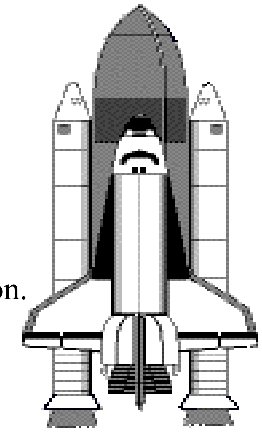
Background: You have learned that an object falling near the surface of the earth accelerates at a rate of 9.8 meters/second/second. This means that regardless of mass, two objects will fall at the same rate. But we know that this is not always true. Imagine dropping a rock and piece of paper from the top of a building. According to the principles of acceleration due to gravity, the piece of paper and rock should hit the ground at the same time, but we know that the rock will reach the ground before the piece of paper. How can this be true? The objects fall at different rates because of **air resistance**, the force that air exerts on all objects. Air resistance acts in opposition to gravity, so that while gravity is pulling down on an object, air resistance is pushing up. If air resistance is acting upon both the rock and piece of paper, why do they reach the ground at different times? This occurs because air resistance is related to surface area, such that the greater the surface area, the greater the air resistance. The piece of paper has more surface area than the rock and therefore encounters greater air resistance, causing it to fall more slowly. So objects fall at 9.8 m/sec/sec when gravity is the *only* force present. Therefore, the only place the rock and piece of paper will fall at the same velocity is in a **vacuum**, which is a space devoid of air resistance.

Materials:
Two sheets of notebook paper

Procedure:
1. Stand on your desk. **Caution: Be careful not to fall!**
2. Hold a piece of paper in each hand out in front of you. Drop them at the same time and note when each hits the ground.
3. Rip one piece of paper in half. Now hold the small piece in one hand and the full-sized piece in another. Drop both and note when each hit the ground.
4. Rip the smaller piece in half again. Repeat step 3.
5. Alter the larger piece of paper so that it hits the ground before the smaller piece.

Conclusions:
In this experiment you used three sizes of paper. If they were all dropped at once, which would hit the ground first and which would hit last? Why is this so? The smaller piece of paper obviously has less mass than the larger piece, but it hits the ground first. What does this prove about the relationship between acceleration and mass? How did you alter the larger piece of paper so that it would reach the ground before the smaller piece?

Name_________________



Vocabulary of *Forces*

Directions : Unscramble the vocabulary word and match it with the correct definition.

_____1. t n o r f c i i

_____2. w o n n e t s c s d n e o a l w

_____3. w l a f o n u s l i v r a e o t n r g a i t v a i

_____4. t g w i h e

_____5. l g l o a i e

_____6. v y a r i t g

_____7. c r f o e

_____8. n t r e i a i

_____9. s m a s

_____10. c l e e a c n o r t i a

_____11. t n w o n e s t i f s r w l a

_____12. t w n o e n s

_____13. s n w e o n t i h t d r w a l

_____14. a a s c i w t o n n e

a. a push or a pull

b. a measure of the force of gravity on an object

c. all objects in the universe are attracted to each other by the force of gravity

d. the units in which force is measured

e. the force that exists when any two objects come into contact with one another

f. the amount of matter in an object

g. for every action there is an equal and opposite reaction

h. force equals mass multiplied by acceleration

i. the ability of an object to resist a change in its motion

j. the scientist responsible for developing the laws of motion

k. the rate of increase of an object's velocity

l. scientist who discovered that objects of unequal masses fall at equal rates of acceleration

m. objects in motion will remain in motion at a constant velocity unless acted upon by an outside force

n. the force of attraction between two objects