National Aeronautics and
Space Administration

Langley Research Center
Hampton, VA 23681-2199

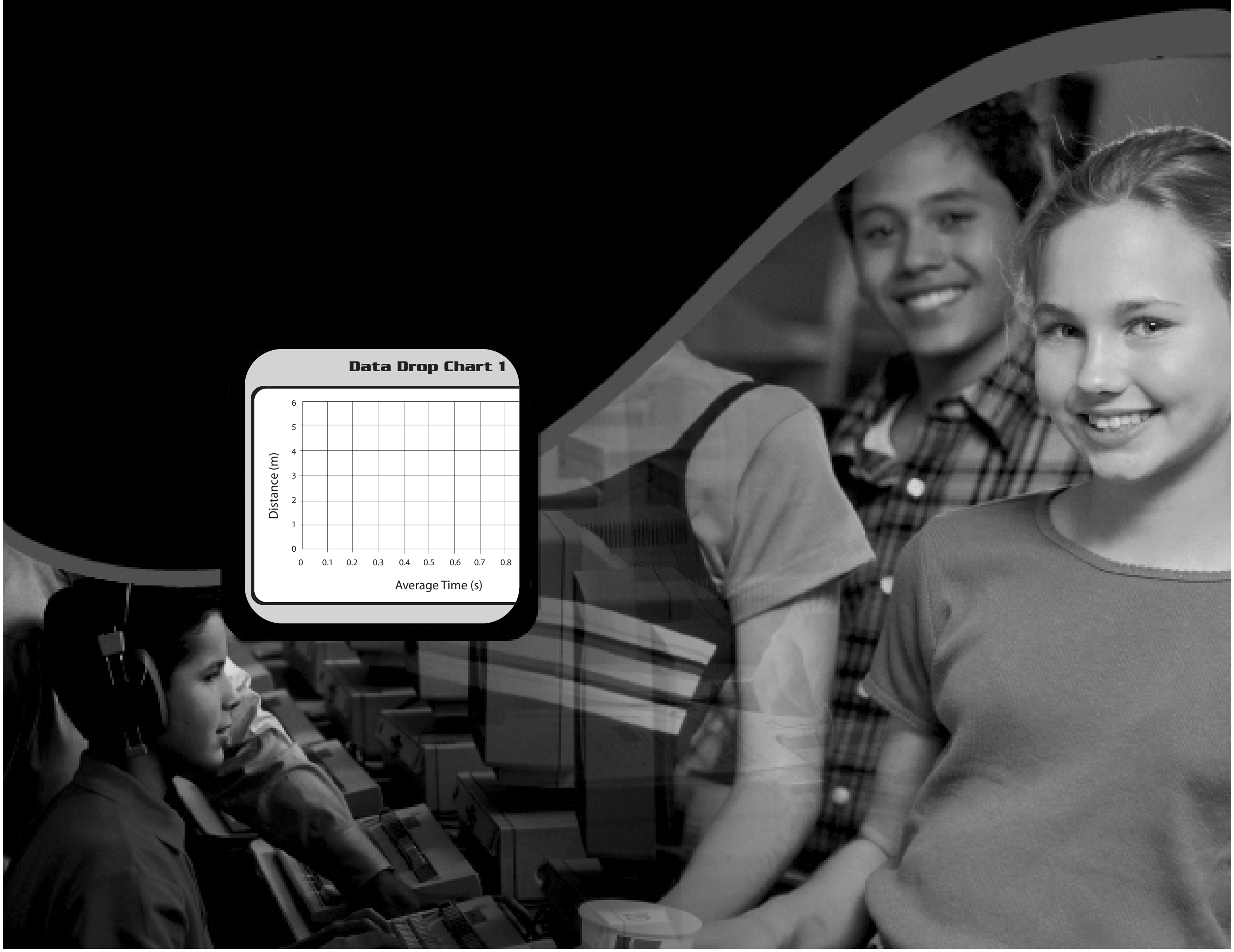
Educational Product	
Educators	Grades 6-8

EG-2002-10-14-LARC

NASA CONNECT™

Measurement, Ratios, and Graphing: Who Added the "Micro" to Gravity?

An Educator Guide with Activities in Mathematics, Science, and Technology



Measurement, Ratios, and Graphing: Who Added the "Micro" to Gravity? is available in electronic format through NASA Spacelink - one of NASA's electronic resources specifically developed for the educational community. This publication and other educational products may be accessed at the following address:
http://spacelink.nasa.gov/products

A PDF version of the educator guide for NASA CONNECT™ can be found at the NASA CONNECT™ web site: **http://connect.larc.nasa.gov**

NASA CONNECT™ is produced by the NASA Center for Distance Learning, a component of the Office of Education at NASA's Langley Research Center, Hampton, VA. The NASA Center for Distance Learning is operated under cooperative agreement NCC-1-02039 with Christopher Newport University, Newport News, VA.

www.aiaa.org

www.cnu.edu

www.epals.com

www.cgcs.org

www.riverdeep.net

www.ntcm.org

www.nasa.gov

http://quest.arc.nasa.gov

www.nec.com

NASA CONNECT™

Measurement, Ratios, and Graphing: Who Added the "Micro" to Gravity?

An Educator Guide with Activities in Mathematics, Science, and Technology

Program Overview

Hands-On Activity

Student Worksheets

Teacher Materials

Free Fall Web Activity

Resources

AIAA FOUNDATION Registered users of NASA CONNECT™ may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail **nasaconnect@aiaa.org**.

CC Captioning provided by NEC Foundation of America

Acknowledgments: Special thanks to Summer 2002 Educators in Residence, Randall Caton, Chris Giersch, Bill Williams, and The National Council of Teachers of Mathematics (NCTM).

Program Overview

SUMMARY AND OBJECTIVES

In *Measurement, Ratios, and Graphing: Who Added the "Micro" to Gravity?*, students will learn about microgravity. They will be introduced to combustion science and the importance of fire safety on the International Space Station. Students will also learn how chemistry plays an important role in microgravity research. They will observe NASA engineers and scientists using measurement, ratios, and graphing to analyze data. By conducting hands-on and web activities, students will make connections between NASA research and the mathematics, science, and technology they learn in their classrooms.

STUDENT INVOLVEMENT

Cue Card Questions

Norbert, NASA CONNECT's™ animated co-host, poses questions throughout the broadcast. These questions direct the instruction and encourage students to think about the concepts being presented. When viewing a videotaped version of NASA CONNECT™, educators have the option to use the Cue Card Review, which gives students an opportunity to reflect and record their answers on the Cue Cards (p.13). NASA CONNECT's™ co-host, Jennifer Pulley, will indicate an appropriate time to pause the videotape and discuss the answers to the questions.

Hands-On Activity

The hands-on activity is teacher created and is aligned with the National Council of Teachers of Mathematics (NCTM) standards, the National Science Education (NSE) standards, and the International Technology Education Association (ITEA) standards. Students will determine the acceleration due to gravity by collecting, organizing, graphing, and analyzing data. They will build an understanding of microgravity.

Free Fall Web Activity

The NASA CONNECT™ Free Fall Web Activity is aligned with the National Council of Teachers of Mathematics (NCTM) standards, the National Science Education (NSE) standards, and the International Technology Education Association (ITEA) standards. Students will investigate apparent weight to see how astronauts in space can feel "weightless". They will also review and solidify concepts of displacement, velocity, acceleration, mass, force, weight, and gravity. To access the NASA CONNECT™ Free Fall Web Activity, go to Dan's Domain on NASA CONNECT's™ web site at http://connect.larc.nasa.gov/dansdomain.html.

RESOURCES

Teacher and student resources (p.17) support, enhance, and extend the NASA CONNECT™ program. Books, periodicals, pamphlets, and web sites provide teachers and students with background information and extensions. In addition to the resources listed in this educator guide, the NASA CONNECT™ web site, <*http://connect.larc.nasa.gov*> offers online resources for teachers, students, and parents.

Hands-On Activity

BACKGROUND

The term zero gravity has been used in the news to explain the feeling of weightlessness experienced by astronauts in the Space Station. Although the term is very descriptive, it is misleading, and we will see why.

When you feel a push or a pull, we say that a force is acting on you. Gravity is a special force that results because two masses attract each other; but what is mass? No one has answered that question very well yet, other than to say it is the amount of stuff in an object, which isn't very clear. An object that has a larger mass is harder to push, and engineers have designed scales to measure mass. Bathroom scales have a spring in them. The more mass you put on the scale, the more the spring stretches and the greater the reading. So, we can measure mass even if we don't quite know how to define it clearly. You know that bathroom scales measure your weight, so how can they measure mass also? Your weight is the force of the Earth on your mass, and it increases as your mass increases. If your mass doubles, then your weight doubles. Then why have two different things - mass and weight? Your mass won't change if you go to the Moon, but your weight will be less there because the Moon has less mass and won't attract you as strongly as the Earth does. We need both concepts to fully understand how objects behave in gravity. Are you confused? Don't worry, it took scholars centuries to get these concepts straight.

The ancient Greeks thought heavier objects fell faster, but they were wrong because they didn't understand gravity. Galileo (1564-1642) was the first to demonstrate through experiment that all bodies fall at roughly the same rate. He still didn't understand gravity, but his contribution of the experimental method was extremely valuable to the progress of science. Newton (1642-1727) put all the ideas of previous scholars together to explain gravity. Through his idea that gravity was a force acting over large distances and resulting from masses attracting each other, Newton was able to explain many things, like the motion of the planets around the sun. Einstein (1879-1955) refined Newton's concept of gravity and changed our concepts of space and time. You just read a very brief history of gravity and if you find it interesting, you can learn more about it as you get older. It takes a lot of thought and math skills to understand gravity, and you can keep increasing your understanding as you grow and develop your mind.

For an object near the Earth's surface , the main gravity force is from the Earth because it is the closest body. The farther away a mass is, the smaller its gravity force, so the Moon and Sun don't have much effect. An object is in free fall when the only force acting on it is due to gravity. An object can free fall near the Earth in two ways: you can drop it, and it will fall straight down (towards the Earth's center), or it can circle the Earth, always freely falling from the straight line path it would take if the Earth's gravity weren't acting. Do you know that you could start a ball orbiting the Earth if you threw it horizontally at 7900 meters per second and it didn't hit anything (like a mountain)? The best baseball pitchers can throw a baseball about 50 meters per second, so it would take a rocket to put an object in orbit.

NASA astronauts on the Space Station feel weightless. The force of gravity on the astronauts at the Space Station is about nine tenths what it is at the surface of the Earth. Although zero gravity is a catchy phrase, we should really say that the astronauts have nearly zero apparent weight because they are freely falling towards the Earth as they circle it. We could also simply say they are in nearly perfect free fall. Being clear about what you mean is very important to your understanding.

NATIONAL STANDARDS

Mathematics (NCTM) Standards

- Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and when possible, symbolic rules.
- Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations.
- Develop an initial conceptual understanding of different uses of variables.
- Model and solve contextualized problems using various representations such as graphs, tables, and equations.
- Build new mathematical knowledge through problem solving.
- Solve problems that arise in mathematics and in other contexts.
- Organize and consolidate mathematical thinking through communication.
- Communicate mathematical thinking coherently and clearly to peers, teacher, and others.
- Analyze and evaluate the mathematical thinking and strategies of others.
- Use the language of mathematics to express mathematical ideas precisely.

Science (NSE) Standards

- Systems, order, and organization
- Change, constancy, and measurement
- Abilities necessary to do scientific inquiry
- Motions and forces
- Abilities of technological design
- Understandings about science and technology
- Science and technology in society

Technology (ITEA) Standards

Abilities for a Technological World

- Use data collected to analyze and interpret trends in order to identify the positive or negative effects of a technology.

Design

- Some technological problems are best solved through experimentation.

Nature of Technology

- Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

INSTRUCTIONAL OBJECTIVES

The student will
- apply appropriate techniques to determine measurements.
- use metric measurement.
- build new mathematical knowledge through investigation and experimentation.
- collect, organize, and graph data for analysis.
- build an understanding of microgravity.

VOCABULARY

acceleration – the rate at which velocity changes

free fall – not constrained by any forces other than gravity

force – a push or a pull

gravity – the attractive force between any two objects because of their masses

mass – the physical material that comprises an object

microgravity – a condition in which the effects of gravity are greatly reduced as compared to the effects experienced on Earth

velocity – a measure of how quickly an object's position is changing

weight – the measure of the force of gravity on an object

PREPARING FOR THE ACTIVITY

Student Materials (3 per student group)

1 ball – select a soccer ball, basketball, softball, tennis ball, golf ball, or raquetball

Data Collection Chart (p. 11)

2 Data Drop Charts (overhead) (p.12)

overhead marker (different colors for each group)

pencil

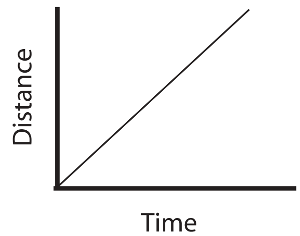
stopwatch

calculator

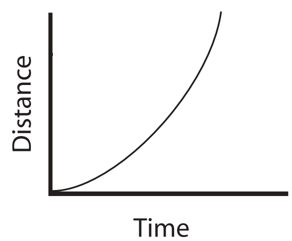
Teacher Materials

Graphing techniques are helpful in understanding the concepts of position, velocity, and acceleration. The following web site provides a great explanation of these concepts:
<http://www.physicsclassroom.com/Class/1DKin/1DKinTOC.html>.
Review the following graphs before conducting the activity.

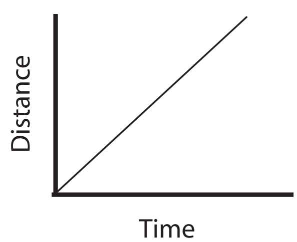
Graph 1: Distance vs. Time
(constant positive velocity)



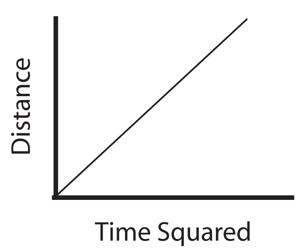
Graph 2: Distance vs. Time
(constant positive acceleration)



Graph 3: Velocity vs. Time
(constant positive acceleration)



Graph 4: Distance vs. Time Squared
(constant positive acceleration)



Graphs 2, 3, and 4 assume the object starts from rest.

Time

Discussion of the activity	10 minutes
Preparing for the activity	5 minutes
Conducting the activity	30 minutes

Teacher Demonstration

1. Select two objects from the classroom such as a pencil and a textbook.
2. Hold both out and drop them simultaneously to show that both objects will hit the floor at the same time even though they are of different masses.
3. Repeat the demo with an eraser and the textbook and then with the eraser and the pencil.

Focus Questions

1. What is the difference between mass and weight? Do you think one will have a greater effect on the experiment than the other?
2. What is free fall? How is it related to microgravity?
3. How do the gravitational pull of the Earth and the gravitational pull of the Moon differ in the way they affect your body?

Advance Preparation

1. Select a location for the drops. A set of bleachers provides a good variation in heights, without using ladders. See Figure 1.

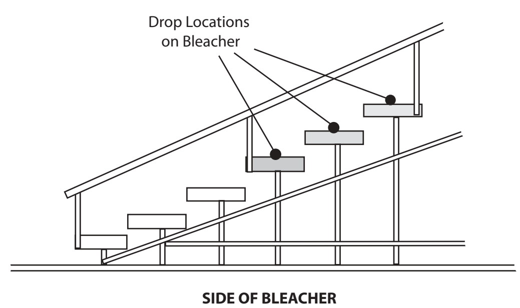


Figure 1

2. Mark the drop heights in even increments, if possible. Eight to ten drop stations create a good graph that students can easily view. Measure each station in meters or inches and use the conversion: 1m = 3.281 ft.
3. Make two overheads of the Data Drop Charts for each group and provide a different colored overhead marker for each group.

THE ACTIVITY

Step 1: Introducing the Activity

A. Organize students into groups of four. Once each group has selected a different ball to use for all their test drops, distribute the student materials.

B. Explain that each student will assume one of four roles as follows:

1. Ball dropper – Hold out the ball at each drop location and release when the retriever/counter says "3, 2, 1, drop. Release on "drop."
2. Timer – Start the stopwatch when the word "Drop" is announced. Stop the stopwatch when the ball hits the ground. Announce the time to the recorder and reset the stopwatch.
3. Recorder – Record times on the Data Drop Chart.
4. Retriever/Counter – Return the ball to the dropper and begin the countdown again ("3, 2,1, Drop") when everyone is ready.

Step 2: Conducting the Activity

A. Have the recorder write down the height of each drop station on the Data Collection Chart (p. 11). The teacher will provide this information.

B. Time and record five drops at each drop station. Only the ball dropper should climb to the drop site, with the rest remaining at ground level.

C. Continue the activity until data have been collected at all drop stations.

D. Average the times for each drop station and record on the Data Collection Chart.

E. Square the average times for each drop station and record.

F. Using height and average time data for each drop station, plot a distance vs. time graph on Data Drop Chart 1.

G. Using height and average time squared data for each drop station, plot a distance vs. time squared graph on Data Drop Chart 2.

Step 3: Analysis

A. Collect the Data Drop Charts from each group.

B. Compare the data on Data Drop Chart 1 for each ball and discuss the shape the data points create. See example of graphs in teacher material.

C. Overlay all Data Drop Chart 1 transparencies to compare the data simultaneously.

D. Compare the data on Data Drop Chart 2 for each ball and discuss the shape the data points create. See example of graphs in teacher material.

E. Overlay all Data Drop Chart 2 transparencies to compare the data simultaneously.

Step 4: Discussion

A. Based on your observations, predict what will happen to the acceleration if the object is dropped from a greater height?

B. Did the shape or surface of the object dropped have any effect on the results? Explain.

C. What other factors might influence the results of the experiment?

D. Predict what you would observe if you could do this experiment on the International Space Station.

Extensions

1. Enter the average time and distance into the graphing calculator and graph the results in a scatter plot. Have students determine the line of best fit.
2. Enter the average time squared and distance information into a graphing calculator and graph the results in a scatter plot. Have students determine the line of best fit.
3. Choose a variety of objects, repeat the experiment, and graph the results.
4. Using the data collected, find the acceleration due to gravity using the formula $a = 2d / t^2$.

Student Worksheets

Name : ______________________________ Date: ______________

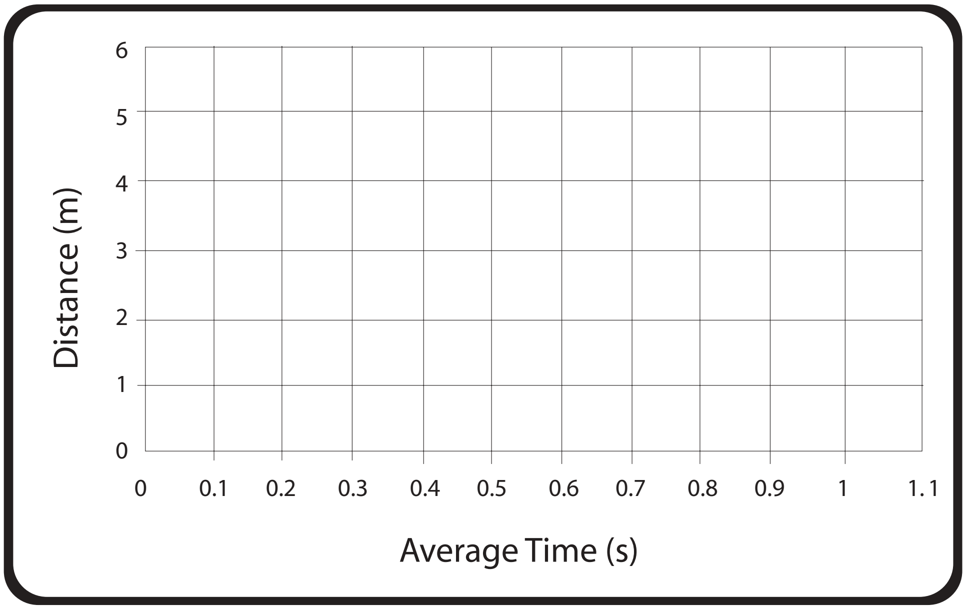
DATA COLLECTION CHART

Height	Distance (m)	Time One (s)	Time Two (s)	Time Three (s)	Time Four (s)	Time Five (s)	Average (s)	Average Time Squared (s^2)
One								
Two								
Three								
Four								
Five								
Six								
Seven								
Eight								
Nine								
Ten								

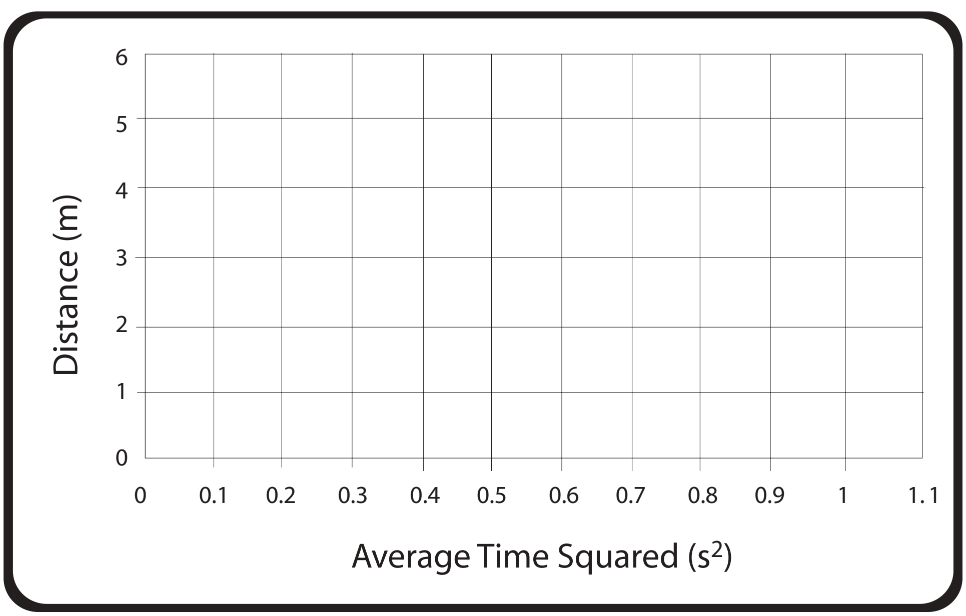
Student Worksheets

Name : ______________________________ Date: ______________

Data Drop Chart 1



Data Drop Chart 2



Name: ______________________________
Date: ______________________________

Cue Cards

Dr. Sandra Olson, Microgravity Combustion Scientist, NASA Glenn Research Center

1. How do fires in space spread differently than on Earth?

   ____

2. From the position vs. time graph, what type of relationship exists for the flamelets?

   ____

3. What does the slope of a position vs. time graph give you?

   ____

Dr. John Pojman, Professor, Department of Chemistry and Biochemistry, University of Southern Mississippi

1. What is buoyancy-induced convection?

   ____

2. What is the relationship between density and volume?

   ____

3. What is the trend in the Density vs. Temperature graph?

   ____

Teacher Materials

Cue Cards

Dr. Sandra Olson, Microgravity Combustion Scientist, NASA Glenn Research Center

1 How do fires in space spread differently than on Earth?

Possible Answer: In space, fires like to spread against the wind, while wildfires on Earth are blown by the wind. Since hot air doesn't rise in a microgravity environment, the only flows in an orbiting spacecraft are due to ventilation fans, cooling fans, or crew movements.

2 From the position vs. time graph, what type of relationship exists for the flamelets?

Possible Answer: A linear relationship

3 What does the slope of a position vs. time graph give you?

Possible Answer: The slope of a position vs. time graph indicates the velocity of an object, in this case the fire.

Dr. John Pojman, Professor, Department of Chemistry and Biochemistry, University of Southern Mississippi

1 What is buoyancy-induced convection?

Possible Answer: Convection is the term for liquid motion. Buoyancy-induced convection is caused by gravity. Differences in the density of the liquid make the lighter fluid rise – we understand this when we say, "heat rises". What we really mean is that hot air is lighter than cold air and so it floats up.

2 What is the relationship between density and volume?

Possible Answer: There is an inverse relationship between density and volume.

3 What is the trend in the Density vs. Temperature graph?

Possible Answer: As the temperature increases, the density decreases.

Free Fall Web Activity

This activity uses a free, exciting, multimedia, object-oriented programming environment called Squeak that runs on 25 different computer platforms. You can download the plug-in for Squeak at www.squeakland.org and then double-click the downloaded icon for easy installation. Once you have the Squeak plug-in installed, you can access the activity at http://connect.larc.nasa.gov/dansdomain.html using either IE or Netscape as a browser. Once the activity loads, click on the orange tab at the left, labeled Navigator, to make it pop up and then click on Escape Browser to remove the browser controls so you have more room. Also click the Navigator tab shut for more room. This activity is designed for use by students, teachers, and parents in the school or home setting. Now you are ready to start the activity.

The purpose of this activity is to investigate apparent weight and to see how astronauts in space can feel "weightless". If their apparent weight is zero, then they feel "weightless." Norbert and Zot are waiting in an elevator for you to investigate what happens when you accelerate the elevator. Velocity is the distance traveled divided by the time it takes. Acceleration is the change in velocity. If the velocity of the elevator moves Norbert and Zot downward, we say their velocity is a positive number, and if the velocity of the elevator moves Norbert and Zot upward, we say their velocity is a negative number. Similarly, if you increase the velocity in the downward direction, we will say the acceleration is a positive number, but if you increase the velocity in the upward direction, we will say the acceleration is a negative number. Positive and negative numbers are essential to describe motion. If these ideas are confusing, there are definitions and activities for you in the active book on the right side of your screen to help you understand the concepts.

If you are a hands-on type and want to try doing something on your own at first, read the brief directions along the left side and start by trying to make Norbert and Zot weightless. Next you should read the active book on the right for important definitions, brief interactivities, explorations you should do, and challenges you should consider. If you want more direction before you start, begin by reading the book starting with the first page and click the little right arrow at the top center to go on.

The developer of Squeak is a great believer that you learn through play. Squeak is challenging play. Have fun and explore.

NATIONAL STANDARDS

Mathematics (NCTM) Standards

• Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and when possible, symbolic rules.

• Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations.

• Develop an initial conceptual understanding of different uses of variables.

• Model and solve contextualized problems using various representations such as graphs, tables, and equations.

• Build new mathematical knowledge through problem solving.

• Solve problems that arise in mathematics and in other contexts.

• Organize and consolidate mathematical thinking through communication.

• Communicate mathematical thinking coherently and clearly to peers, teachers, and others.

• Analyze and evaluate the mathematical thinking and strategies of others.

Science (NSE) Standards

• Abilities necessary to do scientific inquiry

• Motions and forces

• Abilities of technological design

Technology (ITEA) Standards

Abilities for a technological world

• Use data collected to analyze and interpret trends in order to identify the positive or negative effects of a technology.

Design

• Some technological problems are best solved through experimentation.

INSTRUCTIONAL OBJECTIVES

The student will

• understand the concept of free fall and how it affects apparent weight.
• review and solidify concepts of displacement, velocity , acceleration, mass, force, weight, and gravity.
• use graphing skills to analyze and interpret data.
• compare free fall and apparent weight on the Earth to that on the Moon.
• understand how simulations are made from computer programs.

Resources

BOOKS, PAMPHLETS, AND PERIODICALS

American Society of American Engineers: *Heat Transfer in Microgravity Systems: Presentation at 1994 International Mechanical Engineering Congress and Exposition in Chicago*, Illinois, 1994.

Lafferty, *Peter: Force and Motion,* Dorling Kindersley Books, 1992.

Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies, National Academy Press, 1999.

Partin, Beth; *Microgravity*, Livingston Press, 1999.

Videos

Controlled Gravity, 1996

Infinity Series, part 2 – Deep Space: Dance of Gravity

Laws of Gravity, Trese, 1991

WEB SITES

www.microgravity.msfc.nasa.gov

www.microgravity.grc.nasa.gov

www.microgravity.hq.nasa.gov

www.nasakids.com

www.nasaexplorers.com

Figure This

Offers Mathematics Challenges that middle school students can do at home with their families to emphasize the importance of a high-quality mathematics education for all.

http://www.figurethis.org

Engineer Girl

Part of the National Academy of Engineering's Celebrations of Women in the Engineering project. The project brings national attention to the opportunity that engineering presents to people of all ages, but particularly to women and girls.

http://www.engineergirl.org

National Council Teachers of Mathematics

http://www.nctm.org