MICROGRAVITY

A Teacher’s Guide With Activities in Science, Mathematics, and Technology

\[ F = G \frac{m_1 m_2}{r^2} \]
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How To Use This Guide

As opportunities for extended space flight have become available, microgravity research in physical and biological sciences has grown in importance. Using the Space Shuttle and soon the International Space Station, scientists are able to add long term control of gravity's effects to the short list of variables they are to manipulate in their experiments. Although most people are aware of the floating effects of astronauts and things in orbiting spacecraft, few understand what causes microgravity much less how it can be utilized for research.

The purpose of this curriculum supplement guide is to define and explain microgravity and show how microgravity can help us learn about the phenomena of our world. The front section of the guide is designed to provide teachers of science, mathematics, and technology at many levels with a foundation in microgravity science and applications. It begins with background information for the teacher on what microgravity is and how it is created. This is followed with information on the domains of microgravity science research; biotechnology, combustion science, fluid physics, fundamental physics, materials science, and microgravity research geared toward exploration. The background section concludes with a history of microgravity research and the expectations microgravity scientists have for research on the International Space Station.

Following the background information are classroom activities that enable students to experiment with the forces and processes microgravity scientists are investigating today. The activities employ simple and inexpensive materials and apparatus that are widely available in schools. The activities emphasize hands-on involvement, prediction, data collection and interpretation, teamwork, and problem solving. Activity features include objectives, materials and tools lists, management suggestions, assessment ideas, extensions, instructions and illustrations, student work sheets, and student readers. Because many of the activities and demonstrations apply to more than one subject area, a matrix chart relates activities to national standards in science and mathematics and to science process skills.

Finally, the guide concludes with a suggested reading list, NASA educational resources including electronic resources, and an evaluation questionnaire. We would appreciate your assistance in improving this guide in future editions by completing the questionnaire and making suggestions for changes and additions. The evaluation can be sent to us by mail or electronically submitted through the Internet site listed on the form.
Note on Measurement and Format

In developing this guide, metric units of measurement were employed. In a few exceptions, notably within the “Materials and Tools” lists, British units have been listed. In the United States, metric-sized parts such as screws and wood stock are not as accessible as their British equivalents. Therefore, British units have been used to facilitate obtaining required materials.

The main text of this guide uses large print located in a wide column. Subjects relating to mathematics, physical science, and technology are highlighted in bold. Definitions, questions for discussion, and examples are provided in smaller print in the narrow column of each page. Each area highlighted in the text has a corresponding section in the narrow column. This corresponding section first lists applicable Mathematics and Science Content Standards, indicated by grade level: Δ Grades 5–8, □ Grades 9–12. We have attempted to position the appropriate discussion as close as possible to the relevant highlighted text. A key word or phrase in each margin discussion is also highlighted for ease in identifying related text.
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Glossary

**Acceleration**—The rate at which an object’s velocity changes with time.

**Altitude**—Height above Earth’s mean sea level.

**Apparent Weight**—The net sum of all forces acting on a body is its apparent weight.

**Biotechnology**—Any technique that involves the research, manipulation, and manufacturing of biological molecules, tissues, and living organisms to improve or obtain products, or perform specific functions.

**Buoyancy**—Driven Convection Convection created by the difference in density between two or more fluids in a gravitational field.

**Capillarity**—The attraction a liquid has for itself versus the attraction it has for a solid surface, such as the liquid’s container.

**Combustion Science**—The study of the process of burning.

**Concave**—Curved inward like the inner surface of a sphere.

**Convection**—Energy and/or mass transfer in a fluid by means of bulk motion of the fluid.

**Convex**—Curved like the outer surface of a sphere.

**Critical Point**—The temperature at which the differences between liquids and gases disappear. Above that temperature, the liquid smoothly transforms to the gaseous state; boiling disappears.

**Dendrites**—Branching structures that develop as a molten metal solidifies under certain conditions.

**Density**—The mass of a body divided by its volume (average density).

**Differentiation**—The process by which cells and/or tissues undergo a progressive specialization of form or function.

**Diffusion**—Intermixing of atoms and/or molecules in solids, liquids, and gases due to a difference in composition.

**Dopant**—An impurity intentionally added to a pure semiconductor to alter its electronic or optical properties.

**Drop Facility**—Research facility that creates a microgravity environment by permitting experiments to freefall through an enclosed vertical tube.

**Fluid**—Anything that flows (liquid or gas).

**Fluid Physics**—The study of the properties and motions of liquids, gases, and fluid-like solids.

**Force**—An action exerted upon a body in order to change its state, either of rest, or of uniform motion in a straight line.

**Freefall**—Falling in a gravitational field where the acceleration is the same as that due to gravity alone.

**Fundamental Physics**—The study of several physics subfields, including studies where interaction forces are weak, where extremely uniform samples are required, where objects must be freely suspended and their acceleration must be minimized, and where mechanical disturbances that are unavoidably present in Earth-bound laboratories must be eliminated.
G—Universal Gravitational Constant \((6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2)\)

g—The acceleration Earth’s gravitational field exerts on objects at Earth’s surface (approximately 9.8 meters per second squared).

g-jitter—The vibrations experienced by microgravity experiments (for example on parabolic aircraft and the Space Shuttle) that cause effects similar to those that would be caused by a time-varying gravitational field.

Gradient—The variation of a quantity such as temperature with respect to a given parameter, typically distance, \(^°\text{C}/\text{cm}\).

Gravitation—The attraction of objects due to their masses.

Homogeneous—Uniform in structure and/or composition.

Immiscible—The situation where two or more liquids do not mix chemically.

Inertia—A property of matter that causes it to resist changes in velocity.

Joule Heating—Heating a material by flowing an electric current through it.

Law of Universal Gravitation—A law stating that every mass in the universe attracts every other mass with a force proportional to the product of their masses and inversely proportional to the square of the distances between their centers.

Materials Science—The study of developing quantitative and predictive relationships between the processing, structure, and properties of materials.

Microgravity \((\mu\text{g})\)—An environment in which the apparent weight of a system is small compared to its actual weight (due to gravity).

Morphology—The form and structure of an object.

Nucleus—A source upon which something, such as a crystal, grows or develops.

Quasi-steady Acceleration—Accelerations in spacecraft related to the position in the spacecraft, aerodynamic drag, and vehicle rotation.

Regolith—A layer of powder-like dust and loose rock that rests on bedrock. In the case of the moon, fragmentation of surface rocks by meteorite bombardment created much of the regolith material.

Rheology—The scientific study of the deformation and flow of matter.

Satellite—A natural or man-made object that orbits a celestial body.

Semiconductor—A substance, such as germanium and silicon, that is a poor electrical conductor at room temperature but is improved by minute additions of certain substances (dopants) or by the application of heat, light, or voltage; a material with a forbidden energy gap less than 3 eV.
**Skylab**—NASA's first orbital laboratory that was operated in 1973 and 1974.

**Spacelab**—A scientific laboratory developed by the European Space Agency that is carried into Earth orbit in the Space Shuttle's payload bay.

**Speed**—The magnitude of velocity.

**Surfactant**—A substance added to a liquid to change its surface tension.

**Velocity**—The rate at which the position of an object changes with time; it is a vector quantity.

**Weight**—The weight of an object is the gravitational force exerted on it by Earth.
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## Activity Matrix

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