How to Demonstrate Microgravity in your Classroom

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Contents

- Physics of microgravity
- Where can you find microgravity?
- Microgravity Educators Resources
- Microgravity Demonstrator Devices

MICRO- gravity

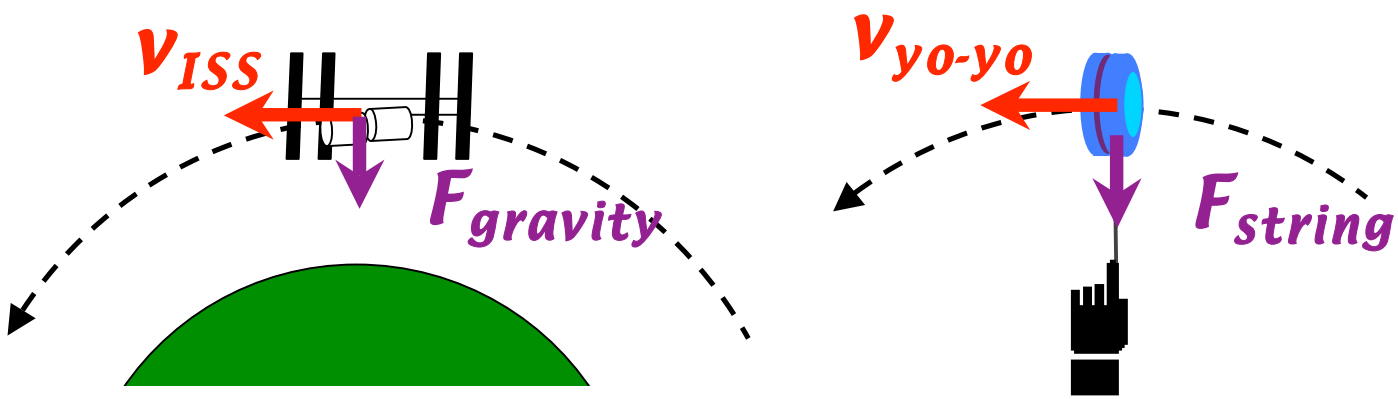
Physics of microgravity

- Microgravity is due to a free-fall condition
  - Gravitational effects are due to restraining forces which stop an item from falling
  - During free-fall, restraining forces are drastically reduced
- It is NOT zero-gravity nor 0-g
  - g-force at ISS altitudes is about 90% of 1-g

REMEMBER, IT'S ALL RELATIVE

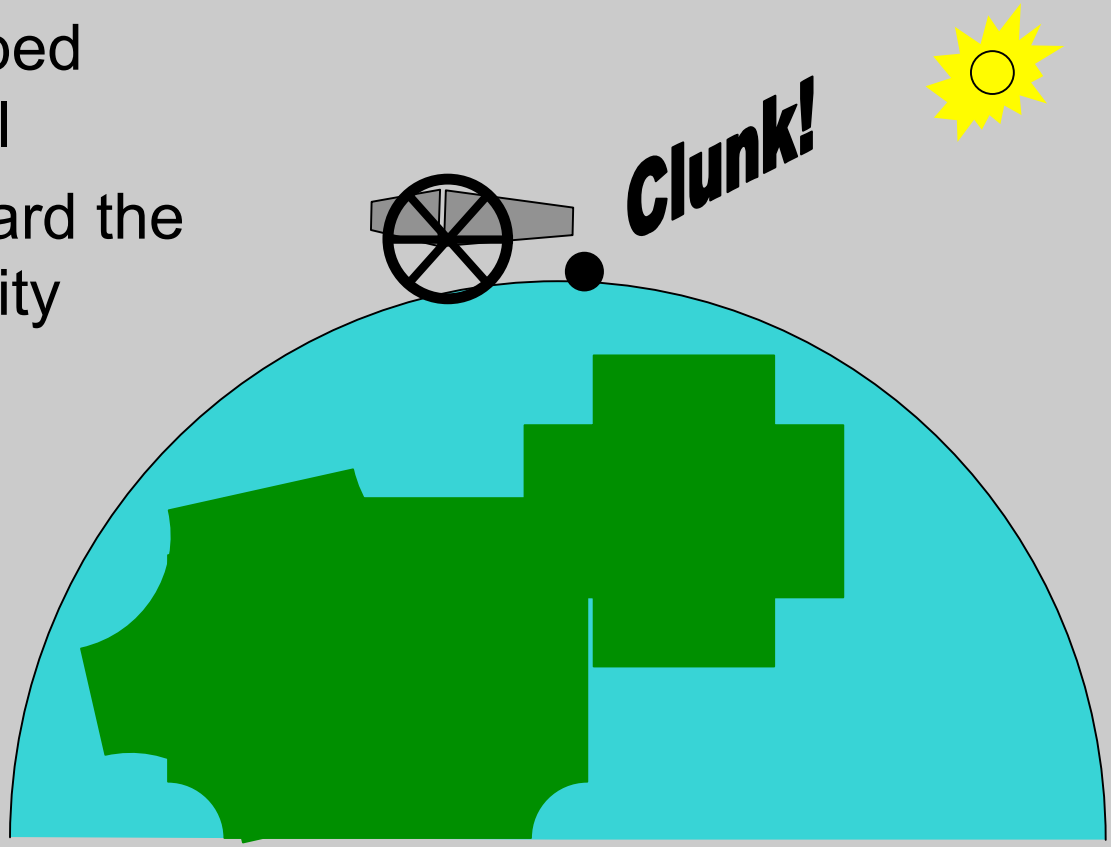
Physics of microgravity

- It is NOT a balance of forces
  - The g-force acts on the ISS and its contents to maintain a circular orbit
    - Like swinging a yo-yo around your hand
    - String acts as gravity
  - If it were 0-g, the ISS would sail off into space!
    - As the yo-yo does when you let go of the string



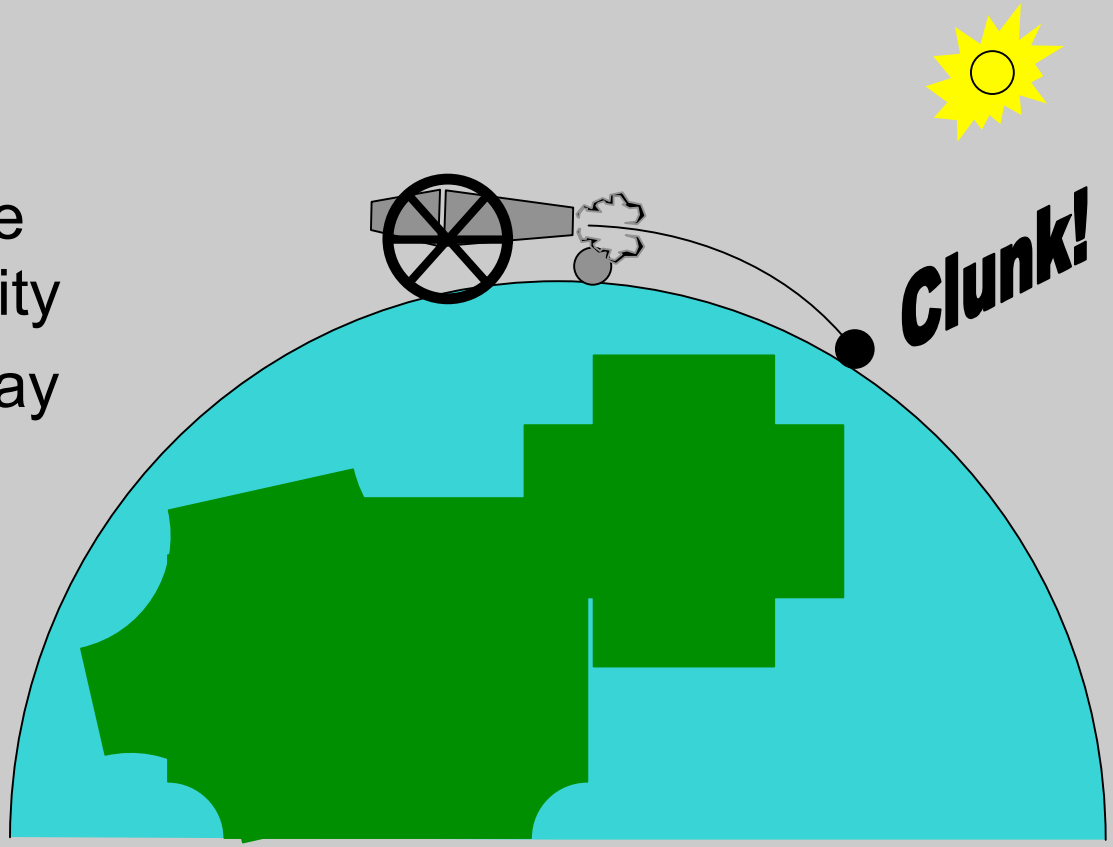
Falling Straight Down

- Cannonball dropped from end of barrel
- Falls straight toward the Earth due to gravity



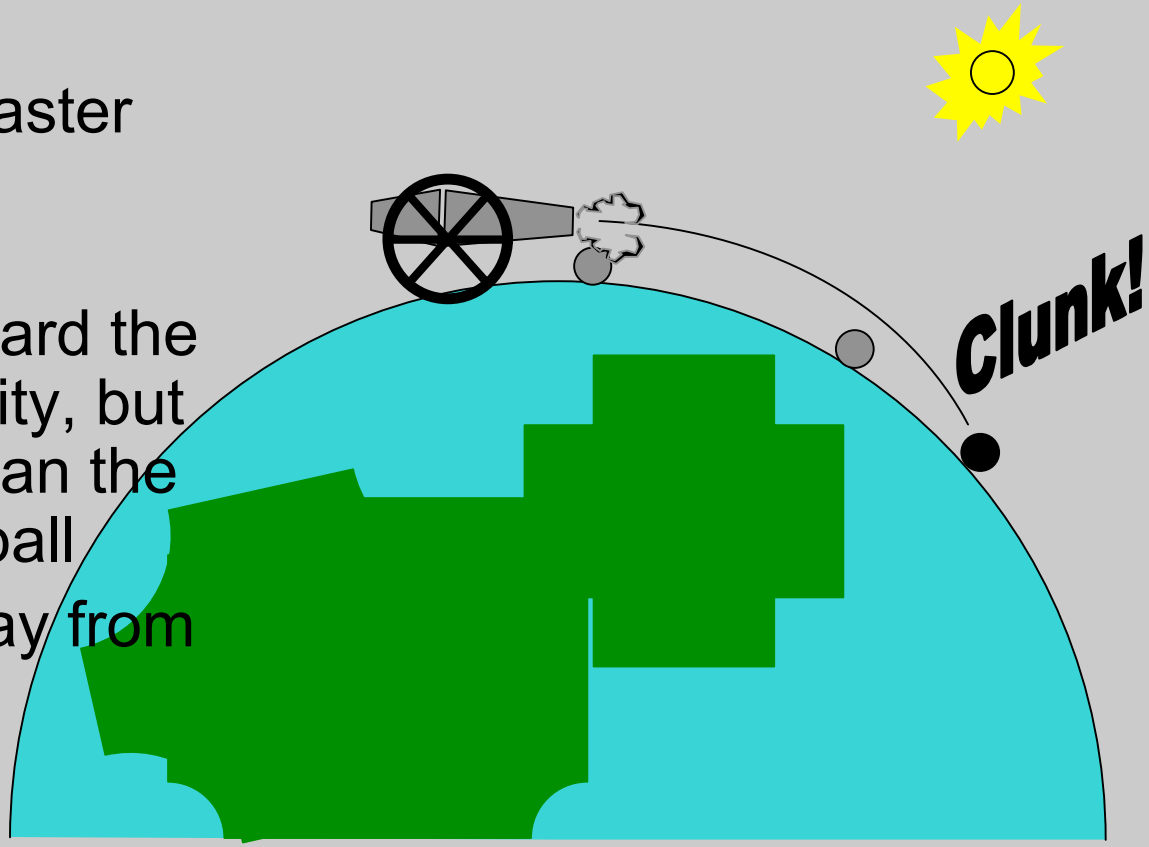
Falling Sideways

- Cannonball shot horizontally
- Curves toward the Earth due to gravity
- Hits the Earth away from the cannon



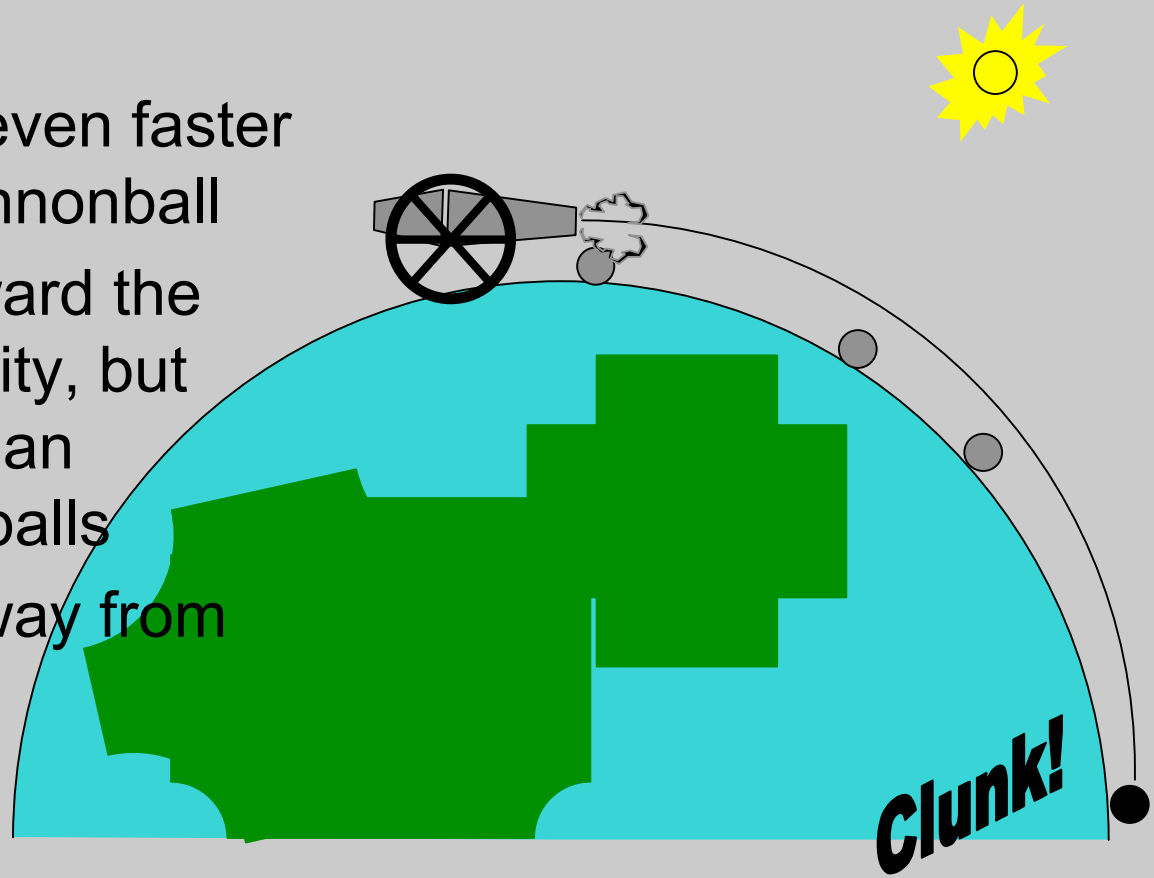
Falling Sideways

- Cannonball shot horizontally, but faster than the previous cannonball
- It also curves toward the Earth due to gravity, but more gradually than the previous cannonball
- Lands farther away from cannon



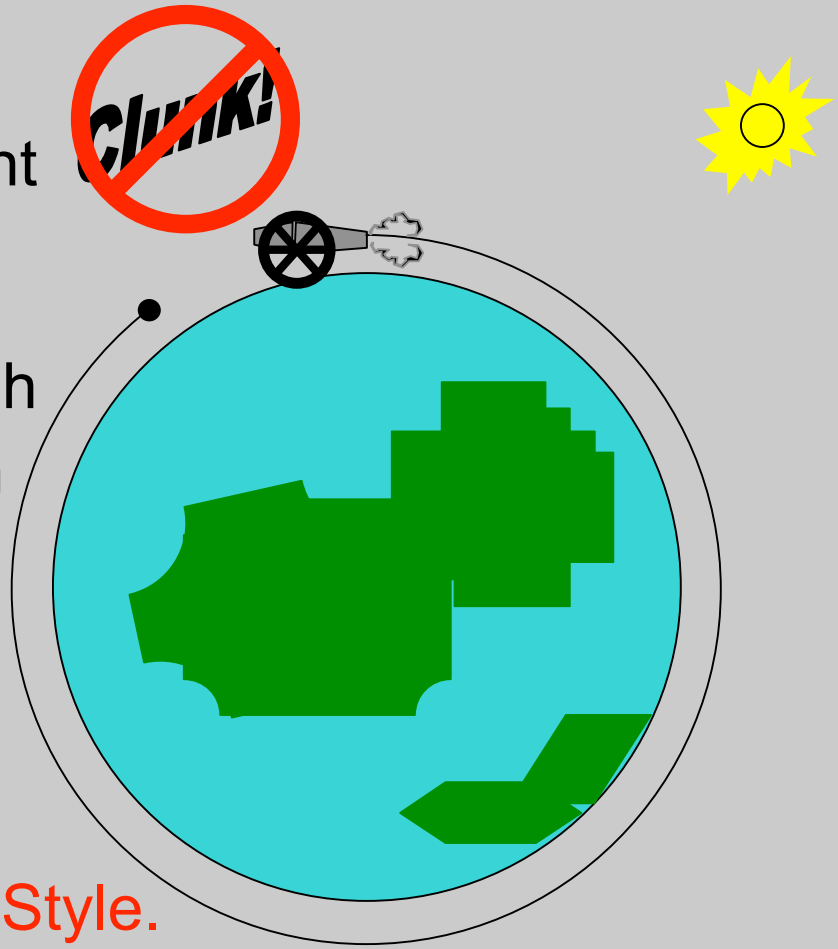
Falling Sideways

- Cannonball shot horizontally, but even faster than previous cannonball
- It also curves toward the Earth due to gravity, but more gradually than previous cannonballs
- Lands farthest away from cannon



Falling with Style

- Cannonball shot horizontally at just the right speed falls with the curvature of the Earth
- Speed is about 30,000 kph
- It curves toward the Earth due to gravity, but so gradually, it falls around the Earth
- Voila, ORBIT!



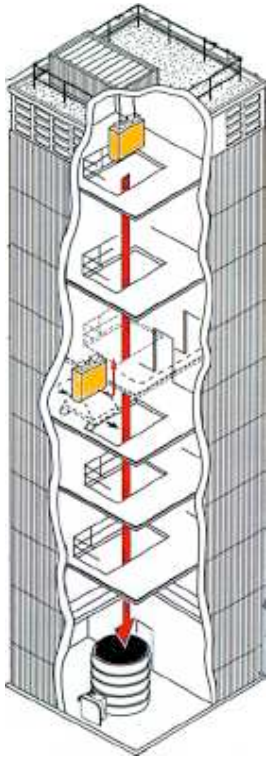
- It's really just Falling with Style.

Falling Straight Down and Falling with Style

- Conceptually the same - accelerating toward the center of the Earth
- Horizontal velocity makes the difference
  - Orbital horizontal speed is about 30,000 km/hr (18,000 mph)
  - Drop tower horizontal speed is 0 km/hr (0 mph)
- So, drop towers can provide free-fall (a.k.a. microgravity conditions) just as ISS does

Where can you find microgravity?

- NASA utilizes microgravity …
  - … in orbit on the ISS.
  - … in orbit on the Shuttle.
  - … in sounding rockets (into space).
  - … in an (airliner-sized) airplane.
  - … in drop towers as ground-based labs.



2.2 Second Drop Tower at NASA Glenn

Microgravity Teacher Resources - SpaceLink -

- Loads of free documentation on SpaceLink web directory
- http://spacelink.nasa.gov
- SpaceLink Index of Microgravity Instructional Materials
- http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Physical.Science/Microgravity/.index.html
- Microgravity Teachers Guide (listed in Microgravity index above)
- http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Physical.Science/Microgravity/Microgravity/.index.html
- Mini-drop Tower Guide (listed in Microgravity index above)
- http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Physical.Science/Microgravity/Microgravity.Demonstrator/.index.html
- Wireless Mini-drop Tower Guide (listed in Microgravity index above)
- http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Physical.Science/Microgravity/Wireless.Drop.Tower.for.Microgravity.Demonstrations/.index.html

Microgravity Teacher Resources - DIME CD-ROM -

- DIME CD-ROM
  - Dropping In a Microgravity Environment high-school-student science competition
  - DIME CD-ROM available by e-mail request to: dime@grc.nasa.gov
  - Teacher Resources link on main page
  - Variety of resources included in directories on CD, examples:
    - Microgravity Teachers Guide
      - CD-ROM/ Teachers_Guides_Resources/MicrogravityTeachersGuide.pdf
    - 2.2 Second Drop Tower tour videos
      - CD-ROM/DT_Realplayer_Videos/droptowertourvideos/56_015.rm
    - Helium balloon in microgravity
      - CD-ROM/Extras/HeliumBalloonYellow_Full.mov

Microgravity Teacher Resources - Additional Items -

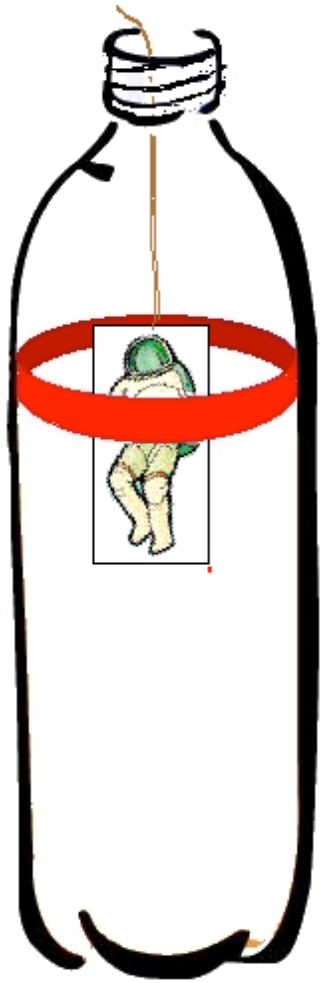
- Informal Web Page of Amusement Park Physics products
  `http://microgravity.grc.nasa.gov/physicsday/index.html`
  - Acceleration match game for amusement park rides
  - NASA drop tower height comparison with amusement park rides
  - NASA microgravity aircraft comparison with roller coasters
  - Middle school teachers guide
    - *Amusement Park Physics with a NASA Twist*
- NASA educational products available for free
  - Contact a local NASA Educator Resource Center (ERC) from an on-line list:
  - `http://www.nasa.gov/audience/foreducators/k-4/contacts/ERCN_State_Listing.html` <-- put all that on one line
- NASA educational products available for a nominal fee ($$)
  - Central Operation of Resources for Educators (CORE) catalog has more than 200 NASA produced videocassette, slide, and CD-ROM programs available for a minimal charge.
  - `http://core.nasa.gov/`

Microgravity Demonstration Devices - Simple -

- Astronaut in a bottle
  - Description on next page
- Leaky water bottle or can
  - Activity sheet and explanation are included here
  - Alternative activity sheet on page 87 of *Microgravity Teachers Guide*
- Balloon popper
  - Activity sheet and explanation are included here
  - Alternative activity sheet on page 84 of *Microgravity Teachers Guide*

Astronaut in a bottle

- Equipment
  - 2-liter clear plastic bottle
  - Cardboard astronaut
  - String
- Procedure
  - Draw broad stripe around bottle
  - Attach string to cardboard astronaut
  - Hold string in neck of bottle so astronaut is even with the line
  - First, release just the string and hold the bottle
    - Observe astronaut falling to bottle bottom
  - Then, reset and release string and bottle together
    - Observe astronaut falling with bottle during drop
- Astronaut is 'floating' in falling bottle just as real astronauts 'float' in ISS
  - Both cases are examples of free-fall

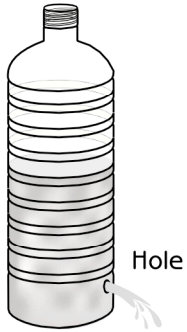


cutout

Leaky water bottle

Before drop/toss

Clear plastic bottle, small hole at bottom, filled with water, and no cap.



1. Why does the water flow out the hole before the bottle is dropped or tossed?

_____

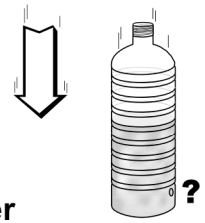
_____

_____

_____

2. When the water bottle is *dropped* the flow of water:

a) becomes faster
b) stays the same
c) becomes slower
d) stops



Explain why the flow of water behaves this way.

_____

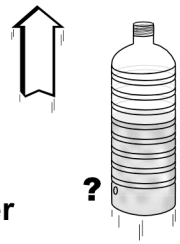
_____

_____

_____

3. When the water bottle is *tossed upward* the flow of water:

a) becomes faster
b) stays the same
c) becomes slower
d) stops



Explain why the flow of water behaves this way.

_____

_____

_____

_____

4. What is meant by 'free-fall'?

_____

_____

_____

_____

5. What do freely falling objects experience?

_____

_____

_____

_____

Leaky water bottle - explanation

▪**Why does the water flow out of the hole before the bottle is dropped or tossed?**

A hand exerts a force on the bottle to stop it from falling. The rigid bottle then exerts a force on the water to stop it from falling. Being a liquid, the water squirts through the hole due to the gravity force pulling it downward.

▪**When the water bottle is dropped, the flow of water:** **(**d) stops

▪**Explain why the flow of water behaves this way.**

The water is falling due to gravity so it doesn't need to 'sneak' out the hole to fall. The bottle is falling with the water and doesn't exert a force on the water.

▪**What is meant by "free-fall"?**

An object is in free fall when it is accelerating at the rate of gravitational acceleration and without any external retarding or accelerating forces.

▪**When the bottle is tossed upward, the flow of water:** **(**d) stops

(The toss should be smooth so as to not spin or tumble the bottle.)

▪**Explain why the flow of water behaves this way.**

Again, once the bottle and water are free from the hand, they are in free-fall. In this case, there is an initial velocity upwards, but both the bottle and water are falling toward the Earth. (For the short time that the hand accelerates the bottle and water upward, the water flowing out *does* increase, but only until the hand releases the bottle.)

▪**What do freely falling objects experience?**

The force we feel as weight is the retarding force of a floor or chair to keep us from falling. A free-falling object does not have such a retarding force, so it feels 'weightless'.

Try it yourself!

Instructions: (It is best to try this outdoors)

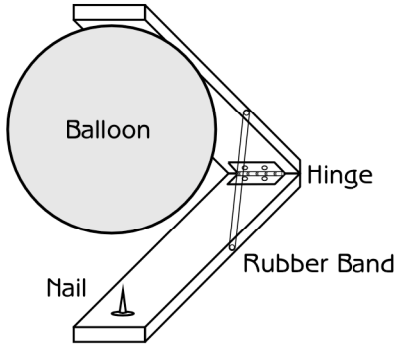
1. Have an adult, with a knife or awl, poke a small circular hole in the side of the bottle, near the bottom.
2. Cover the hole with your thumb and fill the bottle with water.
3. Uncover the hole and the water streams out (with the cap off).
4. Before the water runs out, drop the bottle. Watch whether the water comes out faster, slower, or the same.
5. Refill the bottle, uncover the hole, and toss the bottle straight upward or upward at an angle (while keeping the bottle upright). Again watch the water stream.

Balloon popper

1. **Identify the forces acting on the Balloon Buster just before it is dropped.**

   1) _____
   2) _____
   3) _____
   4) _____
   5) _____

   Hint: There may be less than five forces.



2. **Air resistance has what kind of effect on the falling Balloon Buster?**
   a) Large
   b) Medium
   c) Small
   d) Almost none

3. **When or where in the fall does the balloon pop?**
   a) Right after it is released
   b) Half way down
   c) When it hits the ground or floor
   d) The balloon does not pop

4. **While it is falling, what force causes the Balloon Buster to close?**

   _____
   _____
   _____

5. **Explain why the Balloon Buster does not close before it is dropped.**

   _____
   _____
   _____

Balloon popper - explanation

▪**Identify the forces acting on the Balloon Buster just before it is dropped.**

A hand exerts a force on the top bar to keep the Balloon Buster from falling. Gravitational attraction is exerting a force on the entire apparatus and balloon, pulling them downward. The gravitation force on the lower arm causes it to stretch the rubber band, generating an internal force, which tends to hold the lower arm up.

▪**Air resistance has what kind of effect on the falling Balloon Buster?**

▪ **(**d) almost none because the balloon pops before the apparatus gains any significant speed through the air

▪**When or where in the fall does the balloon pop?**

(a) Right after it is released

The rubber band exerts an internal force which pulls the two arms together. Without the retarding force of the hand holding the upper arm, the rubber band snaps the two arms together, popping the balloon.

▪**While it is falling, what force causes the Balloon Buster to close?**

The internal force caused by the stretched rubber band.

▪**Explain why the Balloon Buster does not close before it is dropped.**

The hand holds the upper arm while gravity pulls the lower arm downward.

Try it yourself!

▪**Build your own Balloon Buster**

The main framework is made from two pieces of hardwood (to withstand repeated drops), a hinge, and two screws. Each hardwood piece is about 5 cm by 2 cm and about 30 cm long. Pins or sharp nails can be held in place with a rubber lab stopper. The balloon neck is held in place with a smooth V-shaped slot or a spring-type clothes pin. A screw is put in the side of the upper and lower arms but not screwed in flush with the wood to provide a place for the rubber band to be inserted. The rubber band should be of sufficient strength when stretched to nearly balance the weight of the lower arm before dropping.

Microgravity Demonstration Devices - Simple -

- Movies
  - Water balloon (on DIME CD-ROM) on KC-135
    - Series of movies are in *movie* folder, first file name: balloo01.mpg
  - Helium balloon (on DIME CD-ROM) in 2.2 Second Drop Tower
    - In *Extras* folder, file name: HeliumBalloonYellow_Full.mov
  - On-orbit crew videos (food, toys, crew actions)
    - Available from ERC and/or CORE
    - Check an ERC video list:
    - `http://www.grc.nasa.gov/WWW/OEP/ERCNlist.htm`
    - Examples:
      - Astrosmiles
      - Physics of Toys in Space
      - Toys in Space II
      - Eating And Sleeping In Space

Microgravity Demonstration Devices - Moderately complicated -

- Accelerometer & data logger
  - Use in the classroom and at amusement park
  - Toss and catch accelerometer - low-g during free fall
  - Attach accelerometer to various drop containers
    - Observe low-g levels for different frontal areas, such as:
      - heavy text book vs. horizontal cardboard
      - Broom handle (straight down) vs. large plywood sheet (sideways)
    - Investigate terminal velocity for falling in air
  - Amusement park rides (see our physics day web site)

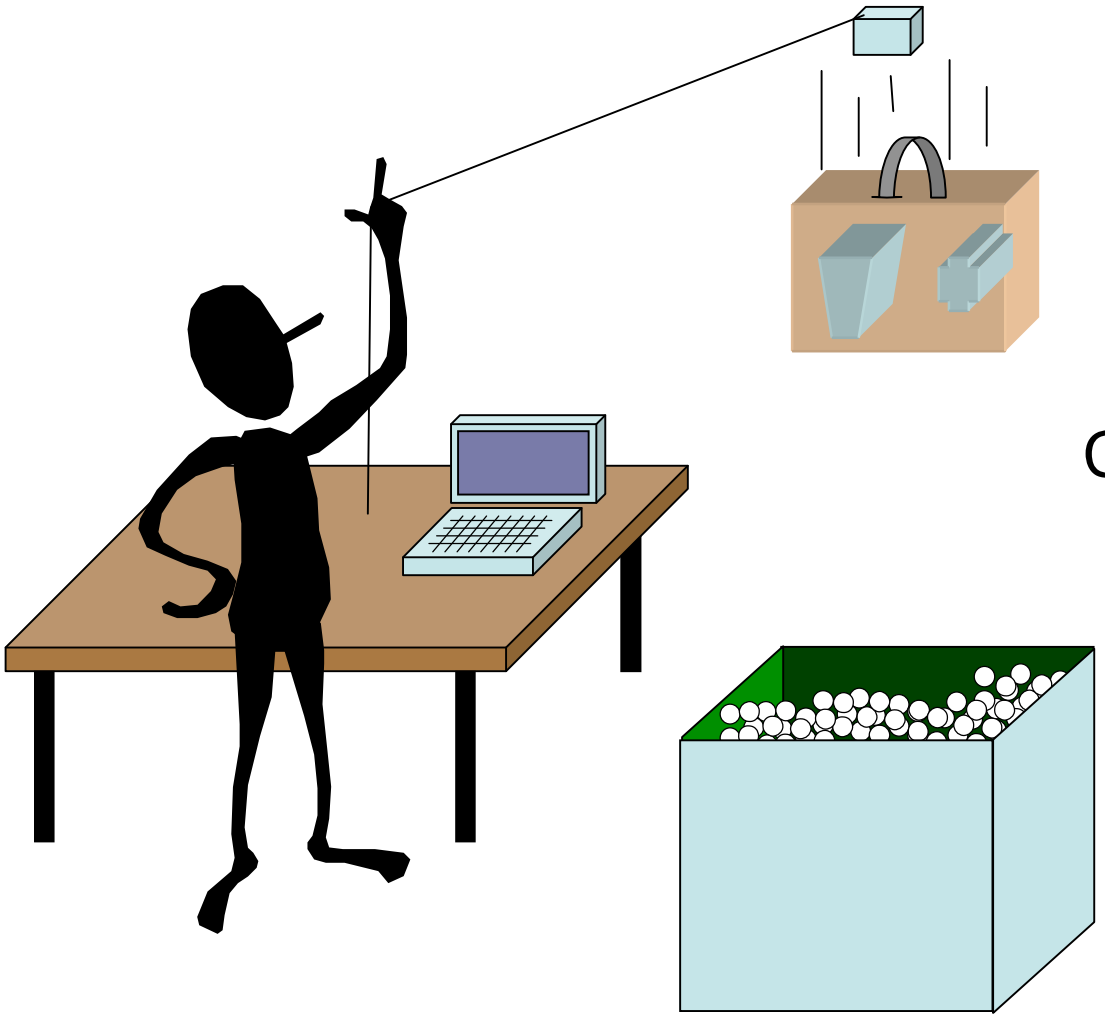
    `http://microgravity.grc.nasa.gov/physicsday/index.html`
    - Free fall conditions (i.e. low-g) on some roller coasters
    - Variety of other accelerations may be observed (e.g. linear, centripetal)
    - Use it safely with positive restraint (vest or waist pack)
  - Example product:
    - Vernier LabPro with 3-axis accelerometer
    - Add barometer for height indication of amusement park rides

Drop into something soft!

Microgravity Demonstration Devices - Advanced -

- Drop tower demonstrator
  - Demonstrates microgravity effects on science
- Versions
  - Original version (See SpaceLink page for teachers guide URL)
    - Compact design for easy transportation and setup
  - Wireless version (See SpaceLink page for teachers guide URL)
    - Inexpensive design with no wires or ropes on carriage
  - Classroom concept (Illustrated on next page)
    - Simple & inexpensive for fixed location
    - May use existing resources for video recording and playback
      - Classroom computers and/or VCR/TV
      - Computer should have video input software, preferably with editing, titling and export functions
      - VCR should have quality slow-motion or single frame motion
    - Video options: board-level camera or X10 camera

Classroom drop tower concept



Gate latch

Experiment carriage with camera

Computer (or VCR/TV)

Packing peanuts

Catch box

Questions?

- Further information is available on-line
  - NASA web pages
    - `http://www.nasa.gov/home/index.html`
    - `http://www.nasa.gov/lb/home/index.html` (slow connections)
    - `http://www.nasa.gov/home/index.html?flash=0` (non-flash version)
  - Microgravity web pages
    - `http://microgravity.nasa.gov`
    - `http://microgravity.grc.nasa.gov`
- Questions about this page may be addressed to the author:
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