# Microgravity in Classrooms and at NASA


**Diane McElwain, Ph.D**

Education Specialist
NASA Glenn Research Center
Cleveland, Ohio

*Presenter*

**Richard DeLombard**
Mr. Microgravity, ltd

Electrical Engineer & Project Manager
Retired from NASA Glenn Research Center
Cleveland, Ohio

# Contents

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

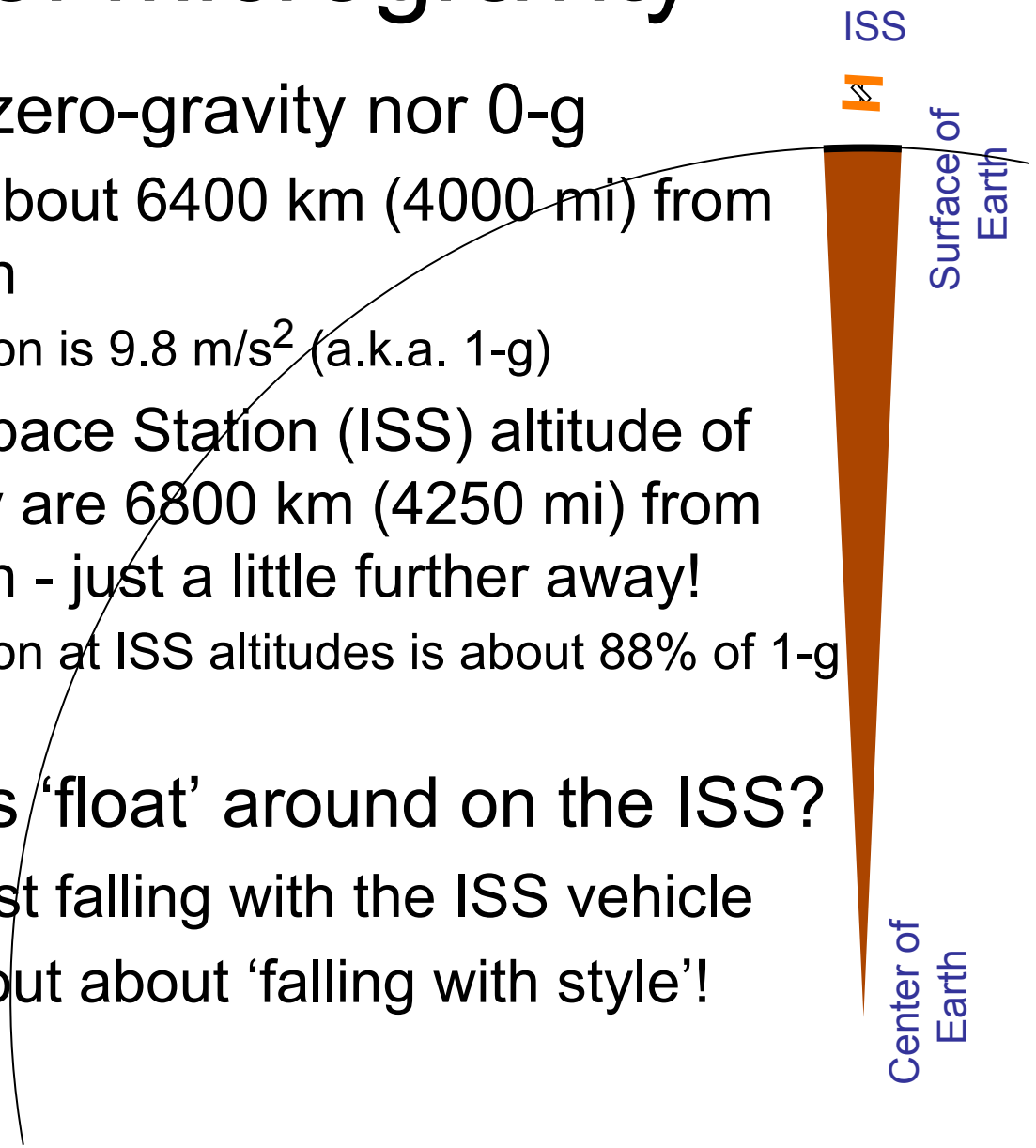
# Physics of microgravity

- Microgravity is due to a free-fall condition
  - Gravitational ***effects*** are due to restraining forces which stop an item from falling
    - The floor stops you from falling by exerting a force on your feet.
    - A bathroom scale shows this force as your weight.
  - In free fall, restraining forces are drastically reduced
    - Everything is falling at the same rate.
    - A person falling with a bathroom scale would not 'weigh' anything as they fall (neglecting air drag).

(She <u>is</u> wearing a parachute for safety.)

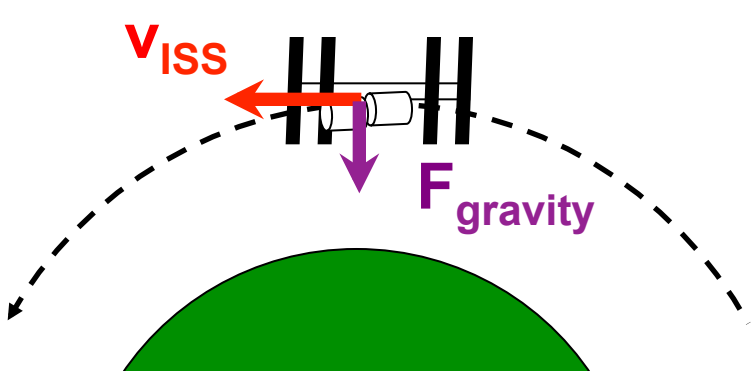
# Physics of microgravity

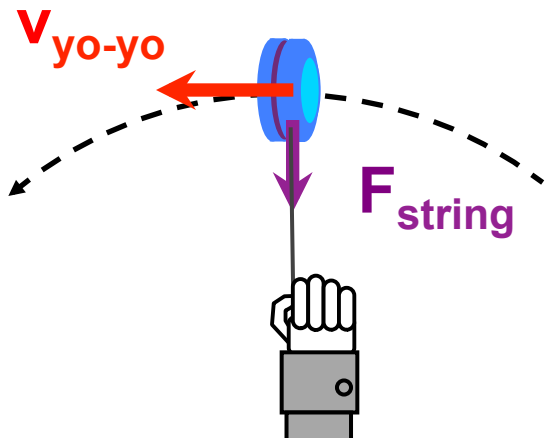
- Microgravity is ***NOT*** zero-gravity nor 0-g
  - At sea-level, we are about 6400 km (4000 mi) from the center of the Earth
    - gravitational acceleration is 9.8 m/s$^2$ (a.k.a. 1-g)
  - At the International Space Station (ISS) altitude of 400 km (250 mi), they are 6800 km (4250 mi) from the center of the Earth - just a little further away!
    - gravitational acceleration at ISS altitudes is about 88% of 1-g or about 8.7 m/s$^2$
- So why do astronauts 'float' around on the ISS?
  - The astronauts are just falling with the ISS vehicle
  - Keep reading to find out about 'falling with style'!



# Physics of microgravity

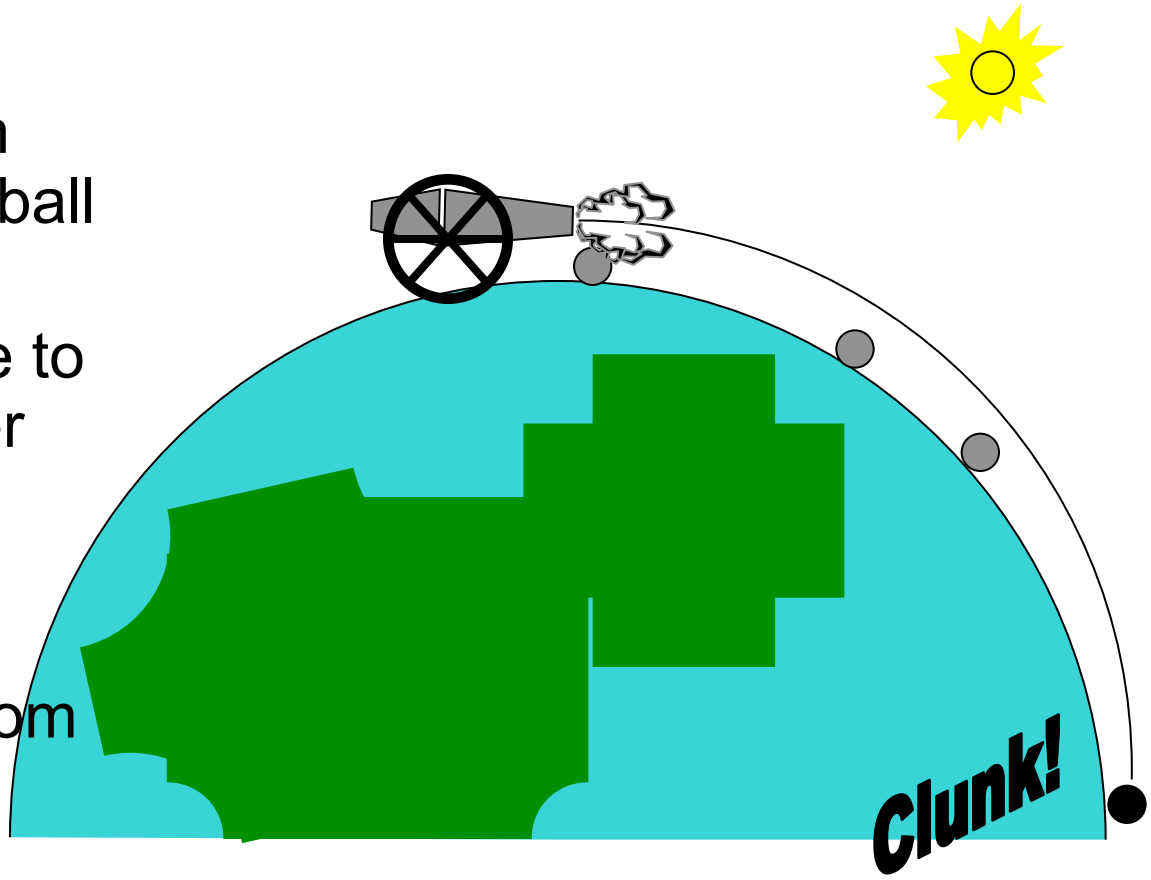
- It is ***NOT*** a balance of forces
  - The gravitational force acts on the ISS and its contents to maintain a circular orbit
    - Like swinging a yo-yo around in a circle
    - String acts as gravity
  - If it were 0-g, the ISS would sail off into space!
    - As the yo-yo does when you let go of the string
    - In classroom, demonstrate with a foam yo-yo or a ball on a string



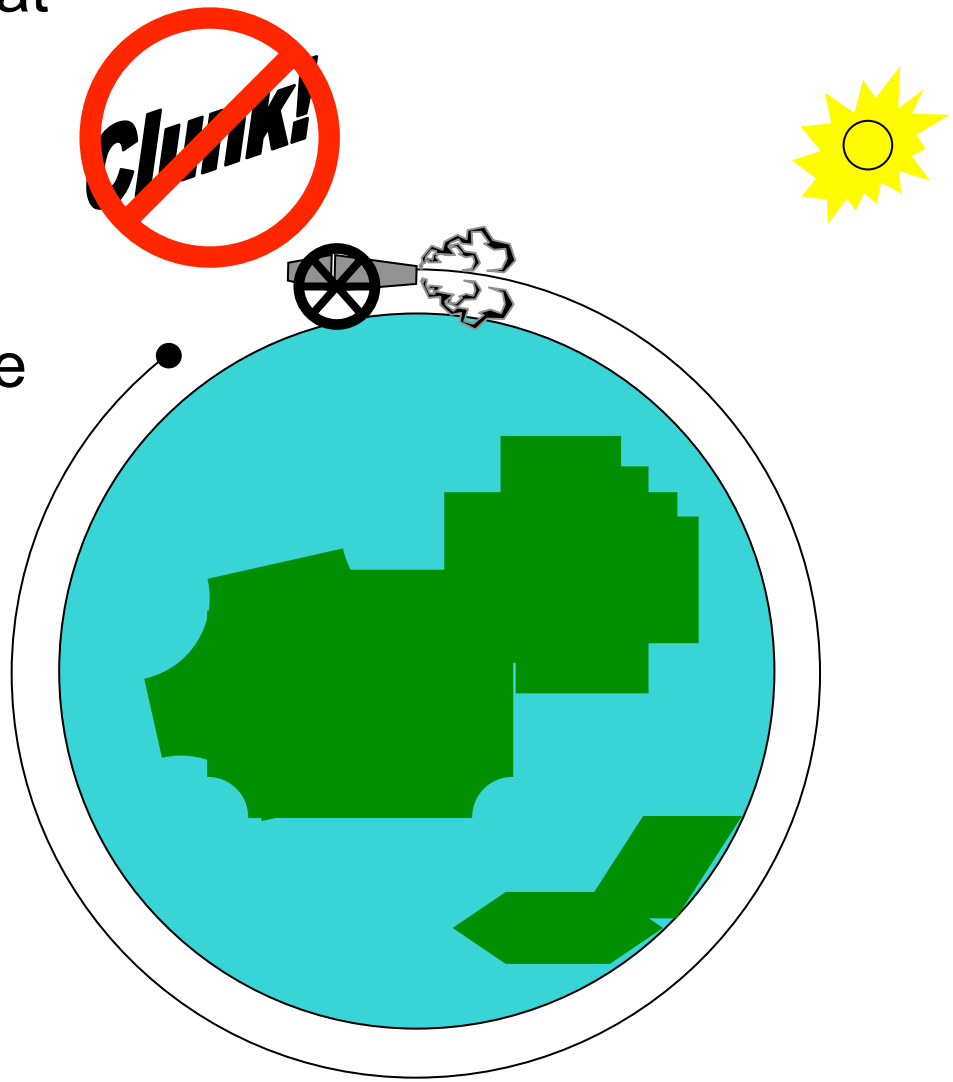
# Falling Sideways

- Cannonballs shot horizontally
- Each one faster than the previous cannonball
- Cannonballs curve toward the Earth due to gravity, but go further than previous cannonballs
- Cannonballs land farther and farther from cannon



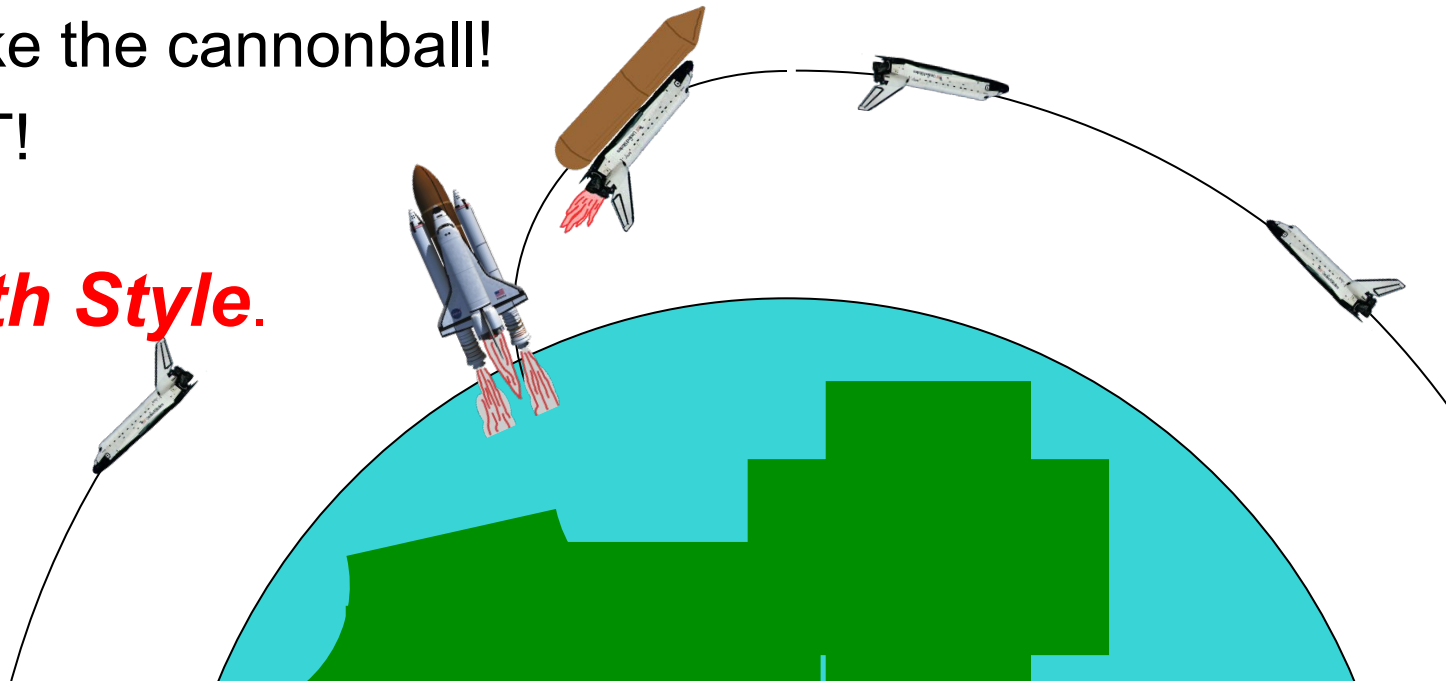
# Falling with Style

- Cannonball shot horizontally at just the right speed falls with the curvature of the Earth
- Speed is about 30,000 km/hr (18,000 mph)
- It curves toward the Earth due to gravity, but so gradually, it falls around the Earth
- Voila, ORBIT!
- It is really just ***Falling with Style***.



# Launching with Style

- Shuttle takes off vertically
- As it climbs, it gradually arcs over and develops the proper orbital speed sideways
- When the engines stop, the Shuttle is falling with the curvature of the Earth, just like the cannonball!
- Voila, ORBIT!
- It is also just ***Falling with Style***.



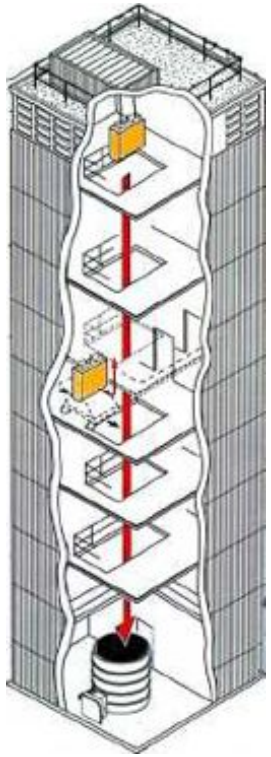
# Falling Straight Down and Falling with Style

- 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

- Falling with style may be demonstrated in your classroom by dropping a foam ball straight down and then throwing it sideways faster and faster

# Where can you find microgravity?

- Microgravity exists …
  - … en route to the moon while coasting.
  - … in orbit on the ISS.
  - … in orbit on the Shuttle.
  - … in sounding rockets (into space).
  - … in an airplane flying a parabolic path.
  - … in drop towers as ground-based labs.
  - … in your classroom.



*2.2 Second Drop Tower at NASA Glenn Research Center*

# Microgravity Demonstration Devices
# - Simple -

- Incredibly Cheap Free Fall Demonstrator
- Astronaut in a bottle
- Leaky water bottle or can
- Magnet Shish-ka-bob
- Balloon popper

- Plus the aforementioned ….
  - Soft yo-yo (or foam ball) on a string
  - Foam ball to drop and throw sideways

# Incredibly Cheap Free Fall Demonstrator

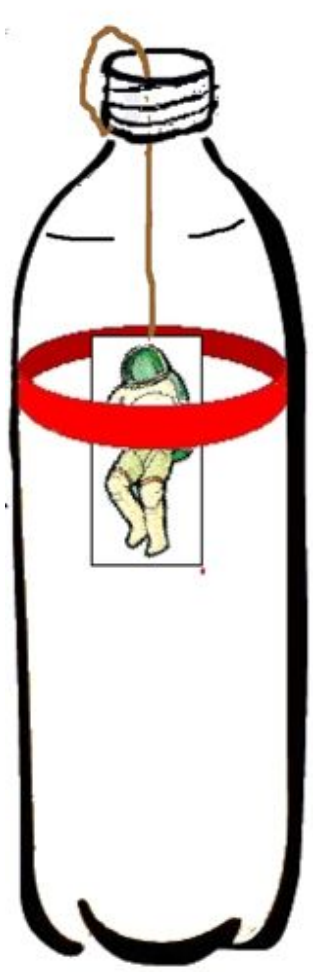
- Equipment
  - Feather
  - Plastic cup
- Procedure
  - Drop the feather first and observe how it falls
  - Put the feather in the bottom of the cup
  - Drop the cup with the feather sitting inside
  - Observe how the feather falls
- Observations during the drops:
  - The feather itself falls slowly to the floor
  - The feather falls with the cup when it's inside the cup
- Why?
  - The feather's low mass (compared with the cup) and large frontal area causes a low terminal velocity due to air drag.
  - When the feather is falling in the cup, it is not exposed to the air going past it. The air surrounding the feather is falling with the feather inside the cup. The cup blocks the air for the feather so the feather falls just as fast as the cup.
  - The cup's mass results in a higher terminal velocity than the feather by itself.

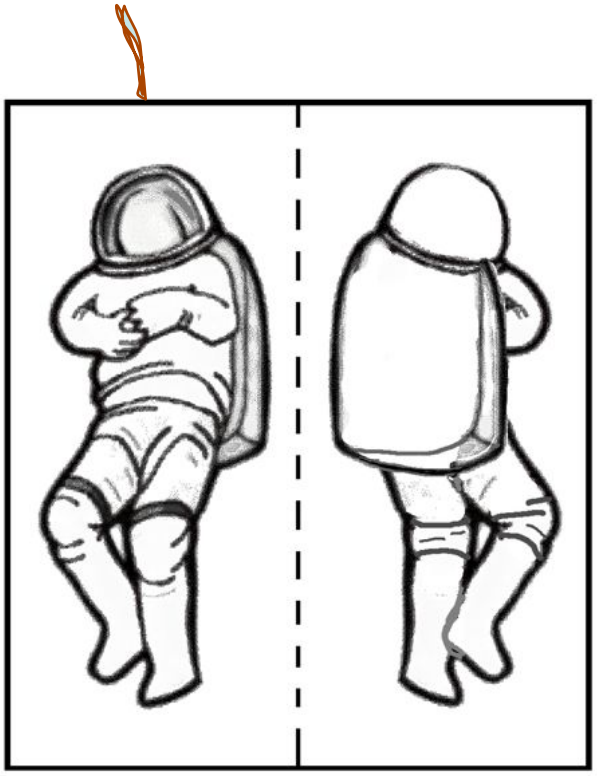
***Gravity makes the feather fall at the same rate as the cup at 9.8 m/s$^2$.***

# Astronaut in a bottle

## Free-fall & ‘weightless’ demo

- Equipment
  - 2-liter clear plastic bottle
  - Colored tape or marker
  - Cardboard astronaut
  - String
- Procedure
  - Draw broad stripe on bottle with tape or marker
  - Attach string to cardboard astronaut
  - Hold string in neck of bottle with a finger so astronaut is even with the line (as shown)
  - 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 the International Space Station (ISS)
  - Both cases are examples of free-fall
  - The ISS, though, is going 30,000 $^{km}/_{hr}$ sideways while it falls around the Earth!





Cut out, fold, and paste with end of string inside.

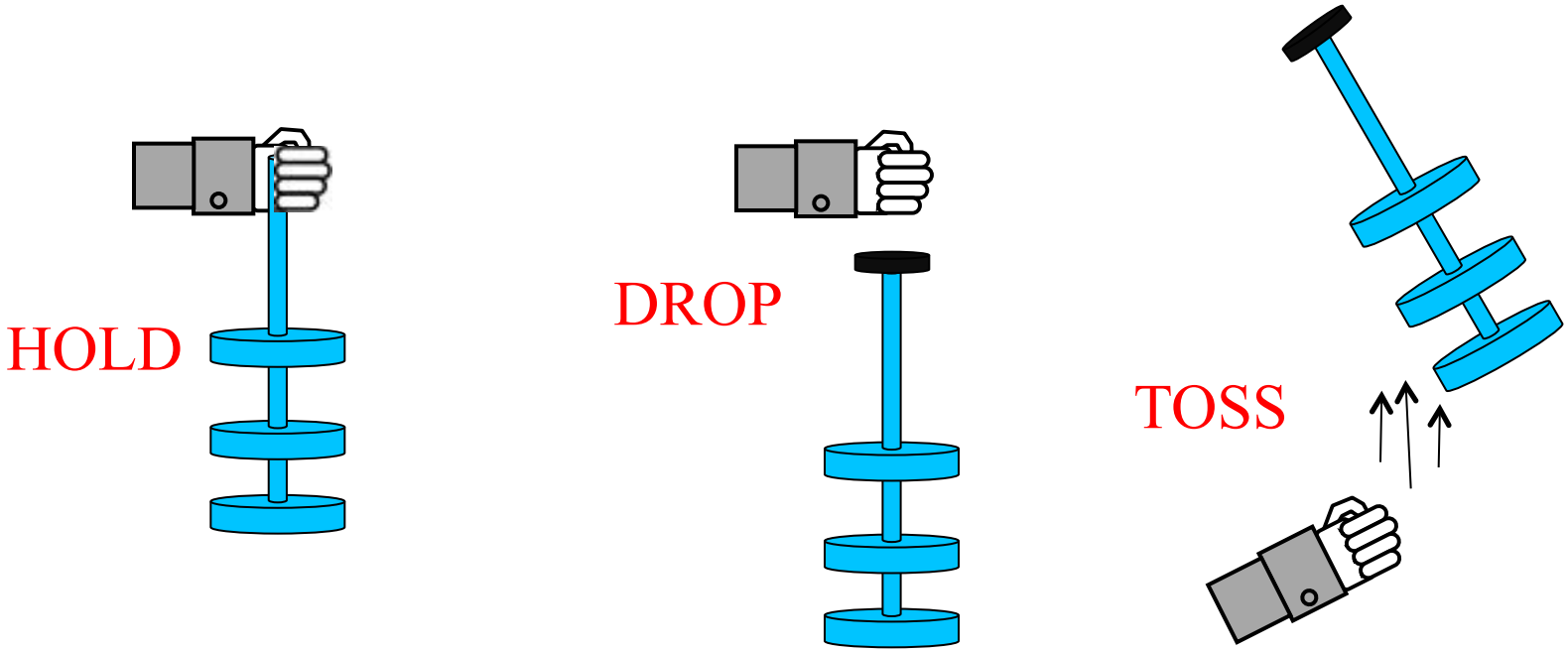
# Leaky water bottle

- Observe the water & stream when bottle is held.
- Release the bottle to fall into the bucket and observe the water stream while falling.
- Toss the bottle straight up (don't spin or tumble) and observe the water stream while falling up and down.


WHAT DOES THE WATER DO? WHAT FORCES ARE THERE?

# Magnet Shish-ka-bob

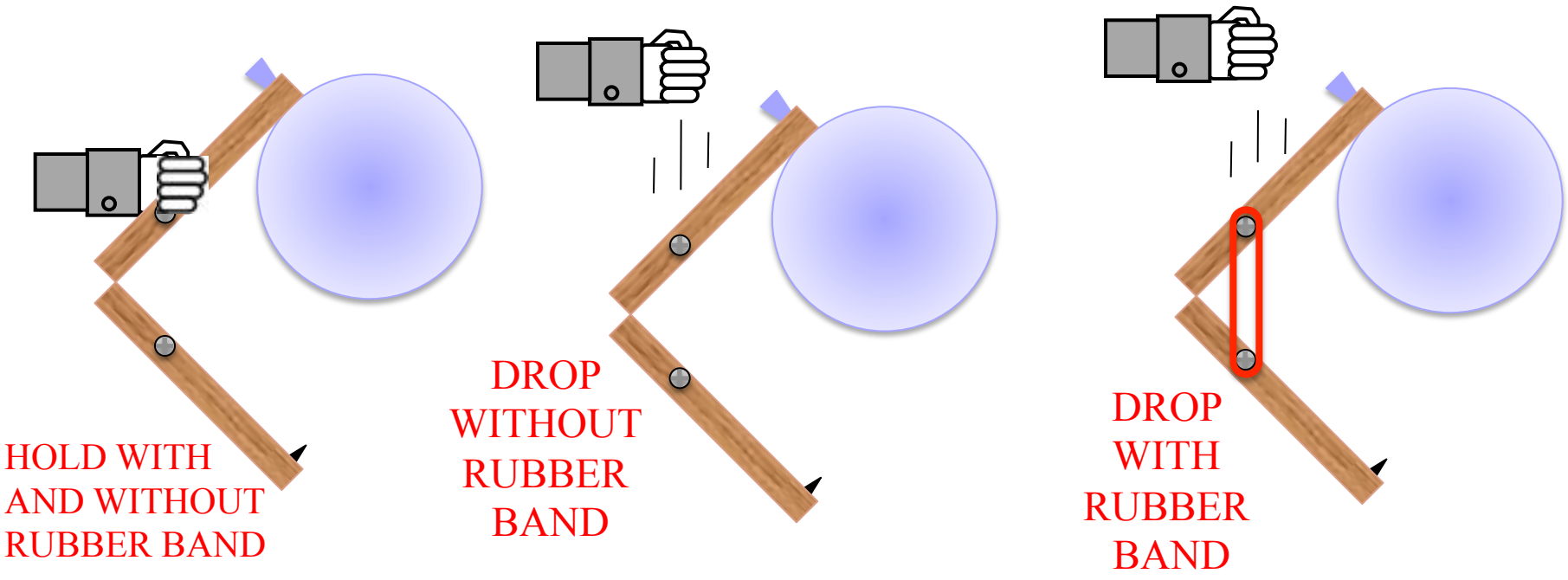
- Hold the rod by the top. Describe the magnet's positions. What forces are involved?
- Release the rod. Observe action of magnets.
- Cradle magnets and rod together in hand and then gently toss the rod and magnets up. Make sure you throw both the rod and magnets. Observe action of magnets.




WHAT DO THE MAGNETS DO? WHY? (Neglect stick mass.)

# Balloon popper

- Hold the balloon popper without a rubber band installed. What forces are involved?
- Release the balloon popper (*catch it before it hits the floor*). Observe action.
- Repeat those two steps WITH rubber band installed. What happens?  Why?



# Microgravity Demonstration Devices - Movies -

- Movies
  - Water balloon in microgravity on DC-9 on-line at:
    `http://spaceflightsystems.grc.nasa.gov/WaterBalloon/`
  - Helium balloon in 2.2 Second Drop Tower on YouTube at:
    `http://tinyurl.com/HeBalloonNASA`
  - On-orbit crew videos (food, toys, crew actions)
    - Available from NASA ERC and/or CORE (see References)
    - 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 informal physics day web site)

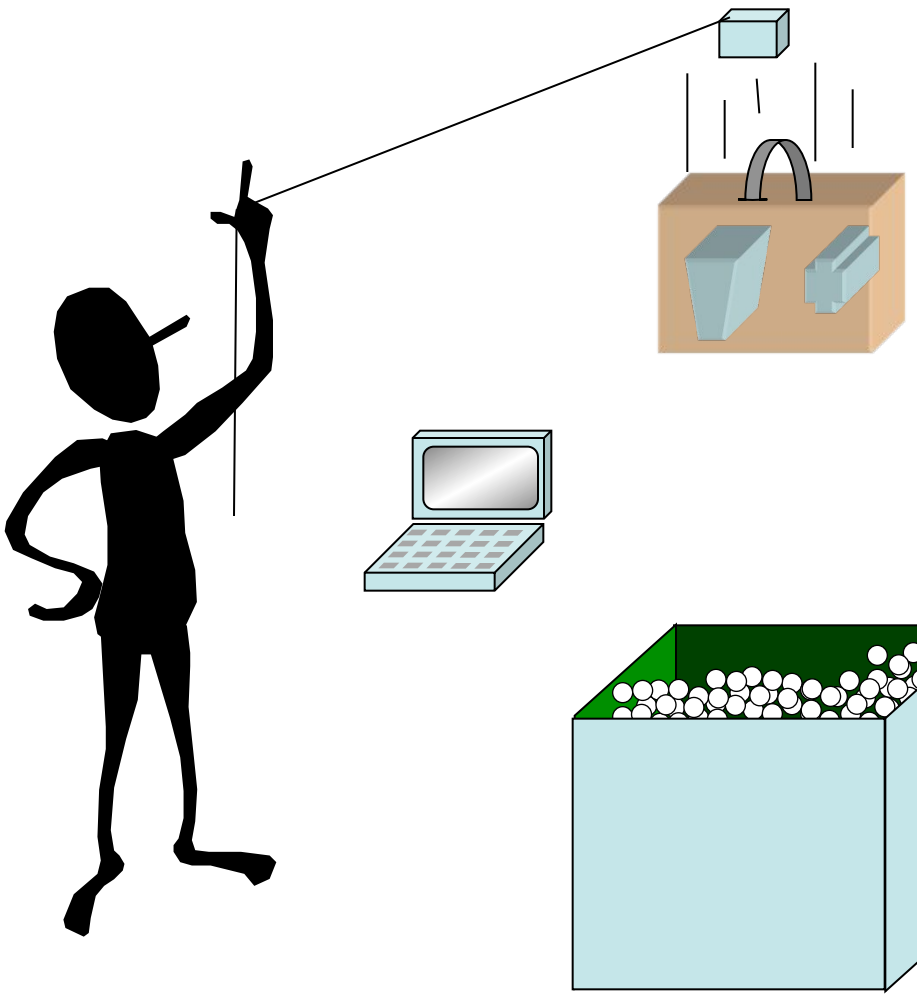
    `http://tinyurl.com/NASAAPPD`
    - Free fall conditions (i.e. low-g) on some roller coasters
    - Variety of other accelerations may be observed (e.g. linear, centripetal)
    - Use it safely with positive restraint (vest or waist pack)
    - Add barometer for height indication of amusement park rides

**Drop into something soft!**

# Microgravity Demonstration Devices
# - Advanced -

- Drop tower demonstrator
  - Demonstrates microgravity effects on science
- Versions
  - Original NASA version
    - Compact, rugged design for easy transportation and setup
  - Classroom version
    - Simple & inexpensive
    - May use existing resources for video recording and playback
      - Classroom VCR/TV and/or computers
      - VCR should have quality slow-motion or single frame motion
      - Computer should have video input and video recording software
      - Camera options: standard digital camera, surveillance camera, or pc-board camera

# Classroom drop tower concept



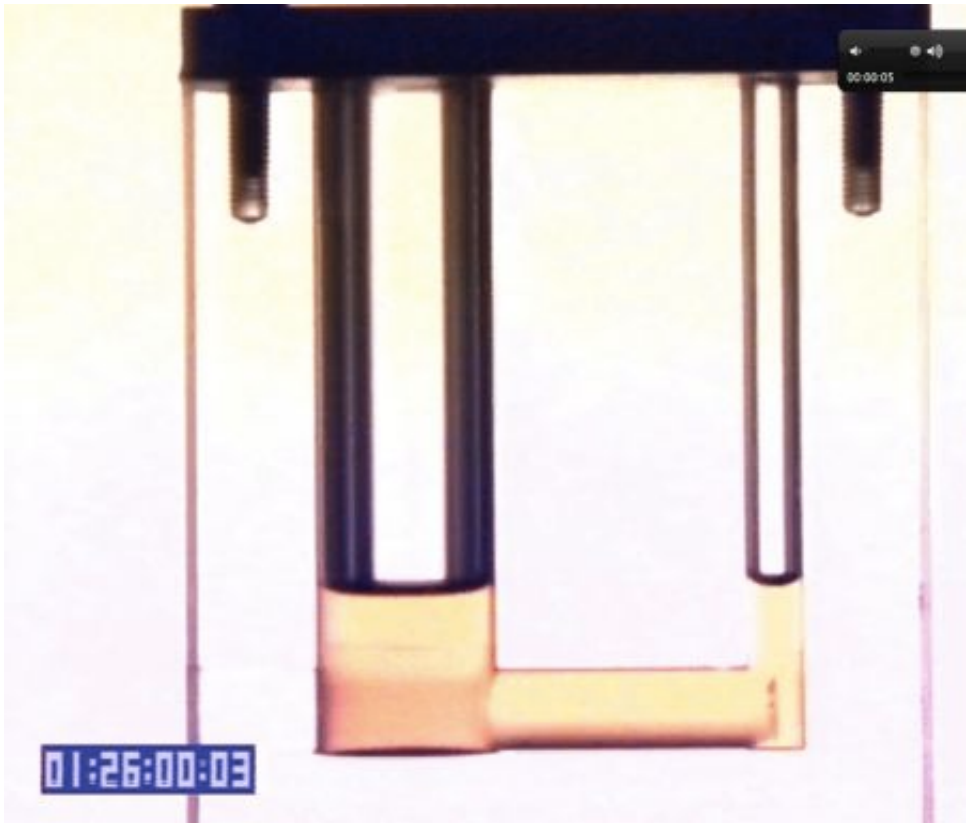
Gate latch on ceiling or drop by hand

Experiment carriage with camera

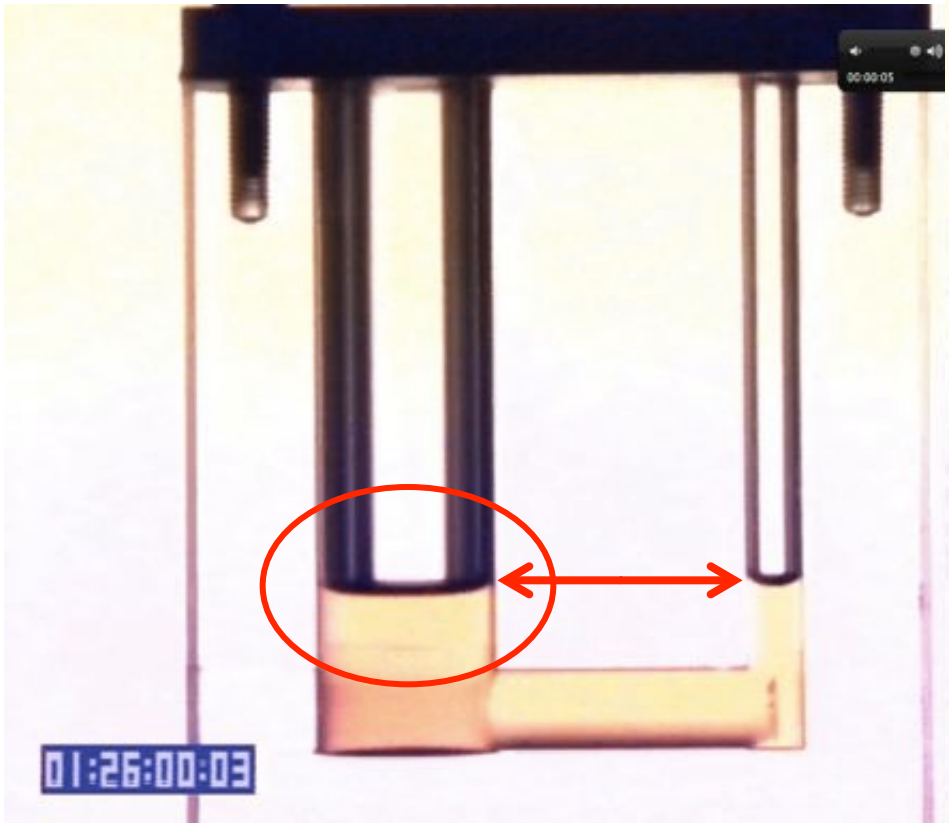
Computer or VCR/TV

Packing peanuts

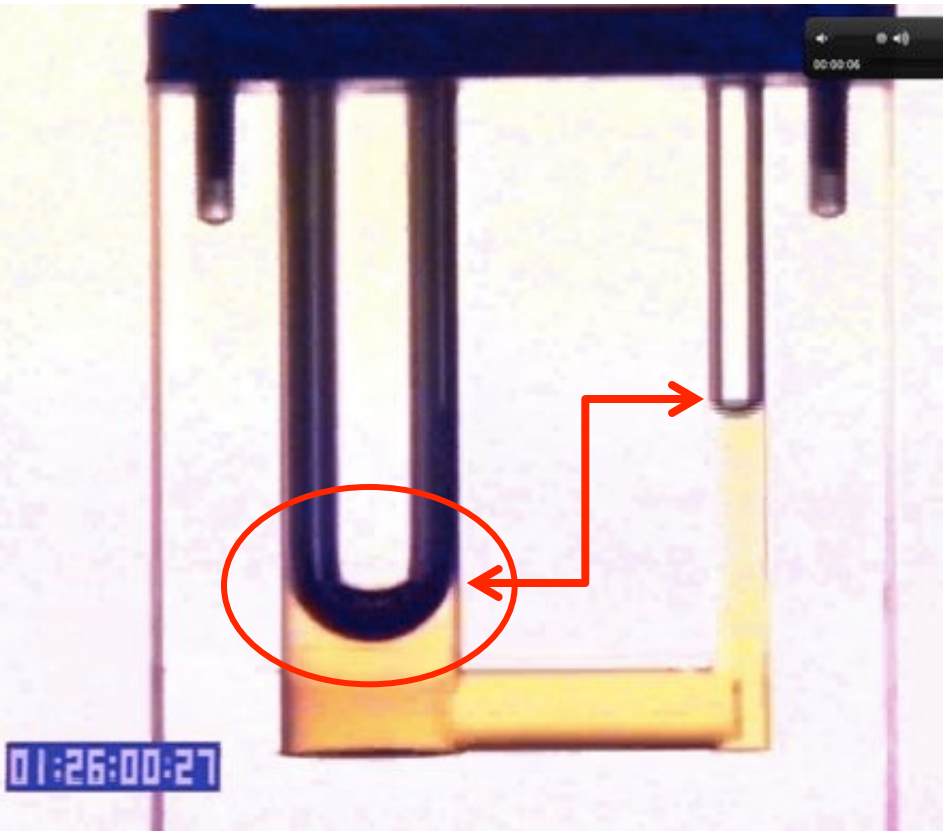
Catch box




Double capillary
tube in 1-g



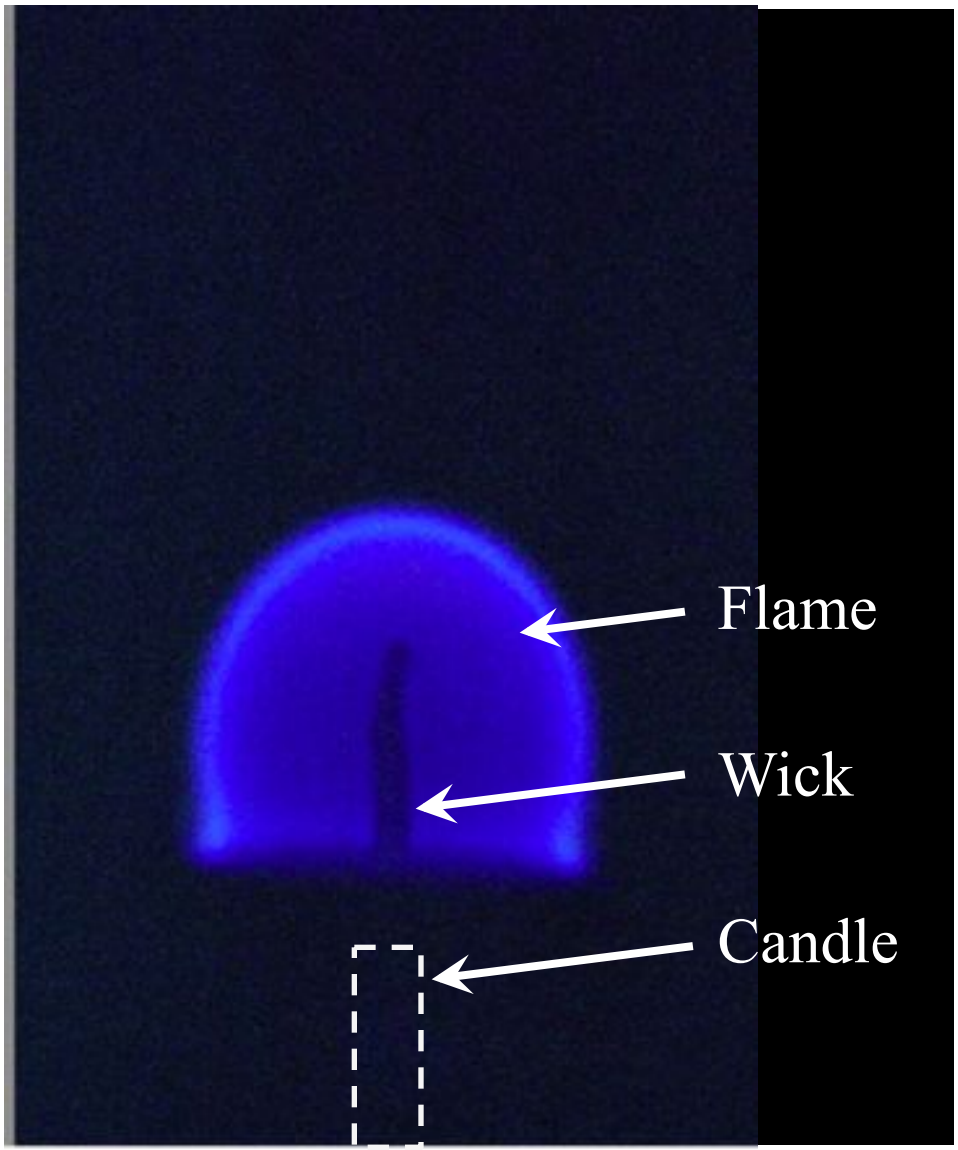

Double capillary tube in 1-g




Double capillary tube in microgravity

A candle flame in normal gravity.

A candle flame in normal gravity.




A candle flame in microgravity.

# Summary

- Demonstrate microgravity in your classroom by dropping things!
- Consider making a mini-drop tower in your classroom


Questions?
Comments?

# Questions later?

- These charts are available on-line.

  `http://tinyurl.com/ugSEEC`
- If you have questions or comments about this material, we want to hear about it!
- Please let us know how you use this material in your classroom!


| | |
|---|---|
| Richard DeLombard | dime@lists.nasa.gov |
| Diane L. McElwain | diane.l.mcelwain@nasa.gov |


# Further study!

- Students can use some of these topics to create science fair projects
  - *A Wisconsin middle school student did quite well in her science fair after I explained the leaky water bottle concept to her. She built an entire science fair project based on a plastic bottle with a hole, and got a superior!*

# References and Additional Reading

# Microgravity On-line Educator Resources

- Loads of free information on NASA web pages

  `http://education.nasa.gov/home/index.html`

- NASA Educational Materials

  `http://tinyurl.com/NASA-EduMaterial`

- What is Microgravity?

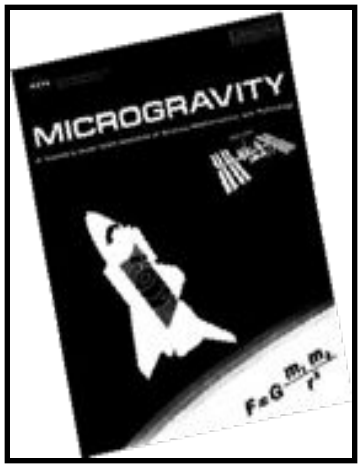
  `http://tinyurl.com/WhatIsUG`

- Microgravity Teachers Guide

  `http://tinyurl.com/MTGuide`

- NASA Space Place

  `http://tinyurl.com/SP-Orbits` (Orbital cannonballs!)
  `http://tinyurl.com/SP-ULaws` (Universal Laws)
  `http://tinyurl.com/SP-Kids` (Kids)




**URLs can be case sensitive!**
**"G" is not "g" - be careful!**

# Microgravity Educator Resources - Additional Items -


- NASA educational products available for free
  - Contact a local NASA Educator Resource Center (ERC) from an on-line list:
  - `http://tinyurl.com/ListERC`
- 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://tinyurl.com/CORE-home`
- Informal Web Page of Amusement Park Physics products

  `http://tinyurl.com/APPD-info`
  - 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*

# Future Space Travelers

- Our astronauts that will go to the **moon** or an **asteroid** have probably just graduated from college.
- Another generation of NASA's astronauts are in your classrooms now!
  - They probably don't realize their destiny!
  - Imagine if someone had told a 12-year old Neil Armstrong that he would not only walk on the moon, but he would be the first human to do so!
- The engineers and scientists that will help make those missions happen are sitting at desks next to those future astronauts.
- Please continue to inspire and motivate our future astronauts, engineers, and scientists!