How to Make a Microgravity Drop Tower for your Classroom

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- Pre-Test
- Microgravity orientation
- How to make a Classroom Drop Tower
- Microgravity demonstrator devices
- Drop tower experiments

Pre-Test

Some questions to see what you know.

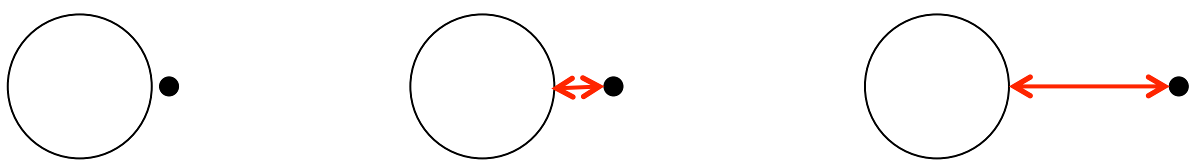
Why do astronauts 'float' in the ISS?

We have 1-g here on Earth. About how much of that do they have on the ISS?

Multiple choice:

0%, 10%, 25%, 50%, 75%, 90%, 100%

Earth-ISS >> Which is most correct?

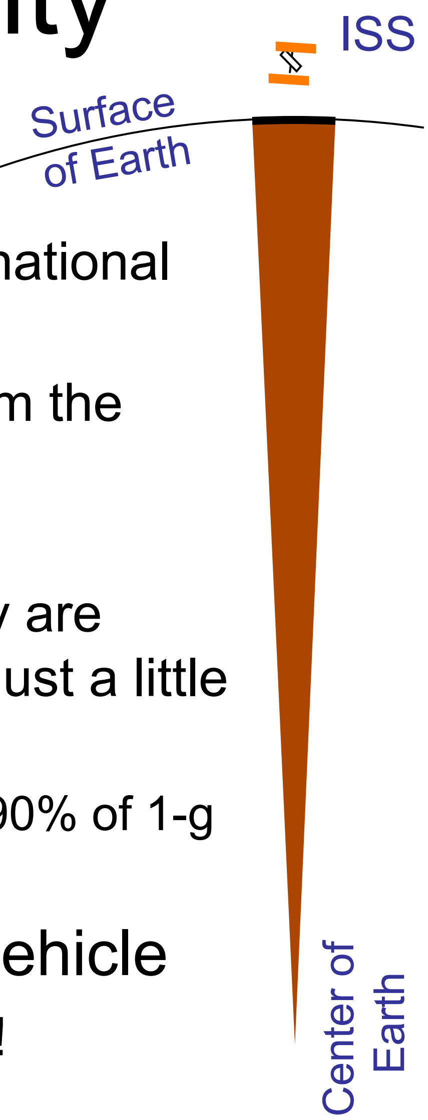


Physics of microgravity

- 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 with 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.

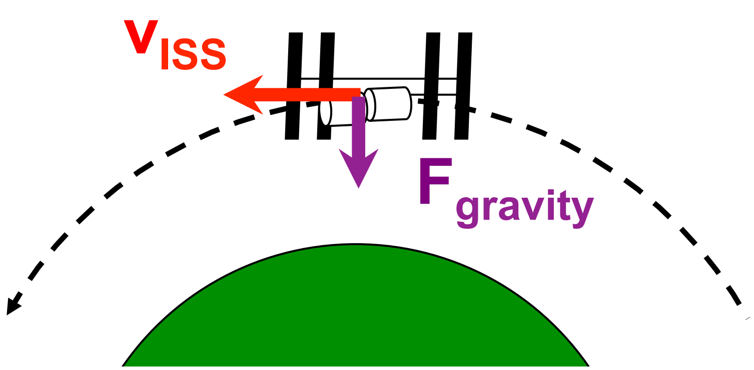
Physics of microgravity

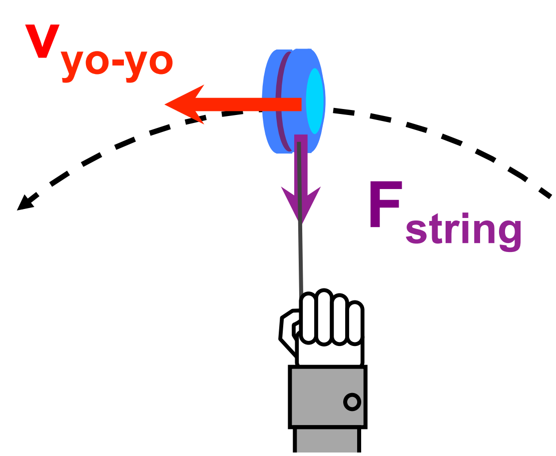
- Microgravity is **NOT** zero-gravity nor 0-g
  - So why do astronauts ‘float’ around on the International Space Station (ISS)?
  - At sea-level, we are about 6400 km (4000 mi) from the center of the Earth
    - gravitational acceleration is 9.8 m/s^2 (a.k.a. 1-g)
  - At a nominal ISS altitude of 400 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 90% of 1-g or about 8.8 m/s^2
- The astronauts are just falling with the ISS vehicle
  - Keep reading to find out about ‘falling with style’!



Physics of microgravity

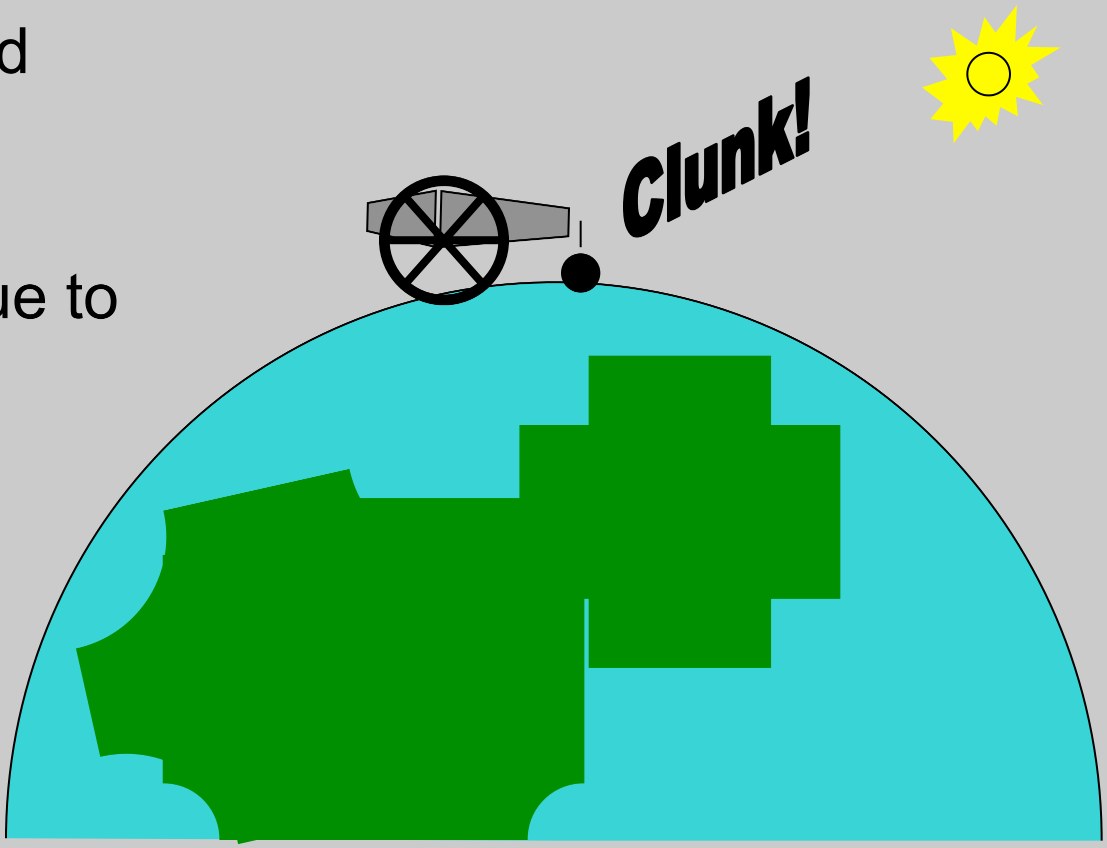
- It is **NOT** a balance of forces
  - The gravitational force acts on the ISS and its contents to maintain a circular orbit
    - Like swinging a yo-yo around in a circle
    - String acts as gravity
  - If it were 0-g, the ISS would sail off into space!
    - As the yo-yo does when you let go of the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





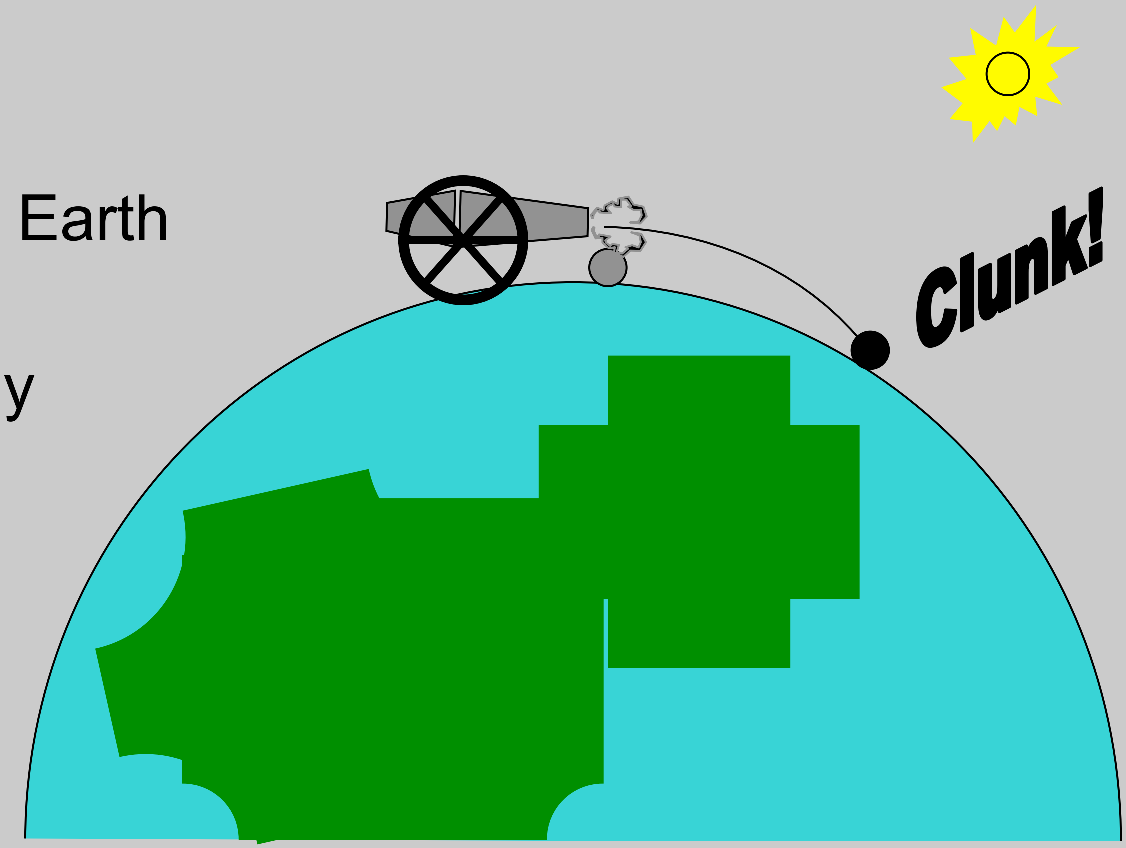
Falling Straight Down

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



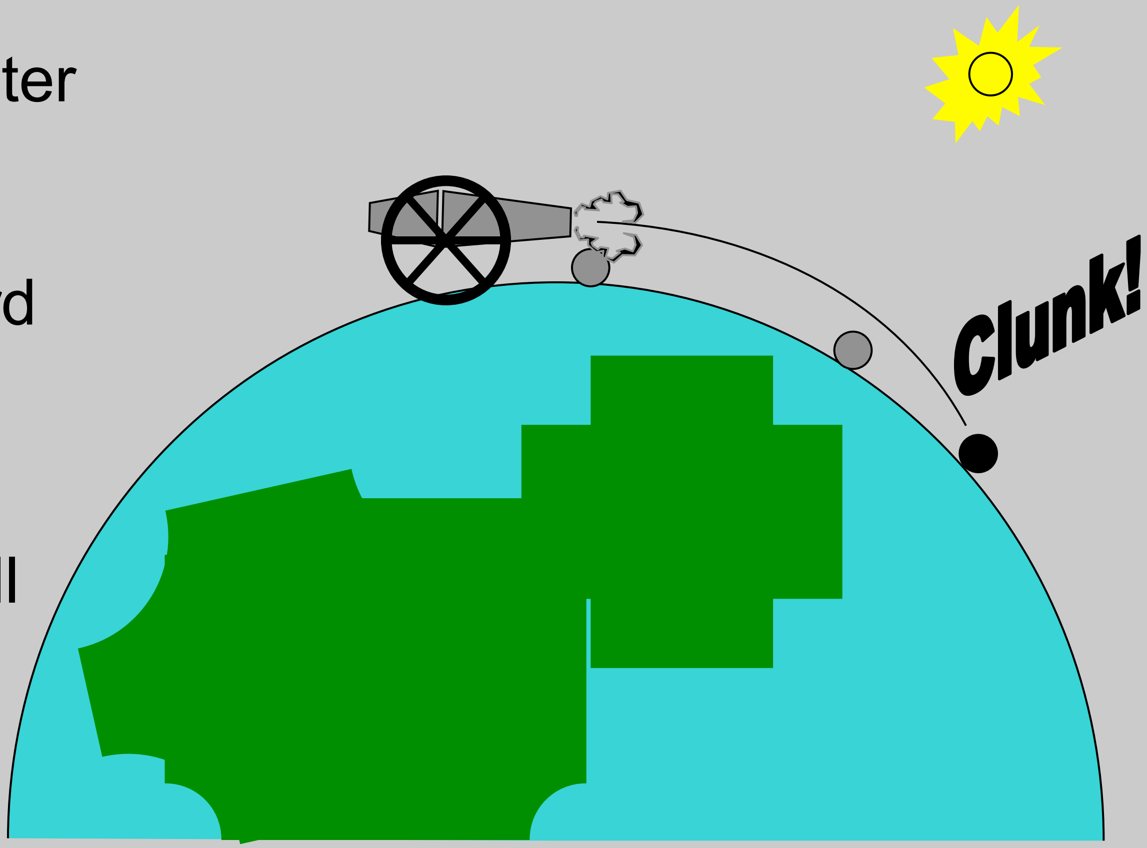
Falling Sideways

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



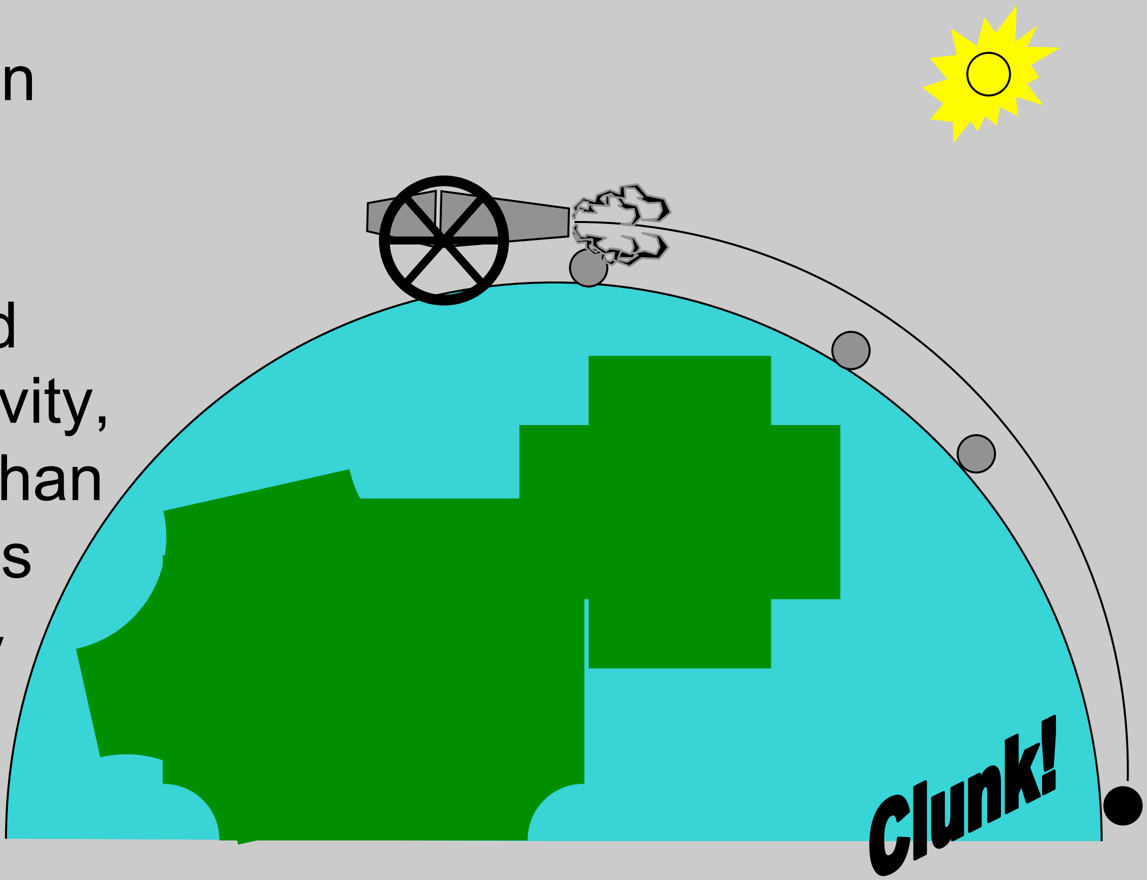
Falling Sideways

- 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



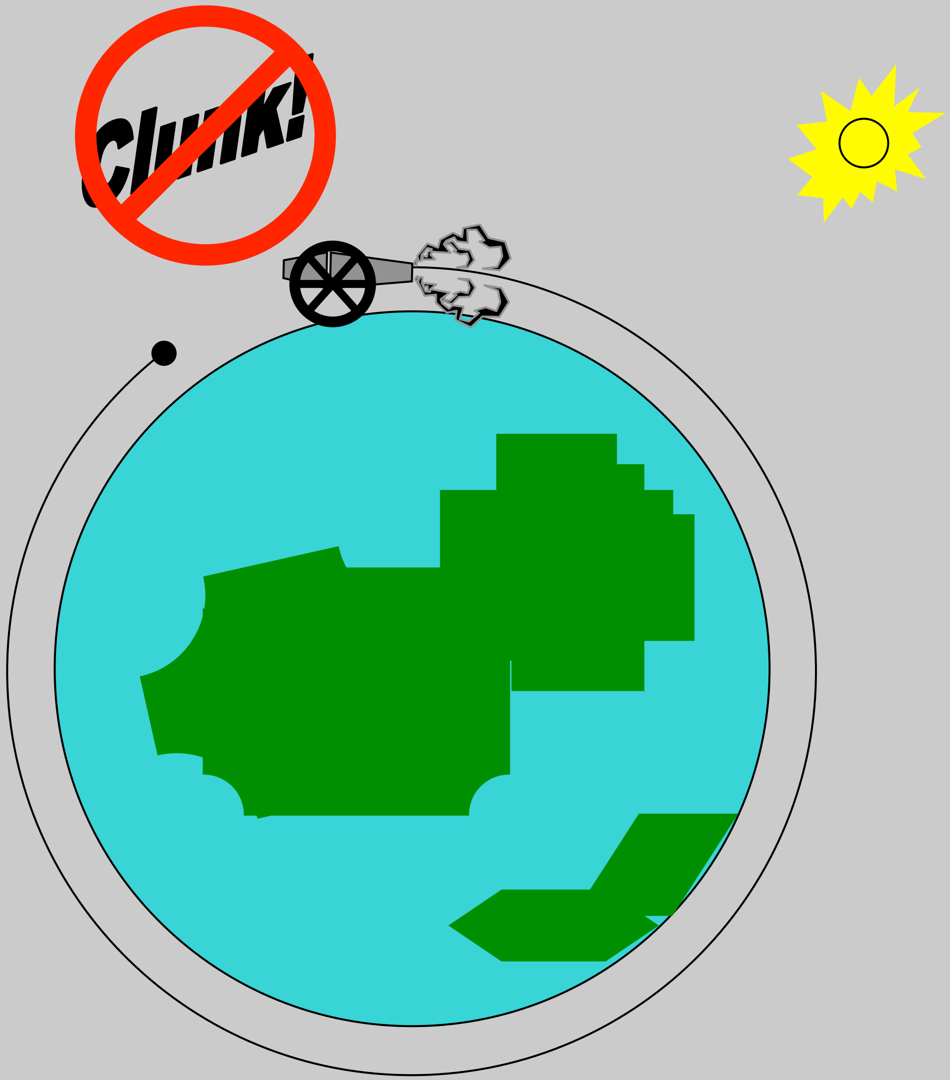
Falling Sideways

- 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



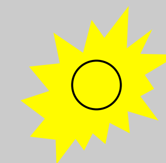
Falling with Style

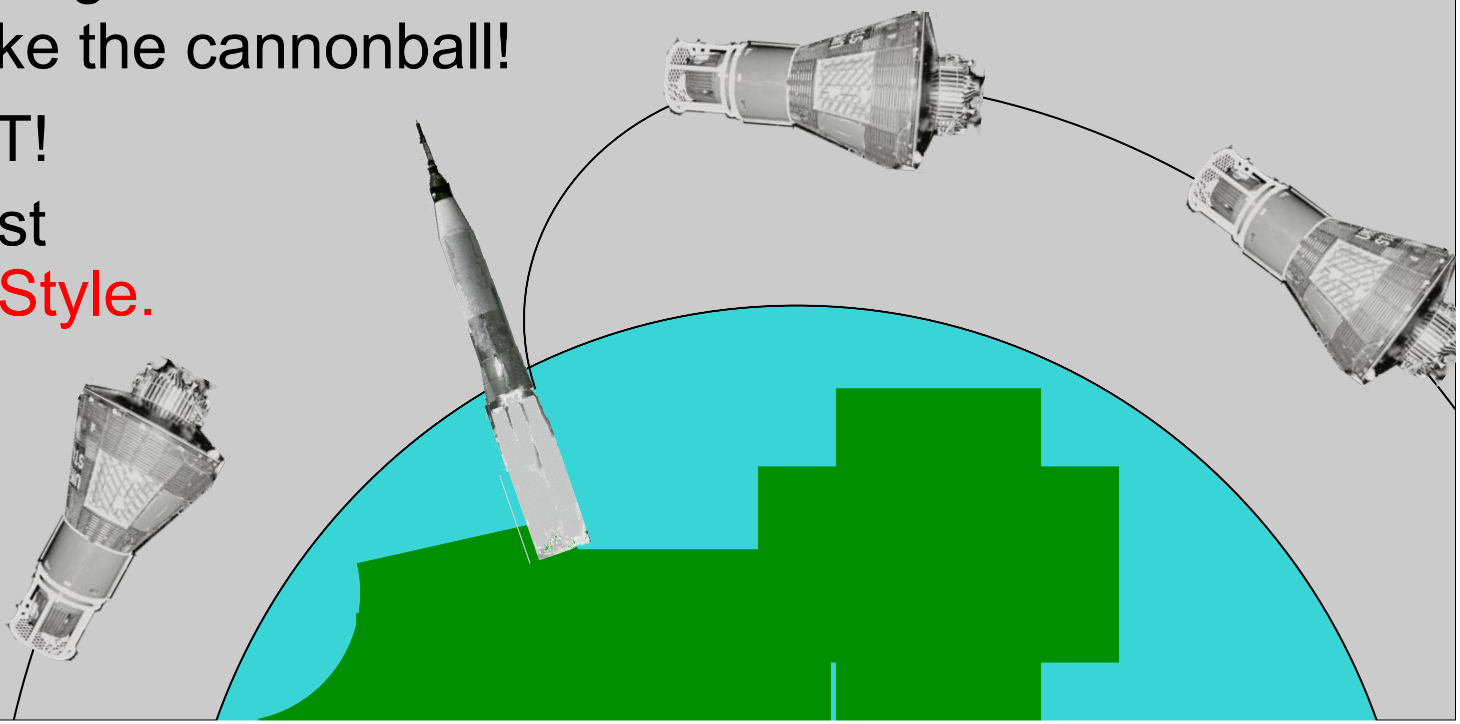
- Cannonball shot horizontally at just the right speed falls with the curvature of the Earth
- Speed is about 28,000 km/hr
- It curves toward the Earth due to gravity, but so gradually, it falls around the Earth
- Voila, ORBIT!
- It is really just Falling with Style.



Launching with Style

- Rockets take off vertically
- Gradually, as it climbs, it develops the proper orbital speed sideways
- When the engines stop, the space vehicle is falling with the curvature of the Earth, just like the cannonball!
- Voila, ORBIT!
- It is 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 28,000 km/hr (17,500 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.

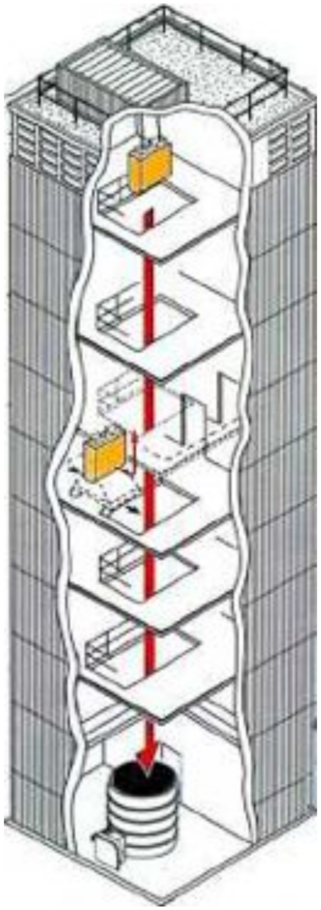
  … in orbit on the ISS.

  … in sounding rockets (into space).

  … in an (airliner-sized) airplane.

  … in drop towers as ground-based labs.

  … in your classroom.



2.2 Second Drop Tower at NASA Glenn

Microgravity On-line Educator Resources

- Loads of free microgravity information on NASA web pages
- `http://tinyurl.com/ugHomePg`

- NASA Educational Materials
- `http://www.nasa.gov/education/materials`

- Microgravity Teachers Guide
- `http://tinyurl.com/NASAugEG`

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/NASA-ERC`

- Informal Web Page of Amusement Park Physics products

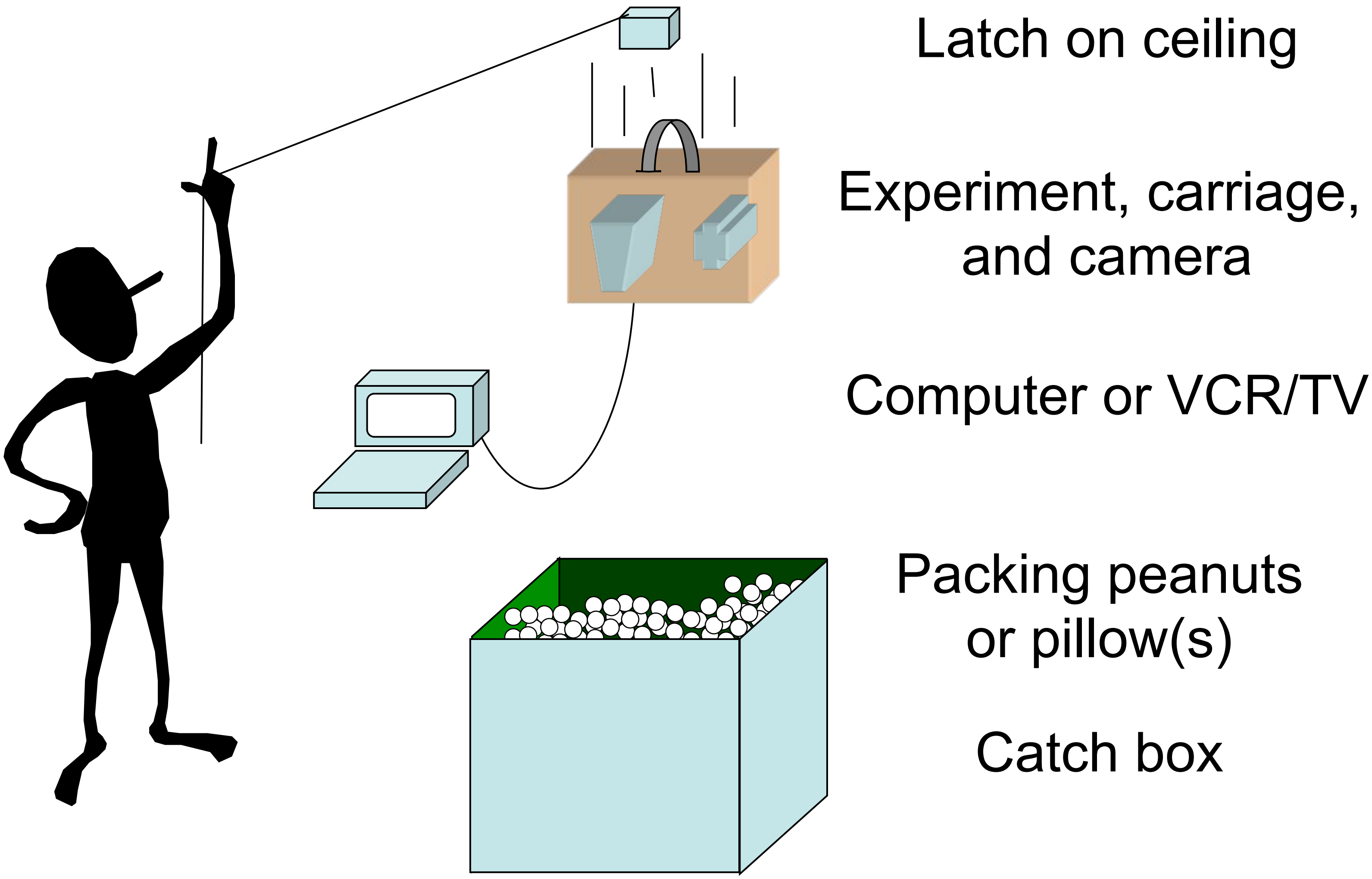
  `http://tinyurl.com/NASA-APP1`
  - Acceleration match game for amusement park rides
  - NASA drop tower height comparison with amusement park rides
  - NASA microgravity aircraft comparison with roller coasters
  - Middle school teachers guide
    - *Amusement Park Physics with a NASA Twist*

How to Make a Classroom Drop Tower

- Video camera
- Experiment carriage (aka plastic box)
- Experiment demonstration devices (aka toys)
- Video recorder and playback (aka computer)
- Soft-landing container (aka catch box)
- Power supply and cables
- Miscellaneous stuff (bolts, nuts, hook & loop material, etc.)

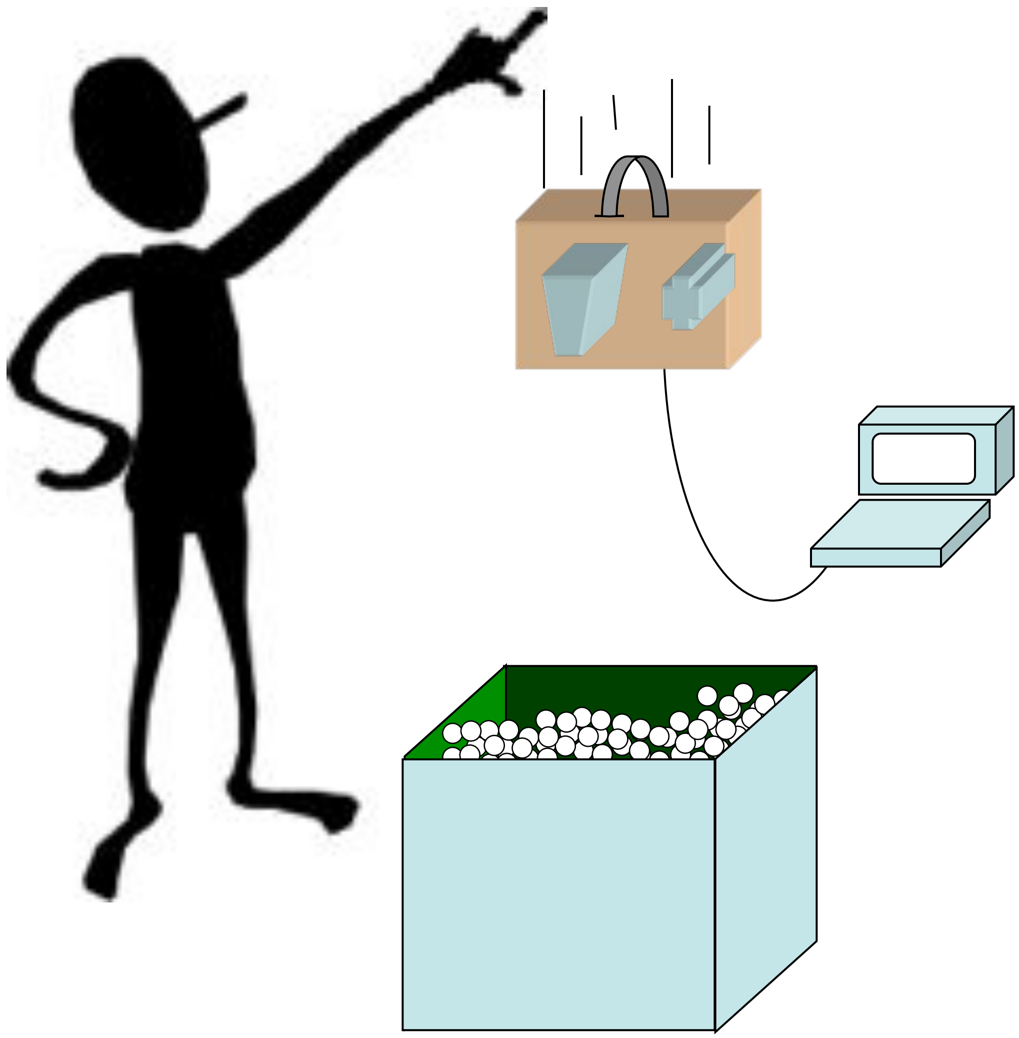
Classroom drop tower concept

Release by ceiling latch



Classroom drop tower concept

Release by hand



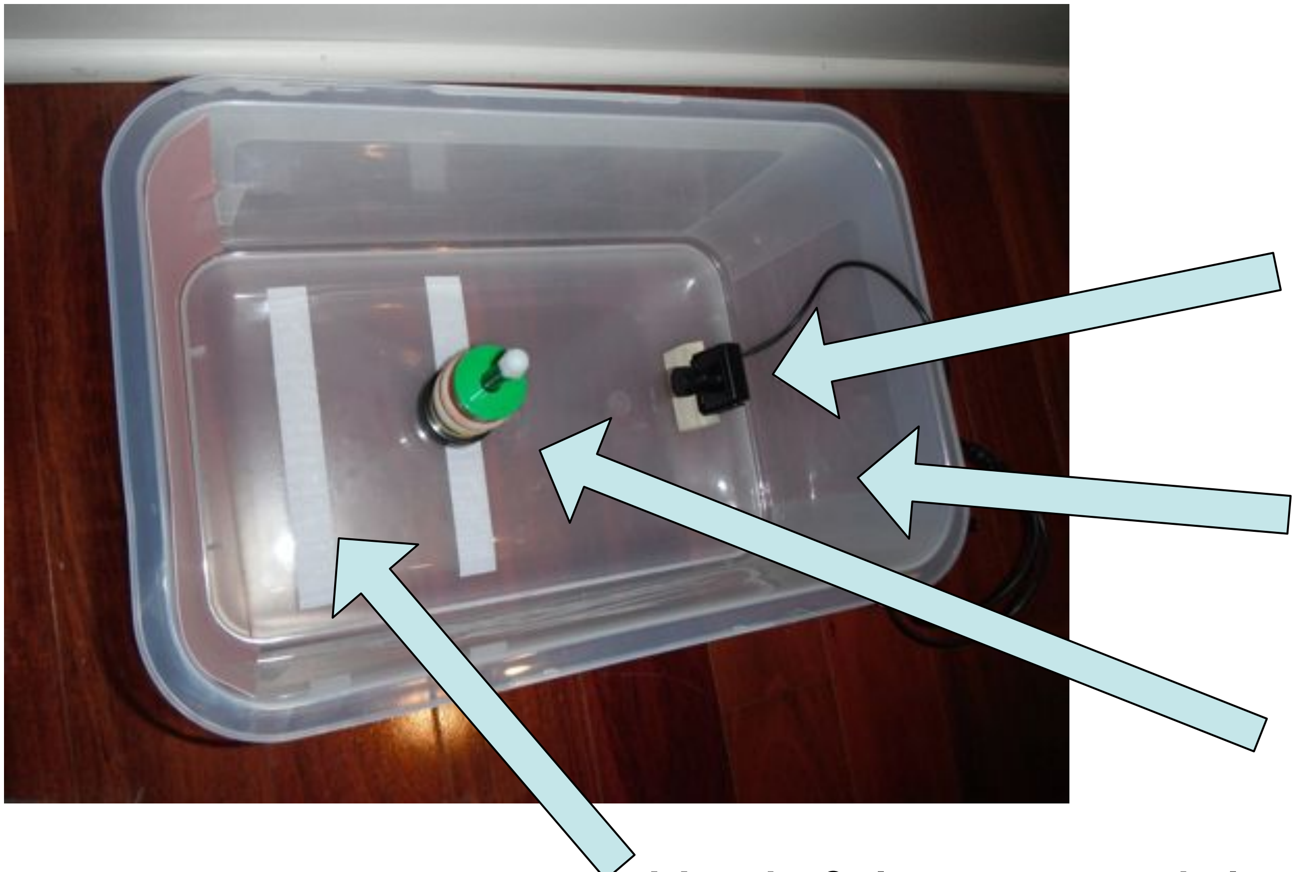
Experiment, carriage, and camera

Computer or VCR/TV

Packing peanuts or pillow(s)

Catch box

Classroom drop tower



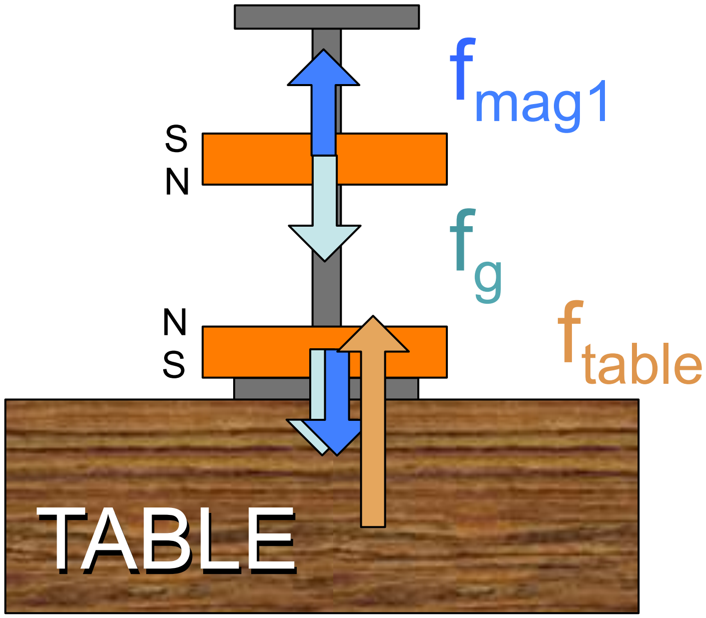
Yes, it can be that simple!

Camera Considerations

- Type of camera
  - Commercial digital camera with video mode
  - Home video camera
  - ‘PC board’ camera
  - *Mechanical mechanisms may be damaged*
- Close-up focus capability
  - 10 cm to 30 cm depending on box size
- Video rate and resolution
  - 30 frames per second
  - about 350 lines resolution
  - i.e. better than a ‘webcam’
- Output
  - Wired to recorder or memory card storage
- Mounting capability
  - Most brand-name cameras include tripod mount hole for a bolt

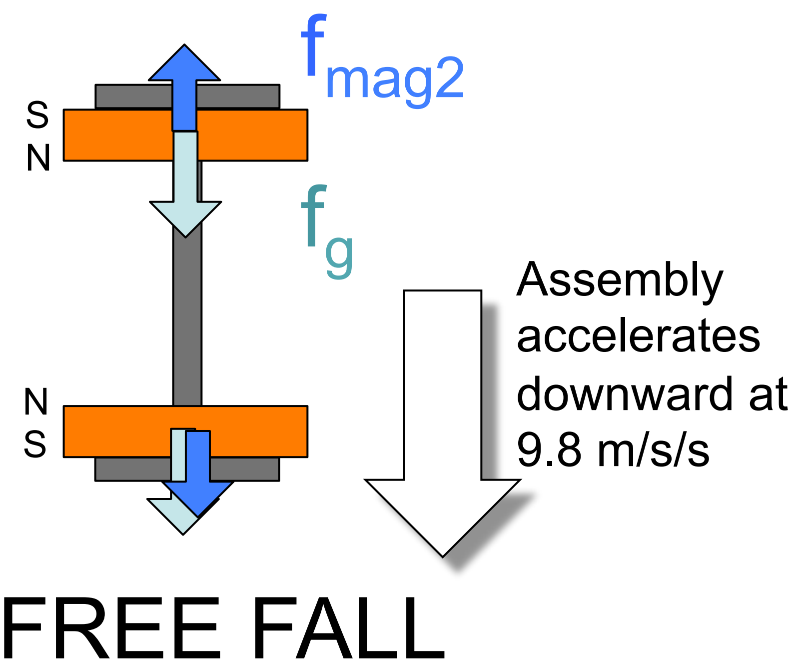
Experiment Considerations

- In general, microgravity difference is seen when an experiment has an internal force countered by gravity in 1-g condition.
- A very simple example are two repelling magnets where one magnet repels another to 'levitate' it.



Experiment Considerations

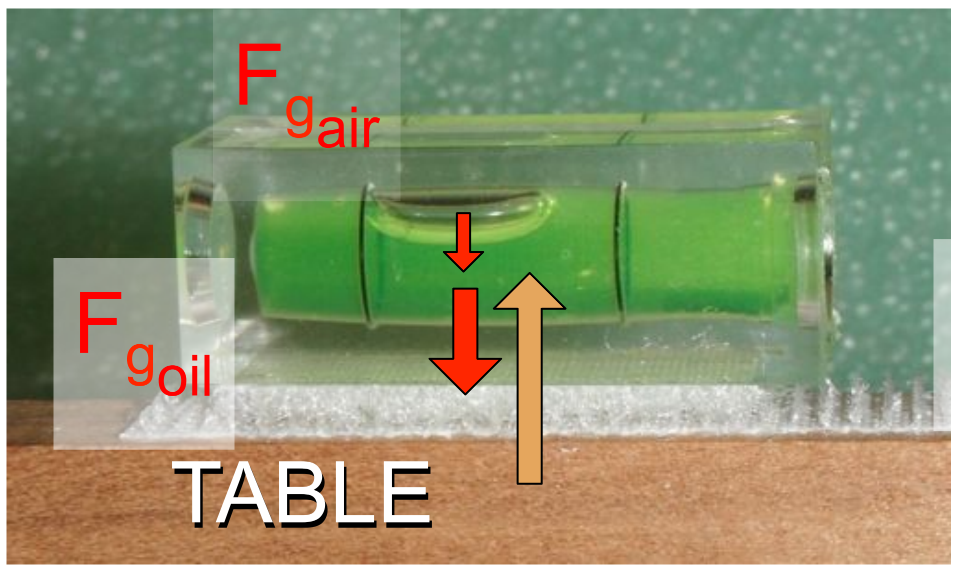
- In free fall, the force from the table has been removed and the assembly is able to fall downward.
- The unbalanced force on the lower magnet and frame allows them to fall away from the upper magnet.
- The magnets push apart due to their internal repulsive force.



(Reactive forces on frame are not shown.)

Experiment Considerations

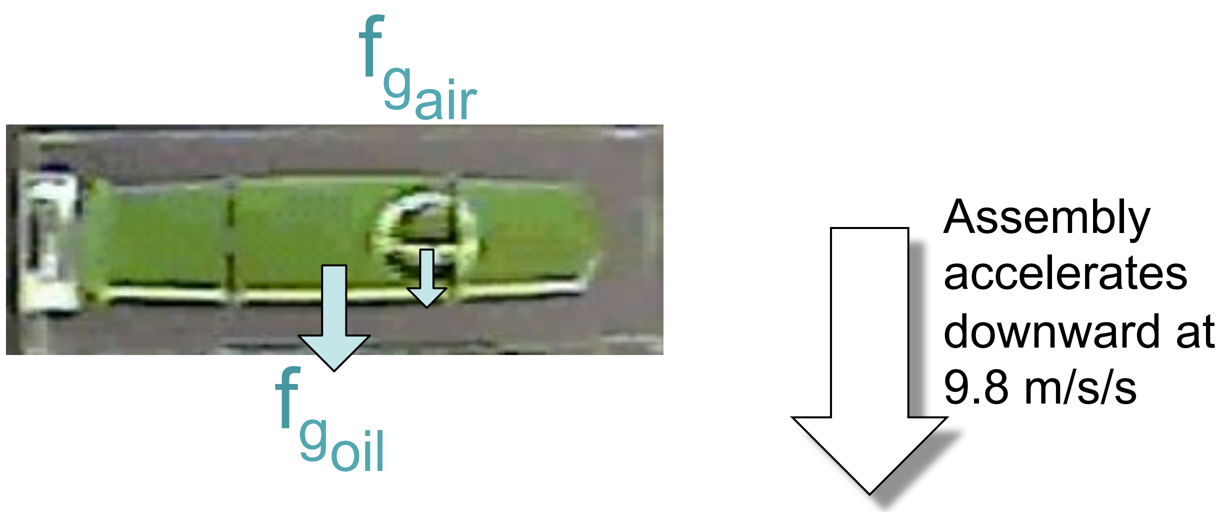
- Another simple example is a bubble level such as one a carpenter uses. An air bubble is submerged in a light-weight oil.
- The force by the table causes the heavier oil to settle at the bottom, forcing the lighter-weight air bubble upwards against the container.
- Remember, gravity pulls DOWN on the air!



(Other forces not shown for simplicity.)

Experiment Considerations

- In free fall, the force from the table has been removed and the bubble level is able to fall downward.
- Fluid forces of the oil at the surface of the bubble pull the air bubble into a spherical shape away from the container walls.



(Plastic container gravitational force not shown for simplicity.)

Experiment Considerations

- What action would result from dropping two wood ‘wheels’ on a stick?
- Why?
- Think about it before trying it.

- (With no internal force, they will keep their positions on the frame.)

Some goodies will be dispensed after the hands-on time!

- Must be present to receive goodies.
- Drawn by random from your session cards.

Try a Classroom Drop Tower

- Instructions for operating the video software are adjacent to the computer.
- Please work in teams.
- Develop a hypothesis about the outcome before a drop.

- THINK ABOUT HOW YOU CAN MAKE ONE OF THESE FOR YOUR CLASSROOM!

Summary

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

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!

- Some students might like a microgravity experiment of their own design! Check the new CELERE program:

  `http://spaceflightsystems.grc.nasa.gov/CELERE/`

- Some students might be interested in a NASA microgravity aircraft ride when they are in college via NASA JSC's student program.

  `http://microgravityuniversity.jsc.nasa.gov/`

Future Space Travelers

- Our next lunar astronauts that will go to the **moon** in about 15 years have probably just graduated from college.
- The next generation of NASA's astronauts are in your classrooms now!
- The four astronauts that will depart for **Mars** in about 25 years are probably in middle school or high school today.
  - 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!


Questions?
Comments?
Let's explore
microgravity!

Questions later?

- Further information is available on-line
  - NASA web pages
    - `http://www.nasa.gov`
  - NASA social media connections
    - `http://www.nasa.gov/connect/index.html`

- Questions about this material may be addressed to the authors:

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BONUS EXTRAS!

Other microgravity demonstrations for your classroom!

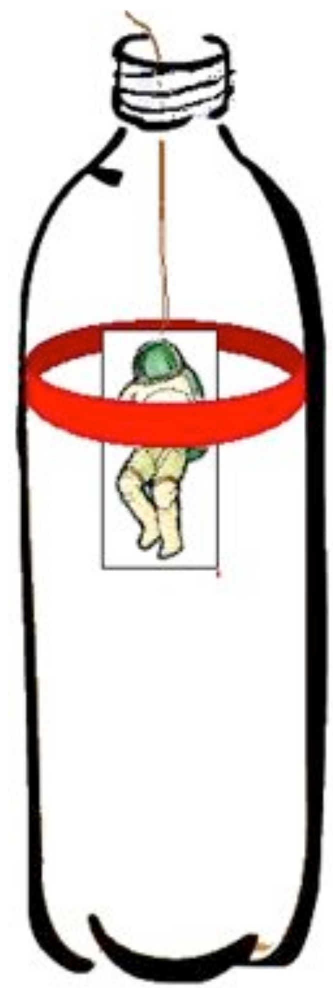
Microgravity Demonstration Devices
- Simple -

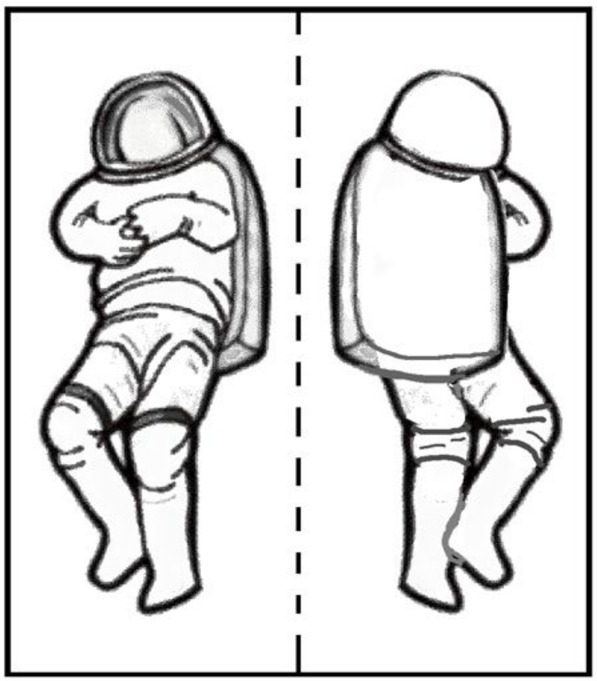
- Astronaut in a bottle
- Leaky water bottle or can
- Balloon popper
- Magnets on a stick

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 / hour sideways while it falls around the Earth!





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

Leaky water bottle

Free-fall & ‘weightless’ demo

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?

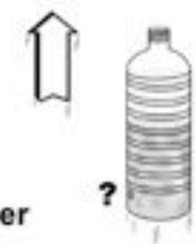
2. When the water bottle is *dropped* the flow of water:

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)

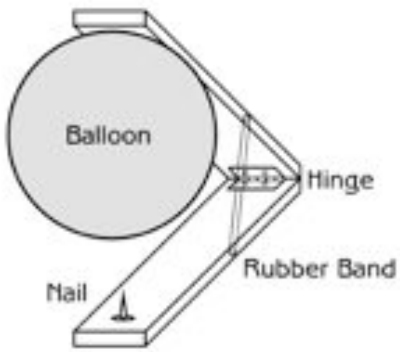
1. Have an adult, with a knife or awl, poke a small circular hole in the side of the bottle, near the bottom.
2. Cover the hole with your thumb and fill the bottle with water.
3. Uncover the hole and the water streams out (with the cap off).
4. Before the water runs out, drop the bottle. Watch whether 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.

Magnets on a Stick

- These simple devices may be made for observations by students.
- Dropping and catching or gently tossing assembly up.
- How do the actions differ between magnets and wood?
- Why?

Microgravity Demonstration Devices - Movies -

- Movies
  - Water balloons popped in microgravity
    - `http://tinyurl.com/WBGRC`
  - Helium balloon dropped in 2.2 Second Drop Tower
    - `http://tinyurl.com/YellowHeBalloon`
  - On-orbit crew videos (food, toys, crew actions)
    - Available from ERC and/or CORE
    - Check an ERC video list:
    - `http://tinyurl.com/NASA-ERC`
    - 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://exploration.grc.nasa.gov/outreach/appd/appd_resources.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)
    - Add barometer for height indication of amusement park rides
  - Example product:
    - Vernier LabPro with 3-axis accelerometer

    -- Note: use of trade name does not imply endorsement by NASA. --

Drop into something soft!

Microgravity Demonstration Devices - Advanced -

- Drop tower demonstrator
  - Demonstrates microgravity effects on science
- Versions
  - Original version
    - Compact, rugged design for easy transportation and setup
  - Wireless version
    - Inexpensive design with no wires or ropes on carriage
  - Classroom concept
    - Simple & inexpensive for fixed location
    - 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 software, preferably with editing, titling and export functions
    - Video options: surveillance camera or board-level camera

THE END ***(FINALLY)***