LOGISTICS
Class grade/age: 5-6th grade
Class size: 20 students
Instructional Time: 110 minutes (two 55-minute lessons)
Location: Science Lab or Classroom
Safety Considerations: [Allies to help determine others]
• wear goggles while launching rockets
• follow the activity rules (specified below, page 5)

BACKGROUND:
The history of rocket science began in ancient Greece in 400 B.C. with the documentation of the first unofficial aerospace engineer, Archytas. He impressed Tarentum citizens by fashioning a wooden pigeon that operated on Newton’s third law of Motion (for every action there is an equal and opposite reaction) 2,100 years before the formal coining of these laws. Fast forward through time to when the Wright Brothers explored man-made flight, which then led to the development of gliders and planes. Soon, the post-WWII and the 1950’s Space Race to the moon between America and Russia began.

Russia took the lead in 1957 with Sputnik, the first man-made satellite to orbit the Earth. In 1958 the United States launched the Explorer I American satellite, designed by Wernher von Braun. The National Aeronautics and Space Administration (NASA), an agency committed to exploring space, was created by the federal government in that same year, which resulted in a new kind of engineer – the aerospace engineer; a modern-day Archytas.

Aerospace engineers concern themselves with four main flight forces: gravity/weight (toward the earth), lift (perpendicular to drag), drag (opposes thrust), and thrust (in the direction of the vehicle’s forward motion). Designing rocket launchers is an important engineering task because a rocket must overcome the forces of gravity and drag in order to lift-off and begin ascent.

SUMMARY OF ACTIVITIES:
This is a two-part lesson (55 minutes for each Part). The class will be told that all current NASA rocket launchers are no longer useable because all of the available rocket-fuel sources on Earth have been depleted. Students will serve as NASA engineers tasked with developing non-fuel-based rocket launcher prototypes in an effort to maintain current and future NASA space programs and missions.
During Part 1, students will work in groups to design, build, and test a rocket-launcher prototype. Student groups will have an opportunity to share their designs and identify specific Points of Failure (POF’s) to try and overcome any problems with their launcher prototypes. The teacher will facilitate student discovery of related concepts and discuss common vocabulary (such as gravity, thrust, POF, aerospace engineer, etc.).

During Part 2, students will test how different loads impact their rockets’ launch-distance. This will help them discover the relationship between mass and force which addresses aspects of Newton’s 2nd Law of Motion (see Appendix for additional information about Newton’s 2nd law of motion). Student-built rocket-launchers will need to meet certain performance criteria in line with a series of simulated NASA missions by launching a model rocket that is carrying a defined payload (representing different loads for a given mission such as spacecrafts, people, supplies, equipment, robots, satellites, etc.) to a minimal height (representing the model-scaled distance to the various targets of each NASA mission). Students will have time to redesign, rebuild, and retest their launchers to meet the additional parameters and to address any specific POF’s.

STANDARDS:
NGSS-3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

NGSS-3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

NGSS-MS-PS2-2. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, the larger force causes a larger change in motion.

OBJECTIVES:
The students will …
1. design and build a prototype rocket launcher using a limited set of simple materials,
2. test how their team’s launcher works when the rockets are empty vs. carrying a load,
3. explore Newton’s 2nd Law of Motion,
4. simulate aspects of some NASA space programs/missions, and
5. test whether their launcher can accomplish a series of NASA missions.
MATERIALS:
- 12” plastic ruler – 10
- 10 Binder clips, large
- Awl, metal – 1 (1 per class, adult/teacher use only)
- Meter stick – 1
- Pencil, sharpened – 5 (1/group)
- Goggles, 10 (2/launch station)

Advanced Preparation Materials

Launch Kits
- Bags, brown paper lunch-size, 5
- Plastic Cups, large 16oz, – 10 cups (2/group)
- Plastic Cups, small 8oz, 10 cups (2/group)
- Rubber bands, variety of sizes and thicknesses – 100 (20/group)
- Pony beads any color, 10/group – 50 beads
- Popsicle sticks, wooden any width and thickness – 20 (5/group)
- Jumbo craft sticks, 2/group – 10 sticks
- Pencils, unsharpened, 1/group – 5 pencils
- Latex balloon, standard size, 1/group – 5 balloons
- Tape, masking – 5 rolls (1/group)
- Scissors, 1/group – 5 pair
- Sharpie, 5 (1/group)
- Assembled Rocket (see next)

Rockets, from Estes Viking kits
- Nose cone, 5 (1/group)
- Body tube, 5 (1/group)
- Yellow pacer tool, 5 (1/group)
- Fins, 5 sets (1 set/group, optional/extension)

Height Scales
- String/yarn, 1 skein
- Scissors
- Tape, Masking – 5 rolls (1/group, plus for height scales)
- Measuring tape/meter stick, 1

Play-doh Payloads
- Digital scales, 5 (1 for adv. prep and 5 for each group in activity 4)
- Play-doh any color – 1 lb bucket (45g/group)
- Plastic wrap, 1 box (for adv. prep and for activity 3)

Handouts/printables
- Copy paper, white - 10 sheets (2/group)
- Student page doc.
- NASA launch pad doc.
- Blue copy paper, 10 sheets (1/launch station plus extra)
ADVANCED PREPARATION INSTRUCTIONS:
1) Put together five Launcher kits (one/group) by placing all materials listed above in a brown paper bag; noting individual amounts/group.
2) Assemble rockets and place them into the brown paper bag with the other launcher kit supplies.
   - To assemble rocket, insert the nose cone in one end of the rocket body and the yellow cylindrical hollow tube into the other end.
   - Include the rocket’s fins in the paper bag (optional for students and may be a good time-filler; see extensions).
   - Remove and put away additional unused supplies from kit: decals, green engine block, launch lug, streamer, nose cone insert, and shock cord.
3) Make five height scales to be hung up on a wall with the bottom affixed at three feet above the floor; this will represent the designated distances for each mission.
   - Cut a length of string/yarn 5ft long.
   - Use masking tape to secure the string to a surface for easy measuring. Use measuring tape/a meter stick to identify various distances along the string.
   - Mark off various distances by folding the masking tape onto itself with the string inside. The very bottom tape “flag” represents three-feet above floor.
   - Label the tape “flags” with letter for the various missions (see table 1 on student page) using a sharpie from the launcher kit materials.
4) Make a pair of rocket payloads for each group to test in activity 3, Part 2.
   - Using one of the five digital scales, make two Play-doh “payloads” per group equaling 5-grams and 40-grams, respectively. You should have 10 total Play-doh payloads ready before class (two payloads for each group, a small 5g and a large 40g). Wrap each with plastic wrap and label each with their mass using one of the sharpie markers from the launcher kits.
5) Print five copies of each of the following:
   - Student Page doc double-sided on white copy paper. The group will complete it together.
   - NASA launch pad doc single-sided on blue cardstock.

CLASSROOM SET-UP:
1) Set up five “official” launch pad stations where each launcher can be put to the test.
   - Make sure there is adequate space between all the stations.
   - Place blue sheet of cardstock on the floor to represent the “launch pad”.
   - Hang up the height-scale on the wall above the blue paper so the bottom masking tape “flag” is three-feet above the floor.
   - Have a digital scale ready to set at each station for part 2.
2) Have materials in a convenient location in the classroom to handout or for students to collect.
ACTIVITIES:
Part 1
Activity 1: Build a Rocket Launcher
Activity 2: Finalize & Test Rocket Launcher for “Basic Mission”

Part 2
Activity 3: Testing Payloads for “Payload Mission”
Activity 4: Launches for “NASA Missions”

Introduction: Welcome & Overview
Estimated Time: 5-10 minutes

Procedures:
1) Enthusiastically welcome students to class and ask them to define “rocket science” – accept any response (limit responses to 4-5 max, for time). Some ideal answers include: [Allies help brainstorm possible answers.]

2) Introduce the problem/story line: Sources of fossil fuels are becoming increasingly limited on Earth. Thus, in order to maintain various current space programs without an adequate supply of rocket fuel, NASA has been tasked with getting rockets into space without the traditional launch mechanism of burning large amounts of fuel. NASA needs to develop an alternative rocket-launching mechanism for their latest non-fuel-burning rocket, “the Viking”. Students are to imagine they are NASA aerospace engineers who must work on a group that builds a rocket-launcher prototype. These prototypes will help NASA develop new non-fuel-burning rocket launchers. These model rockets will need to reach various vertical distances, representing different space-mission targets (such as Earth’s moon, Mars, and Jupiter). Students will be expected to launch their rockets vertically. As a culminating experience, students will attempt to accomplish a variety of missions (see part II) for some actual NASA Missions/Programs.

3) Announce that the first activity will be to begin building and testing their rocket launchers. Put students into groups of four (about 5 groups depending on attendance) before moving on to Activity 1.

PART I
Activity 1: Build a Rocket Launcher
Estimated Time: 20 minutes

Materials:
- 5 Launch Kits with Rockets in a brown paper bag (1/group)
- Height scales, 5 (made in advance, 1/launch station)
- Launch-pads (blue card stock), 5 (1/launch station)

Procedures:
1) Students should be in groups of four for all of the activities.

2) Announce the task: Within 15 minutes, students must build (and test) a simple rocket launcher that can launch an empty “Viking” Model Rocket (Viking Estes #1949) using the limited supplies (provided in paper bag).
   - This task is listed as “BUILDING MISSION” on the student page. Have students circle Yes/No after working toward this mission.
   - The first goal for using the launcher (officially done in next activity)
is to use the rocket-launcher prototypes to launch an empty rocket a minimum height of 5-feet and is listed as the “BASIC MISSION” on the student page.

- Try to announce how much time is left at 5-minute intervals.
- If any group needs to make a hole in any of the cups during the building process, have them use a sharpie to mark a “dot” onto the cup where the hole is desired and bring it up to the teacher or to a group leader who can use an awl to make the hole/s.
- Make sure groups know they should be prepared to demonstrate and explain how their launcher works at the end of this Activity.

- Announce Activity RULES:
  o All safety considerations and classroom procedures are to be followed at all times.
  o Everyone’s ideas are valuable and should be heard and/or tried within a group; don’t waste time arguing over whose idea is better – try them both out or decide as a group what is preferred and move on.
  o When testing the rockets, make sure the little yellow tube insert is at the bottom (to ensure integrity of the bottom part of the rocket while launching). Teacher should model/demo this to the class.
  o Students SHOULD NOT launch rockets without a supervisor at their station. Teacher needs to ensure safety and make sure all teachers and groups leaders are at a designated station throughout the entire lesson.
  o Students SHOULD NOT launch without a countdown. This way, everyone in the group is aware of what is happening and when. Only two people per group should operate the launcher at a time (both wearing goggles) so make sure the students know this BEFORE building; the other two students need to step away for safety, but they will watch and record observations for the group. Encourage them to take turns doing each task.
  o NEVER launch the rocket with anything other than the launchers built in class.
  o NEVER face the rocket in any direction but vertically up.

3) Give each group a launcher kit (paper-bag filled with the supplies) to build their rocket-launcher; a rocket is included. Have students remove the contents of the bag and brainstorm ideas of how these materials can be used to build a rocket launcher.

4) Allow the building and testing to begin.
- Build a suitable launcher: Students must use the limited materials to build their launcher and start to test how it works.
- Modify designs, as needed to meet the criteria for the BASIC MISSION (next activity)
Transition to Next Activity (10-15 minutes): Conduct a “community debrief”. First, explain to students that even though we are working in different groups, we are all working toward a common goal as NASA engineers: To design an alternative non-fuel based rocket-launcher prototype. Explain that it is common to have many people/teams/groups working on ideas at once in order to try and come up with the best possible outcome/result for the organization. At the end of the 15-minute initial build-period from Activity 1, have each group quickly demonstrate their launcher in front of the class and explain what works well and what isn’t working (Points of Failure) with their launcher. Allow the other groups a chance to offer insight as each group presents/demonstrates their launcher, but limit transition to 10-15 minutes, max.

**Activity 2: Finalize & Test Launcher**  
**Estimated Time:** 15 minutes

**Materials:**
- 5 Launch Kits with Rockets in a brown paper bag (1/group)
- Tape, clear Scotch – 5 rolls (1/group)
- Completed Launchers, 5 (1/group) made in Activity 1
- Blue Sheets of Paper (1/launch station)

**Procedures:**
1) Using the community debrief feedback as needed/desired, allow groups 10 minutes to revise their launchers and attempt their “official launch”.
   - Launches are only “Official” if a teacher or group leader (or adult) is present for the launch and can observe the height reached by the rocket.
   - This is referred to as “BASIC MISSION” on the student page. Have students circle Yes/No after working toward this mission.
2) Once students are ready to officially launch their non-load-bearing rocket, have them report to the “launch pad” area. Have students make sure that a teacher, group leader or other adult is present at the station before they launch. Students in each group should count down from three and launch their rocket at the designated time (have them say “blast off”--or some other phrase—after counting down to “one”).
3) Have students evaluate whether they met the criteria for the basic mission or not (*5-foot vertical height reached*) and confirm this with the teacher/group leader/adult.
4) Depending on the remaining time, groups may again try to modify/fix their launcher until they meet the minimum 5-ft vertical height.

**NOTE:** Students can take a 5-minute bathroom break at this point, if needed.

**Part 2**  
**Introduction:** Regroup/Report-out  
**Estimated time:** 5-10 minutes

**Materials:**
- Ruler – 10 (1/pair of students)
- Binder Clip, Large – 10 (1/pair of students)
Procedures:
1. Regroup from the break and make sure everyone has officially launched their rocket using their simple launcher (using the supervised designated launch pad/station).
2. Have groups report-out whether or not their launcher was able to accomplish the basic mission or not (i.e. reach the specified height of five feet). If not, it’s OK; many great STEM advancements started off as several failures. We learn from our failures so it’s OK if at first you don’t succeed. NASA would use the info obtained from all prototype successes and failures to finalize their design.
   • Ask students: What things have you learned from the first activity? (can be STEM-based or about teamwork, etc.). How might that help you in the future? (students can answer by role-playing as NASA engineer and/or for real).
   • It’s OK if they didn’t reach the height of the basic mission using their launcher; they can still proceed with the activities by revising their launcher until it meets the criteria. Once it does, they can move on to try the NASA Missions.
3. Review important vocabulary thus far [Allies can help us figure out how a 5th or 6th grader would define these terms. A suggestion: Incorporate an inquiry discussion about how these forces apply in airplanes vs. rockets.]
   • Gravity –
   • Thrust –
   • Others? –
4. Have students begin to explore the concept of payload by handing them a binder clip and ruler. They need to try to balance the ruler with the binder clip attached at various vertical heights along the ruler: place bottom of binder clip at 1”, 5”, and 10” along the ruler. The teacher may demonstrate this with the student supplies or with a meter stick.
   • Here they will discover that payload works best at the top. [other concepts too?]
   • NOTES: Announce that when testing the clip at the bottom, it cannot be in contact with their hands at all; only the ruler can be used as a base – absolutely no part of the clip may be used as a part of the base.

Activity 3: Testing Payloads

Estimated Time: 15 minutes

Materials:
• Launcher (from prior activities)
• Rocket (from prior activities)
• Height Scales, 1/launch station
• Play-doh payload, 5 sets (1/group)
• Digital scales, 5 (1/group)
• Plastic wrap, 1 roll
• Scotch tape, 5 rolls (1/group)
• Blue Sheets of card stock (1/launch station)
Procedures:
1. NOTE: DO NOT ALLOW STUDENTS TO PUT PLAY DO INSIDE THE ROCKET BODY TUBE! Only add the load externally using plastic wrap and tape.
2. Begin by asking students what is missing from our model rockets? (Answers will vary, but might include parts of the rocket, such as “fins” – which is OK, but ask “what else”? The important thing that is missing is the rocket’s load; up until this point we have been launching empty rockets. Rockets don’t usually launch into space without carrying some type of load for a particular mission).
3. Announce that we will be modeling rocket payload using Play-doh and distribute materials.
   - This is referred to as “PAYLOAD MISSION” on the student page. Have students circle Yes/No after working toward this mission.
4. Have students run launch trials using rockets that are carrying a load.
   - Students will use plastic wrap and tape to attach each pre-constructed Play-doh payload (5g or 40g) to the outside of the rocket. DO NOT PUT PLAY DOH INSIDE ROCKET BODY TUBE.
     i. Ask: “Where do you think we should attach these loads?” (answer should be near the top after having done the prior activity; ALSO, you can reinforce the EXTERNAL placement of the load using plastic wrap and tape).
     - Do small (5g) and large (40g) payloads separately.
     - Try to have rockets reach a minimum height of 5ft.
5. Have student groups share how the launchers performed when a load was added to the rockets.
6. Address any newly discovered vocab and other rocket-related terms from intro activity with the binder clip/ruler. [Allies can help us determine student-friendly definitions and any other necessary concepts]
   - Payload –
   - Others? –

Transition to next Activity (5-10 minutes): Lead a discussion about how the load impacted the launch of the Rocket. What relationship can be deduced from these results? (If the Rocket is carrying more mass it means a greater force is required to reach the same vertical distances upon launching => this is Newton’s 2nd Law of Motion). Ask: Does anyone’s launcher require modifications in order to meet the height requirement?

Activity 4: Launch Missions Estimated Time: 20 minutes
Materials:
- Finalized launcher
- Rocket (from prior activities)
- Height Scales, 1/launch station
- Play-doh payload, 5 sets (1/group).
- Digital scales, 5 (1/group)
- Plastic wrap, 1 roll
- Scotch tape, 5 rolls (1/group)
**Goal:**
*Can your students accomplish some NASA-inspired Space Missions? Have them follow the student page and use their launcher to send their rocket to various heights while carrying a particular load.*

**Procedure:**
1. By this time students have used their launcher prototype to send rockets off with and without a load. They may have needed to incorporate modifications into their launcher design in order to reach a variety of heights. Now they will use the remaining class time (except the 5-minute wrap-up) to attempt various missions (and possibly alter their launcher).
   - **NOTE:** not all groups are expected to successfully complete every mission but there are multiple mission challenges in the event that one groups’ launcher performs well; this way that particular group will have additional challenges to meet while other groups may need to modify their launcher before attempting each mission.
2. Quickly review the NASA missions that each group will attempt ([www.nasa.gov](http://www.nasa.gov)). Short summaries of the missions are also listed in the Student Page doc. Ask students to identify any mission-specific items that would contribute to the load in our rockets? (*mostly spacecrafts, people, supplies, robots, equipment, etc.*).

<table>
<thead>
<tr>
<th>ACTUAL NASA MISSIONS – BRIEF SUMMARIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>ISS 2000 – current</strong>: The International Space Station has had humans on it continuously since November 2000. The crew conducts research in many disciplines to advance scientific knowledge in Earth, space, physical, and biological sciences for the benefit of people living on our home planet.</td>
</tr>
<tr>
<td>• <strong>ARM 2013 – current</strong>: Asteroid Redirect Mission is the first-ever robotic mission to visit a large near-Earth asteroid, collect a multi-ton boulder from its surface, and redirect it into a stable orbit around the moon. This mission will demonstrate planetary defense techniques to deflect dangerous asteroids and protect Earth if needed in the future.</td>
</tr>
<tr>
<td>• <strong>LADEE 2013 – 2014</strong>: pronounced “Laddie”, this mission is a robotic mission to orbit the moon and gather detailed information about the lunar atmosphere, conditions near the surface and environmental influences on lunar dust which will address long-standing unknowns, and help scientists understand other planetary bodies.</td>
</tr>
<tr>
<td>• <strong>Journey to Mars 1960’s – current</strong>: There are six current missions involving Mars explorations addressing things like Martian geology, climate, and mineralogy as well as water availability and possible life forms.</td>
</tr>
<tr>
<td>• <strong>Europa – future</strong>: This mission to Jupiter’s moon, Europa, will allow NASA to conduct detailed reconnaissance of Jupiter’s moon Europa and investigate whether the icy moon could harbor conditions suitable for life.</td>
</tr>
</tbody>
</table>

3. Groups may need to modify their launcher, if needed, so their rockets can be launched with a given load and still meet the various height requirements for the different missions.
   - Encourage students to “divide and conquer” to make good use of the little time that remains.

4. Students should complete their student page while testing and making observations about launch height and mass.
   - There should be a digital scale at each station where students can reform the Play-Doh into the appropriate payload masses (table 1, student page).
5. Facilitate launches at the supervised launch stations/launch pads to ensure safety and have a consistent point of reference for meeting the height requirements. You will need to make sure all teachers and groups leaders are at a designated station throughout the lesson.

6. Announce amount of time remaining approximately every 5 minutes to keep students on task.

7. In the last few (maybe five) minutes of this activity allow each group to do one final “official launch” to demonstrate how their launcher works.
   • Have them pick a mission and launch their rocket with the mission-specific load in order to demonstrate whether their launchers can meet the vertical height criterion.

WRAP-UP ENTIRE LESSON  
Estimated Time: 5 minutes

Procedure:
1) Review the basic concepts of how mass impacted the amount of force that was needed for the rockets to reach a certain distances. Allow students to describe the relationship before pointing out that these are principles related to Newton’s 2nd Law of motion.
   • You can help the students visualize this relationship by drawing on the board during student comments/discussion (see extensions).
2) Have students share their conclusions about how additional loads affected the performance of their rocket launcher in meeting the criteria for each mission.

Assessment:
1) Informal observation of student progress during building/testing
2) Discussion-based assessments during transitions and wrap-up
3) Evaluating performance of each group’s rocket launcher for rockets with and without a load.
4) Completion of the student page
5) Demonstration of Rocket-Launcher performance

Clean-up:
1) Students should make sure that all reusable supplies are returned and all consumables are disposed of safely.
2) Students should ensure that their work areas are clean.

RELEVANT FUN FACTS:
1) NASA is currently studying the effect of being in space on the human body by having pair of astronauts spend one year in space. One of them has a twin brother back on Earth who can be used as a control for making comparisons at the end of the year.
2) The International Space Station has been continuously occupied by more than 200 people from 15 countries since Nov 2000.
3) If humans could travel at the speed of light, it would only take 43 minutes to reach Jupiter! Traveling by space shuttle would take 2.2 years. Traveling at a highway vehicle speed of 65mph, it would take you about 850 years!!
Possible Extensions:

1. Use the rocket model’s fins to decorate or embellish their rockets and discuss the role of fins in rocket trajectory/stability; however, using fins to stabilize flight path may not be applicable on a model rocket.
2. Address the acceleration aspect of Newton’s 2nd law for more advanced students (see appendix).
3. Emphasize other forces, lift and drag since gravity and thrust are addressed in this lesson; as well as other concepts in rocketry such as center of pressure and center of gravity.
4. Address how building prototypes can help with the design process (cost-effective, easier on a small scale, may spark other ideas, etc.)
5. Graphing data as it is collected: height of launch vs. mass (mission-specific) students could use different colored-circle stickers on large graph paper OR use a simpler approach, such as a higher/lower qualitative assessment (with mass or without mass) for each mission.

REFERENCES:


APPENDIX:

**Newton’s 2nd Law of Motion** states that a net force acting on an object causes that object to accelerate (change in velocity) and that the force required to accelerated a heavier mass is greater than the force required to accelerate a lighter mass according to the equation: \( f = ma. \) Acceleration is a change in an object’s speed or direction. The force is directly proportional to the mass at constant acceleration; the mass and acceleration of an object is inversely proportional at constant force; and finally, the force is directly proportional to the acceleration of an object at constant mass.

Suggested discussion: Draw the following on the board and ask students to complete blanks after the arrow using capital and lower case letters to signify the same variable of a different magnitude (capital letters mean greater magnitude; NOTE that it is for our purposes and not the official algebraic notation as mentioned earlier in the lesson).

- @ constant acceleration (direct)
  - \( F \rightarrow M \)
  - \( f \rightarrow m \)

- @ constant force (inverse)
  - \( F \rightarrow m \)
  - \( f \rightarrow M \)

- @ constant mass (direct)
  - \( F \rightarrow A \)
  - \( f \rightarrow a \)

**Summary of relationships in Newton’s 2nd law of motion:**

- If the acceleration is the same for two objects with different masses, then the force applied to the object with the smaller mass is less than the force applied to the object with the larger mass (direct relationship between force and mass @ constant acceleration). Which requires more force?
  - a mac truck OR a motorcycle to slow down at a stoplight = a mac truck
  - a propeller plane OR a 747 passenger airplane to speed up during take-off = a 747 passenger airplane
• If the same force is applied to two objects with different masses, then the acceleration of the object with the smaller mass is greater than the acceleration of the object with the larger mass (inverse relationship between mass and acceleration @ constant force). Which will travel farther because of the greater acceleration?
  o If both are flung from a slingshot with equal force:
    a heavy rock OR a ping pong ball = heavy rock
  o If both are shot from a cannon with equal force:
    a basketball OR a metal cannonball = metal cannonball

• If a different force is applied to the same object in two different situations, then when a smaller force is applied it has a lesser acceleration than when a larger force is applied to the same object (direct relationship between force and acceleration @ constant mass). In which of the two situations is a greater force applied to the same object to achieve a greater acceleration?
  o a plastic pellet shot from a compressed gas Airsoft gun OR shot from a spring Airsoft gun = shot from a compressed gas Airsoft gun
  o a tennis ball served by you OR served by one of the pro Williams sisters = served by one of the pro Williams sisters