

GRADES

K-12

Rockets Away

propulsion

Aeronautics
Research
Mission
Directorate





(Photo courtesy of NASA - www.nasaimages.org)

Rockets Away

Lesson Overview

In this lesson students will discover Isaac Newton's Third Law, which states "To every action, there is always an equal and opposite reaction". Through experimentation with different propellants, students will learn how pressures and chemical reactions can be used to generate the thrust needed to launch their own rocket.

Objectives

Students will:

1. Learn how thrust is produced by creating a Hero engine.
2. Discover how thrust is generated through the use of compressed air. (Ages K-6)
3. Discover that thrust can be generated through the use of compressed air. (Ages 7-12)
4. Demonstrate how thrust is generated through chemical reaction.

Materials:

In the Box

Large tank
Stomp Rocket Kit
Air Rocket Kit
Bicycle pump
Stop watch

Provided by User:

Empty soda can with opener still attached
(one per two students)

18 - 24" length of string or fishing line
(one per two students)

Medium sized nail
(one per two students)

Water

35mm Film Canisters - the clear Fuji Film™ ones work best (1 per group)

Alka-Seltzer™ or other type of effervescent tablets (at least 6 per group)

Fine permanent marker (1 per group)

Yard stick / long ruler (1 per group)

Butter knife / pill cutter (1 per group)

GRADES

K-12

Time Requirements: 3 hours 30 minutes

Background

The History of the Rocket

For centuries, rockets have played an important role in human civilization. Dating back to 1300 BC, the Chinese used rocket power to make arrows fly farther than was possible with a regular bow. Countries have been destroyed and created all due to the humble rocket. Even the U.S. National Anthem refers to “the rocket’s red glare”!

It wasn’t until 1686 that, thanks to the Englishman Sir Isaac Newton (Img. 1), we truly understood how and why they worked. His theory, that “To every action, there is always an equal and opposite reaction”, demonstrated quite simply that if Object A exerts a force on Object B, then Object B exerts an equal force on Object A, but in the opposite direction (Fig.1).

In “Action & Reaction” (Fig. 1) you can see that the jet engine (A) is creating exhaust gasses (B). As the engine pushes the gasses outward, those same gasses exert a force on the engine, pushing it forward. This is how the thrust is produced, generating the energy our rocket needs for flight.

After World War II, the United States and the Soviet Union engaged in what became known as “The Space Race”. Initially, both sides planned to use modified missiles capable of carrying passengers instead of their usual, more lethal payloads. By using the world’s first Intercontinental Ballistic Missile, the R-7 Semyorka rocket, the USSR ultimately won the first round in 1957 with the launch of the Spunik I. In 1962, the Soviets were also the first country to put a human into space. Yuri Gagarin’s flight lasted just an hour and forty-eight minutes but provided America with much needed inspiration as just three days later, President John F. Kennedy pledged to place a man on the Moon by decade’s end.

Project Mercury was the United States’ first manned space program, with John H. Glenn being of the first American in true orbit. (Alan Shepard was the first to fly, but his mission was not intended to reach orbit.) Mercury led the way for the Gemini program, which was based around a Titan intercontinental ballistic missile. With missions lasting up to 14 days, the Gemini astronauts demonstrated successful space walks and docking procedures, both of which would be vital to any lunar mission.

The quest to land a man on the Moon was accomplished at 10:56 p.m. EDT on July 20th, 1969 when Neil Armstrong and Buzz Aldrin set foot on the Moon, while Michael Collins circled the Moon in the Command Module. The liftoff for the Apollo 11 crew was on a Saturn V rocket developed especially to launch the different Apollo astronaut crews to the Moon.

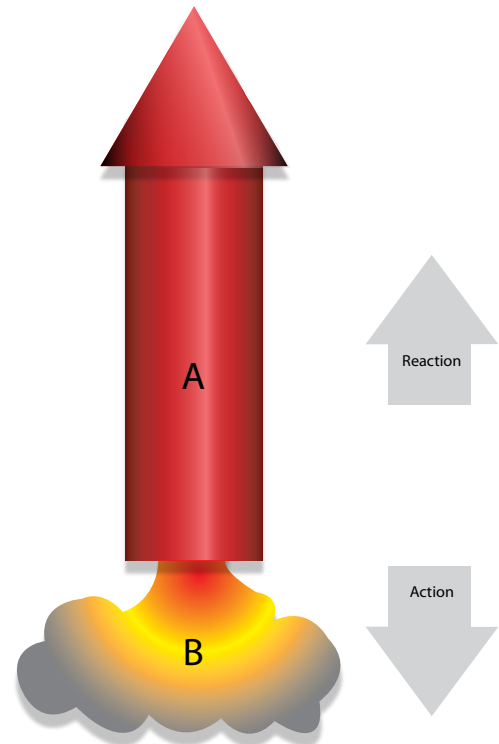


Fig. 1 Action & Reaction



Img. 1 Sir Isaac Newton (age 46)

The timeline below highlights some of human space flight's milestones. Starting with the Sputnik capsule back in 1957 all the way through to the end of the Space Shuttle program in 2011.



Img. 2 A history of manned space flight

Activity 1

The Aeolipile or Hero Engine

GRADES
K-12
Time Requirement: 30 minutes

Materials:
In the Box:

Large tank

Provided by User:

 Empty soda can with opener still attached
(one per two students)

 18 – 24" length of
string or fishing line
(one per two students)

 Medium sized nail
(one per two students)

Water

Worksheets:

 Hero Engine
(Worksheet 1)

Reference Materials:

None

Key Terms:

The Aeolipile

Thrust

Newton's Third

Law of Motion

Force

Objective:

Students will learn how thrust is produced by creating a Hero engine.

Activity Overview:

The Aeolipile (Img. 2) or Hero engine was invented by Hero of Alexandria in 1 BC . He used a water-filled copper sphere that when heated, generated steam which could be used to create motion. For safety, we will use the thrust provided by the release of water instead of steam.

Activity:

1. **Fill the tank with water and place in a safe area.**
This area WILL get wet during the activity.
2. **Divide the class into pairs and provide each pair with string, a nail and a soda can.**
3. **Have the students tie the string onto the opener of the soda can so that when in use, the can is able to rotate freely on the string.**



Img. 2 A reproduction of Hero's Engine



CAUTION: Exercise caution when handling the nails. Supervision may be necessary if working with younger students.

4. Using the nail, have students make two equally spaced holes in the side of the can, near the base. Before removing, push the nail to the left in order to slant the hole in that direction.
5. Have the students submerge the can in the tank of water. Once full, lift the can out of the water using the string and count the rotations the can makes. Record the number of rotations in the "2 holes" column of Worksheet 1.
6. Have the students add additional holes to the can and repeat the experiment several times, recording the number of holes and number of rotations made by the can on the worksheet.



Discussion Points:

1. Why did the soda can rotate when it was lifted out of the water?

As the water escaped from the soda can, it generated a force away from the can. As per Newton's Third Law of Motion, that also created an equal but opposite force which pushed towards the can. Since the can was held in place by the string, it caused the resultant rotational force to turn the can.



2. What happened when additional holes were added to the can? Did it rotate more or less?

While each student's answer will be different, it should be discovered that the can initially rotated faster but stopped sooner. This is because the additional flow of water created more force but that meant that the water ran out sooner.

3. How could the Hero engine be used in a real life scenario?

Answers will vary but anything that requires a turning force could be modified to use a Hero engine. In actuality, it is not known if Hero ever used this device.

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

PHYSICAL SCIENCE

- Property of objects and materials

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
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PHYSICAL SCIENCE

- Properties and changes of properties in matter

SCIENCE AND TECHNOLOGY

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NATIONAL SCIENCE STANDARDS 9-12

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Activity 2

Stomp Rocket

GRADES
K-12
Time Requirement: 30 minutes

Materials:
In the Box:

Stomp Rocket Kit

Provided by User:

None

Worksheets:

None

Key Terms:

Thrust

Objective:

To discover how thrust is generated through the use of compressed air.

Activity Overview:

In this activity, students will demonstrate how compressed air can be used to power a rocket.

WARNING: This activity should be performed outdoors or in a room with a high ceiling.

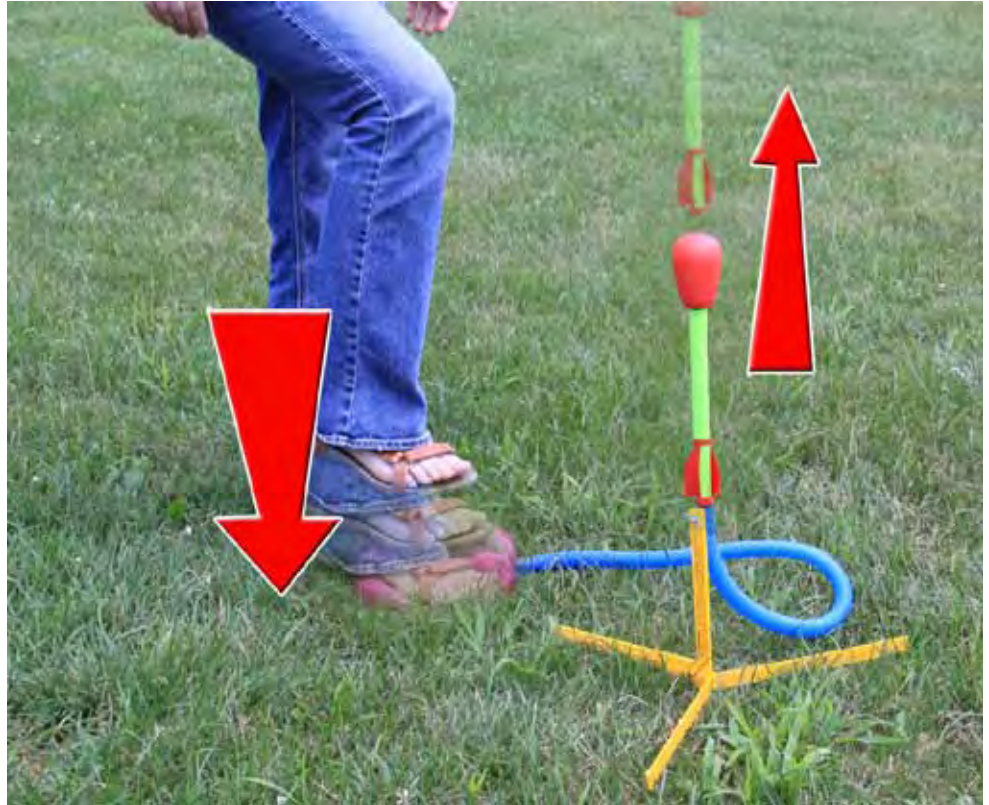
NOTE: This activity is best suited for younger students who are being introduced to compressed air for the first time. For older students, [Activity 3 – Air Rocket](#) may be a better option.

Activity:

1. Create a “safe zone” that can be used to safely launch the rocket. Explain to the students that as the rocket will fall back to Earth, it is important they always watch where it will land and move if necessary.
2. Construct the launch pad using the instructions provided in the kit.



3. **Demonstrate to the students how the rocket works by placing the rocket onto the launch tube and stepping on the stomp bottle.** If desired, have the students provide a countdown prior to launch.
4. **Repeat with each student, allowing them to apply different amounts of pressure to the stomp bottle such as by jumping on or gently squeezing the bottle.**



Discussion Points:

1. **What caused the rocket to launch?**
As you pressed on the stomp bottle it compressed the air inside. This compressed air created a force that passed down the hose and into the rocket. The force into the rocket created an opposing force that pushed the rocket away from the launch pad.
2. **Why did it sometimes launch higher than others?**
Because the rocket relies on air pressure for thrust, the higher air pressures provided more thrust for the rocket. The larger students or those who jumped or stomped on the bottle generated much higher air pressures than those who gently pressed or squeezed the bottle.

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Activity 3

Air Rocket

GRADES **K-12****Time Requirement:** 60 minutes**Materials:**In the box:

Air Rocket Kit

Bicycle pump

Stop watch

Provided by User:

None

Worksheets:

None

Worksheet:Air Rocket
(Worksheet 2)**Objective:**

To discover that thrust can be generated through the use of compressed air.

Activity Overview:

In this activity, students will experience how compressed air can be used to power a rocket.

WARNING: This activity **MUST** be performed outdoors.*NOTE: This activity is best suited for older students as it involves the use of high pressure compressed air. For younger students, [Activity 2 – Stomp Rocket](#) may be a better option.***Activity:**

1. **Create a “safe zone” that can be used to safely launch the rocket.** As this experiment creates high powered projectiles, it is vital that the safe zone be sufficiently large and roped off to ensure the safety of those around you. A sports field will work well for this activity.
2. **Construct the launch pad using the instructions provided in the kit.**
3. **The kit includes red and white disks which are referred to by the manufacturer as “Photons” (white) and “Bozons” (red).** These plastic disks are used to control the height that the rocket can reach by altering the pressure required for launch.

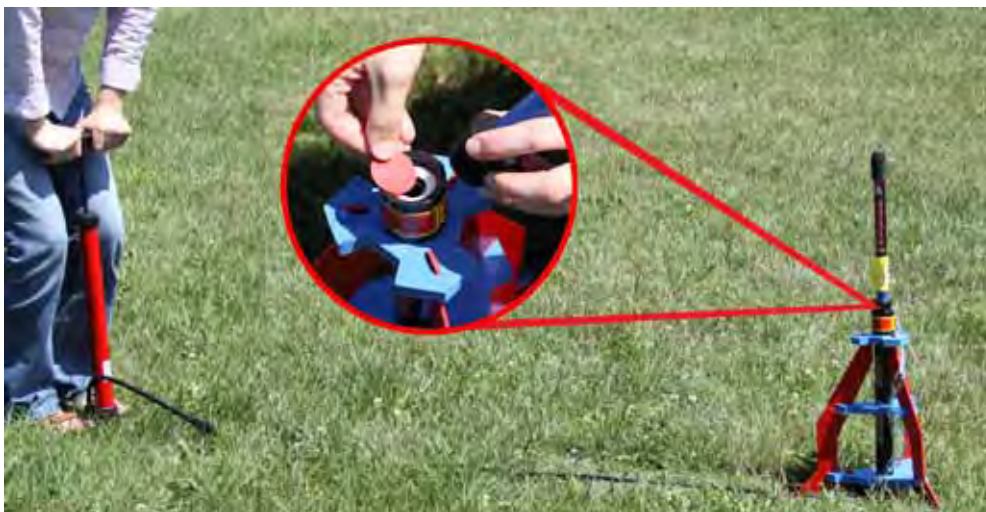


Disk Combination	Approximate number of pumps to launch	Approximate Height	Pressure
1 White	3	250 ft.	40 psi
2 White	5	500 ft.	80 psi
1 Red	7	600 ft.	90 psi

Table 1: Air Rocket disk combination specifications

CAUTION: At no time should you exceed 2 red disks or 150psi.

- Next, have the students take turns launching the rocket using the 3 disk combinations listed in Table 1 while others use the stopwatch to record the time it spends in flight, collecting the results onto their worksheet. Repeat as necessary to ensure all the students have had an opportunity to both time and launch the rocket.
- Using the worksheet, plot the results of the 3 different disk combinations to compare time of flight with the amount of air pressure required to launch the rocket.



Discussion Points:

- What caused the rocket to launch?**
As you pushed on the bicycle pump it compressed the air inside the launch tower. Once the air pressure limit was reached, as determined by the selected disk, it released that air into the rocket. This force created an opposing force which pushed the rocket away from the launch pad.
- Discuss the data the students plotted. Is there a direct correlation between time flown and air pressure?**
This will vary due to environmental factors such as gusty winds but it should be discovered that there is a fairly linear correlation between them. (The line plotted should be somewhat straight.)

3. **How does the propulsion system of this rocket differ from those used by NASA?**
Apart from the main difference of rocket fuel vs. compressed air, the primary difference is that with real rockets, the fuel is stored and burned in the rocket itself, whereas with the air rocket the air is stored externally prior to launch.
4. **What are the benefits and drawbacks of such a design?**
With the fuel stored externally it means the rocket can be much lighter since on launch, it only has to lift its own weight. With stored fuel, the rocket also needs additional thrust in order to lift the weight of the rocket and the fuel skyward. The biggest drawback however is that with an external supply, once the rocket has left the launch tower it no longer has any propulsion and will start to slow down immediately. With an on-board supply the rocket will continue to accelerate until the fuel supply is exhausted.

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NATIONAL MATH STANDARDS K-12

NUMBER AND OPERATIONS

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

ALGEBRA

- Represent and analyze mathematical situations and structures using algebraic symbols
- Use mathematical models to represent and understand quantitative relationships

MEASUREMENT

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements.

DATA ANALYSIS AND PROBABILITY

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

- Problem Solving
- Communication
- Connections
- Representation

Activity 4

Alka-Seltzer™ Rocket

GRADES K-12**Time Requirement:** 60 minutes**Materials:**In the Box:

None

Provided by User:

35mm film canisters
the clear FujiFilm™
one work best
(1 per group)

Water

Alka-Seltzer™
or other type of
effervescent tablets
(at least 6 per group)

Fine permanent marker
(1 per group)

Yard stick / long ruler
(1 per group)

Butter knife / pill cutter
(1 per group)

Worksheets:

Alka-Seltzer™ Rocket
(Worksheet 3)

Key Terms:

Thrust

Objective:

To demonstrate how thrust is generated through chemical reaction.

Activity Overview:

By using an effervescent tablet to create carbon dioxide, students will demonstrate the explosive force of a gas by measuring how high it can launch a film canister.

Activity:

1. **Divide the students into groups of two. Have each group perform the remaining steps.**

2. **Start by dividing the canister into quarters by marking lines on the side.** This will be used to measure the quantity of water used later.

3. **Create a control launch.**

To do this:

- a. Have one student hold the ruler vertically in preparation of the launch.
- b. Fill the film canister one quarter full of water.
- c. Cut a tablet into quarters and place just one quarter into the water. Quickly replace the lid.
- d. Shake the canister for a few seconds, then place it lid-side down on a table.
- e. Wait for launch!
- f. Measure and record the height that the canister reached on the worksheet.

4. **Try various combinations of tablet and water quantities in order to determine which combination lifts the canister the highest.** Record the results on the worksheet.





Discussion Points:

1. **What causes the canister to suddenly jump into the air?**

When the effervescent tablet interacts with water it produces carbon dioxide gas. As this gas builds up inside the canister, it pressurizes, generating energy. Eventually, the friction of the lid cannot hold back this building pressure and releases, allowing the gas to escape. This force creates the opposing force that lifts the canister into the air.

2. **What combination of water and tablet quantities provided the most lift?**

While the students' answers will vary, it should be discovered that some air is needed in the canister to provide the best results. This is because the carbon dioxide needs space to build and compress. With a canister full of water the gas has no option but to escape immediately, preventing pressure from building up.

3. **What else can be done to increase the height of the canister?**

Greater height requires an increase in pressure inside the canister. This can be done for example by securing the lid with tape or glue, or by adding additional tablets.

NATIONAL SCIENCE STANDARDS K-4

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PHYSICAL SCIENCE

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DATA ANALYSIS AND PROBABILITY

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PROCESS

- Problem Solving
- Communication
- Connections
- Representation



Reference Materials

Glossary

The Aeolipile:

A rocket-style engine that rotates when the water inside is heated, producing steam; often considered the first steam engine or reaction steam turbine

Compressed Air:

Air that is currently at a pressure higher than the atmospheric pressure; often used as a source of power for machines

Force:

An influence on a body which produces (or attempts to produce) a change in movement, direction or shape

Geosynchronous Orbit:

An orbit that completes one revolution in the same amount of time it takes for the Earth to rotate once on its axis. This means that an orbiting object, such as a satellite, would be in the same position of the sky at the same time each day. This should not be confused with a Geostationary Orbit, where the object stays in the same position regardless of the time of day

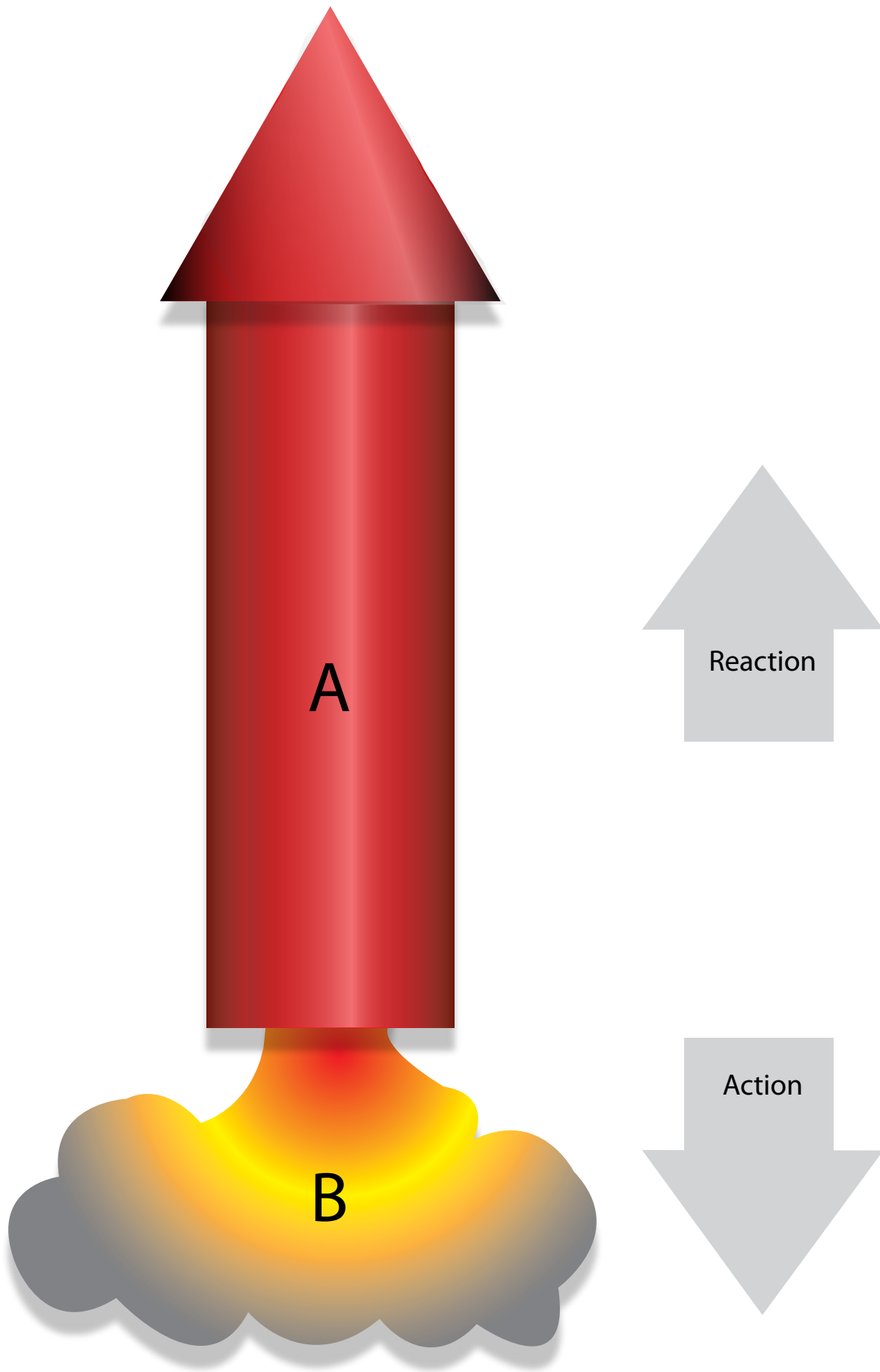
Newton's Third Law of Motion:

To every action, there is always an equal and opposite reaction.

Thrust:

A reactive, linear force exerted in order to propel an object in the opposite direction

Fig. 1 Action & Reaction



Img. 2 A history of manned space flight



Caption: The Vostok Rocket
Country: USSR
Rocket: Vostok (R-7 Derivative)
Cosmonaut: Yuri Gagarin
Fact: The first man to enter Earth's orbit



Caption: The Launch of Mercury 7 on an Atlas rocket
Country: USA
Rocket: Atlas
Astronauts: John Glenn
Fact: The first American in Earth's orbit



Caption: A Soyuz rocket being delivered to the launch pad
Country: USSR
Rocket: Soyuz
Cosmonaut: Colonel Vladimir Komarov
Fact: First confirmed fatality when the capsule crashed upon landing



Caption: The launch of the Space Shuttle Columbia
Country: USA
Rocket: Space Shuttle Columbia (OV-102)
Astronauts: John Young, Robert Crippen
Fact: The first flight of the US Space Shuttle program

October 4th
1957



Caption: The Sputnik Capsule
Country: USSR
Rocket: R-7
Cosmonaut: Unmanned
Fact: The first man-made object to orbit the Earth

April 12th
1961



Caption: The launch of Mercury 3 on a Redstone rocket
Country: USA
Rocket: Redstone
Astronaut: Alan Shepard
Fact: The first American in sub-orbital flight

May 5th
1961

February 20th
1962



Caption: The Launch of Gemini III
Country: USA
Rocket: Titan II
Astronauts: Virgil "Gus" Grissom, John Young
Fact: First manned flight of the Gemini program

March 23rd
1965

April 24th
1968



Caption: The Saturn 5 Rocket carrying Apollo 11
Country: USA
Rocket: Saturn V
Astronauts: Neil Armstrong, Edwin "Buzz" Aldrin, Michael Collins
Fact: Took the first men to land on the Moon

July 20th
1969

April 12th
1981

July 8th
2011



Caption: Landing of Space Shuttle Atlantis
Country: USA
Rocket: Space Shuttle Atlantis (OV-104)
Astronauts: Chris Ferguson, Doug Hurley, Rex Walheim, Sandy Magnus
Fact: The final flight of the US Space Shuttle program



Student Worksheets

Worksheet 1

Hero Engine

Record the number of revolutions your can makes in the table below.

	2 Holes	_____ Holes	_____ Holes	_____ Holes	_____ Holes
Number of Rotations					

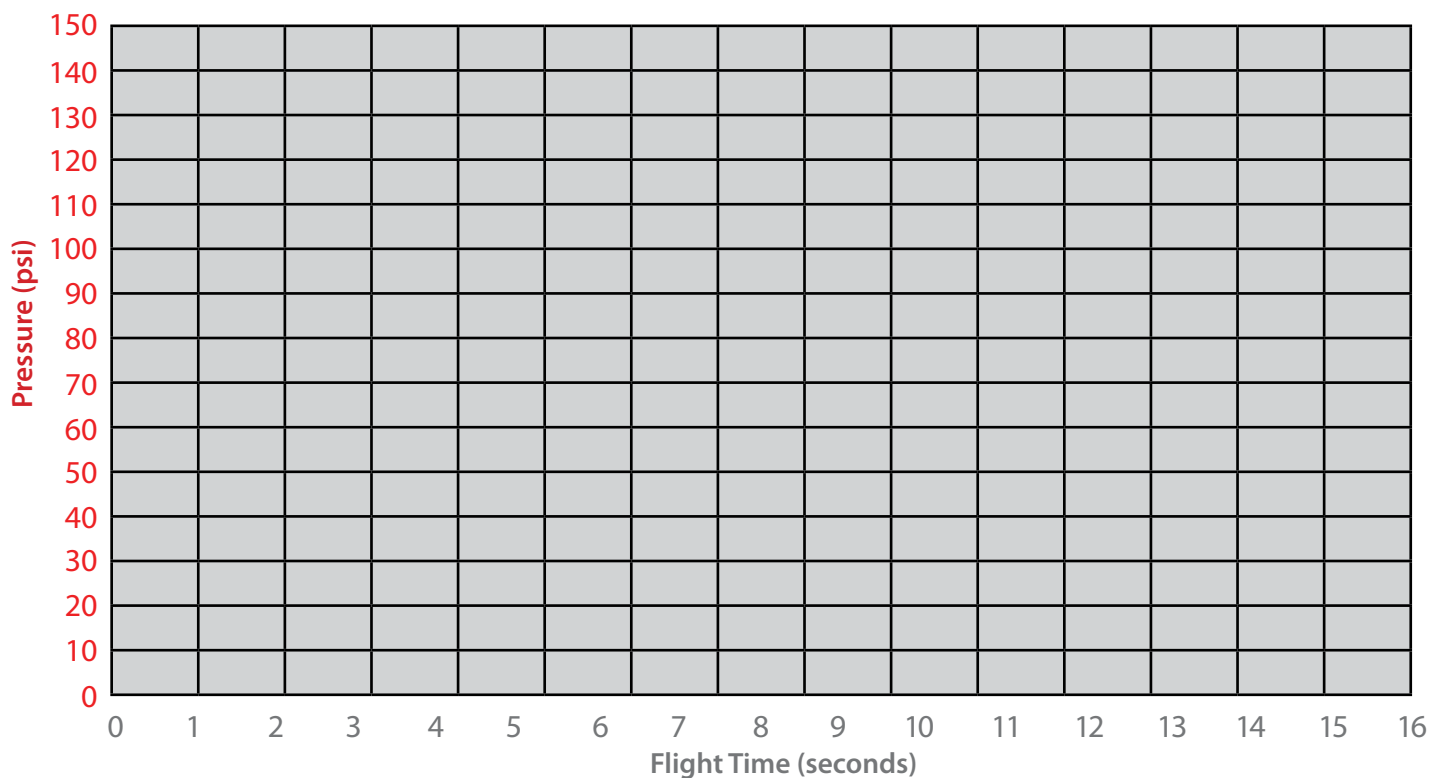
Worksheet 2

Air Rocket

Record the rocket's total time airborne for each combination of disks in the tables below.

Disks	1 White Disk	2 White Disks	1 Red Disks
Flight Time			

Graph your results from the table above.



Worksheet 3 Alka-Seltzer™ Rocket

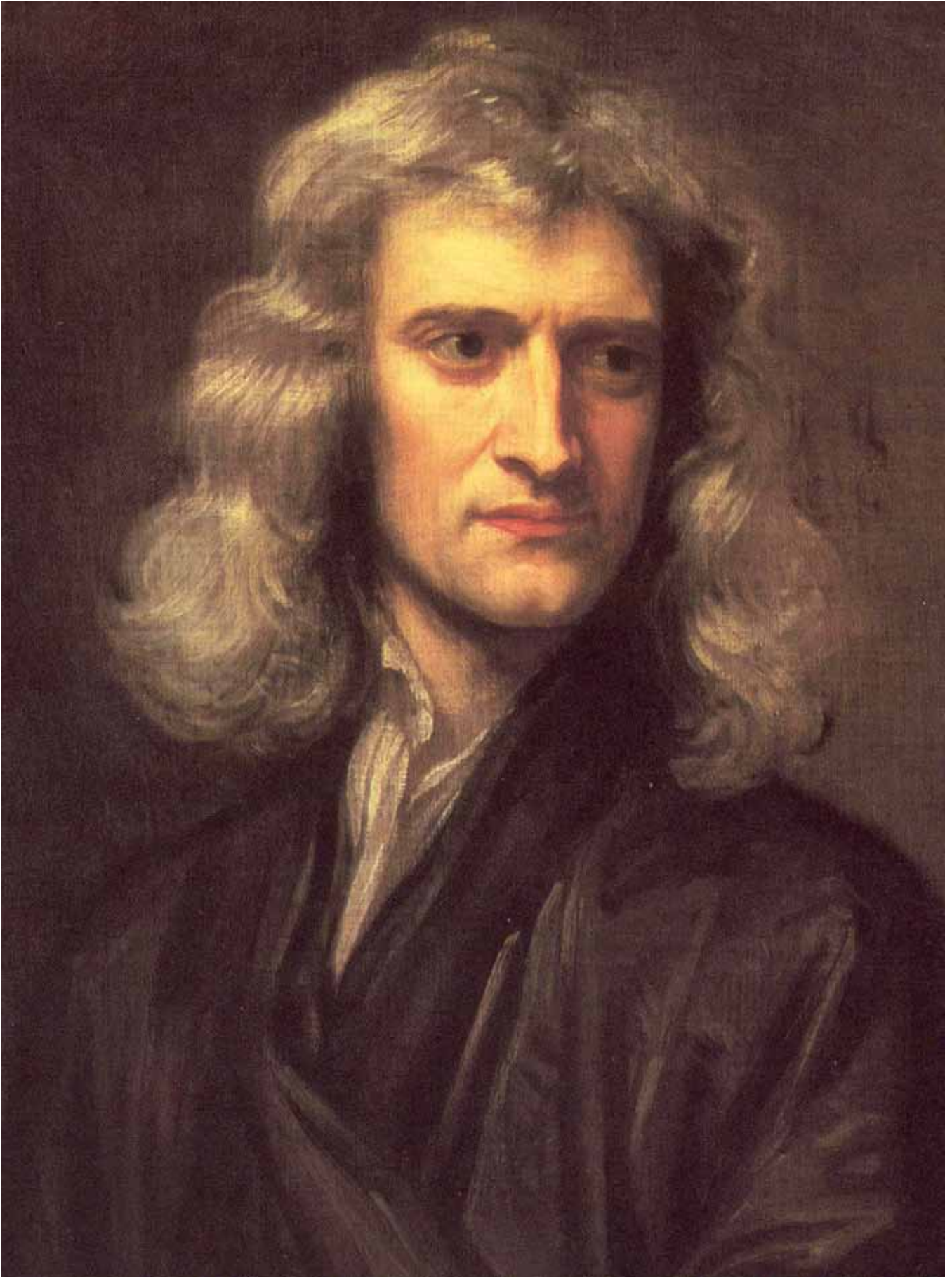
Record the height achieved by the canister for each combination of water amount and tablet pieces in the table below.

Water	1/4 Full	_____ Full	_____ Full	_____ Full
Tablets				
1/4 Tablet				
_____ Tablet				
_____ Tablet				
_____ Tablet				
_____ Tablet				
_____ Tablet				
_____ Tablet				
_____ Tablet				



Images

Img. 1 Sir Isaac Newton (age 46)



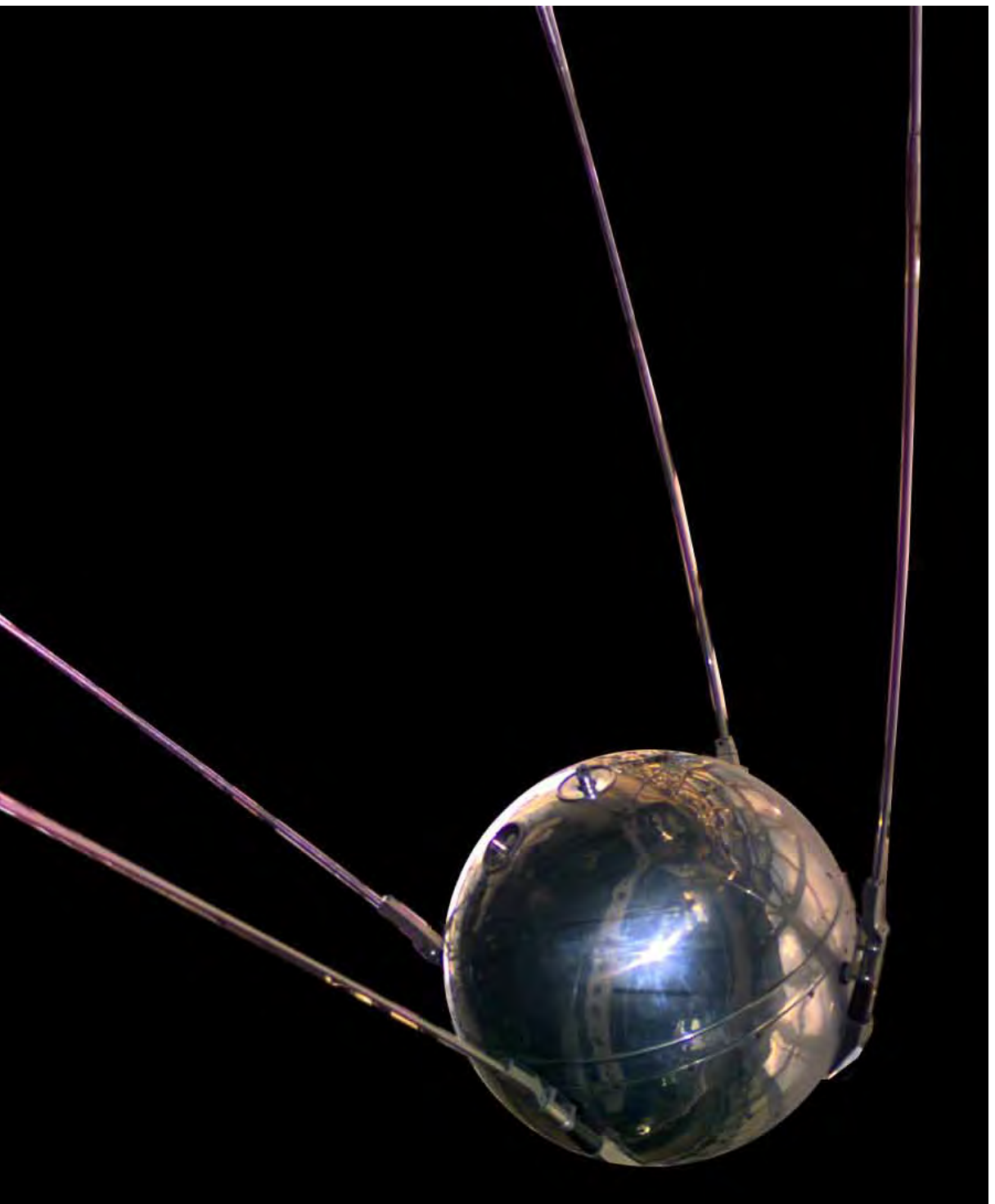
(Painting by Sir Godfrey Kneller - 1689)

Img. 2 A reproduction of Hero's Engine



(Photo courtesy of Tamorlan - Attribution 3.0 hlv)

Img. 3 The Sputnik Capsule



(Photo courtesy of NASA - www.nasaimages.org)

Img. 4 The Vostok Rocket



(Image courtesy of Sergei Korolyov - GNU Free Documentation License)

Img. 5 The launch of Mercury 3 on a Redstone rocket



(Photo courtesy of NASA - www.nasaimages.org)

Img. 6 The Launch of Mercury 7 on an Atlas rocket



(Photo courtesy of NASA - www.nasaimages.org)

Img. 7 The Launch of Gemini III on a Titan rocket



(Photo courtesy of NASA - www.nasaimages.org)

Img. 8 A Soyuz rocket being delivered to the launch pad



(Photo courtesy of NASA - www.nasaimages.org)

Img. 9 The Saturn 5 Rocket carrying Apollo 11



(Photo courtesy of NASA - www.nasaimages.org)

Img. 10 The launch of the Space Shuttle Columbia



(Photo courtesy of NASA - www.nasaimages.org)

Img. 11 Landing of Space Shuttle Atlantis



(Photo courtesy of NASA - www.nasaimages.org)

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