Lesson Plan
The Gravity of Émilie du Châtelet

Gabrielle-Émilie Le Tonnelier de Breteuil, Marquise du Châtelet**.**

Image courtesy of La Château Breteuil, painted by Maurice Quentin de la Tour.

Grade Level(s): K-5	**Subject(s): History, Physics**

In-Class Time: 40-45 minutes	**Prep Time: 7-10 minutes**

Materials

- Internet access
- A computer and projector to show a short video
- Two lightweight items of the same weight, and two heavier items of the same weight (such as balls, erasers, blocks, or toys)
- Yard stick
- A bin of wet sand (if sand is inaccessible, flour or malleable clay should suffice)
- Materials to put below the wet sandbox for cleanup, such as newspaper, paper, towels, or paper towels

Objective

This lesson focuses on the life and work of Gabrielle-Émilie Le Tonnelier de Breteuil, Marquise du Châtelet, more commonly known as Émilie du Châtelet. Students will learn about gravity, understanding that gravity pulls objects down, and that it pulls heavier objects down with more force than lighter objects. Students will repeat a simpler version of du Châtelet's own experiment, dropping small objects of different sizes into wet sand from different heights. They will predict the result of the experiment, carry it out, and explore to see how gravity affects these objects.

Introduction

With vital contributions to the advancement of physics, mathematics, and philosophy to her name, Émilie de Breteuil du Châtelet was nothing short of revolutionary. Although she passed away at the age of 42 due to childbirth complications, du Châtelet was an intellectual and a freethinker of her time, continuing to stand up for her own individuality, right to education, and contributions to the sciences while also running both a family and her own experiments and maintaining her position in the 1700s French aristocracy. Some of her most notable work concerned the physics of heat transfer (published anonymously in a compilation with other works by Voltaire and Leonhard Euler), the philosophy of different ways of thinking about physics, reflections and expansions of Newtons ideas, and the translation of Newton's entire *Philosophiæ Naturalis Principia Mathematica* (including her own annotations and explanations of his theory). This last work was published after she passed away.

Gabrielle-Émilie Le Tonnelier de Breteuil, Marquise du Châtelet, was born in 1706 into French aristocracy in Paris. For women, this was a society where being knowledgeable in science and math was more likely to be mocked than respected;[1] looks and poise were far more valuable than intelligence. However, her social position and parents allowed her to pursue far more tutoring than most women at the time, granted her open access to their family library, and provided an environment where other intellectuals of the time would be accessible to her.[2] Émilie's father, Louis Nicolas le Tonnelier de Breteuil, held a position in the court of Louis XIV and was supportive of her curiosity, allowing and arranging her tutoring in six languages, sports, and science.[3] When Émilie had her own house later in life, she made an extensive library holding many thousands of books and was known to invite experts

[1] Perl Morrow, *Notable Women in Mathematics: A Biographical Dictionary* (Westport, Connecticut: Greenwood Press, 1998), 39.
[2] Patrick Monahan, "A Pitt science historian shares stories of an overlooked woman scientist," Pittwire, University of Pittsburgh, last modified March 31, 2022, https://www.pitt.edu/pittwire/features-articles/emilie-du-chatelet-newton.
[3] Mary Waithe, *A History of Women Philosophers*, volume 3, (Springer, Dordrecht, 1991), 128. https://doi.org/10.1007/978-94-011-3790-4_8.

and intellectuals to the house to continue her education.[4] Émilie continued to find creative ways to expand her education, despite her role as a woman, even dressing up as a man to do so. Later in life, as Émilie grew the community of (predominantly male) intellectuals around her, she was known to dress as a man to be allowed into male-only cafes, where intellectual discussions often took place.[5] Although most of her work was published anonymously in order to avoid the stigma of female authorship, it is likely that those working in her fields knew that Émilie was responsible for the work.

Émilie married Marquis Florent-Claude du Châtelet at 18, who was often away in the army during their marriage. As he was away, Émilie continued her intellectual pursuits, cultivated both her connections with scholarly aristocracy and well-known strength in gambling, and continued a longstanding affair with Voltaire (François-Marie Arouet).[6] Émilie and Voltaire worked together on many scientific and philosophical projects, holding frequent discussions within the intellectual community around them and running experiments. However, given her position as a woman in history, Émilie is often remembered as his mistress rather than for her own incredible intellect. Voltaire, as did many of the other members of their society, recognized and respected Émilie's intelligence. Voltaire even called her his "divine Émilie,"[7] often writing notes and poetry inspired by her:

> "Her noble mind brightens every room.
> She's possessed of charm and wit,
> Though sometimes shows too much of it.
> She has, I assure you, a genius rare.
> With Horace and Newton, she can compare…"[8]

Du Châtelet and Voltaire seem to have worked together on many scientific and philosophical projects, although she did not get direct credit for many of them. Their bond ran deep; Émilie even secretly housed Voltaire in a country home while he was being persecuted for his radical public criticisms of Parisian society.[9] It was also at this country estate that Émilie's extensive library could be found, and where many notable experts gathered for discussions and networking, giving Émilie even more opportunity for intellectual challenge and stimulation. Émilie produced some of her most well-known works during this time when she predominantly lived and experimented at her estate, both in tandem with Voltaire and on her own.

---

[4] Ernie Tretkoff, "This Month in Physics History December 1706: Birth of Émilie du Châtelet," *APS News*, 17, no. 11 (December 2008) https://www.aps.org/publications/apsnews/200812/physicshistory.cfm.
[5] Morrow 40.
[6] Tretkoff.
[7] Judith Zinsser. "Translating Newton's Principia: The Marquise du Chatelet's Revisions and Additions for a French Audience," *Notes and Records of the Royal Society of London* 55, no. 2 (May 2001): 227, https://doi.org/10.1098/rsnr.2001.0140.
[8] "Emilie du Chatelet," History 60, University of California Irvine, accessed June 30, 2022, http://faculty.humanities.uci.edu/bjbecker/revoltingideas/Émilie.html#divine.
[9] Morrow, 41.

She and Voltaire both entered papers into a 1737 competition by the French Academy of Sciences, where her experiments on light and heat, which had been performed in secret, were first published. Then in 1738, Émilie co-wrote *Elements of Newton's Philosophy*, to be published under Voltaire's name.[10] Two years later, she published a manuscript, *Foundations of Physics*. This text concerned the philosophy of physics, discussing the ideas of Newtonian, Cartesian, and Leibnizian philosophies. The work was both highly praised and controversial, as views on different interpretation of physics were hotly debated at the time, along with enlightenment debates (such as those surrounding the basis of religion in science).

She was not only well educated on Newtonian physics, but also expanded on Newton's ideas. In one of her many experiments, Émilie adapted Willem Jacob 's Gravesande's experiment by combining it with Gottfried Leibniz's theory. Gravesande's experiment involved dropping heavy balls into soft clay to study gravity and kinetic energy. Newton had previously thought that $E = mv$, but, with this experiment, Gravesande was able to show that it was more likely that $E = mv^2$. (We now know it today to be $E = ½ mv^2$). Émilie and Willem likely had many discussions on the matter, and Émilie provided further justification for the idea in her *Foundations of Physics* manuscript.

However in 1749, at the age of 42, Émilie du Châtelet became pregnant with her fourth child. Geriatric pregnancies at the time came with a likely death sentence, and Émilie recognized that she probably had limited time left. With this knowledge, Émilie did not submit to a peaceful end-of-life, but instead dedicated sleepless nights to her final project. During her pregnancy, du Châtelet made a full translation of Newton's *Philosophiæ Naturalis Principia Mathematica*, not only translating it, but also adding her own annotations, explanations, and comments to his work. Finishing the piece took immense amounts of work, with Émilie herself writing that she would "… get up at nine, sometimes at eight… and keep on till five in the morning."[11] Her work was published after she passed away and continues to stand as the sole French translation.

In her lifetime, Émilie du Châtelet not only contributed to the worlds of mathematics, philosophy, and physics, but she also remained outspoken for women's right to education. In the 1735 preface of du Châtelet's translation of Mandeville's *Fable of the Bees*, Émilie wrote "…women have a right to speak out for their education… I confess that if I were king, I would conduct the following experiment. I would correct this abuse that has cut short a full half of the human race. I would get women to participate in all the privileges of humanity, especially those of the mind."[12] She repeatedly used her wit and education to enter intellectual debates and advocate for herself.

After her death, Voltaire wrote a preface to du Châtelet's translation of Newton's *Philosophiæ Naturalis Principia Mathematica* that honored Émilie's role as a revolutionary woman: "It is unusual for a woman to know simple geometry, let alone the sophisticated mathematics needed to

[10] Morrow.
[11] Morrow, 42.
[12] "Emilie du Chatelet."

understand the ideas in Newton's immortal work. Clearly, Mme la Marquise du Châtelet has mastered the teaching of that great man. We have seen two miracles: one, that Newton wrote this work in the first place; the other, that a lady has translated and explained it… Mme du Châtelet has rendered a double service to future generations of scholars…"[13]

Instructions/Activities

Engage: 2-5 Minutes

Teachers will introduce students to Émilie du Châtelet by showing a very brief (2:16) video from Studies Weekly (link found here and in Required Resources).	
What is the teacher doing? Show the Studies Weekly 'Émilie du Châtelet' video to introduce students to Émilie's life (link found here and in Required Resources). Teachers can choose to only show from 0:34 to the end of the video for a shortened biography. This video serves as a short recount of some of Émilie's life accomplishments.	**What are the students doing?** Become acquainted with du Châtelet through the Studies Weekly video.

Explain: 3-5 Minutes

The teacher will lead students in a class-wide exchange, highlighting key points pertaining to Émilie's life. Questions are provided and deliberated, and Émilie's story is reflected on as a group.	
What is the teacher doing? Lead the class in participating in a discussion regarding du Châtelet. In this, they will review her life and accomplishments. Key points for teachers to highlight are listed in the 'Main Discussion Points' listed below and in the Supplemental Materials for this Lesson Plan.	**What are the students doing?** As a class, students will reflect on du Châtelet's life, accomplishments, and work in physics.

Engage: 2-5 Minutes

Teachers will then discuss gravity with students, asking them what they know and explaining concepts with the provided discussion questions. Teachers will then reinforce the concept by playing a review video, which they may pick based on the class grade level. For classes of grades K-2, teachers may show a brief (1:17) song video from Generation Genius (link found here and in Required Resources). For

[13] "Emilie du Chatelet."

classes of grades 3-5, teachers may play a short (4:28) PBS Learning video (link found here and in Required Resources).	
What is the teacher doing? The teacher will first lead a class discussion to gauge student knowledge of the concept of gravity. They will explain that gravity is a force that pulls objects down, and the strength of the force depends on the objects weight. Then, the teacher will show students a review video of what gravity is (either the K-2 video or the 3-5 video). Potential discussion points and questions for this activity are listed below and in the Supplemental Materials for this lesson plan.	**What are the students doing?** Students will participate in a discussion of what gravity is, talking with each other and answering teachers' questions, learning main points relating to the concept of gravity. They will then watch the video relevant to their grade level to review and remember the concepts.

Explore: 25-30 Minutes

Students will experiment with gravity like Émilie du Châtelet did! Teachers will run an experiment dropping objects of different sizes and different masses from two different heights into wet sand. Students will first predict which object they believe will make a deeper impression and fall quicker, discussing it before the experiment based on what they previously learned about gravity. Then, students will observe how fast the different sized objects fell as well as how deep of impressions the objects made in the sand compared to their different weights. Volunteers will be called up to drop the objects, under the teachers' supervision. Teachers can modify their own involvement and supervision based on the grade level.	
What is the teacher doing? Teachers will follow the detailed Lesson Plan Activity Instructions found below and in the Supplemental Materials to this lesson plan. In this activity, student will have the opportunity to freely explore and experiment with gravity as Émilie du Châtelet did. Teachers can modify the experiment based on the classroom.	**What are the students doing?** Students will aid the teacher in demonstrating Émilie's gravity experiments. They will make and discuss predictions of what they believe will happen, help to run the actual experiment, and be free to select different objects to explore.

Required/Recommended Reading and Resources

Video

- GenerationGenius. "The Gravity SONG | Science for Kids | Grades K-2." YouTube video, 1:17 minutes. Posted December 2019. https://youtu.be/AmsVWgjtyns.
    - This is the video meant for grades K-2 to review the concept of gravity.

- PBSLearning. “Gravity! | Science Trek.” PBSLearning Media video, 4:28 minutes. Accessed July 2022. https://www.pbslearningmedia.org/resource/idptv11.sci.phys.maf.d4kgrav/gravity/.
    - This is the video meant for grades 3-5 to review the concept of gravity.
- Studies Weekly. “Émilie du Châtelet.” YouTube video, 2:16 minutes. Posted May 2015. https://www.youtube.com/watch?v=hS0nNgVlPJE.
    - This is the introductory video of who Emilie du Chatelet was.

Main Discussion Points

Main Discussion Points can be found in the Supplemental Materials to this lesson plan. The following are main points for teachers to highlight regarding Émilie du Châtelet’s life.

- Émilie du Châtelet was a scientist in the 1700s.
- She lived in France and was a member of the aristocracy.
- Émilie was an intellectual that was ahead of her time and worked with very famous and revolutionary people in history.
- Émilie made very large contributions to physics, math, and philosophy.
- Émilie advocated for herself and her education, despite people telling her that she should not pursue it.
- Émilie translated and explained many famous and difficult works so that more people could learn from them.

Discussion Points and Questions

Discussion Points and Questions can be found in the Supplemental Materials to this lesson plan. The answers to the questions can also be found in the Supplemental Materials.

The following are potential questions to discuss with students to gauge what they know about gravity and how it works. It will be a question-and-answer style lecture.

1. [teacher holds up a classroom object, such as a toy or eraser] What do you think will happen if I let go of this? Why?
2. Can anyone tell me what gravity is?
3. What is mass? Does something with more mass have more or less gravity?
4. Which of the following objects have more mass? [the teacher may also use classroom objects as comparison examples]
    a. A beachball or a beagle
    b. The earth or the moon
    c. A book or a feather
    d. A frying pan or a pillow
    e. A paper cup or a coffee mug
5. Do bigger objects have more gravity than smaller objects?

The following are the key takeaways that students should learn from the discussion.

- Gravity from the Earth pulls objects down.

- Mass can be understood as the measure of how much stuff something has or is made of.
- Objects can be the same size but have different masses.
- If an object has more mass, it has more gravity.
- Heavier (more massive) objects are pulled down more than lighter (less massive) objects.

Activity Instructions

In this classroom activity, students will experiment with the gravity of different size objects, like Émilie du Châtelet did. Activity Instructions can also be found in the Supplemental Materials to this lesson plan.

Materials

- Two items of the same light weight, and two of the same heavier weight (such as balls, erasers, blocks, or toys)
- Yard stick
- A bin of wet sand (if sand is inaccessible, flour or malleable clay should suffice)
- Materials to put below the wet sandbox for cleanup, such as newspaper, paper, towels, or paper towels

Set Up

- Teachers will set up a box/container with wet sand in a clear area of the room. Newspaper/towels will be placed underneath the bin in case of spillover. If sand is unavailable, any variation of flour or malleable clay will work as well.

Part I

Depth of impressions with objects of the same weight at different heights

- Teachers will first provide students with two objects of the same mass to drop in the wet sand, such as balls, blocks, or erasers. With the teacher's supervision, students will experiment dropping the two objects of the same weight at one foot versus three feet with the meter stick. Students must first raise their hand to predict which they think will leave a deeper impression and why. Next, students will act as volunteers to drop the objects with the teachers supervision. The teacher should hold the yard stick, measuring heights, and confirming which impression is deeper.
- This should result in the ball dropped at a greater height leaving a deeper imprint then the lower height ball. Students should learn that this is because gravity made the higher ball fall faster.
- In Emilie's experiment, she dropped heavy balls into clay from different heights, measuring their velocities as compared to the depth of the impressions that they made in an adaptation from Willem Gravesandes's experiment. She found that the impression depth created by the balls is a

square factor of the velocity in which the balls fell. This means that objects at a greater height have more time for their velocity to accelerate, resulting in their making deeper imprints.

Part II

Depth of impressions with objects of different weight at the same height

- Next, teachers will lead another demonstration to look at the imprint depth left from two objects of different weights at the same height of two feet.
- This should result in the heavier/more massive object leaving a deeper imprint than the lighter one.

Part III

Exploratory: students may choose

- Teachers will encourage the students to explore more about the gravity experiments on their own. After the main demonstrations are finished, students are free to pick any classroom objects (within reason) to drop into the bin. Students will raise their hands to pick any two small classroom objects to drop into the bin and decide what heights they want to drop them from.
- After called on, a short discussion will take place on which object between two chosen ones will make a deeper impression. Students will then be able to go up to the box and drop the objects with the teacher's supervision.
- The teacher will assist in running the demonstration smoothly, holding the yard stick, measuring heights, and calling which object made the deeper instruction. If student predictions were incorrect, the teacher will open a discussion to the students of why and explain when needed.

Further Reading and Additional Resources

- Alan Gilchrist. "Dropping Balls." Youtube video, 3:17 minutes. Posted October 2013. https://www.youtube.com/watch?v=mPLqqycxtYI.
    - This is a higher-level high school experiment similar to what Émilie du Châtelet did. It is a good demonstration to get a general idea of what to do in an experiment, although we will omit the calculations for younger grades.
- "Du Châtelet (1706-1749)." *Project Vox*. Duke University Libraries. Accessed June 29, 2022. https://projectvox.org/du-Châtelet-1706-1749/.
    - This source serves as a wonderful resource to learn more about Émilie du Châtelet. It is a compilation of texts, portraits, chronology, primary sources, secondary sources, philosophies and teaching, correspondence, connections, and online resources relating to du Châtelet.
- "Forces and Motion." *K5 Learning*. K5 Learning. 2021. https://www.k5learning.com/science-worksheets/first-grade-1/forces-machines/movement.

- The possible extension activity is inspired by this lesson plan based on forces and motion.

- Gavrilod. "Émilie du Châtelet." Youtube video, 12:45 minutes. Posted march 2018. https://youtu.be/QZNhtL6Qu6g.
  - This source is a short documentary-like review of Émilie's life, including theatrical clips. The teacher may select clips from this video to show students if they wish for more illustration of her life. Reference to the experiment dropping balls into clay begins at 8:05.

Extensions

Science Activity

Teachers will assign the corresponding extension activity worksheet as homework. The worksheet and its answer key are attached in the Supplemental Materials section of this Lesson Plan, centering around properties of gravity learned in today's lesson. Students will circle which ball from two options they believe will fall the fastest due to gravity, with differences in ball size.

Related AIP Teacher's Guides on the History of the Physical Sciences:

- The Heritage of All Mankind – Abdus Salam and the Four Fundamental Forces
- Laura Bassi's School of Experimental Physics
- Katherine Clerk Maxwell and Color Mixing of Light
- Subtle Discrimination

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

Speaking & Listening	
CCSS.ELA-LITERACY.SL.1.1	Participate in collaborative conversations with diverse partners about grade 1 topics and texts with peers and adults in small and larger groups.
CCSS.ELA-LITERACY.SL.1.1.A	Follow agreed-upon rules for discussions (e.g., listening to others with care, speaking one at a time about the topics and texts under discussion).
CCSS.ELA-LITERACY.SL.1.1.B	Build on others' talk in conversations by responding to the comments of others through multiple exchanges.
CCSS.ELA-LITERACY.SL.1.2	Ask and answer questions about key details in a text read aloud or information presented orally or through other media.
CCSS.ELA-LITERACY.SL.1.3	Ask and answer questions about what a speaker says in order to gather additional information or clarify something that is not understood.

CCSS.ELA-LITERACY.SL.1.6	Produce complete sentences when appropriate to task and situation. (See grade 1 Language standards 1 and 3 here for specific expectations.)
CCSS.ELA-LITERACY.RF.4.4	Read with sufficient accuracy and fluency to support comprehension.
CCSS.ELA-LITERACY.SL.4.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 4 topics and texts*, building on others' ideas and expressing their own clearly.
CCSS.ELA-LITERACY.SL.4.1.B	Follow agreed-upon rules for discussions and carry out assigned roles.
CCSS.ELA-LITERACY.SL.4.1.C	Pose and respond to specific questions to clarify or follow up on information, and make comments that contribute to the discussion and link to the remarks of others.
CCSS.ELA-LITERACY.SL.4.1.D	Review the key ideas expressed and explain their own ideas and understanding in light of the discussion.
CCSS.ELA-LITERACY.SL.4.2	Paraphrase portions of a text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.
CCSS.ELA-LITERACY.SL.4.3	Identify the reasons and evidence a speaker provides to support particular points.

Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Physical Sciences	
K-PS2-1 Motion and Stability: Forces and Interactions	Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. Grade: K-2
K-PS2-2 Motion and Stability: Forces and Interactions	Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull. Grade: K-2
2-PS1-2 Matter and Its Interactions	Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose. Grade: K-2
3-PS2-2 Motion and Stability: Forces and Interactions	Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. Grade: 3-5
5-PS2-1 Motion and Stability: Forces and Interactions	Support an argument that the gravitational force exerted by Earth on objects is directed down. Grade: 3-5