HISTORICAL NOTES AND DISCUSSION GUIDE

MATHEATRE

THE PEOPLE

Gabrielle Émilie Le Tonnelier de Breteuil, Marquise du Châtelet (1706-1749) – born into French nobility, "Émilie," as she was known, was a natural philosopher and mathematician. Her best known and most impactful contribution to math and physics is the law of conservation of energy and the equation $Ek=1/2\ mv^2$, which reconceptualized the understanding of kinetic energy. She translated and expanded upon Isaac Newton's *Principia Mathematica* (effectively uniting the contentious conflicting views of Newton and Leibniz), and wrote one of the first fundamental textbooks on physics, as well as philosophical treatises on happiness. As a noblewoman, Émilie rebelled against many traditional gender expectations of her time, while also benefitting from many class privileges.

François-Marie Arouet aka Voltaire (1694-1778) – a notorious and prolific writer, Voltaire wrote poetry, plays, essays, novels, histories and scientific papers. An outspoken critic of French monarchy, Voltaire was repeatedly imprisoned and exiled and his books banned for openly satirizing society, government, religion and other institutions of the time. He made some questionable romantic choices later in his life, and some of his literary devices made use of harmful takes on gender, race and culture (for instance, setting plays in "exotic" locales such as South America and Africa in order to satirize issues happening close to home). Voltaire's writing, while socially progressive in its context, was still entrenched in dominant European attitudes of the time and far from perfect. His writing had far-ranging influence that contributed to the modernization of many European institutions.

THE FRIENDSHIP

The real Émilie and Voltaire were prominent figures of the Enlightenment--an era of European history marked by intellectual reason, empirical pursuit of knowledge, and philosophical development of ideals surrounding themes of liberty and happiness. The Enlightenment spurred widespread cultural shifts in ideals and attitudes about government, organized religion, science, and personal liberties. While Émilie was part of the French nobility and Voltaire was not, the two had a complex and unconventional relationship from when they first met in 1733 until Émilie's untimely death in 1749. With the full knowledge and understanding of Émilie's husband the Marquis du Châtelet, she and Voltaire pursued a romance which matured over time into a close platonic friendship while they each moved on to other romantic relationships. While Émilie was mathematically inclined since childhood, Voltaire developed an interest in math and science as a result of her influence. The two collaborated on scientific experiments (such as research on the physical nature of fire) and literary pursuits (such as Voltaire's biography of Isaac Newton, for which Émilie helped him understand the math). While Voltaire repeatedly got into trouble with authorities, Émilie had the social connections and resources to help him get out of it, and the two shared a lifestyle marked by adventures in creativity and rejection of convention. Émilie and Voltaire were part of a generation of socially critical European philosophers and intellectuals that led to demise of France's monarchy in the French Revolution.



"QUELIC-QUELOC" FRIENDS

"Tambara" – a fictionalized friend of Émilie's, an expert on math of the Yoruba people of Nigeria and West Africa--a culture known for expressing creativity and function (including architecture and urban planning) through mathematically complex fractals. Ethnomathematics is the study of relationships between math and culture, particularly in Indigenous cultures outside of dominant European paradigms.

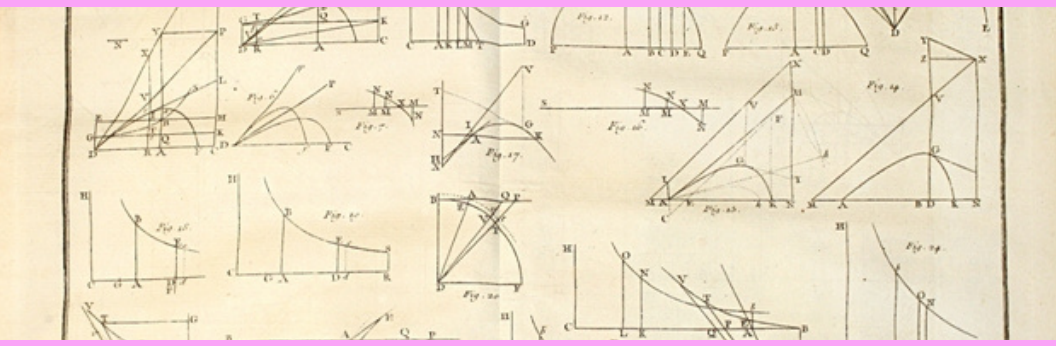
祖沖之 (Zǔ Chōngzhī) (429-500) was a Chinese astronomer, mathematician, politician and writer. Among his many astronomical achievements is the development of the Dà míng Calendar in China. Together with his son **祖暅之 (Zǔ Gèngzhī) (480-525)** the pair, using a system of sticks and rods, calculated pi to seven decimal places--a precision for which they held the world record until the 1600s.

محمد بن موسی خوارزمی (Muḥammad ibn Mūsā al-Khwārizmī) (c.780-847) was a Persian polymath whose many contributions to mathematics, astronomy and geography include the introduction of principles that earn him the description as the "founder" of algebra. His work also led to the introduction of the base-10 decimal positional number system (using Hindu-Arabic numbers) to the Western world. His name is linguistically embedded in an English word we use today: "algorithm"

OTHER CHARACTERS

Louise Bénédicte de Bourbon, Duchesse du Maine (1676-1753) was a noblewoman who cultivated a subversive court at her home in Sceaux, just twenty kilometers in distance but a world away from the rigid royal court of Versailles. Though she had inherited the privileges of a French princess, the French monarchy kept its distance from her, and she had a reputation for being a character with a love for sensation and drama. Much like Émilie's salons at her home in nearby Cirey, the Duchesse hosted many of the Enlightenment's most prominent thinkers, writers and philosophers for legendary parties and theatrical events.

Jean-Frédéric Phélypeaux, Count of Maurepas (c.1701-1781) was Voltaire's infamous nemesis. Phélypeaux was trained from childhood to be secretary of state to the king of France, an office purchased for him by his father. This inherited privilege made him scorn Voltaire as a self-made poet, so in April 1725, when Voltaire ran afoul of an arrogant aristocrat, Phélypeaux had Voltaire thrown into prison at the Bastille. In 1734, Phélypeaux placed another order for Voltaire's arrest, this time for a book Voltaire had published criticizing the French monarchy--a pattern of unsuccessfully trying to arrest, humiliate, and censor the poet.



THE MATH

KEY TERMS AND CONCEPTS

Momentum - The quantity of motion of a moving object, measured as a product of its mass and velocity.

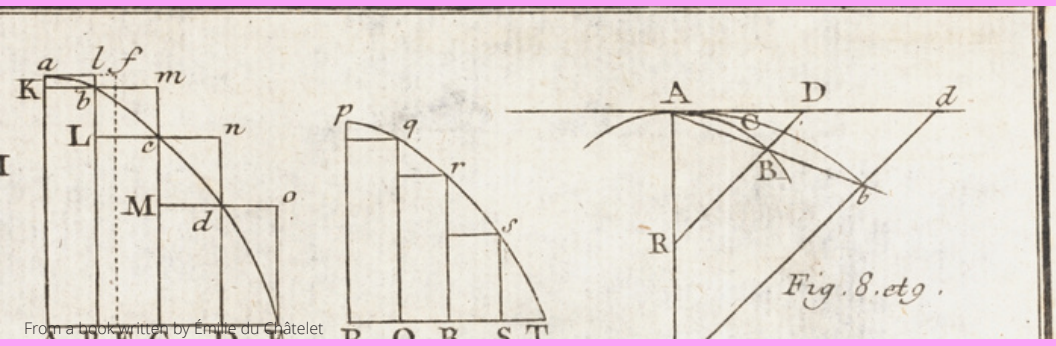
Mass - A quantity representing the amount of matter in an object. It can also be defined as the quantity of inertia (resistance to acceleration) possessed by an object.

Velocity - The rate at which an object changes position.

Proportional - Having corresponding elements with a constant ratio.

Squared - The product of a number multiplied by itself.

Number systems– Notation to express or represent numeric quantities. Hindu-Arabic numerals (1, 2, 3, etc) are now common worldwide in the modern era, alongside symbols specific to some languages. Other examples of number systems briefly mentioned in the show include Babylonia's base-60 cuneiform numerals, and counting rods used in ancient China. Interesting fact: The Roman numeral system (I, II, III, etc) was commonly calculated on an abacus, and this system co-existed in Europe alongside the Hindu-Arabic system, which could be easily calculated on paper, for around 500 years. It was the early pressures of capitalism that shifted the mainstream preference to a numeric system that left a paper trail that could be audited.



From a book written by Émilie du Châtelet

THE MATH

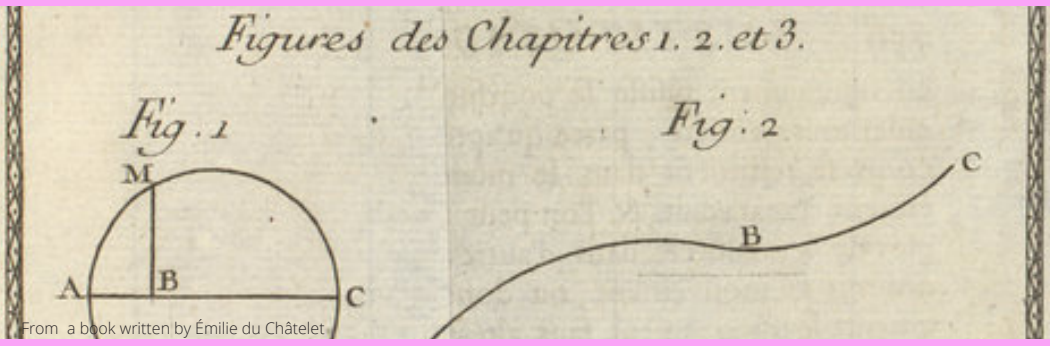
KEY TERMS AND CONCEPTS

Base - In the context of number systems, base is how digits are combined to represent quantities. It is the number around which the system is organized. While base-10 is common, there are many living Indigenous cultures that currently use other base systems, including the Yoruba, Igbo and Banda cultures of Africa, the Inuit-Yupik-Unangax languages of North America, Aztec, Maya, and other cultures of Central and South America, Dzhonkha of Bhutan, the Ainu language of northern Japan, the Chukchi language of eastern Siberia, and many, many more. Interesting fact: Yoruba's base-20 system uses a complex pattern based on the number ogún (20). The first four numbers of each decade are created by adding to the word for the prior decade, and the fifth through ninth numbers are created by subtracting from the next decade.

Second equation of motion - Equations of motion describe the behavior of a physical system as a set of mathematical functions in terms of dynamic variables. The second equation of motion ($s = s0 + v0t + ½at^2$) describes the displacement of an object under constant acceleration.

Acceleration - The rate at which an object changes velocity.

Polygon- A flat two-dimensional shape with three or more straight sides that are fully closed.



From a book written by Émilie du Châtelet

THE MATH

KEY TERMS AND CONCEPTS

pi (π) -- The ratio of a circle's circumference to its area. This mathematical constant is rounded to approximately 3.14, but has been calculated to over 34 trillion decimal places...so far.

Irrational - In math, a real number that cannot be expressed as a whole number divided by another whole number and is not an imaginary number. "Irrational" meaning "without ratio."

The Pythagorean theorem – A fundamental geometric relation among the three sides of a right triangle--the sum of the areas of the two squares on the legs (a and b) equals the area of the square on the hypotenuse (c). Though attributed to Greek philosopher Pythagoras (c. 570 BCE-495 BCE), this relationship was known to mathematicians in India, China, Egypt, Babylonia and likely elsewhere at least 2,000 years before Pythagoras recorded the proof which bears his name today.

The Circle Equation - A circle centered on the origin (0,0) can be defined as $r=\sqrt{}(x^2 + y^2)$. Using the Pythagorean theorem, plotting every triangle with a given value of r creates a circle with the radius of *r*. This idea is credited to the Greek geometer Apollonius of Perga, 1750 years before the Cartesian graph was invented.

Locus - For a circle, a set of points on a plane at the same distance from the center point.

Hypotenuse - The longest side of a right triangle.

From a German edition of a book written by Émilie du Châtelet

THE MATH

KEY TERMS AND CONCEPTS

Reduction - Rewriting of an expression into a simpler form.

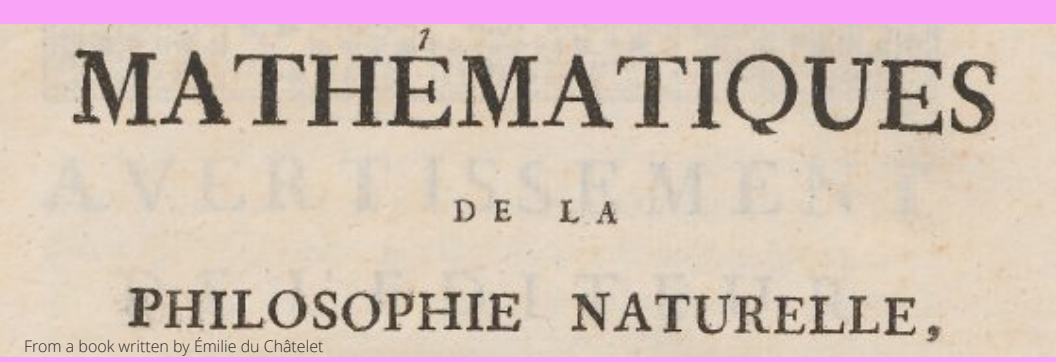
Balance - A balanced equation is an equation where both sides of the equals sign (=) are equal.

Quadratic equation - An equation containing at least one variable multiplied by itself once (to a degree of 2), but containing no variables of higher powers

al-jabr - Variously translated as "completion," "reunion of broken parts," and similar terms, this Arabic phrase coined by al-Khwarizmi is the origin of "algebra." al-Khwarizmi did not use symbols, but published his equations in words and diagrams. Later iterations of this branch of mathematics introduced symbols to express variables, such as *x*, *y*, *z*.

Expected value - A long-run average value of random variables. It also indicates the probability-weighted average of all possible values. Its formula can be written as $EV = \Sigma P(Xi) * Xi$; where $P(Xi)$ is the probability of a variable and Xi is the variable.

Average - A calculated "central" value of a set of numbers. To calculate it: add up all the numbers, then divide by how many numbers there are.



From a book written by Émilie du Châtelet

THE MATH

KEY TERMS AND CONCEPTS

Random Variable - A variable in which the value of the variable is dependent on the outcome of a random occurrence.

Estimate - To roughly calculate a value as an educated guess.

Weighted average - A calculation that takes into account the varying degrees of importance of the numbers in a data set.

Cartesian coordinates - A system that specifies each point uniquely by a pair of numerical coordinates, which are the signed distances from two fixed perpendicular oriented lines, measured in the same unit of length. Written in the 2-D form as (x,y), where x is the horizontal position and y is the vertical position.

Axis - A reference line drawn on a graph.

Derivative - The instantaneous rate of change of a function with respect to one of its variables--equivalent to finding the slope of the tangent line to the function at a point.

Integral - The area under a graph's curve. "Integration" is the process of adding slices with infinitesimal width to find a whole.

Kinetic energy - The energy of motion, observable as the movement of an object, particle, or set of particles.

HISTORICAL NOTES

THIS PLAY IS UTTER FAN FICTION, BUT INSPIRED BY HISTORY

"But it should be the right amount of laughter..." -As a playwright, Voltaire was highly sensitive and concerned about his words being upstaged. Stories say that disruptive audience members sometimes sent Voltaire into a spiral because he believed they were laughing at his text (and not in a good way).

"Émilie sits, dropping rocks into the mud." - This is a reference to a series of experiments conducted by Émilie and Voltaire's contemporary, Willem 'sGravesande. In 1722, Willem and his assistant Voltaire experimented by dropping brass balls from varying heights into a surface of soft clay. These experiments showed that a ball with twice the speed of another would indent the clay at a depth four times greater, concluding that the correct expression for an object's kinetic energy (or "live force" as it was called at the time) is proportional to velocity squared. These experiments led to Émilie du Châtelet's hypothesis of the *conservation of total energy*. She conceptualized energy as distinct from momentum, and quantified its relationship to mass and velocity.

HISTORICAL NOTES

"**A wheelwright works on Émilie's wrecked carriage...**" – The entire scenario of the play's present action is based (very loosely) on two true stories. Émilie du Châtelet was a voracious gambler and card player, and one night while playing with high ranking French nobles at Fontainebleau, she lost hand after hand, despite her keen ability to count cards and calculate probabilities. To address her frustration, Voltaire, having observed some sketchy maneuvers on part of her opponents, said plainly to Émilie--in English (which both he and Émilie had learned to speak fluently)--"what do you expect when you're playing with cheaters?" His mistake was assuming that no one at the French court could understand the English language. The reaction of the affronted nobles compelled them to flee the party in a carriage--and when it reached its destination, Émilie stepped out alone, having secretly arranged, mid-trip, to send Voltaire off on a separate horse to hide with their friend the Duchesse du Maine. On another zany night of capers, the two friends were traveling at night and their carriage broke down on the side of the road. Accounts by witnesses of this night say the two friends sat in the dark, looking at the stars and talking about science late into the night.

"**Come on Émilie, you love Quelic-Queloc!**" – While social media as we know it was well after Émilie's time, the real Émilie was at the heart of an active network of scientists, learners, and intellectuals who corresponded with Émilie by letter and flocked to visit her castle in Cirey (in northeastern France), to participate in salons discussing the latest developments in science, math, literature and other intellectual pursuits. (These visits also included theatrical productions of operas and performances of many of Voltaire's plays, in which Émilie always played the lead.) Émilie's far-reaching web of followers even had a name for themselves--
Les Émiliens.

"Did making that Quelic-Queloc with Frederick of Prussia make you feel good about yourself?" - The real Voltaire made some serious lapses in judgement as a friend. He had a bad habit of falling prey to gossip in order to position himself favorably with people in power. The last straw in their real-life romance was when Frederick, the King of Prussia (a region that is now part of modern-day Germany) leaked a letter he had solicited from Voltaire saying dismissive things about Émilie's book on physics. Frederick and Voltaire's relationship was complicated, and Voltaire fell prey to Frederick's manipulation.

"Tails, you give me that cup of coffee." - The importation of coffee, a bean indigineous to Africa, played a major part in the social culture of the Enlightenment era, and some historians suggest the practice of coming together to converse for hours over the stimulating drink accelerated the scientific developments of the time period. Coffee consumed in Europe was produced by the labor of people, many from Africa, who were enslaved by Europeans to farm colonized land in tropical climes. The real Voltaire reportedly drank up to 42 cups of coffee per day.

DISCUSSION QUESTIONS

1. It's (hopefully) obvious that the real historical figures in this play did not have access to social media, phones, or the internet. Why do you think the authors chose to use these anachronistic devices and modernize the comic sensibilities? Does this change the way you view history? How or how not?

2. The math in this play builds from the fundamental idea of number symbols and base systems (for instance, base-10 vs base-20). How does your engagement with math change when you change the perspective of your base? Bonus: pick a different number system and try some simple arithmetic.

3. When Émilie and Voltaire first meet, Voltaire doesn't see himself as a "math person." What happened in his character journey that made him change his mind? And for that matter, what even IS a "math person?"

4. A circle in love with a triangle. x solving for y (why?). How do mathematical metaphors demonstrate the stages of Émilie and Voltaire's relationship, and how do the depictions of their relationship affect your understanding of the math concepts?

DISCUSSION QUESTIONS

5. Every culture across the world and throughout history has engaged with math, and Émilie argues that numeric languages are humanity's greatest achievement. An ongoing philosophical debate centers around the question of whether math is an objective truth that humans have discovered, or a construct that humans have created. What do you think?

6. Voltaire thinks Émilie can "math our way out" of their trouble. In your opinion, what are situations in which math can--or cannot--be used as a blunt tool?

7. Émilie tells Voltaire that being "good" at math doesn't mean you can crunch numbers quickly or know everything off the top of your head. Do you agree? Why do you think society tends to equate competency with speed?

8. Voltaire is preoccupied with his Quelic-Queloc account being banned, and the real Voltaire's books and plays were often banned for their critical content. What are the consequences of stifling expression of controversial ideas?

DISCUSSION QUESTIONS

9. Émilie says graphing is "the biggest thing in math since sliced cones." Why was the development of the graph--linking geometry with algebra and paving the way for calculus--so important? What else did graphing make possible?

10. Phélypeaux used math to solve for Émilie and Voltaire's location, after using math to cheat at a card game--effectively using math for nefarious purposes. Can math be said to have moral qualities such as "good" or "bad"? Why or why not?

11. In Émilie's final test between Voltaire and Phélypeaux, she calls Voltaire as the winner even though he didn't know the answer. How does admitting what you don't know make you a stronger mathematician?

12. Voltaire says that the beauty of math is all its relationships--for instance the relationship between a derivative and its integral. What are some mathematical relationships that surprise, delight, or intrigue you?

RECOMMENDED READING

Émilie's Dramatic Sarcastic Mathematics Playlist is utter fan fiction, with heavy inspiration from history. For more, check out these books, which were major inspirations of the play's authors.

Bodanis, David: *Passionate Minds: Émilie du Châtelet, Voltaire, and the Great Love Affair of the Enlightenment*

Du Châtelet, Émilie: *The Art of Happiness: The Reflections of Madame du Châtelet*

Zinsser, Judith: *Émilie Du Châtelet: Daring Genius of the Enlightenment*

And for more about math:

Joseph, George Gheverghese: *The Crest of the Peacock: Non-European Roots of Mathematics*

DK: *The Math Book: Big Ideas Simply Explained*

Orlin, Ben: *Math with Bad Drawings*

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Matheatre's podcast,
History Science Theatre PODCAST,
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for free on all major podcast platforms.

TikTok, Instagram: @matheatre_steam

Émilie's Dramatic Sarcastic Mathematics Playlist
was written and performed by
Ricky Coates and Sadie Bowman,
with music and lyrics by Sadie Bowman and orchestration by Joe McMorrow.
Directed by Shermona Mitchell.
With digital appearances by Ninchai Nok-Chiclana, Edison Lee, Jackie Lee, @danthehistoryman, Shermona Mitchell, Sparkle Leigh, Matthew Kessen, and art by Ben Orlin.

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