

Lesson Plan

On the Shoulders of Giants: Inertia from Ibn Sīnā to Newton



**Depiction of Persian Polymath Avicenna,
An Early Contributor to the Law of Inertia**

Photography by Adam Jones, of Silver Vase from the Museum at BuAli Sina Mausoleum

Grade Level(s): Middle School, High School and College

Subject(s): Physics, History

Supplements: The Law of Inertia and Newtons Three Laws of Motion

This lesson plan highlights the contributions of thinkers in the Islamic Golden Age to early physics concepts. One of these is the law of inertia, which this lesson plan introduces. This teaching guide is intended to be used alongside an introductory class section on the law of inertia, but it can also be used to supplement other topics including Snell's law and observational astronomy (for a more complete list, view extensions).

In-Class Time: [50 – 70 minutes]

Prep Time: [30 – 60 minutes]

Materials

- Materials for Demo (Recommended demo requires a beaker, a large sheet of paper, and a flat tabletop, or substitutes for these materials)
- Copies of Discussion Questions and Reading Handout (found in Supplemental Materials)
- Useful, but not required:
 - A/V equipment
 - Internet Access

Objective

This teaching guide introduces the law of inertia. In addition to presenting this crucial concept, the lesson provides a historical background behind Newton's First Law which highlights the contributions of scholars during the Islamic Golden Age.

Introduction

This lesson plan introduces the key topic of inertia and highlights the origins of the law of inertia before Galileo and Newton. Newton consolidated understandings of motion from scholars around the world into three concise laws.¹ The similarity between the understandings of science in the Islamic Golden Age and European natural philosophy in regards to inertia is shown below, through three separate formulations of the law of inertia:

Formulation from the Islamic Golden Age (translated): No [object] begins to move or comes to rest of itself.²

Newton's First Law (translated): Every [object] persists in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by force impressed.³

Modern Law of Inertia: In an inertial frame, an object at rest remains at rest and an object at a constant velocity remains at that velocity unless acted upon by a force.

The Persian scholar Abu 'Alī ibn Sīnā, Latinized by European scholars as Avicenna, contributed to the formulation of the law of inertia. Ibn Sīnā was one of many Muslim scholars who advanced knowledge of the natural world in the Middle East between the 8th and 13th centuries (referred to as the Islamic Golden Age). The Islamic Golden Age was characterized by cultural and religious diversity, as well as the exchange of knowledge and technology from across the world. Muslim scholars preserved academic texts from many regions, including Ancient Greece, and built on them to contribute to knowledge of the

¹ S. Schaffer, *Hist. Sci* xlvii (2009): <https://doi.org/10.1177/007327530904700301>.

² E. Hecht, *Phys. Teach* 53, 80 (2015): <https://doi.org/10.1119/1.4905802>.

³ I. Newton edited by I.B. Cohen and A. Whitman, *Principia Mathematica* (University of California Press, Berkeley, 1999).

Before beginning this lesson, it may also be useful to refresh lecture material on the topic of inertia, and the related topics of mass, net force, and free body diagrams (or whichever of these topics falls within the scope of the class).

Instructions/Activities

Engage: 2-5 Minutes

The instructor engages students with a demonstration on inertia. The tablecloth pull demo is described below but can be substituted with a different demo on inertia (there are many online materials for this topic, one of which is listed in the footnotes).⁵

What is the teacher doing?

Note: Practice the demo before class begins.

For this demo, instructors will need:

1. Dishes or place settings (non-breakable dishes may be preferred, at least for practice). Heavier dishes are better. You can weigh down lighter dishes with water.
2. A tablecloth without hems or a similar cloth (smoother is better)
3. A flat tabletop. There should not be rim on the edge.

Alternatively, a beaker can be used in place of the dishes and a large sheet of paper can be used instead of a cloth. The substitutes will make the demonstration much easier.

The instructor places the tablecloth on the tabletop. The cloth should only cover the tabletop; leave the rest hanging over the edge. Smooth any wrinkles. Then set up the dishes. Take hold of the edge of the tablecloth and gently pull. The dishes will move with the cloth. Point this out to the class. Reset the demonstration as before. Then, hold the tablecloth firmly. Pull downward and outward as rapidly as possible. The dishes may move somewhat but they should remain on the table without the tablecloth when done correctly.

A filmed version of this demo can be found [here](#) (time: 4:29-5:00), in a demo compilation made by

What are the students doing?

Students are observing the principle of inertia through a demonstration.

⁵ G.S. Rahi and A. Y. Abokor, Inertia Experiments and Demonstrations <<http://faculty.uncfsu.edu/grahi/inertiaexp.pdf>> (Accessed 18 June 2020).

the 2020 Society of Physics Students Interns, or in the Supplemental Materials section. ⁶	
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Explore: 10-15 Minutes

Students will explore the topic of inertia by discussing the demonstration.	
<p>What is the teacher doing? Split students into small groups (about 3-4 per group). Prompt them to discuss the demonstration. Discussion questions are provided (as a handout, or simply verbally or visually). The discussion questions are included below, as well as in Supplemental Materials (note that the questions for the explore section are found in part one of the handout). Bring the class back together to share (and revise) their answers as a whole.</p> <p>If desired, collect answers for evaluation.</p>	<p>What are the students doing? Students work in groups to answer the discussion questions on the demonstration. If instructed, they will complete the handout and submit their answers to the teacher.</p>

Explain: 15-20 Minutes

Use the explain portion of the class to present lecture material on the topic of inertia. This portion of the class can be tailored to meet the content goals of the instructor.	
<p>What is the teacher doing? The instructor gives a lecture on inertia (possible lecture notes are provided in the Supplemental Materials). The teacher answers any questions presented by the class.</p> <p>Recommended Topics to Highlight:</p> <ul style="list-style-type: none"> • Inertia • Mass • Net Force <p>Recommended Further Topics (as time allows):</p> <ul style="list-style-type: none"> • Free Body Diagrams • Newton’s Second Law 	<p>What are the students doing? Students are listening and taking notes, verbalizing any questions, and responding to instructor prompts.</p>

Elaborate: 20-30 Minutes

For the elaborate section of the lesson, teachers will have students read about the Islamic Golden Age and encourage reflection on the material.
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⁶ Maria Stokes, Tablecloth Pull Demo, in “SPS Demo Competition 2020”, posted by SPS National, YouTube video, 17 July 2020 <https://www.youtube.com/watch?v=O1K3aXv9f3w>.

<p>What is the teacher doing?</p> <p>Introduce the history of the Islamic Golden Age by explaining that many developments in early physics were in part due to scholars during the Islamic Golden Age, including the formulation of the law of inertia (which can serve as a great transition point). Then hand out the historical enrichment piece found in the Supplemental Materials. Give students time to read the handout. Afterward, encourage them to reflect on one or more of the discussion questions found below and in Supplemental Materials. Direct them to think or write down individual responses, and then encourage students to share their answers either in small groups or as a whole class. Student responses can be collected (or made into a homework assignment) for evaluation.</p> <p>A visual version of the timeline can be found here and may be useful for younger classrooms, where instructors may choose to present the timeline along with a verbal background based on the handout.</p>	<p>What are the students doing?</p> <p>Students read the handout on the Islamic Golden Age. They consider one or more of the discussion questions individually, and then in groups. Students submit their reflections if instructed.</p>
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Evaluate:

There are several opportunities for evaluation. Instructors can collect student responses from either the Explore or Elaborate section. Teachers could also evaluate this material through regular assignment and exam questions regarding inertia. Finally, teachers can utilize the extension assignment.

Required/Recommended Reading and Resources

- All required reading and resources are available in the Supplemental Materials section including:
 - Discussion Questions Handout
 - Discussion Questions Solution
 - Historical Enrichment Handout
 - Inertia Lecture Outline
- A video of the cloth pull demo can be found [here](#) (time: 4:29-5:00), in a demo compilation made by the 2020 Society of Physics Students Interns.
- Other demos on inertia may be substituted for the one included in the Engage section. The following source provides a helpful list of possible demos: G.S. Rahi and A. Y. Abokor, Inertia Experiments and Demonstrations <http://faculty.uncfsu.edu/grahi/inertiaexp.pdf> (Accessed 18 June 2020).

- physicsclassroom.com has useful diagrams regarding the topic of inertia which could be added to the Explore portion of this lesson plan. Instructors may also find this site useful for student evaluation beyond the in-class questions. Consult their sections “First Law,” “Inertia and Mass,” and “Balanced vs. Unbalanced Forces.”
- A visual representation of the timeline in the Elaborate section is linked [here](#).

Discussion Questions

Discussion Questions can also be found as a Handout with a corresponding Answer Key in the Supplemental Materials to this lesson plan.

For the Explore Section:

1. Describe what happened when the following occurred:
 - a. The tablecloth was pulled slowly
 - b. The tablecloth was rapidly removed
2. Why did the dishes move with the tablecloth initially?
3. Why did the dishes stay on the table when the tablecloth was removed quickly?

For the Elaborate Section:

1. How can the history of physics be useful to physics as a whole?
2. How did diversity benefit scholarship during the Islamic Golden Age?
3. Compare and contrast the forms of the law of inertia developed by Ibn Sīnā, Newton, and the modern formulation.
4. What conclusions can you draw from the timeline of events provided at the end of the reading?

Further Reading and Additional Resources

- Instructors may find the following two books useful in providing further information on the Islamic Golden Age:
 - J. Al-Khalili, The House of Wisdom: How Arabic Science Saved Ancient Knowledge and Gave Us the Renaissance (The Penguin Press, New York, 2011), pg. 35-48 and 67-97
 - J. Lyon, House of Wisdom: How the Arabs Transformed Western Civilization (Bloomsbury Press, New York, 2009), pg. 55-77
- Additionally, E. Hecht’s article in Phys. Teach 53, 80 (2015) offers further detail on Newton’s First Law.
- F. Espinoza’s article in Phys. Ed. 40, 2 (2005) discusses the implementation of the history of motion within physics classrooms.

Extensions

Research Activity

Teachers will assign each student a physics concept from the following list, all of which were formulated to some degree during the Islamic Golden Age. This list is not all-inclusive, and not all topics may apply to every physics course. Topics could also be expanded to include all forms of science (including evolution, experimental method, medicine, etc.).

- Snell’s law or the law of refraction
- Power
- Quadratic formula
- Newton’s Law of Gravitation
- Earth’s Rotation
- Solar System
- Star Charts
- Radius and Circumference

Students will research the topic of their choice and prepare a 1-2 page paper (or a short presentation) as an assignment. Students should introduce the physics topic and summarize the historical context of its formulation.

Related AIP Teacher’s Guides

- The Heritage of All Mankind

Common Core Standards

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

Speaking & Listening	
<u>CCSS.ELA-LITERACY.SL.11-12.1</u>	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
History/Social Studies	
<u>CCSS.ELA-LITERACY.RH.9-10.3</u>	Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.
<u>CCSS.ELA-LITERACY.RH.11-12.4</u>	Determine the meaning of words and phrases as they are used in a text, including analyzing how an author uses and refines the meaning of a key term over the course of a text (e.g., how Madison defines <i>faction</i> in <i>Federalist No. 10</i>).
Subject Writing (applicable for the Extension Activity)	
<u>CCSS.ELA-LITERACY.WHST.11-12.1</u>	Write arguments focused on <i>discipline-specific content</i> .
<u>CCSS.ELA-LITERACY.WHST.11-12.2</u>	Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
<u>CCSS.ELA-LITERACY.WHST.11-12.4</u>	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
<u>CCSS.ELA-LITERACY.WHST.11-12.5</u>	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
<u>CCSS.ELA-LITERACY.WHST.11-12.7</u>	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
<u>CCSS.ELA-LITERACY.WHST.11-12.8</u>	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific

	task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
<u>CCSS.ELA-LITERACY.WHST.11-12.9</u>	Draw evidence from informational texts to support analysis, reflection, and research.

Next Generation Science Standards

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

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