

The Heritage of All Mankind – Abdus Salam and the Four Fundamental Forces



Dr. Abdus Salam at the Fifth International Conference on High Energy Physics (ICHEP)

Image courtesy of Emilio Segrè Visual Archives.

Grade Level(s): High School and College

Subject(s): [History, Physics]

Supplements: Fundamental Forces

Abdus Salam worked in theoretical physics to unify the electromagnetic and the weak nuclear force. For this reason, this lesson introduces the four fundamental forces. More advanced courses can focus on topics in particle or high energy physics, such as fusion or particle decay, or they may wish to examine Feynman Diagrams for the weak force.

In-Class Time: [50 – 70 minutes]

Prep Time: [30 – 60 minutes]

Materials

- A/V Equipment recommended
- Copies of Reading Handouts and Discussion Sections, found in Supplemental Materials. Optional PowerPoint Video also included.
- Classroom Internet Access helpful but not required
- Optional: material for lecture, such as equipment for demonstrations, visual aids, etc.

Objective

This teaching guide focuses on the life and work of Dr. Abdus Salam, the first Muslim Physics Nobel Laureate. In addition to highlighting his contributions to the advancement of science in nations underrepresented in the scientific community, this lesson plan also covers the electroweak force, which he jointly discovered. Depending on content goals, this lesson will introduce students to the four fundamental forces or to the use of oral history interviews in the study of history.

Introduction

This introduction covers three topics that are part of the lecture: the life of Dr. Abdus Salam, the electroweak force, and oral history.

Dr. Abdus Salam:¹

Abdus Salam was born in Pakistan. He was a gifted student and was awarded a state scholarship. He completed his Ph.D. in physics at St. John's College, Cambridge, making a name for himself in the physics community before he had finished his studies. Salam returned to Pakistan to develop physics research at Imperial College and the University of Punjab, but he faced professional roadblocks. Furthermore, he faced religious persecution during the Anti-Ahmadiyya Riots, because he was an Ahmadi Muslim. As a result, he moved to England; there he conducted work that would lead to a Nobel Prize in Physics, for his contributions to "the theory of the unified weak and electromagnetic interaction between elementary particles, including, inter alia, the prediction of the weak neutral current."² He was the first Muslim to win the Nobel Prize; however, Pakistan did not legally recognize that he was Muslim, given the political success of several groups who opposed Ahmadiyya Islam.

Through difficulties, Abdus Salam was always committed to Pakistan and other countries in the Global South. In addition to his work in physics, he devoted his life to serving Pakistan. Salam founded the International Centre for Theoretical Physics in Trieste, Italy, which allows scientists from countries without the extensive academic resources to work on research and engage the scientific community. He also served as Chief Scientific Advisor to the President of Pakistan. Three themes in Salam's life appear—

¹ F. Dyson, Proceedings of the American Physical Society 143, 347 (1999); G. Fraser, Cosmic Anger: Abdus Salam – The First Muslim Nobel Scientist (Oxford University Press, New York, 2008); T. W. B. Kibble, Biographical Memoirs of the Fellows of the Royal Society 44, 387 (1998); M. Lewis, "Abdus Salam – Biographical," <<https://www.nobelprize.org/prizes/physics/1979/salam/biographical/>>

² NobelPrize.org, "The Nobel Prize in Physics 1979," <<https://www.nobelprize.org/prizes/physics/1979/summary/>>

his faith, his love for physics, and his commitment to developing science in countries that are underrepresented in the international physics community. This lesson explores these themes.

The Electroweak Force:³

Abdus Salam won the Nobel Prize, along with Steven Weinberg and Sheldon Glashow, for electroweak theory. Particles experience four fundamental forces: gravity, the electromagnetic force, the strong nuclear force, and the weak nuclear force. Salam realized that at high temperatures, the electromagnetic and weak nuclear force were the same. He showed that the two forces were components of one unified force, the electroweak force.

Many physics topics can be taught in connection to unified theory. Introductory classes can cover the four forces, with an emphasis on gravity and the electromagnetic force, along with a conceptual explanation of Dr. Salam’s contributions. More advanced courses can focus on topics in particle or high energy physics, such as fusion, particle decay, etc. Consider which relevant physics topics to include for your class (possible introductory-level lecture notes on the fundamental forces are included).

Oral History:

If desired, this lesson plan can be used to introduce oral histories instead of a physics topic. Major parts of oral history include the processes of conducting, recording, transcribing, and analyzing interviews. Interviews can serve as a powerful historical tool, by providing detail and perspective. There are many considerations involved with developing oral history, which requires skills in question asking and training prior to interviews. Students will explore these ideas and increase their understanding of Dr. Abdus Salam by examining an interview transcript.

A Note on Terminology:

Terms such as “third world” and “developing country” are no longer in use by the World Bank and some other international organizations, given their origin in the Cold War and their focus on developmental or cultural differences. In this document, either specific classifications or regional locators, such as “Global South,” are used. Note that “third world” and “developing” are used in some of the cited materials. You may wish to make a note of this to your classroom. Further discussions regarding the history and use of these terms can be found in the “Further Reading and Additional Resources” section at the end of the teaching guide.

Instructions/Activities

Engage: 3-5 Minutes

Teachers draw students’ attention to Dr. Abdus Salam by projecting excerpts from his Nobel Prize Banquet Speech.

³ SciShow, “Weak Interaction: The Four Fundamental Forces of Physics #2” <https://www.youtube.com/watch?v=cnL_nwmCLpY> (Accessed 26 June 2020); Hyperphysics, “Fundamental Forces” <<http://hyperphysics.phy-astr.gsu.edu/hbase/Forces/funfor.html#c5>> (Accessed 26 June 2020); The Editors of Encyclopaedia Britannica, “Fundamental Interaction” <<https://www.britannica.com/science/fundamental-interaction>> (Accessed 26 June 2020).

<p>What is the teacher doing? Teachers project the slide (found in Supplementary Materials) with excerpts from Abdus Salam’s Nobel Prize Banquet Speech. Encourage students to briefly consider what he said.</p> <p>Tell students that Abdus Salam was a theoretical physicist who not only won a Nobel Prize for his work but who was also dedicated to empowering and improving physics in countries underrepresented in the subject area.</p>	<p>What are the students doing? Students are introduced to Abdus Salam and consider his statements.</p>
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Explore: 15-20 Minutes

<p>Students will explore the life and work of Dr. Abdus Salam.</p>	
<p>What is the teacher doing? Introduce the life and work of Dr. Abdus Salam. Information on his life and work is contained in the Supplemental Materials Section in 3 formats. Select your preferred format (video, PowerPoint, or reading handout).</p> <p>Distribute or project the Discussion Questions (found in Supplemental Materials). Instruct students to answer them in groups of 3-4.</p>	<p>What are the students doing? Learn about Dr. Abdus Salam. Respond to the discussion questions in a group.</p>

Explain: 10-15 Minutes

<p>Facilitate a class discussion of the questions. Ask students to volunteer their answers, and explain them in further detail.</p>	
<p>What is the teacher doing? Facilitate class discussion on Abdus Salam, covering the answers to the discussion questions (found in Supplemental Materials). Instructors can add detail (talking points provided below).</p> <ol style="list-style-type: none"> 1. Abdus Salam was offered a position at Princeton (where he completed some research while working to his Ph.D.). Salam could have chosen to remain in England or move to the USA, as he had made a name for himself in the physics community. However, he felt an obligation to his country, which had funded his education. He returned to develop Pakistani physics. He was able to continue his 	<p>What are the students doing? Review answers to the Discussion Questions as a class. Engage in discussion, and listen to instructor explanation.</p> <p>If instructed, submit answers to the Discussion Questions to the teacher for evaluation.</p>

<p>research in Pakistan, but his efforts to develop research were hindered by the structure of education, and he faced religious persecution. His experiences motivated his commitment to the ICPT.⁴</p> <ol style="list-style-type: none"> ICTP appoints Associates from countries underrepresented in the international physics community who could travel to Trieste to do research and scientific activities. Associates can visit ICTP three times in a six-year period, up to nine months total. ICTP also offers courses and workshops. Highlight his love for physics as a transition to the “Elaborate” portion of the class. For the Alternative Elaborate option, focus on his commitment to developing physics globally, as the interview students will examine examines this. <p>If desired, collect student answers to the Discussion Questions for evaluation.</p>	
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Elaborate: 20-30 Minutes

<p>Use the elaborate section to cover a physics topic that fits within your regular curriculum. Instructors can find a possible lecture (introductory level) outline on the four fundamental forces. Higher-level physics courses may want to discuss electroweak unification in more depth or examine Feynman Diagrams for the weak force.</p>	
<p>What is the teacher doing? Instructors cover a physics topic relevant to their curriculum while highlighting the contributions of Abdus Salam. Given his work on unified field theory, the four fundamental forces are a natural focus point for introductory physics. Instructors who wish to cover the fundamental forces should introduce each one, as well as explain that the electromagnetic force and weak force are two subsets of the electroweak force (the discovery of which won Abdus Salam, Steven Weinberg and Sheldon Glashow the Nobel Prize).</p> <p>Further elaborations on the introduction of the four fundamental forces can include the following: the universal law of gravitation,</p>	<p>What are the students doing? Students are listening to the lecture, taking notes, and asking any questions they may have.</p>

⁴ T. W. B. Kibble, Biographical Memoirs of the Fellows of the Royal Society 44, 387 (1998)

<p>Lorentz force law, the processes of fusion or proton decay, etc.</p> <p>Additional resources for the lecture portion of the class are found in the Required/Recommended Reading and Resources.</p>	
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Alternative Elaborate: 15-30 Minutes

<p>A second option for the elaborate section will further dedicate class time to the history of science. Students will read an interview excerpt about Dr. Abdus Salam and be introduced to oral history.</p>	
<p>What is the teacher doing? The instructor hands out the interview excerpt and discussion questions (found in Supplemental Materials). These can be completed individually or in groups, or be used for a class-wide discussion.</p> <p>Teachers may collect these for evaluation.</p>	<p>What are the students doing? Students learn more about Abdus Salam and are introduced to oral history by reading the interview excerpt and answering the discussion questions.</p> <p>Students submit their work if directed.</p>

Evaluate:

<p>Instructors can collect student answers to the discussion questions from the Explore and Explain portion of the class. Furthermore, the Elaborate Section can be evaluated (for Option 1, assess student understanding using questions from your courses' textbook or cover on an upcoming exam; for Option 2, collect student responses to the discussion questions).</p>

Required/Recommended Reading and Resources

Required Resources:

- Biography Discussion Questions and Solutions
- Biography PowerPoint
 - OR Biography Handout
 - OR a Video narration of the PowerPoint, available on the AIP History YouTube Channel: <https://www.youtube.com/watch?v=sKYy7vEArk>
- Lecture Outline on the four fundamental forces
- Oral History Handout and Oral History Handout Solutions
- All required resources are located in the Supplemental Materials section or are linked in this teaching guide.

Recommended Resources:

- For further biographical information on Abdus Salam consult:
 - T. W. B. Kibble, Biographical Memoirs of the Fellows of the Royal Society 44, 387 (1998), accessible [here](#).

- For the full interview with Gordon Feldman, visit the Niels Bohr Library & Archive [website](#).
- The following resources may be helpful for the Elaborate section on the four fundamental forces:
 - SciShow has videos on each of the four fundamental forces. Their video on the weak force is [linked](#).
 - CERN briefly discusses work on [unification](#).
 - [Hyperphysics](#) has descriptions of the four fundamental forces, including a useful table.
 - The Society of Physics Students has prepared [demonstrations](#) on a wide range of topics. Those on gravity and electromagnetism could be used along with this material.

Discussion Questions

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

Discussion Questions on Abdus Salam's Biography:

- What decision was Abdus Salam faced with after completing his Ph.D.? If you were in his position, do you think you would have made the same decision? Why or why not?
- How does the ICTP support global science?
- There are several themes, or aspects of Abdus Salam's life, shown throughout the biography. Identify at least one and discuss how it motivated him.

Discussion Questions for Oral History (Alternative Elaborate Section):

- What new information (that was not covered in the biography) did you pick up about Abdus Salam from this interview?
- What are the differences between an interview for journalism and an oral history interview?
- You have now read both short segments of written and oral history. Compare them, discussing strengths and weaknesses of both media.
- What aspects of Abdus Salam's character and life were clarified in the interview?

Further Reading and Additional Resources

The following two sources discuss appropriate terminology to be used in place of "third world" and similar terms.

- Mark Silver on NPR discusses "If You Shouldn't Call It The Third World, What Should You Call It?" [here](#).
- Nour Dados and Raewyn Connell "The Global South" via [sagepub](#).

Extensions

Ethics Expansion:

Dr. Abdus Salam publicly advocated for the peaceful use of nuclear research. He was also the Scientific Advisor to the President of Pakistan during the country's development of nuclear weapons. His involvement with nuclear research can serve as the starting point for a discussion on science ethics. Two initial sources to consult or direct students to consult follow. Students can explore the topic in a paper or instructors can facilitate a classroom discussion after providing background.

- Alex Wellerstein, a historian of science and an assistant professor at the Stevens Institute of Technology, discusses the first atomic bomb in his New York Times [article](#) at the 70th anniversary of this testing. It is a good introduction piece. He also has a list of useful resources on his [blog](#).
- Norman Dombey explores Abdus Salam’s involvement in the Nuclear Program in “[Abdus Salam: A Reappraisal](#).” Note that this source is not peer-reviewed.
- Nina Byers’ “[Physicists and the 1945 Decision to Drop the Bomb](#)” highlights the considerations of physicists in the decision to use nuclear weapons.

Physics Expansion: Each of the fundamental forces can be further expanded in additional class sections. Useful sources for expansion lectures are located in the above Required/Recommended Reading and Resources.

Related AIP Teacher’s Guides:

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

Common Core Standards

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

Speaking & Listening	
CCSS.ELA-LITERACY.SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.11-12.1	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	
CCSS.ELA-LITERACY.RH.9-10.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text.
CCSS.ELA-LITERACY.RH.11-12.1	Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.
CCSS.ELA-LITERACY.RH.11-12.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.
CCSS.ELA-LITERACY.RH.11-12.4	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</i> No. 10).

Next Generation Science Standards

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