The Einstein Revolution Teacher Support Materials

This document is designed to aid teachers looking to use this material in their own classroom. Given the variety of classes that might use this content, this guide is kept intentionally high level (History instead of US History, Physics instead of AP Physics AB).

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By Class Type

For History Classes:

- Time was a critical aspect of Einstein's early success and the revolutionary nature of his breakthroughs. The history of measuring and distributing time is discussed in Lesson 1 and 2, with a particular focus on the later 19th century.
- While Lesson 4 (General Relativity) is primarily focused on the physics of General Relativity, Video 6 places one of the experimental tests for General Relativity in a broader historical and cultural context.
- Lesson 5 (The Assassin of Relativity) reviews a unique time in Einstein's life, while he was defending a friend and colleague, Friedrich Adler, who in 1916 had assassinated the head of government of the Habsburg Monarchy. This lecture also touches on topics related to WWI politics.
- Lesson 5 (The Art of Relativity) deals with the cultural and artistic reactions to Einstein's theories of relativity, with a special focus on the inter-war period.
- Lesson 6 (The Philosophy of Relativity) explores the influence of 19th century philosophy on Einstein's intellectual formation, but also Einstein's impact on early 20th century philosophical movements like logical positivism.
- Lesson 7 discusses the rise of anti-Semitism and Aryan physics in Germany in the inter-war period, but also what it meant to be a female physicist in that period. The second half of the lesson details the planning of the German and American atomic bomb projects during WWII.
- Lesson 10 covers the debates surrounding the proliferation of nuclear weapons after WWII.
- While the lessons on quantum mechanics are largely physics oriented, there are a few historically oriented videos.
    - Lesson 8 (Quantum Debates) Video 1 provides a historical overview of the Solvay conference, where some of the foundations of quantum mechanics were laid.
    - Lesson 9 (Quantum Mechanics after Einstein) Video 1 is an interview that illustrates a historical turning point in the practice of physics in the 1970s.
    - Lesson 9 (Quantum Mechanics after Einstein) Video 4 provides a good overview of the history of quantum mechanics.
- Lesson 10 provides an overview of Einstein's political views throughout his life (his pacifism and internationalism, his position towards nuclear weapons, his reactions against racism – Videos 1-2) and his religious views (Video 3).
- Lesson 11 is the conclusion to the course and provides a high level review and closing thoughts for the highlights of Einstein's life and impacts.

For Physics Classes:

- Time was a critical aspect of Einstein's early success and the revolutionary nature of his breakthroughs. Time and the nature of simultaneity are discussed in Lessons 1 and 2. While these lectures are more historically focused, they setup the class over the nature of time. The following are more oriented towards physics from these lectures:
    - Lesson 1 Video 2 discusses the nature of the Ether
    - Lesson 2 Video 5 discusses why Einstein eliminated the Ether
    - Lesson 2 Video 6 illuminates the nature of time in Einstein's model
    - Lesson 2 Video 7 reviews the nature of simultaneity in a relativistic universe by using the light-clock as a thought model
- Lesson 3 interprets Einstein's papers from 1905 as being connected by an underlying reasoning style:
    - Lesson 3 video 3 covers Einstein's paper on Brownian Motion
    - Lesson 3 video 4 covers Einstein's explanation of the photoelectric effect and his heuristic use of photons
    - Lesson 3 video 5 covers Einstein's famous formula $E=mc^2$.
- Special Relativity is discussed in Lesson 4 (Space-time). These videos provide a good overview of the physics that informs special relativity without getting too technical. The lesson introduces space-time diagrams to review the concept of simultaneity and causality in special relativity, and to derive the Lorentz length contraction
- Lecture 4 (General Relativity) deals with Einstein's development of General Relativity, and covers the equivalence principle, the introduction of Non-Euclidean geometry, Einstein's three tests of General Relativity, and their experimental confirmation. This lecture would do well to introduce the concepts, place them in a historical context, and show how they influence physics to this day.
- While Lesson 5 (The Assassin of Relativity) is primarily historical focused, it also deals with a series of paradoxes brought against Einstein's special relativity. Video 5 introduces and explains the Twin Paradox through an original play based on a dialogue by Einstein.
- Nuclear Physics spans Lesson 7 and Lesson 8 (Nuclear Proliferation) with a heavy mix of physics and history. The physics covers both the fundamentals of nuclear fission, and the technical challenges of building an atomic bomb. The physics is most prevalent in the second half of Lesson 7 (Fission, Women in Physics and the Rise of the Nazis) and throughout Lesson 7 (The Nazi Bomb and Los Alamos). Lesson 8 (Nuclear Proliferation) video 2 reviews fusion. These videos would make a good supplement to a nuclear physics module to help place the principles in a historical context.

- Quantum Physics is covered over the course of Lesson 8 (Quantum Debates) and Lesson 9. Lesson 8 (Quantum Debates) is focused on the foundations of Quantum Physics, and the debates between Einstein and Bohr concerning the complementary and incompleteness of quantum mechanics. Lesson 9 builds on this foundation to discuss further philosophical aspects regarding the interpretation of quantum mechanics. Special attention is given to the phenomena of entanglement and Bell's inequality, and their impact on the development of for quantum computing, quantum encryption and quantum money.

For Art Classes:

While Art/Film/Literature is not the main focus of this course, there are elements that could prove useful.

- Lesson 1 Video 1 introduces Einstein's impact on the art world by looking at Binnie Hale.
- Lesson 1 Video 7 uses a video based art exhibit by Kentridge and Galison to explore the meaning of time.
- Lesson 4 (General Relativity) Video 6 shows how architecture, art, and film influenced the testing of physical theories (the bending of starlight).
- Lesson 5 (The Art of Relativity) is focused on how the theory of relativity interacted with the art world.
    - Video 1 reviews Muybridge and Abbott (Flatland)
    - Video 2 looks at Jouffret, Picasso, Bragdon, and Boccioni.
    - Video 3 contains Covert, Höch, Dalí, Breton, Echaurren,
    - Video 4 examines poetry, specifically Williams and Cummings.
    - Video 5 introduces a play called Einstein on the Beach.
- Lesson 6 (The Philosophy of Relativity) Video 7 ties the Bauhaus movement to logical positivism
- Lesson 6 (Cosmology) Video 2 examines the artistic impact of the initial understanding of the Big Bang.
- Lesson 7 (The Nazi Bomb and Los Alamos) Video 5 is an interview focused on a graphic novel from a survivor from the bombing of Hiroshima.
- Lesson 11 Video 3 is a review of Einstein style and his impact on the world at large, including the artistic realm.

For Philosophy Classes:

While Philosophy is not the main focus of this course, one lecture is dedicated to it, and there are elements of philosophy spread throughout the course.

- Lesson 6 (The Philosophy of Relativity) is focused on Philosophy.
    - Video 1 reviews the philosophical ideas that contributed to the intellectual formation of Einstein
    - Video 2 discusses the limits of Einstein's positivism.
    - Video 3 reviews Einstein's influence over the Vienna Circle
    - Video 4 discusses the impact of the rise of Nazism in Germany on the Vienna Circle.
    - Video 5 discusses the modernity of Einstein.
- Lesson 6 (Cosmology) Video 2 looks at the religious and philosophical implications of the evidence for the Big Bang.
- Lesson 10 Video 3 reviews Einstein's interaction with religious leaders and the philosophical implications.

By Video Type

Interviews:

- Lesson 2 Video 2 features an interview with Richard Ketchen in the Collection of Historical Instruments at Harvard. The interview discusses how time was kept and distributed around 1900.
- Lesson 3 Video 2 features an interview with Gerald Holton. The interview discusses what it means for a scientist to have a style and what Einstein's style was.
- Lesson 5 (General Relativity) Video 8 features an interview with Andy Strominger. This interview brings Einstein's theories into the modern age and shows how they are impacting the cutting edge of physics research.
- Lesson 7 (The Nazi Bomb and Los Alamos) Video 5 features an interview with Hillary Chute. This video shows how graphic novels could be used to capture the horrors of nuclear war. A survivor of the bombing of Hiroshima authored the particular graphic novel discussed.
- Lesson 9 (Quantum Mechanics after Einstein) Video 1 features an interview with David Kaiser, the author of *How the Hippies Saved Physics*. The discussion centers on how fundamental questions became a focus of physics again after World War II through a group called Fundamental Fysiks.
- Lesson 9 (Quantum Mechanics after Einstein) Video 3 features an interview with Mikhail Lukin. The conversation revolves around quantum technologies, like quantum computing and quantum banking.

Demonstrations:

- Lesson 1 Video 3 shows a historical instrument that was used to coordinate time.
- Lesson 2 Video 1 shows a magnet and coil producing a current, used to illustrate the importance of the frame of reference.
- Lesson 2 Video 5 contains an interferometer, which was used to disprove the presence of an ether.
- Lesson 5 (General Relativity) Video 2 shows drawing on a globe to illustrate non-Euclidean geometry.
- Lesson 7 (The Nazi Bomb and Los Alamos) Video 2 shows a piece of uranium from German reactor Haigerloch.
- Lesson 8 (Quantum Debates) Video 2 shows a tube with flame to illustrate standing waves.
- Lesson 8 (Quantum Debates) Video 7 shows constructive and destructive interference of waves in water using a wave generator and two slits. Used to clarify the wave/particle duality in quantum theory.

Animations:

- Lesson 2 Video 7 provides a series of animations that illustrate the principles of simultaneity in a relativistic system.
- Lesson 3 Video 3 contains an animation of Brownian motion.
- Lesson 3 Video 4 animates the quantized nature of the photoelectric effect.
- Lesson 4 (Space-time) Videos 2 through 4 use animation to illustrate in greater detail the nature of simultaneity in space-time as part of the theory of special relativity.
- Lesson 4 (Space-time) Video 5 walks through the derivation of the Lorentz contraction.
- Lesson 4 (Space-time) Video 6 shows the nature of space-time distance in the theory of special relativity.
- Lesson 4 (General Relativity) Video 1 illustrates the basic principles of general relativity.
- Lesson 4 (General Relativity) provides an analysis of the equivalence principle through non-Euclidean geometry.
- Lesson 4 (General Relativity) Video 5 animates the physics behind the Doppler shift.
- Lesson 4 (General Relativity) Video 7 shows how starlight is bent by gravity.
- Lesson 5 (The Art of Relativity) Video 1 illustrates how the Muybridge horse appears when in motion.
- Lesson 6 (Cosmology) Videos 3 through 5 provide illustrations behind the big bang.
- Lesson 9 (Quantum Philosophy) Video 2 provides an in depth animation of Bell's Inequality.
- Lesson 9 (Quantum Mechanics after Einstein) provides a detailed animation to explain the principles behind quantum cryptography.