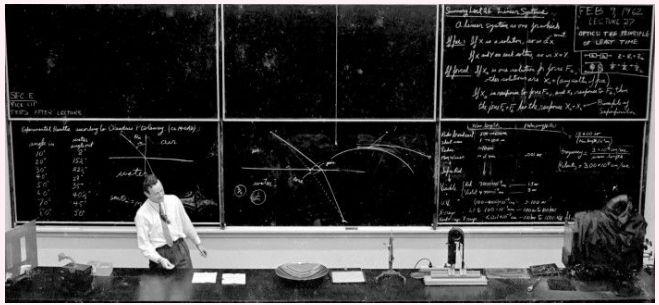
LECTURE I

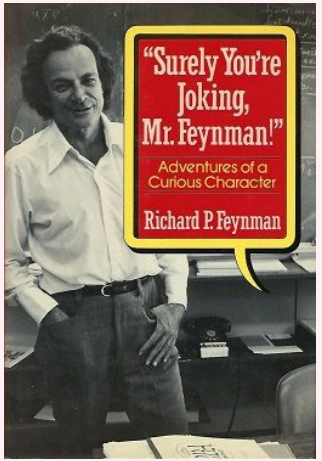
COURSE INTRODUCTION

Foundations of Science I
Prof. Overbey
3/31/25

FEYNMAN LECTURES

Who was Richard Feynman?





Quantum Physicist: Feynman developed a revolutionary way of describing the behavior of subatomic particles using what are now called *Feynman diagrams*. His contributions earned him the 1965 Nobel Prize in Physics.

Teacher and Communicator: Beyond his scientific achievements, Feynman was celebrated for his engaging teaching style at Caltech, where he made physics feel intuitive and fun.

Cultural Icon of Science: His charm, wit, and iconoclastic attitude made him a beloved public figure. His autobiographical books like *Surely You're Joking, Mr. Feynman!* continue to inspire generations of students and thinkers.

THE CARGO CULT

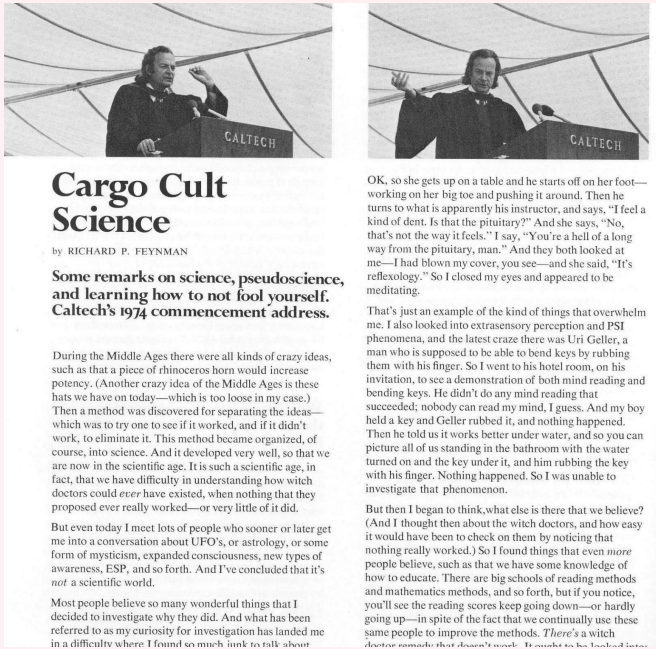
Key idea from *Surely You're Joking, Mr. Feynman!*

What Is a Cargo Cult?

During and after World War II, islanders in the South Pacific saw planes arriving full of cargo—food, tools, medicine. These supplies were brought by military forces who built airstrips, used radios, wore uniforms, and performed routines that preceded the arrival of these goods.

After the war, when the military left and the planes stopped coming, some islanders tried to bring the cargo back.

How did they do this?



THE CARGO CULT

Key idea from *Surely You're Joking, Mr. Feynman!*

They built imitation airstrips, control towers out of bamboo, and even mimicked the actions of soldiers with makeshift "headsets." But no planes arrived.

They were copying the **form** of what they had seen, without understanding the **function**.

FEYNMAN'S CARGO CULT SCIENCE

Feynman coined the term **"cargo cult science"** to describe scientific practices that have the appearance of being rigorous and methodical, but lack the *true spirit of inquiry*. These are cases where people:

- Perform experiments without proper controls
- Publish results selectively
- Ignore inconvenient data
- Follow rituals of scientific work without actually questioning or testing their assumptions

He argued that *real science* means **utter honesty, deep skepticism, and a constant effort to not fool yourself**—because you are the easiest person to fool.

FEYNMAN LECTURES

Why are we using Feynman's lectures?

We're using the Feynman Lectures not just because they teach physics well, but because they embody the **opposite of cargo cult science**. They teach us how to:

- **Think critically** about physical principles
- **Question assumptions** and ask "Why?" instead of just "How?"
- **Value understanding** over rote memorization
- **See beauty and logic** in how science actually works

We're learning how to avoid becoming ritualistic imitators of science in order to apply scientific principles to make sense of the world and technology.

FEYNMAN LECTURES

How are we using the Feynman lectures?

During the course you will be provided with a list of questions about how the world works.

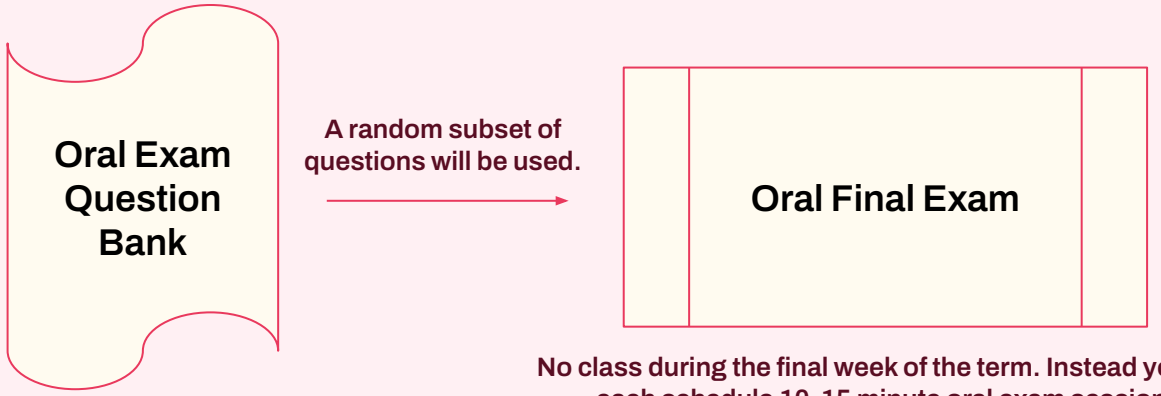
For example: ***Why don't satellites in low Earth orbit fall to the ground?***

The Feynman lectures will be **your resource for finding the fundamental equations and principles in physics** for answering these questions.

FEYNMAN LECTURES

What is the list of questions for?

The list of questions is your exam question bank. These are the exact questions that you will need to be prepared to answer for your final **oral** exam.



No class during the final week of the term. Instead you will each schedule 10-15 minute oral exam session.

FOUNDATIONS OF SCIENCE I

Learning Foci

Paradigms of Science

What is science and how does scientific progress happen?

Sources: Popper, Kuhn, Lakatos, and Feyerabend

Evaluation: Reflection HW(s) and Reading Week Essay

Core Physics Principles

Fundamentals of:

- Classical Mechanics
- Thermodynamics
- Electromagnetism
- Energy
- Quantum and relativity

Sources: The Feynman Lectures

Evaluation: Oral Exam, In-class oral exam practice sessions

Engagement with Physics in the Real World

How does physics translate into the real world? How is it used to design technology?

Sources: Lunch Lectures with local Austin companies and organizations

Evaluation: Reflection HWs

Most Abstract

Least Abstract

CAMPUS-WIDE LUNCH LECTURES

In the large lecture hall on select Mondays, 12:50-2pm.

- We are working with engineers, scientists, and entrepreneurs with tight schedules. We will notify you ASAP when these are scheduled.
- The first is next Monday, Apr 7
- On days there is a lunch lecture, there will **not** be an afternoon lecture.
- Take notes! They'll help you with your reflection HWs.

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PARADIGMS OF SCIENCE

WHAT MAKES SCIENCE *SCIENCE?*

HOW IS IT DIFFERENT FROM OTHER DISCIPLES LIKE ART, HISTORY, OR RELIGION?

Instructions:

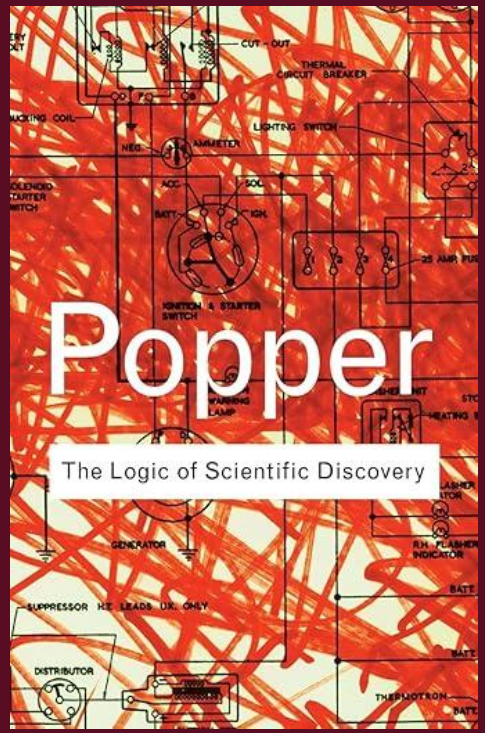
- Write 3–5 bullet points as a group.
- Include any disagreements or uncertainties (those are valuable!).
- You can draw diagrams, flowcharts, etc., if helpful.

THESE ARE EXACTLY THE KINDS OF QUESTIONS POPPER, KUHN, LAKATOS, AND FEYERABEND WRESTLED WITH—OFTEN IN DISAGREEMENT.

LET'S SEE HOW THEIR ANSWERS CHALLENGE OR EXPAND WHAT WE JUST TALKED ABOUT...

KARL POPPER: FALSIFIABILITY

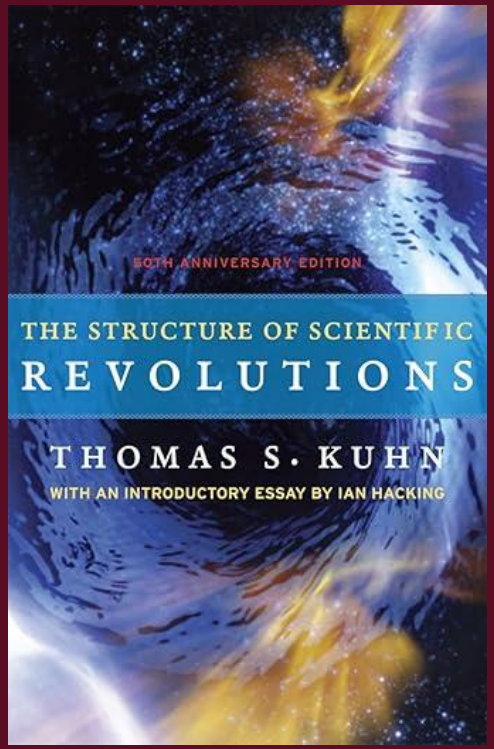
“The Logic of Scientific Discovery” (1934)



- Science advances not by verifying theories, but by **subjecting them to tests that could potentially prove them wrong**.
- A theory is scientific only if it is **falsifiable**—that is, if there exists a possible observation or experiment which could demonstrate the theory to be false.
- Mere confirmation is never enough, for any number of confirming instances cannot rule out that the next one may refute the theory.
- Thus, genuine science progresses through **bold conjectures and rigorous refutations**. By this standard, astrology or psychoanalysis may be rich in anecdotal confirmations, but they fail to offer testable predictions that could, in principle, be falsified.
- In contrast, Einstein’s theory of relativity gained credibility precisely because it **risked refutation—and passed the test.**

THOMAS KUHN: PARADIGM SHIFTS

"The Structure of Scientific Revolutions" (1962)



- Scientific development does not follow a straightforward, cumulative path toward truth.
- Instead, it proceeds through alternating periods of **"normal science"**, where scientists operate within a shared framework or **paradigm**, and **revolutionary science**, in which fundamental assumptions are overturned.
- During normal science, researchers solve puzzles that the current paradigm defines and deems relevant. But over time, **anomalies**—observations that the paradigm cannot explain—accumulate.
- Eventually, these lead to a **crisis** and the emergence of a new paradigm that redefines what counts as science. This shift is not merely logical but also sociological, as communities of scientists change their worldview.
- Thus, science is not always a linear march toward objective truth, but a **series of revolutions in perspective**.

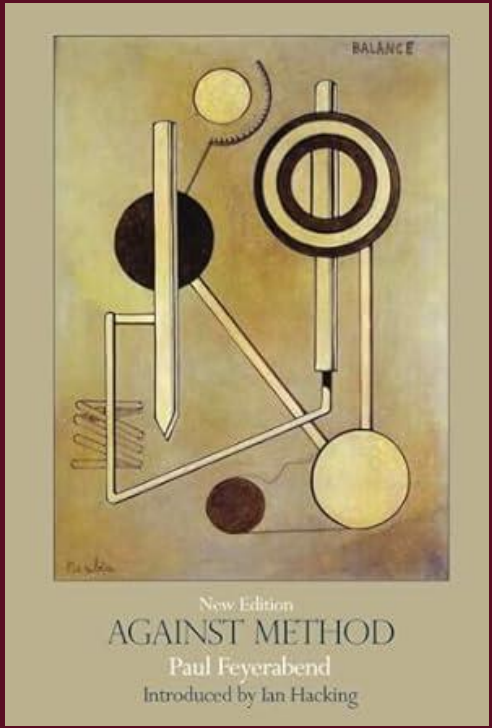
IMRE LAKATOS: RESEARCH PROGRAMS

“The Methodology of Scientific Research Programmes” (1978)

- Scientific knowledge evolves not through isolated theories, but through competing **research programs**, each with a structured core of assumptions.
- A **progressive research program** leads to new predictions and discoveries, while a **degenerative one** fails to grow and must invent ad hoc excuses for its failures.
- Unlike Popper’s view, science does not reject theories after a single falsification; instead, scientists protect the **“hard core”** of a theory by adjusting its auxiliary hypotheses.
- What matters is whether a program leads to **novel predictions that are empirically confirmed**.
- Therefore, the rationality of science lies not in instant refutations, but in the **long-term success** of a research program compared to its rivals.

PAUL FEYERABEND: ANYTHING GOES

“Against Method” (1975)



- The idea that science progresses by a single, universal method is a myth.
- History shows that many great scientific breakthroughs—Galileo’s telescopic discoveries, for instance—were achieved by **breaking the rules** of what was then considered proper science.
- Attempts to define a fixed “scientific method” only constrain creativity and suppress alternatives.
- In reality, **science is a patchwork of approaches, traditions, and sometimes contradictions**, and its success owes much to this diversity.
- Thus, Feyerabend argues for **epistemological anarchism**: there is no method that is always right, and “**anything goes**” if it helps us advance knowledge. Science thrives not on rigid rules, but on the freedom to innovate.

Full document in class Github.

Scientific Paradigms: Reflection Assignment

Introduction

During reading week, you will compare two texts by different philosophers of science. This reflection assignment is intended to introduce you to key ideas from each thinker so you can make an informed choice about which two to focus on for your comparison.

You have received the introductory excerpts from books by **Karl Popper**, **Thomas Kuhn**, **Imre Lakatos**, and **Paul Feyerabend** in class. Use these texts—along with insights from our in-class discussions—to develop thoughtful responses to the questions provided.

Turn-In Instructions

- Your answers must be **handwritten** and **legible**, completed on **lined paper**.
- Assignments will be assessed based on the **depth of reflection** and your **engagement with the philosophical ideas** presented.
- **Due: Friday at 12:00 PM (noon)**
- **Submission:** Bring to my office (library office). If I am not in my office, please slide your assignment **under my door**.

Assignment Overview

After reading the provided introductory excerpts from **Karl Popper**, **Thomas Kuhn**, **Imre Lakatos**, and **Paul Feyerabend**, you will write a short reflection addressing the following four questions. Each answer should be approximately **one to two paragraphs** (100–200 words), demonstrating thoughtful engagement with the ideas and your own critical thinking.

COURSE WEBSITE

https://github.com/eliah-o/Foundations-of-Science-I