FOUNDATIONS OF SCIENCE I

ORAL EXAM DETAILS AND BOOTCAMP

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OUTLINE

- Oral exam structure
- Reading and preparing for the exam
- An example
- How we will practice

ORAL EXAM STRUCTURE

- Final week of class. You will be asked to answer 1 or 2 questions in detail in under 10 minutes.

- Rooted in the Feynman Lectures .. one such question could be:

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.

WHY THE FEYNMAN LECTURES?

We’re using the Feynman Lectures because they teach us how to:

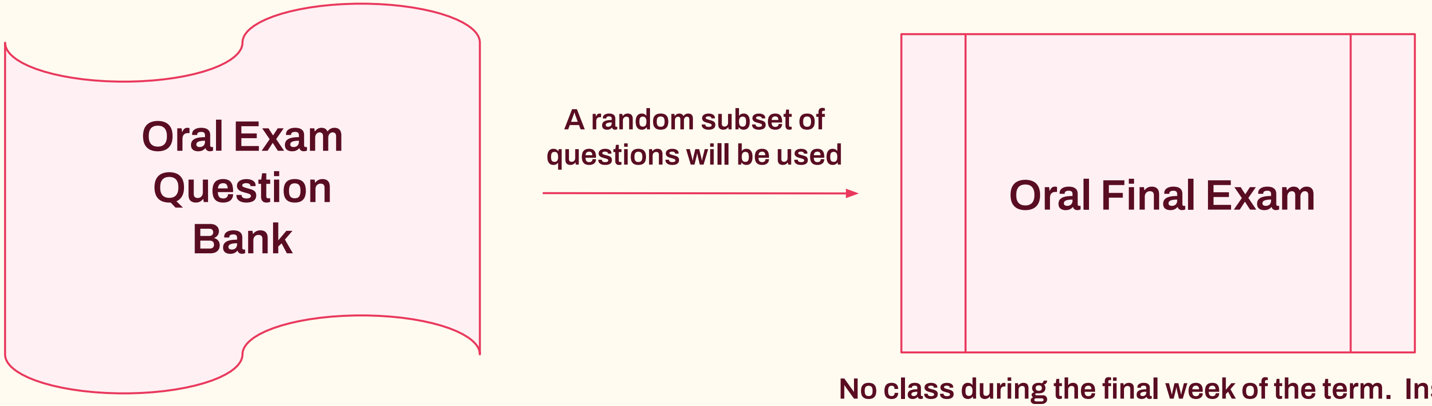
- Think critically about physical principles
- Question assumptions and ask “Why?” instead of just “How?”
- Value understanding over rote memorization
- See beauty and logic in how science actually works

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.

LIST OF QUESTIONS

What’s 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 all will schedule a ~10 minute oral exam session

TYPES OF READING

EXPLORATORY READING
VS
GOAL-ORIENTED READING

TYPES OF READING

Dimension	Exploratory Reading	Goal-Driven Reading
Primary Goal	Build understanding, curiosity, and conceptual depth	
Approach	Open-ended, broad, inquisitive	
Common Contexts	Studying new topics, reviewing literature, ideation	
Reading Style	Linear or meandering, open to tangents	
Strategies Used	- Previewing structure - Annotating ideas - Asking 'What is this about?' and 'How does this fit in?' - Making connections to other knowledge	
Cognitive Emphasis	Comprehension, synthesis, curiosity	
Outcome	Deeper understanding, broad mental models	

TYPES OF READING

Dimension	Exploratory Reading	Goal-Driven Reading
Primary Goal	Build understanding, curiosity, and conceptual depth	Find specific information or achieve a task
Approach	Open-ended, broad, inquisitive	Focused, selective, purposeful
Common Contexts	Studying new topics, reviewing literature, ideation	Solving a case, answering a question, doing research
Reading Style	Linear or meandering, open to tangents	Non-linear, skips to relevant parts
Strategies Used	- Previewing structure - Annotating ideas - Asking 'What is this about?' and 'How does this fit in?' - Making connections to other knowledge	- Skimming for keywords - Asking 'Does this help answer my question?' - Extracting relevant details - Applying content to a specific case
Cognitive Emphasis	Comprehension, synthesis, curiosity	Analysis, evaluation, decision-making
Outcome	Deeper understanding, broad mental models	Problem resolution, task completion, actionable insight

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Reading Week **Oral Exam Prep**

ORAL EXAM

BLUEPRINT/EXAMPLE

QUESTIONS

1. Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

2. Why do we feel "thrown outward" on a turning carousel, even though there's no outward force?

3. How does a ball bounce differently from a piece of clay?

ANSWERING A QUESTION

Blueprint

1) Restate the Question
2) State the Key Concept(s)
3) Present the Relevant Equation(s)
4) Interpret the Result
5) Conclude your answer

EXAMPLE

Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

ANSWERING A QUESTION

Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

1) Restate the Question

Start with a quick paraphrase to anchor the discussion.

> "The question is about why all objects — including a feather — fall at the same rate in a vacuum, and what causes the difference in behavior in air?"

ANSWERING A QUESTION

Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

2) State the Key Concept(s)

Identify and explain the central idea in clear language.

> "This involves **Newton's Second Law of Motion** and the concept of **air resistance**. In a vacuum, gravity is the only force acting on a falling object. In air, the object also experiences a resistive force — **drag** — which opposes motion. This explains the difference in how objects fall in different environments."

ANSWERING A QUESTION

Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

3) Present the Relevant Equation(s)

> Starting with Newton's Second Law:
>
> $$F = ma$$
>
> In a vacuum, the only force is gravity:
>
> $$F_{\text{gravity}} = mg$$
>
> So we substitute into Newton's law: $ma = mg \Rightarrow a = g$

In air, we must account for **air resistance**. Feynman presents two common models:

Linear drag (for small objects or low speeds): $F_{\text{drag}} = -kv$

Quadratic drag (for larger objects or higher speeds): $F_{\text{drag}} = -cv^2$

- k and c are constants depending on air density, object shape, and cross-sectional area
- v is velocity
- The negative sign shows the drag force opposes motion

At **terminal velocity**, drag balances gravity:

Linear case: $mg = kv$

Quadratic case: $mg = cv^2$

These equations explain why the feather slows down in air but not in a vacuum.

ANSWERING A QUESTION

Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

4) Interpret the Result

> "A feather has a small mass and a large surface area, so the drag force becomes significant very quickly as it falls. In air, the net force becomes small as air resistance nearly balances gravity, so the feather falls slowly. Eventually, the feather reaches **terminal velocity**, where:
>
> $$mg = cv^2 \quad \text{or} \quad mg = kv$$
>
> meaning it stops accelerating and continues falling at a constant slow speed.
>
> In a vacuum, however, there's no drag force. The feather experiences only gravity, so it accelerates just like any other object and its velocity increases indefinitely (no terminal velocity)"

ANSWERING A QUESTION

Why does a feather drift down slowly through air but fall at the same rate as a hammer in a vacuum?

5) Conclude your answer

> “In summary, all objects fall at the same rate in a vacuum because mass cancels out in F=ma when only gravity is present. A feather falls more slowly in air because of air resistance, modeled by $-kv$ or $-cv^2$, which reduces its acceleration. But in a vacuum, with no air resistance, the feather falls just as fast as a rock.”

PRACTICE EXAM SESSIONS

Starting next week, we will do graded oral exam in-class practice sessions (part of your 30% course engagement grade).

- 3 students will present per week.
- They will each receive one question, one week in advance.
- Classmates will perform peer-review during class to identify strengths and weaknesses in the answer.

Each week will have questions from a different topic:

1. Classical Mechanics
2. Thermodynamics
3. Electromagnetism
4. Energy
5. Quantum and Relativity

PRACTICE STRUCTURE

Presentation Component (4-7 min)

Student will present the answer to their question

- A whiteboard will be available
- Target 4-7 minutes
- Use the answer structure from lecture
- Class will take notes

Peer Review Component (10 min max)

Student will leave the room and the class will evaluate their answer

- Similar to the process of scientific peer-review

Defense Component (10 min max)

Student will re-enter the room and answer questions from the class to defend their answer.

Blueprint

1) Restate the Question
2) State the Key Concept(s)
3) Present the Relevant Equation(s)
4) Interpret the Result
5) Conclude your answer

CLASS SCHEDULE (APPROXIMATE)

Date	Topic	Students (3 max)
Tue Apr 22	Classical Mechanics	Jack, Eitan
Fri Apr 25	Classical Mechanics	Charis, Ethan
Fri May 2	Thermodynamics	Sayer, Alexandra, Wade
Reading Week	–	–
Tue May 13	Electromagnetism	India, Nicole, Kyle
Fri May 23	Energy I	Lauren, Jake, Lille
Tue June 3	Energy II	J.T., Faith, Ewa
Fri June 6	Quantum and Relativity	John, McKenna, Ian

CLASSICAL MECHANICS

Question Options

1. Why do astronauts feel weightless on the International Space Station?
2. Why does pulling a wagon slowly require less effort than pulling it quickly and stopping suddenly?
3. Why does a car need to slow down before taking a sharp curve?
4. How are submarines stable in water, and how do they differ from a boat's stability?

THERMODYNAMICS

Question Options

1. Why does water boil at a lower temperature on top of a mountain than at sea level (Sayer)?
2. Why does opening the freezer door ultimately warm up the kitchen instead of cooling it (Alexandra)?
3. Why is coastal weather milder than inland weather at the same latitude (Wade)?

ELECTROMAGNETISM

Question Options

1. Why does your hair stand up when you rub a balloon on it? (India)
2. How does wireless charging work? (Kyle)
3. How is lightning created in a thunderstorm, and why are you usually safe inside of a car during a lightning strike? (Nicole)

ENERGY I

Question Options

1. How does the energy in food relate to the energy your body uses to move? (Lauren)
2. Why can a car engine only convert part of the gasoline's energy into motion? (Jake)
3. What forms of energy are involved when you ride a bicycle uphill and coast downhill? (Lille)

ENERGY II

Question Options

1. How does an atomic bomb work? (Faith)
2. What is a nuclear power plant and how does it create energy? (J.T.)
3. We say that mass is just another form of energy, thanks to E=mc^2. Does that mean a rock sitting on the ground is full of usable energy? If so, why can’t we extract it easily? (Ewa)

QUANTUM AND RELATIVITY

Question Options

1. What would happen if you could travel near the speed of light? (John)
2. Why can’t we know both the position and velocity of an electron precisely? (Ian)
3. Why is Schrödinger’s cat considered both alive and dead before the box is opened? What does this thought experiment say about the role of measurement in quantum physics? (McKenna)

REMINDERS

- All answers must be based on content from the **Feynman lectures**.
- LLMs - such as ChatGPT, Claude, and Perplexity - may steer answers in the wrong direction by pulling from content outside these lectures and should be used with extreme caution and/or provide incorrect information.
- HOWEVER, **<u>LLMs are an extremely useful tool for understanding content from the Feynman lectures</u>** that you may find challenging and are highly **encouraged** for that purpose.