# 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.

Oral Exam Question Bank

A random subset of questions will be used →

Oral Final Exam

No class during the final week of the term. Instead, you all will schedule a ~10 minute oral exam session
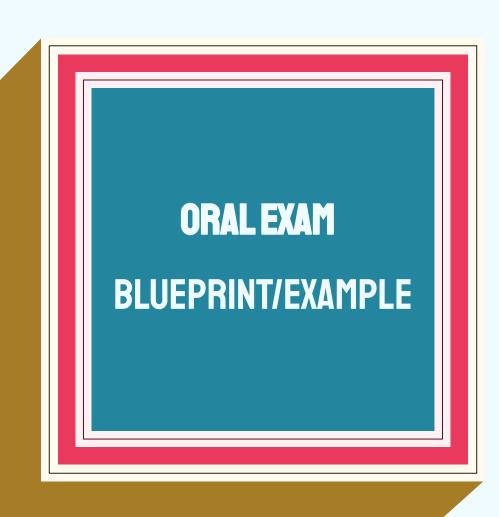
# TYPES OF READING

# 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<br>- Annotating ideas<br>- Asking 'What is this about?' and 'How does this fit in?'<br>- Making connections to other knowledge | |
| **Cognitive Emphasis** | Comprehension, synthesis, curiosity | |
| **Outcome** | Deeper understanding, broad mental models | |

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| **Approach** | Open-ended, broad, inquisitive | Focused, selective, purposeful |
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| **Reading Style** | Linear or meandering, open to tangents | Non-linear, skips to relevant parts |
| **Strategies Used** | - Previewing structure<br>- Annotating ideas<br>- Asking 'What is this about?' and 'How does this fit in?'<br>- Making connections to other knowledge | - Skimming for keywords<br>- Asking 'Does this help answer my question?'<br>- Extracting relevant details<br>- Applying content to a specific case |
| **Cognitive Emphasis** | Comprehension, synthesis, curiosity | Analysis, evaluation, decision-making |
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**Reading Week Essay**       **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): $F_{\mathrm{drag}} = -kv$

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

- 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 | Lauren, Jake, Lille |
| Tue June 3 | Energy | 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?

# 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.