Chief Reader Report on Student Responses:

2025 AP® Physics C: Mechanics Free-Response Questions

• Number of Students Scored	66,267		
• Number of Readers	840		
• Score Distribution	Exam Score	N	%At
	5	14,360	21.7%
	4	15,873	24.0%
	3	18,225	27.5%
	2	10,608	16.0%
	1	7,201	10.9%
• Global Mean	3.30		

The following comments on the 2025 free-response questions for AP® Physics C: Mechanics were summarized by the Chief Reader, Brian Utter, Teaching Professor and Associate Dean of Undergraduate Education, University of California, Merced. They give an overview of each free-response question and of how students performed on the question, including typical student errors. General comments regarding the skills and content that students frequently have the most problems with are included. Some suggestions for improving student preparation in these areas are also provided. Teachers are encouraged to attend a College Board workshop to learn strategies for improving student performance in specific areas.

Question 1

Task: Mathematical Routines
Topic: Momentum

	Max Points:	Mean Score:
A1	1	0.86
A2	1	0.60
A3	1	0.46
A4	1	0.27
A5	1	0.50
A6	1	0.46
A7	1	0.06
B1	1	0.83
B2	1	0.74
B3	1	0.56

Overall Mean Score: 5.34/10

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Represent the momentum of a system by drawing an arrow, including a block before a collision and a system before and after a totally inelastic collision
- Derive an expression for the change in momentum of a block when an impulse is applied to the block given a totally inelastic collision and known momenta for both blocks before the collision
- Recognize and apply the integral expression of impulse or the differential form of Newton's second law to derive an expression for the maximum force given an equation for $F(t)$
- Recognize and apply conservation of momentum to derive an expression for the initial velocity of one of the blocks given the initial velocity of the other block and the speed of the two-block system after the collision

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- About 80% of responses correctly indicated an arrow pointing left with the correct length to represent the initial momentum of Block 2 before the collision.
- A slightly lower percentage calculated the final speed of the blocks after the collision correctly but much fewer (about 20%) determined the change in momentum of a block during the collision correctly.
- Around 60% of responses drew the correct arrow for the system both before and after the collision. Responses often drew a correct arrow for the system after the collision, but the arrow before the collision was not equal in length. A small percentage of incorrect responses confused the pre-collision drawing by drawing two arrows, one representing the momentum of Block 1 before the collision and another representing the momentum of Block 2 before the collision. Many of these responses then drew the correct arrow to represent the post-collision momentum for the system.
- Approximately 70% of responses recognized that a calculus-based equation was required to derive an expression for the maximum force during the collision. The majority of these used an integral expression for impulse. Only a quarter of responses executed the definite integral correctly. Typically, the responses that chose the differential form of Newton's second law approach (about 20% of those that used calculus) did not rearrange the differentials correctly to earn points for integrating. A small percentage of responses that did not use calculus derived a change in velocity over time and then substituted into a Newton's second law equation resulting in an impulse equation that would be correct for a constant applied force. Very few responses (6%) had the correct final expression for F_{max}.

- A large majority of responses recognized the need to use conservation of momentum. About 60% of responses obtained the correct expression for the final momentum of the two-block system, and most of these obtained the correct expression for the initial velocity of Block 1. About 20% of responses determined an initial expression for the velocity for Block 1 that would result if the final velocity of the two-block system was $-v_0$ rather than $+v_0$. Most responses that made this error did not consider that the post-collision velocity could be to the right.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Responses frequently did not demonstrate that the momentum of the two-block system was unchanged during the collision.	• Correct responses represent the momentum of the two-block system with an identical arrow before and after the collision.
• Responses often did not demonstrate the momentum of the two-block system after the collision was equal to the vector sum of the momenta of Block 1 and Block 2.	• Correct responses represent the momentum of the two-block system before the collision as an arrow with length and direction determined by taking the arrow drawn for Block 2 before the collision and adding two to its length if it is drawn to the right or subtracting two units from its length if it is drawn to the left.
• Around 20% of responses did not recognize the need to use an integral for impulse even though the prompt gave a force that varied with time.	• Correct responses wrote the integral form for the impulse or the differential form of Newton's second law as a starting point.
• About 85% of responses did not perform the definite integral correctly.	• Correct responses wrote a correct antiderivative for a sine function with integration limits from 0 to t_c.
• Around half of responses determined the final speed of the blocks after the collision but did not determine the difference in momentum. Only 20% determined an expression for the change in momentum of either block during the collision.	• Correct responses obtained $\Delta p = \frac{18}{7} m v_0$.
• Many responses did not recognize that the velocity of the two blocks was not specified in the prompt. Only the final post-collision speed was given.	• Correct responses recognized that considering the post-collision speed as left resulted in a solution that showed both blocks moving left with velocity $-v_0$ prior to the collision thus the blocks would never collide.

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- The AP Physics 1 Student Workbook has scaffolding for derivation practice. The workbook suggests a two-column chart where the words for each step are on the left side, and the math steps are on the right. The AP Physics 1 Student Workbook pages that would help students prepare for this question are 3D, 3E, and 4G.
- For momentum charts, use them in class discussion as an alternative model or representation of momentum for various systems throughout the year. This can help with applications both with and without mathematical representations.
- For derivations requiring integration, start integration processes in the fall with motion. Focus demonstration and practice problems using definite integrals with limits shown. For instance, when deriving a representation for velocity given the acceleration as a function of time, demonstrate this as a definite integral from 0 to t, rather than an indefinite integral with constant C. This will aid students in setting up derivations with integral expressions for impulse and work in later units.
- For derivations requiring integration, practice by using card sorts matching physics situations with their appropriate integral expression for impulse/work.
- For derivations requiring integration, practice solving problems that require manipulating differentials. For instance, solving more problems that require manipulating the differential form of Newton's second law would help students build more confidence in setting up problems that require a differential equation. This can be done in earlier units. The process of solving differential equations and integration can be connected and scaffolded throughout the year.
- For derivations, model this practice on the board for students throughout the year, starting in the fall and tapering off in the spring when students can use other scaffolded activities to guide this process. Have students practice derivations with groups on whiteboards and follow up with individual practice.
- For derivations, type up a derivation step-by-step. Print it out and cut it up. Provide students with the cut-up derivation and ask them to put the cards in the correct order and justify their work.
- Practice the steps related to the *justify* task verb using multiple modalities for students. Use turn and talk, think-pair-share, peer-reviewing, presenting, or selecting correct student responses as activities to support this skill.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers should direct students to units 3 and 4 progress checks and AP Daily videos on conservation of energy and conservation of momentum.
- Teachers should assign topic questions (Topics 4.2 and 4.3) to monitor progress being made in the mastery of content.

Question 2

Task: Translating Between Representations
Topic: Conservation Laws and Oscillation

	Max Points:	Mean Score:
A1	1	0.80
A2	1	0.73
A3	1	0.77
B1	1	0.87
B2	1	0.66
B3	1	0.54
B4	1	0.34
C1	1	0.40
C2	1	0.72
C3	1	0.73
D1	1	0.62
D2	1	0.53

Overall Mean Score: 7.74/12

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Graph the types of energy, specifically kinetic and spring potential energies, and their relative magnitudes in a system
- Derive an expression using conservation of mechanical energy for a system containing two springs with different spring constants and a block
- Sketch a graph to represent the kinetic energy as a function of time for an oscillating object that is losing energy to friction
- Identify and justify how a feature of the sketched graph would change if the mass were greater

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- Most responses sketched the energy bar graphs correctly, demonstrating understanding of the kinetic and potential energies present in the system. Some responses sketched the bar graph with one spring's energy positive and the other negative but still showed that U_B was twice the magnitude of U_A. A few responses indicated that the kinetic energy was not zero in the initial state of the system.
- Most responses began the derivation with relevant equations, but fewer correctly included both springs, and even fewer correctly included both positions. Responses that began by identifying all the types of energy present in both initial and final state were generally successful at the entire derivation.
- A few responses attempted a derivation beginning with the position equation for simple harmonic motion. Responses that followed this path were less likely to earn full credit on this part of the prompt, though some responses succeeded using this method to find the correct answer.
- Most responses sketched a damped oscillation, but fewer than half the responses correctly represented the kinetic energy as starting at zero and always being greater than or equal to zero. Many responses sketched a graph that represented the position or velocity of a damped harmonic oscillator rather than the kinetic energy of the oscillator.
- Some responses correctly described how a feature of the graph would change, and most of those responses correctly justified the reason for the change.

- A few responses identified a feature that would change but did not describe whether that feature would increase or decrease. A small number of responses identified how a property of the oscillator would change but did not relate that to a feature of the graph.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Responses indicated that spring energy can be positive or negative, depending on whether the spring is compressed or stretched. • Responses indicated that the spring energies were equal for the two springs.	• Responses indicated that both spring energies are positive and that U_B is twice the magnitude of U_A.
• Responses did not include both springs in the energy equation. • Responses used the difference of the two spring constants, rather than the sum, in the initial and final energy states. • Responses treated the spring constants as if the springs were in series rather than parallel.	• Responses included separate spring energy expressions for U_A and U_B, with the correct spring constants, in the initial and final energy states.
• Responses did not include both initial and final spring energies in writing a conservation of energy equation. • Responses included the difference between the initial and final positions of the springs in a single spring energy equation, rather than analyzing the energy at each position.	• Responses included both initial and final spring energies in the conservation of energy equation, evaluated at the two positions x_1 and $\frac{x_1}{2}$.
• Responses equated either the kinetic energy to final spring energy or to the initial spring energy but not to the difference of the final minus initial spring energies.	• Responses wrote conservation of energy equations with distinct initial and final states, including the separate spring energies U_A and U_B in each state, and the kinetic energy of the block in the final state.
• Responses sketched a graph that represented position or velocity as a function of time rather than kinetic energy.	• Responses recognized that kinetic energy is always greater than or equal to zero and sketched a graph with zeros of the kinetic energy spaced $\frac{1}{2}T$ apart.

• Responses identified that increasing the mass of the object would increase the kinetic energy of the object, because the equation for kinetic energy contains mass.	• Responses recognized that the initial energy of the system is all spring potential energy and therefore changing the mass does not change the initial energy. • Responses identified that increasing the mass of the object would increase the period of the oscillation because the period of a simple harmonic oscillator is a function of the mass of the object $\left(T \propto \sqrt{m}\right)$.
• Responses indicated that increasing the mass of the object would lengthen the time for the energy to dissipate from the system.	• Responses indicated that increasing the mass of the object increases that rate of energy dissipation by friction.
• Responses identified a feature of the graph that would change but did not describe whether that feature would increase or decrease.	• Responses identified a feature of the graph and how it would change.

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- When doing a Hooke's law lab, have students measure the force and stretch for two springs separately, then in series and in parallel, so that students directly see and feel that springs in series have a lower effective spring constant, and springs in parallel have a higher effective spring constant.
- When teaching conservation of energy, it is valuable to have students write a clear conservation of energy equation that identifies the types of energy present in each state before making substitutions of algebraic expressions and problem-specific variables. Responses that began by explicitly identifying all types of energy present in both initial and final states were very successful, while responses that jumped into algebraic representations often missed including every component of the energy equation.
- When teaching students to respond to justification prompts, emphasize brevity, clarity, and precision.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers should direct students to units 3 and 7 progress checks and AP Daily videos on conservation of energy and oscillations.
- Teachers should emphasize the behavior of springs connected in series and parallel. Students can be directed to AP Daily videos and topic questions in Topic 2.8 for practice.
- Teachers should assign topic questions (Topics 4.2, 4.3, 7.3, and 7.4) to monitor progress being made in the mastery of content.

Question 3

Task: Experimental Design and Analysis
Topic: Conservation of Energy

	Max Points:	Mean Score:
A1	1	0.74
A2	1	0.78
B1	1	0.54
B2	1	0.47
C1	1	0.74
C2	1	0.71
C3	1	0.80
C4	1	0.81
D1	1	0.49
D2	1	0.50

Overall Mean Score: 6.57/10

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Communicate a procedure to measure quantities using a specific set of equipment to determine the acceleration due to gravity
- Identify a pair of variables that could be plotted to create a linear graph whose slope would help determine an experimental value for the acceleration due to gravity (e.g., velocity squared and two times height)
- Explain how to use the slope of a linear graph to calculate an experimental value for the acceleration due to gravity
- Identify a pair of variables that could be plotted using a given data table to create a linear graph whose slope would help determine an experimental value for the coefficient of friction (e.g., height and stopping distance)
- Calculate the coefficient of friction from a height versus horizontal displacement graph

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- Most responses were able to design an experiment with specific lab equipment and describe a procedure using that equipment. Approximately 80% of responses described an experiment in which the change in height and speed are measured. Some responses included measurements of mass, which indicate the word “only” describing the given materials in prompt on the first page was overlooked.
- Approximately 80% of responses either performed multiple measurements of the same quantity or stated another reasonable way to reduce experimental uncertainty.
- In part B many responses correctly related measurements from part A through conservation of energy. However, many responses demonstrated difficulty connecting the data to create a linear graph whose slope would determine an experimental value for the acceleration due to gravity. Many responses indicated that velocity rather than velocity squared should be plotted versus height, showing a lack of understanding of the relationship between the quantities in an accelerating system.
- Responses that included conservation of energy equations including initial gravitational potential energy and final kinetic energy showed greater success.
- Generally, responses were very successful in identifying variables that would produce a linear graph, labeling axes including units, plotting points, and drawing a best-fit line for the data; although the slope of this line varied significantly.
- In part D, responses typically calculated the slope of the best-fit line; however, many did not connect the slope of the best-fit line to the value for m.

- Responses that included a conservation of energy equation that included initial gravitational potential energy and work done by friction showed a higher success rate on parts C and D.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Responses attempted to use concepts that are not relevant to this scenario or to make measurements that cannot be made with the specified equipment.	• Responses indicate measuring h and v using a meterstick and motion sensor.
• Responses did not indicate how to identify the relationship between dependent and independent variables; for example using $\frac{1}{2}mv_f^{\,2} = mgh \rightarrow v_f^2 = 2gh$ to relate the final speed of an object falling from rest through height h.	• Responses indicated that v^2 should be plotted on the vertical axis and $2h$ on the horizontal axis in part B and that the slope of the best-fit line is the experimental value of g.
• Responses showed difficulty labeling axes with appropriate labels and units including a linear scale.	• Responses indicated h (m) on the vertical axis and x_{max} (m) on the horizontal axis with marked linear scales on both axes.
• Responses showed difficulty describing how to relate the slope of a graph to an unknown quantity.	• Responses plotted h on the vertical axis and x_{max} on the horizontal axis in part C and indicated that the slope of the best-fit line is equal to μ.

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- Ensure that students practice designing and performing laboratory experiments multiple times per unit. Ask students to design an experimental procedure using limited equipment, so that they are used to working within constraints of available measuring devices.
- Incorporate mini-labs where students can use their lab skills to collect relevant data and calculate an unknown quantity using their measurements.
- Ensure that students are practicing data collection and linearization to determine an unknown value and practicing relating data to physics equations to determine values extracted from slopes of best-fit lines.
- Using the AP Physics C: Mechanics reference sheet, ask students to come up with various ways that variables can be manipulated to create a linear graph. Ask them to identify the vertical axis variable and horizontal axis variable and how to use the slope to determine an unknown value. For instance, ask students to find every equation on the equation sheet that includes "*g*." Separate students into groups and assign each group a different equation. Ask each group to identify the vertical axis variable and horizontal axis variable and how to use the slope to determine "*g*."
- At the end of the school year, the AP Daily: Live Review videos provide reviews on particular question types. These videos outline the skills students need to demonstrate on the exam.

- For students who struggle with linearization, the AP Physics 1 Student Workbook is a scaffolded collection of bite-sized practice pages. It helps students practice experimental design and linearization of data applied to conservation of energy, work-energy theorem, and other topics.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers should direct students to Unit 3 progress checks and AP Daily videos on conservation of energy.
- Teachers should assign topic questions (Topics 3.1, 3.3, and 3.4) to monitor progress being made in the mastery of content.

Question 4

Task: Qualitative/Quantitative Translation
Topic: Rotation and Friction

	Max Points:	Mean Score:
A1	1	0.23
A2	1	0.52
A3	1	0.23
B1	1	0.29
B2	1	0.14
B3	1	0.23
C1	1	0.44
C2	1	0.23

Overall Mean Score: 2.30/8

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Compare physical quantities between two different objects (disk and ring) of the same mass and material rolling without slipping up identical ramps
- Apply an appropriate understanding of static and kinetic frictional forces to make a claim
- Justify a claim about the static frictional force using evidence from physical principles by identifying the correct direction of forces on rolling objects
- Apply Newton's second law in both translational and rotational form to describe an object undergoing rolling motion in both linear and angular quantities
- Derive a symbolic expression for friction from known quantities by selecting and following a logical mathematical pathway
- Connect translational and rotational motion using an appropriate equation that contains corresponding linear and angular quantities
- Compare kinetic friction between two different objects of the same mass and material
- Justify a claim about the kinetic frictional force on the two different objects using physical laws for rolling with slipping

How well did the responses address the course content related to this question? How well did the responses integrate the skill(s) required on this question?

- This was a conceptually challenging problem. Most responses correctly compared physical quantities, such as identifying that the two objects had different moments of inertia or traveled different distances, but many responses did not use this evidence to justify their claim. Around a quarter of responses correctly indicated that $f_D < f_R$.
- Most responses were able to identify the correct relationship between *maximum* static friction and the normal force; however, many responses incorrectly assumed that static friction was a constant value and therefore equal for both objects.
- Some responses demonstrated an understanding that static friction was responsible for rolling motion, but most responses did not identify that static friction was directed up the incline.
- Most responses attempted at least one form of Newton's second law, but less than a third of the responses set up a system of equations with both translational and rotational forms of Newton's second law. Many responses did not begin the derivation with equations from the equation sheet provided.
- Some responses incorrectly attempted to use energy conservation instead of Newton's second laws.

- Most responses did not communicate that the friction force was opposite the component of gravity parallel to the ramp, and many responses did not include both friction and gravitational components in the same net force equation. Fewer than 15% correctly accounted for both terms with correct signs in a Newton's second law expression.
- Many responses attempted to connect linear and angular acceleration using an appropriate equation, but some responses inserted gravity directly for acceleration instead of solving a system of equations.
- Most responses compared the kinetic friction between the two objects, but some responses had difficulty understanding the prompt and compared the kinetic energies of the two objects or the frictional force caused by the inclined planes in the two different scenarios.
- Most responses demonstrated an understanding that static and kinetic friction are different by making a claim about kinetic friction in part C that was different from their claim about static friction in part A, but many responses were not able to correctly differentiate between the two types of friction.
- Most responses attempted to justify their claim about kinetic friction, but many responses focused on the functional relationship between rotational inertia and friction in Newton's second law rather than the fundamental physical relationship between the frictional force, the coefficient of friction, and the normal force. Less than half the responses correctly indicated that the kinetic friction forces on the disk and ring would be equal with around a quarter providing a correct justification.

What common student misconceptions or gaps in knowledge were seen in the responses to this question?

Common Misconceptions/Knowledge Gaps	*Responses that Demonstrate Understanding*
• Responses did not attempt to justify their claims by connecting the claim or evidence in the prompt to the reasoning that would address the question.	• Responses made a claim based on evidence in the problem and then connected the claim to the evidence using reasoning that included specific references to fundamental physics principles; for example, connecting the larger rotational inertia of the ring to a smaller angular acceleration as it rolls up the ramp, which implies a smaller linear acceleration, a smaller net force along the incline, and a larger frictional force.
• Responses attempted to justify their claim about static friction using the coefficient of friction and normal force, implying that static frictional force is a constant value.	• Responses justified their claim about static friction with specific references to the net forces and/or accelerations acting on the rolling object. Importantly, static friction is often not at the maximum value, so we cannot assume $f_s = \mu_s F_N$.
• Responses did not use a system of equations to solve for the frictional force.	• Responses included complete net force and net torque equations that were often accompanied by appropriate free-body diagrams.

• Responses did not include opposite directions for the downhill component of the gravitational force and the frictional force in a net force equation.	• Responses include a net force equation with opposite signs for the frictional force and the downhill component of the gravitational force.
• Responses attempted to use conservation of energy to solve for the frictional force.	• A Newton's second law expression using a net force that includes the frictional force was needed. Static friction does not dissipate energy from the system and will not appear in an energy equation.
• Responses attempted to justify their claim about kinetic friction using specific references to torque and moment of inertia, implying that kinetic friction depends on external forces.	• While slipping, $f = f_k = \mu_k F_N$; given that the ramps and masses of the disk and ring are the same, the coefficients of friction and normal forces are the same; therefore, the friction forces are also the same for the disk and ring.

Based on your experience at the AP® Reading with student responses, what advice would you offer teachers to help them improve student performance on the exam?

- Ensure that students know how to connect the evidence from the prompt to a claim using reasoning that extends beyond the evidence.
  - Students need more practice justifying claims with various levels of scaffolding for a variety of topics.
  - When students work through labs in class, scaffold the conclusion with a Claim-Evidence-Reasoning format, but encourage students to consider the reasoning first.
- Ensure students will be able to demonstrate an understanding that static friction is not a constant value.
  - Incorporate a variety of discussion examples where static friction is not at its maximum value to help address this common misconception.
  - When doing a lab with digital forces sensors, be sure students can see that static friction changes and justify why the equation is not an equal sign for static friction.
- Ensure students can recognize the best starting approach when practicing derivations.
  - Focus on multiple paths to a solution and when to use Newton's second law versus energy.
  - AP Classroom has derivation practice available as do old AP Exams. Have students practice derivations with groups on whiteboards and follow up with individual practice.
- Encouraging multiple representations for problem solving helps when problems are challenging.
  - Students who drew a free-body diagram tended to have much better outcomes on this problem. Reinforcing the usefulness of a free-body diagram, even when not required, would help students be more successful.
  - When working through practice problems, students can use whiteboards. Have students try multiple representations, force diagrams, interactive motion maps, and try example numbers in equations to help with translating the information in the QQT.
- At the end of the school year, the AP Daily: Live Review videos provide reviews on each question type. These videos outline the skills students need to demonstrate on the exam.
  - Include qualitative (without equation or numbers) discussions summarizing labs and activities related to the content throughout the year and revisit these discussions again in preparation for the exam.

What resources would you recommend to teachers to better prepare their students for the content and skill(s) required on this question?

- Teachers should direct students to progress checks and AP Daily videos for Unit 5: Torque and Rotational Dynamics and Unit 6: Energy and Momentum of Rotating Systems
- Teachers should assign topic questions (Topics 5.3, 5.6, and 6.5) to monitor progress being made in the mastery of content.