Chief Reader Report on Student Responses:

2025 AP® Physics 2: Algebra-Based Free-Response Questions

• Number of Students Scored	24,322		
• Number of Readers	840		
• Score Distribution	Exam Score	N	%At
	5	5,284	21.7%
	4	7,007	28.8%
	3	5,365	22.1%
	2	4,911	20.2%
	1	1,755	7.2%
• Global Mean	3.38		

The following comments on the 2025 free-response questions for AP® Physics 2: Algebra-Based 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: Magnetism, Current-Carrying Wires, and Lenz's Law

	Max Points:	Mean Score:
A1	1	0.77
A2	1	0.52
A3	1	0.76
A4	1	0.56
A5	1	0.60
A6	1	0.59
A7	1	0.27
B1	1	0.60
B2	1	0.44
B3	1	0.21

Overall Mean Score: 5.32/10

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Indicate the direction of the magnetic field due to a current-carrying wire
- Indicate the direction of the magnetic force exerted on a current-carrying wire that is in a magnetic field
- Equate expressions for the magnetic forces or magnetic fields due to two current-carrying wires on or along, respectively, a third current-carrying wire
- Indicate the direction of the net magnetic field due to the current-carrying wires at a given distance from one of the wires
- Determine the direction of the magnetic field through a nearby loop due to the current-carrying wires by using a right-hand rule
- Indicate the direction of the induced current in a loop that is moving away from the current-carrying wires
- Justify, according to Lenz's law, that the direction of the induced current in the loop results from a decrease in the magnitude of the magnetic field through the loop because the loop is moving away from the current-carrying wires

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 (approximately 78%) indicated the direction of the magnetic field due to a current-carrying wire.
- Many responses (approximately 52%) indicated the direction of the magnetic force exerted on a current-carrying wire that is in a magnetic field that is due to another current-carrying wire.
- Most responses (approximately 76%) recognized the magnetic field and/or magnetic force equations that applied to the scenario under consideration.
- Many responses (approximately 60%) substituted $2I$ into an expression for the magnitude of the magnetic field due to the current in Wire 3 along Wire 1 or the magnitude of the magnetic force that Wire 3 exerts on Wire 1.
- Some responses (approximately 27%) solved for an expression for y_3 in terms of d; many of these responses included a correct expression.
- Many responses (approximately 61%) indicated that the current induced in the loop is clockwise.
- Some responses (approximately 44%) indicated that the direction of the magnetic field through the loop due to the current-carrying wires is into the page.
- Few responses (approximately 21%) appropriately applied Lenz's law to the loop that is moving away from the current-carrying wires.

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 that do not recognize that the magnetic forces due to Wires 2 and 3 exerted on Wire 1 could be equal in magnitude despite differences in both the absolute value of the currents in Wires 2 and 3 and their respective distances from Wire 1	• Responses that substitute appropriate expressions for the current in a wire and the distance from the current-carrying wire into an expression for the magnetic field due to a current-carrying wire • Responses that recognize that both the currents due to Wires 2 and 3 and their distances from Wire 1, respectively, are not equal
• Responses that demonstrate difficulty with identifying and distinguishing between the quantities associated with magnetic force and magnetic field interactions involving current-carrying wires, such as the distance from a wire (used in deriving an expression for the magnitude of the magnetic field), the length of a wire segment (used in deriving an expression for the magnitude of the magnetic force), and the source of the current responsible for generating the magnetic field	• Responses that cancel out the lengths in the equation for the magnetic force due to a current-carrying wire • Responses that substitute the correct distances for r in the equation for the magnetic field due to a current-carrying wire • Responses that substitute the expression for the current in Wire 3 (not the currents for wires 1 or 2) into the equation for the magnetic field due to a current-carrying wire for Wire 3 only
• Responses with incorrect applications of a right-hand rule that can be used to determine that the direction of the magnetic field at the loop is into the page	• Responses that indicate that the external magnetic field due to the current-carrying wires through the loop is into the page
• Responses that indicate that the induced current in the loop is determined by the direction of the external magnetic field that is through the loop	• Responses that indicate that the induced current in the loop is due to a change in the absolute value of the magnetic flux through the loop according to Lenz's law and not due only to the direction of the external magnetic field through the loop
• Responses that incorrectly relate the change in the absolute value of magnetic flux to the direction of the induced magnetic field	• Responses that determine the direction of the induced current in the loop by recognizing that the magnitude of the magnetic field through the loop that is into the page is decreasing. Therefore, an induced magnetic field that is into the page is established to oppose this change (as opposed to a general statement about a changing magnetic flux).

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?

- Students should practice using appropriate right-hand rules to represent directions of magnetic fields due to current-carrying wires and magnetic forces exerted on current-carrying wires in external magnetic fields.
- Students should not just derive an expression for the magnetic field due to current-carrying wires and an expression for the magnetic force exerted on a current-carrying wire due to an external magnetic field; students should understand, through functional dependence, how the current and distance quantities in these expressions affect magnetic field and magnetic force magnitudes.
- Students should justify an answer by stating the direction of quantities (i.e., current and magnetic field) and indicate whether the quantity is increasing or decreasing in absolute value or magnitude.
- Students should not only identify the change in the magnitude of a magnetic field but also understand how Lenz's law applies to a scenario by identifying the directions of the induced current and magnetic field in and through a loop, respectively, magnetic flux that changes in absolute value.

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

- Teachers can direct students to Unit 12 in the *AP Physics 2: Algebra-Based Course and Exam Description* and AP Classroom with a focus on topics 12.1, 12.3, and 12.4 to review the learning objectives and essential knowledge statements.
- Teachers can assign AP Daily videos on magnetic fields, magnetic forces on current-carrying wires, and electromagnetic induction. Topic questions for 12.1, 12.3, and 12.4 should be assigned to monitor mastery of the topics.
- Teachers should have students practice skills 1.A, 2.A, 3.B, and 3.C by drawing diagrams for magnetic forces and fields, deriving physical quantities from fundamental physics principles, and making and justifying claims using physics principles or laws. Teachers should assign the progress checks for Unit 12 to reinforce these skills.

Question 2

Task: Translating Between Representations
Topic: Ideal Gas Law, Thermal Processes, and PV Diagrams

	Max Points:	Mean Score:
A1	1	0.83
A2	1	0.62
A3	1	0.82
B1	1	0.90
B2	1	0.65
B3	1	0.44
B4	1	0.50
C1	1	0.85
C2	1	0.52
C3	1	0.83
D1	1	0.75
D2	1	0.43

Overall Mean Score: 8.19/12

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Create a free-body diagram of the forces exerted on the piston that is in static equilibrium
- Derive an expression for the internal energy of the gas inside the container by using the ideal gas law equation and an expression for the pressure of the gas due to the forces identified in part A
- Sketch a line or curve representing the relationship between pressure and volume as the gas is taken through a thermodynamic process (adding a mass to the piston and allowing the mass-piston system to compress the gas to a new thermodynamic equilibrium state)
- Indicate a new value for the temperature using functional dependence of the three state variables (P, V, and T) that define an ideal gas, and justify that claim by referencing one of the representations from parts A, B, or C

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 (approximately 75%) identified and labeled the three correct forces exerted on the piston (i.e., the gravitational force exerted on the piston, the force that the gas exerts on the piston, and the force exerted on the piston that is due to the atmosphere). Vectors were drawn on the provided dot in the correct direction with arrows; however, many responses did not include the weight of the piston or the force due to the atmosphere. There were also quite a few responses that labeled the arrows as pressure (a scalar quantity) on the free-body diagram instead of the force due to that pressure.

- The ability for responses to demonstrate mastery of the derivation skill (Skill 2.A) has improved from previous years; this is evidenced by the number of correct responses (approximately 63%) to the derivation prompt. A derivation requires multiple algebraic steps and should begin with an equation from the reference information or a fundamental physics concept.
    - The responses indicated that students are better at starting a derivation with an equation from the reference information, which is explicitly indicated in the prompt.
    - Many responses (approximately 55%) indicated an attempt to perform necessary substitutions. Often, however, these substitutions were unclear, and it was difficult for individuals scoring the responses to identify which quantities were substituted; the use of subscripts on quantities/variables could help identify appropriate substitutions. Furthermore, in several responses, one or more substitutions were not performed for the expected, final derived answer that should be expressed in terms of quantities that are specified in the prompt.
    - A significant number of responses did not differentiate between pressure and force.
- Most responses (approximately 73%) that included sketches on the PV diagram for the process described were correct. There were a small number of responses in which a straight line was drawn, rather than a curve. A small number of responses did not include the required arrow that indicates the direction of the process.
- Some responses (approximately 43%) to part D provided a proper justification for the selected claim. When answering part D in the translating between representations task model, students should refer directly to a representation that is used in a previous item part (A, B, or C) of the question. The responses typically did not show a clear connection to what item part was used to support the claim. Responses also displayed a lack of understanding that, in some instances, quantities remain constant; this should be clearly stated.

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 with free-body diagrams that include: o Pressures, which are scalar quantities, which should not be included on a free-body diagram o A generic "applied" force without subscripts that clearly indicate what object is applying the force o A label like F_{piston}, which suggests that an object can exert a force on itself	• Responses that indicate free-body diagrams that include forces that are labeled with an uppercase F and appropriate subscripts (e.g., F_g, F_{atm}, or F_{gas})
• Responses that do not start with an equation from the reference information or a fundamental physics concept/principle	• Responses that start with an equation from the reference information and include organized algebraic steps with correct substitutions: $U = \frac{3}{2}nRT, \quad PV = nRT$ $U = \frac{3}{2}PV$

• Responses that incorrectly express the state of static equilibrium for the forces exerted on the piston in a net force equation—in particular, including forces and pressures in the same net force equation	• Responses that indicate a statement of Newton's second law, which includes forces only. A force due to a pressure (scalar quantity) has a direction and magnitude equal to the product of pressure and area: $PA - P_{atm}A - Mg = 0$
• Responses that sketch a downward-sloping straight line as the graphical representation for two variables that are inversely proportional to each other	• Responses that indicate that the relationship between pressure and volume, when temperature and the number of moles in an ideal gas are held constant, is an inverse relationship. The correct representation includes a curve that is concave up.
• Responses that indicate that when pressure increases, the volume must decrease when applying the ideal gas law	• Responses that indicate how, when using the Ideal gas law, there are four quantities that could change (*P, V, n*, and *T*), and it is important to define what quantities are held constant and what variables are changing

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?

- Teachers should encourage students to read the question carefully and write down information that is different from one scenario to the next scenario. What has changed? What is the student being asked to do and how should it be demonstrated?
- Students should practice drawing free-body diagrams with the arrows starting on and pointing away from the provided dot. Label vectors with familiar/reasonable subscripts or words. The force due to the gas pressure could be labeled F_{gas} or $F_{gas,\ pressure}$ but should not be labeled F_g (typically used for gravitational forces), $F_{\perp}$, or with just the words pressure or gas.
- Students should practice derivations beginning with fundamental principles and clearly substituting given variables. A good strategy is to start with a relevant equation from the reference information and substitute quantities and variables based on the prompt. It is preferred to solve problems symbolically, even with prompts that involve numerical solutions.
- Students should practice sketching qualitative graphs that show how quantities change with respect to one another; many students may know how to accurately plot data points on a grid, but students should demonstrate functional dependence relationships using qualitative graph sketches.
- Teachers should encourage students to use precise language when describing multiple things. It is important to not only describe what variables are changing but to also address the quantities that are being held constant. For example, in the equation $PV = nRT$, a student should state that if n and T are held constant then P is inversely proportional to V.
- In a translating between representations task model, students should identify what item part or sub-item part is being addressed in the justification for the claim. For example, the response might start with "In part A, it is shown that."

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

- Teachers can direct students to Unit 9 in the *AP Physics 2: Algebra-Based Course and Exam Description* and AP Classroom with a focus on topics 9.1, 9.2, 9.3, and 9.4 to review the learning objectives and essential knowledge statements.
- Teachers can assign AP Daily videos on pressure, the Ideal gas law, internal energy of a gas, and pressure-volume graphs. Topic questions for 9.1, 9.2, 9.3, and 9.4 should be assigned to monitor mastery of the topics.
- Teachers should have students practice skills 1.A, 1.C, 2.A, 3.B, and 3.C by drawing diagrams for forces associated with a container (sealed by a movable piston) that is filled with an ideal gas, sketching pressure-volume graphs for thermodynamic processes, deriving physical quantities from fundamental physics principles, and making and justifying claims using physical principles or laws. Teachers should assign the progress checks for Unit 9 to reinforce these skills.

Question 3

Task: Experimental Design and Analysis
Topic: RC Circuits

	Max Points:	Mean Score:
A1	1	0.61
A2	1	0.53
B1	1	0.84
B2	1	0.58
C1	1	0.87
C2	1	0.86
C3	1	0.87
C4	1	0.89
D1	1	0.82
D2	1	0.35

Overall Mean Score: 7.22/10

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Indicate appropriate data to be collected (dimensions of a capacitor and current in an RC circuit) that can be used to predict the time constant of an RC circuit
- Describe an appropriate method to reduce experimental uncertainty (e.g., repeating the procedure multiple times)
- Indicate how the time constant depends on resistance and capacitance
- Describe the relationship between the internal resistance of the battery and current in the circuit and the relationship between the capacitance of a capacitor and the dimensions of the capacitor
- Given the absolute value of the charge stored on one capacitor plate and the absolute value of the electric potential difference across the capacitor, indicate appropriate quantities that can be plotted to produce a linear graph that can be used to determine the capacitance of the capacitor
- Label the axes of a graph with quantities, units, and a linear scale, and then plot data points correctly
- Draw a line or curve that approximates the trend of the plotted data
- Relate the slope of the best-fit line of the graph to the capacitance of the capacitor
- Calculate a value for the capacitance of the capacitor within the accepted range

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?

- Many responses (approximately 63%) indicated appropriate data to be collected for predicting the time constant of the RC circuit. However, some responses included unnecessary experimental procedure steps or were too detailed. For example, some responses included steps that described how to assemble and/or disassemble the circuit that was already described in the free-response question. Some responses included steps on how to connect an ammeter into a circuit. Some responses (approximately 46%) neglected to address how to reduce uncertainty.
- Most responses (approximately 86%) demonstrated an understanding of the relationship between the time constant of an RC circuit and the resistance of the resistor and the capacitance of the capacitor in the RC circuit. However, some responses (approximately 41%) did not explicitly indicate how these quantities would be calculated with the data provided.
- Most responses (approximately 90%) recognized that the absolute value of the charge stored on one capacitor plate should have been plotted as a function of the absolute value of the electric potential difference across the capacitor; however, some responses incorrectly doubled the charge on one capacitor plate.

- Most responses (approximately 85%) demonstrated an understanding of how to use the slope of a best-fit line to determine a value, but some responses incorrectly graphed the absolute value of the charge stored on one capacitor plate as a function of the reciprocal of the absolute value of the electric potential difference, which indicates a misunderstanding of how the slope of a best-fit line can be sketched and analyzed.
- Most responses (approximately 91%) exhibited a strong understanding of graphing, including labeling axes, plotting data, and drawing a best-fit line.
- Although some responses (approximately 37%) correctly incorporated the fact that the absolute value of the charge stored on one capacitor plate included scientific notation, many responses did not. This resulted in a calculated capacitance of the capacitor that was outside the accepted range.

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 that do not indicate a method to reduce experimental uncertainty	• Responses that indicate that multiple measurements of the same quantity (e.g., current in the circuit) can be measured to reduce experimental uncertainty
• Responses that indicate that measuring the current in a circuit over a time interval and multiplying the current by the time can be used to determine the absolute value of the charge stored on one capacitor plate	• Responses that indicate that the current in a RC circuit changes over time, and that the absolute value of the instantaneous charge stored on one capacitor plate cannot be determined by multiplying instantaneous current and time.
• Responses that indicate that the absolute value of the charge stored on one capacitor plate should be doubled to determine the total absolute value of charge stored on a capacitor because a capacitor has two plates	• Responses that indicate that the absolute value of charge stored on one plate is the appropriate amount of charge that is related to the capacitance of a capacitor and the electric potential difference across the capacitor. Therefore, $C = \frac{Q}{\Delta V}$.
• Responses that do not include the scientific notation (e.g., $\times 10^{-10}$) in Table 1 when calculating the capacitance of a capacitor from the slope of a best-fit line (e.g., $C \approx 0.8\text{ F}$)	• Responses that include the scientific notation in Table 1 when calculating the capacitance of a capacitor from the slope of a best-fit line

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?

- Teachers should encourage students to read a question carefully and address all aspects of what is required by the prompts of the question. Common errors include neglecting how to reduce experimental uncertainty and neglecting scientific notation associated with quantities.
- Teachers should emphasize to students the meaning of the variables in the equation $C = \frac{Q}{\Delta V}$ (e.g., Q is the absolute value of charge stored on one capacitor plate).
- When creating graphs of plotted data, students should be careful with details, such as carefully and consistently labeling axes with units.

- Students should practice writing lab procedures, paying attention to what belongs in a procedure and what does not belong. Teachers should consider having students think through what data they need to collect to answer part B prior to answering part A.
- For best-fit line sketching and analysis, students should practice writing the relevant equation and then manipulating the equation into an appropriate form (e.g., $y = mx + b$) before substituting numbers. This work should be written in part D.

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

- Teachers can direct students to units 10 and 11 in the *AP Physics 2: Algebra-Based Course and Exam Description* and AP Classroom with a focus on topics 10.6, 11.2, 11.3, and 11.8 to review the learning objectives and essential knowledge statements.
- Teachers can assign AP Daily videos on simple circuits, resistance and Ohm's law, capacitance, and the time constant for resistor-capacitor circuits. Topic questions for 10.6, 11.2, 11.3, and 11.8 should be assigned to monitor mastery of the topics.
- Teachers should have students practice skills 1.B, 2.B, 2.D, and 3.A by describing experimental procedures, using functional dependence to linearize data, creating quantitative graphs with appropriate scales and units, and calculating unknown quantities from a linearized graph. Teachers should assign the progress checks for units 10 and 11 to reinforce these skills.

Question 4

Task: Qualitative/Quantitative Translation
Topic: Double-Slit Interference

	Max Points:	Mean Score:
A1	1	0.88
A2	1	0.75
A3	1	0.43
B1	1	0.86
B2	1	0.77
B3	1	0.26
C1	1	0.78
C2	1	0.73

Overall Mean Score: 5.42/8

What were the responses to this question expected to demonstrate?

The responses were expected to:

- Indicate whether a claim provided in the free-response question is correct or incorrect (The claim pertains to monochromatic light passing through a double-slit that results in an interference pattern of bright and dark bands.)
- Justify a claim regarding the properties of visible light (e.g., wavelengths, frequencies, and path length differences associated with red and violet light that pass through the slits)
- Derive an expression for the distance between bright bands of an interference pattern using known quantities and physical constants
- Indicate and justify whether an expression derived in part B is or is not consistent with the answer from part A by applying functional dependence between quantities in an expression derived in part B

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 (approximately 89%) identified the differences in wavelengths and/or frequencies between red and violet light.
- Most responses (approximately 78%) related wavelength and frequency using the equation $v = \lambda f$.
- Many responses (approximately 55%) did not demonstrate an understanding of how path length differences relate to interference patterns.
- Most responses (approximately 73%) did not correctly identify y_{max} in the equation $m\lambda = d\left(\frac{y_{max}}{L}\right)$, the distance between either bright Band A or bright Band B and the central bright band, should be doubled when determining the distance between bright Band A and bright Band B.
- Most responses (approximately 76%) demonstrated an understanding of the functional dependence between variables in derived equations.

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 that misunderstand the relationships and differences for wavelengths and frequencies of different colors of light	• Responses that indicate that violet light has a greater frequency and shorter wavelength than those corresponding quantities for red light
• Responses that misunderstand the path length difference of wavefronts	• Responses that indicate that the wavelength of violet light is shorter than the wavelength of red light. Therefore, the path length difference (ΔD) necessary for maximum constructive interference will be shorter for violet light (e.g., $\Delta D = m\lambda$).
• Responses that do not recognize the variables in the equation $m\lambda = d\left(\frac{y_{max}}{L}\right)$	• Responses that indicate that wavelength (λ) is directly proportional to the distance (y_{max}) between each order (m) maxima when slit spacing (d) and screen distance (L) are held constant. Violet light has a shorter wavelength than red light. Therefore, the distance between the two maxima will be shorter for violet light than for red light.
• Responses that misunderstand the order number (m) of maxima and minima	• Responses that indicate that bright Band A is the second bright band from the central maximum. Therefore, $m = 2$. Bright Band B is on the opposite side of the central maximum. Therefore, y_{max} should be doubled to determine the distance between bright bands A and B.

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?

- Students, with the assistance of teachers, should use lasers of different colors (red and green are commonly available) during optical demonstrations to highlight the effect that wavelength/frequency can have on expected outcomes.
- Teachers, when demonstrating single- and double-slit interference, should supplement lessons with diagrams showing how path length difference affects interference patterns.
- Essential knowledge statements 14.8.A.1.iii and 14.8.A.1.iv in the *AP Physics 2: Algebra-Based Course and Exam Description* provide further context for teacher instruction and student learning of the concepts associated with path length difference.
- Teachers should encourage students to identify and refer to each variable on the reference information throughout the course; when modeling how to derive an expression in a classroom, a teacher could refer to the reference information when teachers and students must identify the fundamental concept and/or equation that is used to start the derivation.
- Students should practice using physics language to describe scenarios without deriving equations.
- Students should practice identifying relationships between variables in equations and describing the effect that changing one variable has on the results of an experiment.

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

- Teachers can direct students to units 14 and 15 in the *AP Physics 2: Algebra-Based Course and Exam Description* and AP Classroom with a focus on topics 14.4, 14.8, and 15.1 to review the learning objectives and essential knowledge statements.
- Teachers can assign AP Daily videos on electromagnetic waves, double-slit interference, and wave-particle duality. Topic questions for 14.4, 14.8, and 15.1 should be assigned to monitor mastery of the topics.
- Teachers should have students practice skills 2.A, 2.D, 3.B, and 3.C by deriving physical quantities from fundamental physics principles, using functional dependence to predict factors of change, and making and justifying claims using physics principles or laws. Teachers should assign the progress checks for units 14 and 15 to reinforce these skills.