# Multiple-Choice Answer Key

The following contains the answers to
the multiple-choice questions in this exam.

# Answer Key for AP Physics 1 Practice Exam, Section I

Question 1: D

Question 2: B

Question 3: B

Question 4: C

Question 5: A

Question 6: D

Question 7: B

Question 8: D

Question 9: D

Question 10: A

Question 11: D

Question 12: B

Question 13: C

Question 14: B

Question 15: B

Question 16: A

Question 17: B

Question 18: B

Question 19: B

Question 20: D

Question 21: A

Question 22: D

Question 23: D

Question 24: D

Question 25: A

Question 26: B

Question 27: B

Question 28: A

Question 29: D

Question 30: D

Question 31: B

Question 32: B

Question 33: B

Question 34: A

Question 35: D

Question 36: A

Question 131: A, C

Question 132: C, D

Question 133: A, D

Question 134: A, C

# Free-Response Scoring Guidelines

The following contains the scoring guidelines
for the free-response questions in this exam.

# AP® PHYSICS 1
# 2017 SCORING GUIDELINES

## Question 1

**7 points total** | **Distribution of points**

(a) 4 points

For a correct ranking: 1 point
$(I_3 = I_4) > I_1 > I_2$ or $I_3 = I_4, I_1, I_2$

Note: If an incorrect ranking is given, the explanation may still earn partial credit.

For indicating resistors in series must have the same current, and hence that $I_3 = I_4$ 1 point

For explaining why $I_1$ and $I_2$ must be smaller than $I_3$ and $I_4$ in terms of current splitting at junctions or some other valid explanation 1 point

For explaining why $I_1 > I_2$ in terms of unequal resistances resulting in a current split with more current through the smallest resistance, OR equal potential drops resulting in $I_1R_1 = I_2R_2$ and hence $I_1 > I_2$ 1 point

Example: $(I_3 = I_4) > I_1 > I_2$

All the current through the battery also goes through both $R_3$ and $R_4$, and hence those two currents are the same. At the junctions to and from the parallel branch, the current "splits up" and passes through $R_1$ and $R_2$ before re-merging. So $I_1$ and $I_2$ are both less than $I_3$ and $I_4$. Because $R_2$ has a greater resistance than $R_1$, the current splits unevenly at the junction, with more current in the path with the least resistance. So the current in resistor $R_1$ will be greater than the current in $R_2$.

**Question 1 (continued)**

**Distribution of points**

(b) 2 points

Correct answer: $\Delta V_2 = 1\text{ V}$, $\Delta V_3 = 5\text{ V}$

For recognizing that resistors in parallel have the same potential difference across them, and indicating $\Delta V_2 = 1\text{ V}$ — 1 point

For applying the fact that $\Delta V = 0$ (explicitly or implicitly) for the loop containing the battery, $R_1$ or $R_2$, and both $R_3$ and $R_4$, and obtaining a value of $\Delta V_3$ consistent with $\Delta V_2$ (i.e. $\Delta V_2 + \Delta V_3 = 6\text{ V}$) — 1 point

Example: $\Delta V_2 = 1\text{ V}$ $\Delta V_3 = 5\text{ V}$

Since resistors $R_1$ and $R_2$ are in parallel, they have the same electric potential difference across them, so $\Delta V_2 = \Delta V_1 = 1\text{ V}$. An electron that passes through the battery, $R_2$, $R_3$, $R_4$, and back to the battery has competed one full loop around the circuit. Therefore, its overall potential change is $\Delta V = 0$. Therefore its potential change through the battery, of magnitude 15 V, equals the magnitude of its potential change across $R_2$, $R_3$ and $R_4$: $|\Delta V_2 + \Delta V_3 + \Delta V_4| = 15\text{ V}$. So $\Delta V_3 = 15\text{ V} - 9\text{ V} - 1\text{ V} = 5\text{ V}$.

(c) 1 point

Answer: "Increase"
Note: Reasoning cannot earn credit if incorrect selection is made.

For recognizing that the addition of a wire provides a path of negligible resistance around $R_3$ and therefore reduces the equivalent resistance of the circuit, or other valid explanation. — 1 point

Example: Adding a short circuit across $R_3$ gives the current a resistance-free path around $R_3$. This lowers the overall resistance of the circuit, increasing the current through the battery and hence through $R_1$.

# AP® PHYSICS 1
# 2017 SCORING GUIDELINES

## Question 2

**12 points total** | **Distribution of points**

(a)

i and ii) 2 points

For indicating valid measured quantities — 1 point

Note: This point is not earned if the procedure in part (iii) includes measured quantities or measurement equipment that is not listed in parts (i) and (ii).

For a list of equipment and a plausible way to measure the quantities stated in (a)(i) — 1 point

iii) 3 points

For a practical procedure consistent with the quantities indicated in (a)(i) — 1 point

For a plausible procedure that could be used to experimentally determine frictional torque — 1 point

For including a valid method to reduce experimental uncertainty — 1 point

Example methods:

Method 1: Start the platform rotating and let it rotate freely. Use a feasible method for measuring the angular velocity at two different times.

Method 2: Apply a known external force tangential to the rim of the initially motionless platform. Measure the change in angular velocity as in method 1. Also measure the radius of the platform (or some other valid measurement of lever arm).

Method 3: Measure the torque needed to maintain the platform at a constant angular velocity. Determine if the torque is indeed constant by measuring the angular speed at two different times and seeing if they are the same within experimental uncertainty.

Method 4: With the platform freely rotating, measure angular displacement over some time interval.

(b) 3 points

For a valid expression involving the necessary angular quantity consistent with the procedure in part (a) — 1 point

For explicitly or implicitly relating the calculated quantity to angular acceleration — 1 point

For correctly combining the above two concepts in a way that would yield the frictional torque — 1 point

(c) 2 points

For correctly relating the procedure in parts (a) and (b) to the assumption of dependence or independence of frictional torque on angular speed — 1 point

For connecting the analysis to the dependence of frictional torque on angular speed — 1 point

(d) 2 points

For a modification that has any additional trial at a different angular speed OR correctly and explicitly stating that no modification is necessary — 1 point

For indicating how analysis of the initial or modified experiment could plausibly determine whether frictional torque is independent of angular speed — 1 point

# AP® PHYSICS 1
# 2017 SCORING GUIDELINES

## Question 3

**12 points total** | **Distribution of points**

(a) 2 points

For indicating (explicitly or implicitly) that intersecting the vertical axis corresponds to zero stiffness — 1 point

For correctly indicating that no measurement of stiffness could be zero — 1 point

Example: The vertical axis is where $S = 0$, indicating a substance puts up no resistance to getting stirred. But even at room temperature the oil has *some* stiffness. Hence, the lowest measured stiffness is positive, not zero, and the graph reflects this.

(b) 3 points

For a correct equation: $E_{max} = MgD$ OR $E_{max} = -MgD$ — 1 point

For stating that the maximum energy that can be lost is equal to the initial energy of the system — 1 point

For stating that the initial energy of the system is the initial gravitational potential energy — 1 point

Example: The maximum energy that can be lost is equal to the initial energy, which is all gravitational potential energy: $MgD$.

*Alternate solution for the last 2 points*

*For a statement or the application of mechanical energy as the sum of kinetic and potential energies* — 1 point

*For combining the change in the gravitational potential energy with a small change in kinetic energy as the ball falls to make a valid argument for* $E_{max}$. — 1 point

Example: In a very stiff oil that the ball can barely fall through, it gains essentially no kinetic energy. In this case the overall change in mechanical energy, $\Delta K + \Delta U$, is approximately equal to $\Delta U$ because $\Delta K$ is essentially zero.
So, $E_{max} = |\Delta U| = MgD$.

(c) 2 points

For each of the following, up to a maximum of 2 points — 2 points

1 point for each valid, independent statement that the equation does not match the graph (maximum of 2 points).

1 point for a statement that demonstrates that $E_{lost}$ cannot increase indefinitely.

Example statements (1 point each, any two could be combined for 2 points):

The equation indicates that $E_{lost}$ increases indefinitely with *S*, but the graph has an upper limit for $E_{lost}$.

The equation represents a parabola (or is concave-up), which does not match the graph.

It doesn't make physical sense that $E_{lost}$ could be more than the available potential energy *MgD*.

**Question 3 (continued)**

**Distribution of points**

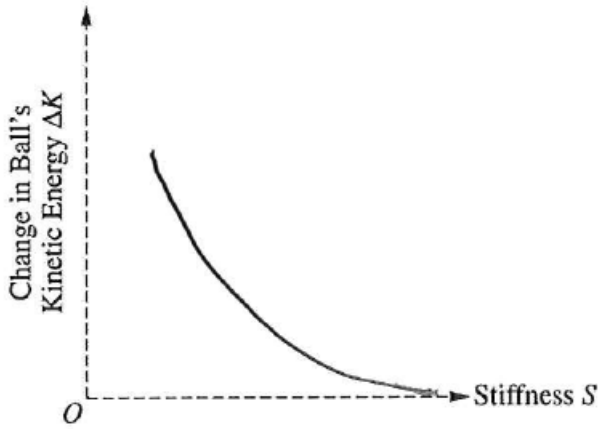
(d) 2 points

Correct answer: "Not plausible"
Note: The explanation can earn the first point if the incorrect selection is made.

For a statement or implication that the equation indicates that $t$ increases as $S$ decreases — 1 point
For a statement or implication that $t$ should be larger as $S$ increases — 1 point
Note: If only one of the above statements is written explicitly, and "Not plausible" is selected, the second point is earned by implication.

Example 1 (2 points): "Not plausible". According to the equation, a less stiff oil makes the sphere take more time to reach the bottom.
Example 2 (2 points): "Not plausible". A greater stiffness means that the ball should take a longer time to fall through the oil.
Example 3 (1 point): "Plausible". The equation says that bigger $S$ means bigger time, which agrees with the idea that a thicker oil resists the ball's motion more.

(e) 3 points




For drawing a concave-upward curve that approaches the horizontal at higher $S$ — 1 point
For having the maximum value of $\Delta K$ at the lowest graphed value of $S$, which can be $S = 0$ or a positive value — 1 point
Note: This point is not earned if the graph indicates that $\Delta K$ approaches infinity as $S$ approaches zero.
For high values of $S$, the graph approaches and does not cross the horizontal axis — 1 point
Note: This point is earned if the graph touches the horizontal axis without crossing it.

# AP® PHYSICS 1
# 2017 SCORING GUIDELINES

## Question 4

**7 points total** **Distribution of points**

(a)

Correct answer: 2 $\theta_{embed}$ 3 $\theta_{pass}$ 1 $\theta_{bounce}$

(b) 7 points

| | |
|---|---|
| For using conservation of momentum | 1 point |
| Note: This point is earned for an indication of how momentum conservation applies to the situation. | |
| For correctly stating or implying that in all three cases the magnitude of the change in the horizontal momentum of the arrow during the collision equals magnitude of the momentum gained by the pumpkin | 1 point |
| For a valid argument explaining why the Bounce arrow must transfer the most momentum | 1 point |
| For stating that the Pass arrow ends up faster than the Embedded arrow or does not transfer as much momentum to the pumpkin immediately after collision | 1 point |
| For indicating (regardless of conclusion about whether the Pass or Embedded arrow ends up going faster after the collision) that the arrow that slowed more during the collision transfers more momentum to the pumpkin | 1 point |
| For an explicit or implicit correct justification, in terms of energy conservation, that the angle reached by the pumpkin is related to the speed of the pumpkin just after the collision | 1 point |
| For a logical, relevant, and internally consistent response that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response | 1 point |

Example: The Bounce arrow is the only one that reverses direction, so has momentum to the left after the collision. By conservation of momentum the pumpkin must then have a greater momentum to the right than the arrow had before the collision. After the Embedded arrow hits, the arrow and pumpkin together have the same momentum as the arrow did just before the collision. The Pass arrow still has some momentum to the right after hitting the pumpkin so by conservation of momentum the pumpkin has less momentum to the right than the arrow did before the collision. By conservation of energy, the maximum angle that the pumpkin reaches depends on the speed of the pumpkin (higher speed means higher angle), so the Bounce arrow pumpkin has the highest angle and the Pass arrow pumpkin has the lowest angle.

# AP® PHYSICS 1
# 2017 SCORING GUIDELINES

## Question 5

**7 points total** **Distribution of points**

(a) 1 point

Answer: "Yes"
Explanation cannot earn credit if "No" is selected.

For a statement of conservation of energy, or explicit reference to the motion or kinetic energy of the string at the moment shown in the diagram — 1 point

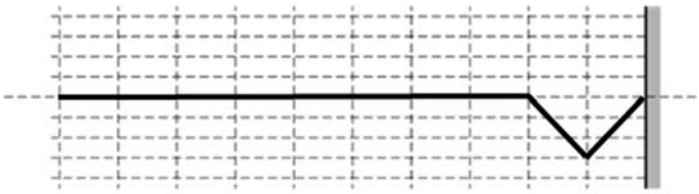
(b) 1 point

Correct Answer: "Neither"
Explanation cannot earn credit if either of the other choices are selected.

For an explanation that both pulses travel at the same speed because wave speed is a property of the string, which does not change — 1 point

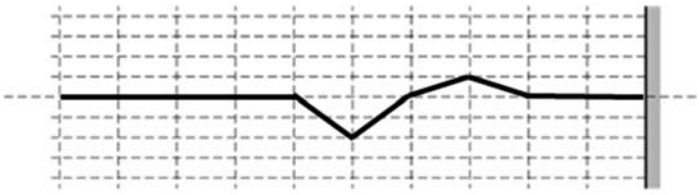
(c)

i) 3 points



For drawing the entire wave pulse below the equilibrium position of the string — 1 point
For drawing a wave pulse with amplitude of $-3$ units — 1 point
Note: This point is not earned if the equilibrium position or left-most portion of the pulse is drawn or indicated at the incorrect height.
For a pulse with symmetric triangular shape that is 2 units wide and located in the rightmost 2 units of the grid, and no other nonzero portions of the string — 1 point
Note: The portion of the string with zero displacement need not be sketched.

ii) 2 points



For a pulse that is a vertical inversion of the original pulse (i.e. 2 unit portion going down and 1 unit portion going up) — 1 point
For a pulse that is a horizontal inversion of the original pulse (i.e. 2 unit portion on the left and 1 unit portion on the right) — 1 point
Note: The portion of the string with zero displacement need not be sketched.

## Scoring Worksheet

The following provides a scoring worksheet and conversion table used for calculating a composite score of the exam.

# 2017 AP Physics 1 Scoring Worksheet

**Section I: Multiple Choice**

_____ × 1.0000 = _____

Number Correct (out of 40) | Weighted Section I Score (Do not round)

**Section II: Free Response**

Question 1 _____ × 0.8888 = _____
(out of 7) (Do not round)

Question 2 _____ × 0.8888 = _____
(out of 12) (Do not round)

Question 3 _____ × 0.8888 = _____
(out of 12) (Do not round)

Question 4 _____ × 0.8888 = _____
(out of 7) (Do not round)

Question 5 _____ × 0.8888 = _____
(out of 7) (Do not round)

Sum = _____
Weighted Section II Score (Do not round)

**Composite Score**

_____ + _____ = _____

Weighted Section I Score | Weighted Section II Score | Composite Score (Round to nearest whole number)

AP Score Conversion Chart
Physics 1

| Composite Score Range | AP Score |
|---|---|
| 55-80 | 5 |
| 42-54 | 4 |
| 32-41 | 3 |
| 20-31 | 2 |
| 0-19 | 1 |

# Question Descriptors and Performance Data

The following contains tables showing the content assessed,
the correct answer, and how AP students performed on each question.

## Multiple-Choice Questions

| Question | Learning Objectives | Essential Knowledge | Science Practices | Key | % Correct |
|---|---|---|---|---|---|
| 1 | 3.A.1.1; 4.A.2.1 | 3.A.1; 4.A.2 | 1.5; 2.2; 6.4 | D | 74 |
| 2 | 3.A.1.1; 3.B.2.1; 4.B.2.1 | 3.A.1; 3.B.2; 4.B.2 | 1.5; 2.2; 1.1; 1.4; 2.2; 2.2 | B | 62 |
| 3 | 6.D.1.1; 6.D.1.2 | 6.D.1 | 1.4; 5.1 | B | 70 |
| 4 | 4.C.1.1 | 4.C.1 | 1.4; 2.2 | C | 66 |
| 5 | 5.B.5.4 | 5.B.5 | 6.4; 7.2 | A | 58 |
| 6 | 3.A.1.1; 3.A.1.3; 3.B.3.3 | 3.A.1; 3.B.3 | 1.5; 2.2; 5.1; 2.2; 5.1 | D | 49 |
| 7 | 3.A.1.1; 3.A.1.3 | 3.A.1 | 1.5; 2.2; 5.1 | B | 78 |
| 8 | 3.B.3.3 | 3.B.3 | 2.2; 5.1 | D | 55 |
| 9 | 3.A.3.1; 3.B.1.3 | 3.A.3; 3.B.1 | 6.4; 1.5; 2.2 | D | 55 |
| 10 | 5.D.2.5 | 5.D.2 | 2.2 | A | 48 |
| 11 | 5.B.5.5 | 5.B.5 | 2.2; 6.4 | D | 51 |
| 12 | 1.B.1.1; 3.C.2.1 | 1.B.1; 3.C.2 | 6.4; 6.4 | B | 41 |
| 13 | 4.D.3.1 | 4.D.3 | 2.2 | C | 61 |
| 14 | 5.B.5.3 | 5.B.5 | 1.4; 2.2 | B | 49 |
| 15 | 5.D.3.1 | 5.D.3 | 6.4 | B | 38 |
| 16 | 2.B.1.1; 3.B.1.1; 3.B.2.1 | 2.B.1; 3.B.1; 3.B.2 | 2.2; 6.4; 1.1; 1.4; 2.2 | A | 38 |
| 17 | 4.B.2.2 | 4.B.2 | 5.1 | B | 37 |
| 18 | 3.E.1.3; 3.E.1.4; 4.C.2.1 | 3.E.1; 4.C.2 | 1.4; 2.2; 2.2; 6.4 | B | 40 |
| 19 | 5.B.9.3; 5.C.3.3 | 5.B.9; 5.C.3 | 2.2; 1.4; 2.2 | B | 49 |
| 20 | 5.C.3.1 | 5.C.3 | 6.4; 7.2 | D | 49 |
| 21 | 6.B.2.1 | 6.B.2 | 1.4 | A | 46 |
| 22 | 3.A.4.1 | 3.A.4 | 1.4; 6.2 | D | 44 |
| 23 | 4.C.1.1; 5.B.3.2 | 4.C.1; 5.B.3 | 1.4; 2.2; 1.4; 2.2 | D | 16 |
| 24 | 3.F.3.1 | 3.F.3 | 6.4; 7.2 | D | 40 |
| 25 | 5.B.3.3 | 5.B.3 | 1.4 | A | 28 |
| 26 | 3.B.1.3; 3.B.2.1 | 3.B.1; 3.B.2 | 1.5; 2.2; 1.1; 1.4; 2.2 | B | 48 |
| 27 | 6.B.1.1 | 6.B.1 | 1.4; 2.2 | B | 11 |
| 28 | 5.D.2.5 | 5.D.2 | 2.1 | A | 48 |
| 29 | 3.B.3.3 | 3.B.3 | 2.2 | D | 21 |
| 30 | 6.D.3.2; 6.D.4.2 | 6.D.3; 6.D.4 | 6.4; 2.2 | D | 69 |
| 31 | 3.F.1.1 | 3.F.1 | 1.4 | B | 27 |
| 32 | 3.A.1.1; 3.B.1.1 | 3.A.1; 3.B.1 | 1.5; 2.2; 6.4 | B | 46 |
| 33 | 3.C.1.2 | 3.C.1 | 2.2 | B | 27 |
| 34 | 4.A.1.1; 5.D.1.1; 5.D.2.1 | 4.A.1; 5.D.1; 5.D.2 | 1.2; 6.4; 6.4; 7.2 | A | 24 |
| 35 | 4.A.1.1 | 4.A.1 | 1.2; 1.4; 6.4 | D | 24 |
| 36 | 4.C.2.1; 5.B.5.5 | 4.C.2; 5.B.5 | 6.4; 2.2; 6.4 | A | 23 |

| Question | Learning Objectives | Essential Knowledge | Science Practices | Key | % Correct |
|---|---|---|---|---|---|
| 131 | 5.B.9.3 | 5.B.9 | 2.2 | A,C | 42 |
| 132 | 5.D.1.2 | 5.D.1 | 5.1; 5.3 | C,D | 43 |
| 133 | 3.A.3.1; 3.A.3.3; 3.A.4.2; 3.A.4.3 | 3.A.3; 3.A.4 | 6.4; 7.2; 1.4; 6.4; 7.2; 1.4 | A,D | 36 |
| 134 | 6.D.1.2 | 6.D.1 | 4.2 | A,C | 32 |

## Free-Response Questions

| Question | Learning Objectives | Essential Knowledge | Science Practices | Mean Score |
|---|---|---|---|---|
| 1 | 5.B.9.3; 5.C.3.1; 5.C.3.3 | 5.B.9; 5.C.3 | 2.2; 6.4; 6.4; 1.4; 2.2 | 2.62 |
| 2 | 3.A.1.2; 3.A.1.3; 3.F.2.2; 3.F.3.3; 4.D.3.2 | 3.A.1; 3.F.2; 3.F.3; 4.D.3 | 4.2; 5.1; 4.1; 4.2; 5.1; 4.1; 4.2; 5.1; 4.1; 4.2 | 3.08 |
| 3 | 2.B.1.1; 3.A.1.1; 3.A.3.1; 3.B.1.1; 3.C.4.1; 4.C.1.1; 4.C.1.2; 4.C.2.1; 5.B.1.2; 5.B.3.1; 5.B.4.1; 5.B.4.2; 5.B.5.1; 5.B.5.4 | 2.B.1; 3.A.1; 3.A.3; 3.B.1; 3.C.1; 3.C.4; 4.C.1; 4.C.2; 5.B.1; 5.B.3; 5.B.4; 5.B.5 | 2.2; 7.2; 1.5; 2.2; 6.4; 6.4; 7.2; 6.1; 1.4; 2.1; 2.2; 6.4; 6.4; 1.5; 2.2; 6.4; 7.2; 6.4; 7.2; 1.4; 2.1; 2.2; 5.1; 6.4; 7.2 | 4.25 |
| 4 | 3.A.1.1; 3.A.4.1; 3.A.4.2; 3.B.1.1; 5.B.3.1; 5.B.3.3; 5.B.4.1; 5.B.4.2; 5.D.1.5; 5.D.2.1; 5.D.2.5 | 1.A.1; 3.A.1; 3.A.4; 3.B.1; 5.B.3; 5.B.4; 5.D.1; 5.D.2 | 1.5; 1.4; 6.2; 6.4; 6.4; 2.2; 6.4; 1.4; 2.2; 6.4; 1.4; 2.2; 2.2; 6.4; 2.1; 2.2 | 1.13 |
| 5 | 5.B.4.1; 6.A.1.2; 6.D.1.1 | 5.B.4; 6.A.1; 6.D.1 | 6.4; 7.2; 1.2; 1.1; 1.4 | 3.57 |

# AP Physics 1: Algebra-Based

**The College Board**

The College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success — including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools. The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.