2017

AP CollegeBoard

AP Physics 2: Algebra-Based

Scoring Guidelines

© 2017 The College Board. College Board, Advanced Placement Program, AP, AP Central, and the acorn logo are registered trademarks of the College Board. Visit the College Board on the Web: www.collegeboard.org.

AP Central is the official online home for the AP Program: apcentral.collegeboard.org

AP® PHYSICS
2017 SCORING GUIDELINES

General Notes About 2017 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution embeds the application of that equation to the problem in other work, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 1

10 points total | **Distribution of points**

(a)

i. 1 point

For indicating that student Y is correct in stating that the water moves faster at point *B*, and not indicating any other aspect — 1 point

ii. 2 points

Student Y's statement that P_B is greater than P_A is not correct.

For a correct indication of how height affects pressure using the Bernoulli equation (i.e., conservation of energy principles) — 1 point

For correct indication of how the speed affects pressure using the Bernoulli equation (i.e., conservation of energy principles) — 1 point

Example: The pressure at point *B* is not greater. Because the water at *B* is moving faster and is higher than at point *A*, the kinetic energy and the gravitational potential energy terms in Bernoulli's equation are both greater. Because the sum of pressure and these energy terms is a constant, the pressure must be less.

iii. 1 point

For indicating one of the following: — 1 point

- Student Z is correct in stating that the potential energy of the water-Earth system has increased.
- Student Z is correct in stating that conservation of energy applies.
- Stating that nothing is correct or giving no response, with a justification in (iv).

iv. 1 point

For indicating that student Z is incorrect in stating that the speed is less at point *B*, not indicating any other aspect, and using continuity or the Bernoulli equation (i.e., conservation of energy principles) to show that it is greater — 1 point

OR

if third bullet for (iii) applies, indicating that work is done on the water due to the pressure difference, so the energy is not constant

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 1 (continued)

Distribution of points

(b)

i. 2 points

For a correct application of the continuity equation including substitutions 1 point

$A_A v_A = A_B v_B$

$v_B = A_A v_A / A_B = r_A^2 v_A / r_B^2 = (2.5 \text{ cm})^2 (0.5 \text{ m/s}) / (1.5 \text{ cm})^2$

For a correct answer with units 1 point

$v_B = 1.4 \text{ m/s}$

ii. 1 point

For an application of Bernoulli's equation to this situation and substitutions consistent with (b)(i) 1 point

$$P_A + \rho g y_A + \frac{1}{2}\rho v_A^2 = P_B + \rho g y_B + \frac{1}{2}\rho v_B^2$$

$$P_B = P_A + \rho g (y_A - y_B) + \frac{1}{2}\rho \left(v_A^2 - v_B^2\right)$$

$$P_B = 2 \times 10^5 + (1000)(10)(-5) + \frac{1}{2}(1000)\left(0.5^2 - 1.4^2\right) = 2 \times 10^5 - 50000 - 855$$

$$P_B = 1.5 \times 10^5 \text{ Pa}$$

(c)

i. 1 point

For substituting correctly in an appropriate equation for determining the pressure 1 point

$P = P_0 + \rho g h_A = 1 \times 10^5 \text{ Pa} + \left(1000 \text{ kg/m}^3\right)\left(10 \text{ m/s}^2\right)(6 \text{ m})$

$P = 1.6 \times 10^5 \text{ Pa}$

ii. 1 point

For indicating that the buoyant force is toward the top of the page and gravity is toward the bottom of the page, with the buoyant force longer 1 point

Student can draw lots of pressure forces around the dot instead of one buoyant force, as long as there is no buoyant force labeled and they add up to a net buoyant force that is longer than the gravitational force.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 2

12 points total | **Distribution of points**

(a)

i. 5 points

For drawing a circuit with the battery, rod, and ammeter in series (rods can be drawn to look like rods, or schematically as resistors)	1 point
For drawing the voltmeter parallel to the rod, or indicating that the setting on the power supply will be used	1 point
For measuring potential difference and current for a rod	1 point
For measuring the length and diameter of a rod	1 point
For including multiple trials with appropriate controls Examples: 1) Use one rod and apply different potential differences 2) Use different rods	1 point

ii. 2 points

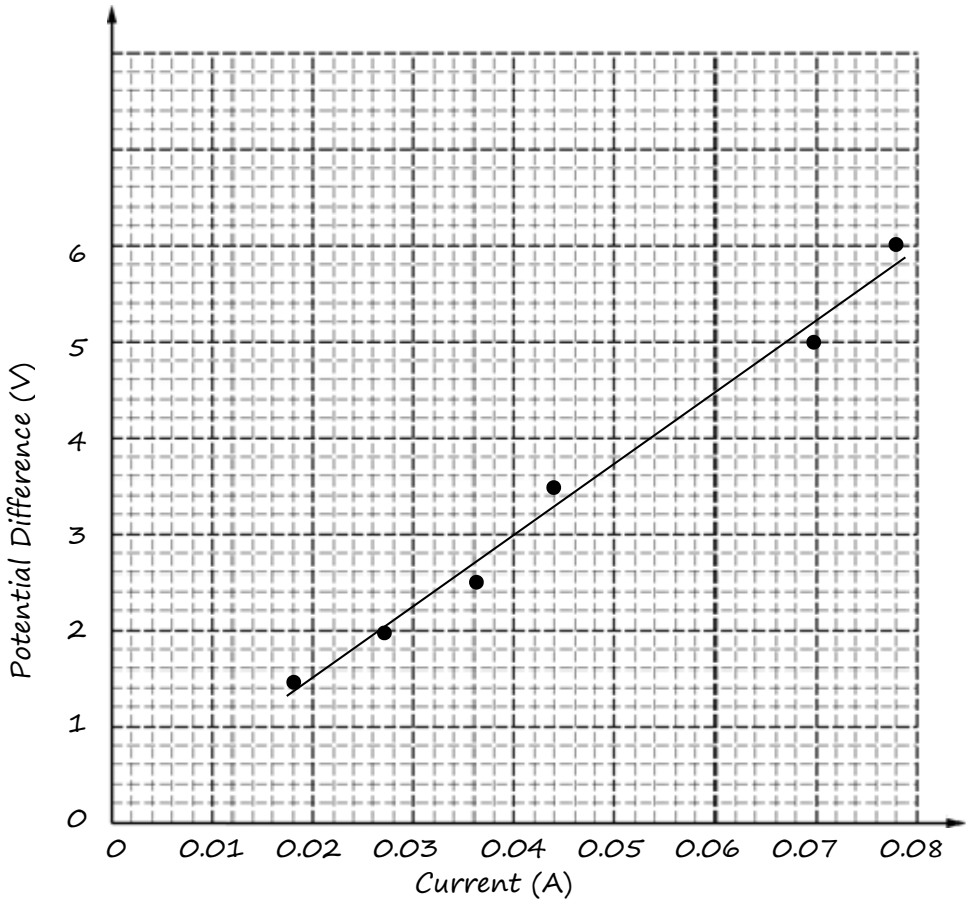
For graphing appropriate quantities whose slope can be used to calculate resistance directly or indirectly	1 point
For correctly stating how the slope relates to the resistivity	1 point

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 2 (continued)

Distribution of points

(b) 3 points



For plotting the data on the graph with potential difference on one axis and current on the other, labeled with units, using a reasonable scale — 1 point

For a clearly shown calculation of slope from a reasonable best-fit line — 1 point

For a correct answer with units — 1 point

Acceptable range is $70 - 79\ \Omega$.

For a graph of I as a function of V, the slope should end up near $0.013\ \Omega^{-1}$ and the resistance is the inverse

For a graph of V as a function of I, the slope should end up near $74\ \Omega$ and equals the resistance

For the example shown above

$$\text{slope} = \frac{(5.8 - 2.4)\ \text{V}}{(0.078 - 0.032)\ \text{A}} = 73.9\ \Omega$$

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 2 (continued)

Distribution of points

(c)

i. 1 point

For indicating that the internal resistance of the power supply will not affect the data acquired, with correct reasoning — 1 point

Example: Because potential difference is measured across each rod, $\Delta V/I$ is not affected by the internal resistance of the battery.

ii. 1 point

For indicating either: — 1 point

The students should be concerned because a change in temperature causes a change in the resistance or resistivity.

OR

The students should not be concerned because any change in resistivity as the temperature increases is small compared to measurement error.

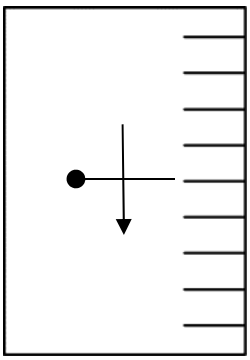
© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 3

12 points total **Distribution of points**

(a) 2 points



For the arrow drawn upside down relative to the object 1 point
For bar/circle drawn left-to-right reversed relative to the object or consistent with an (incorrect) upright arrow 1 point

(b)

i. 1 point

For correctly showing a calculation of the focal length and a correct answer with units 1 point

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{20\text{ cm}} + \frac{1}{30\text{ cm}}$$

$$f = 12\text{ cm}$$

ii. 1 point

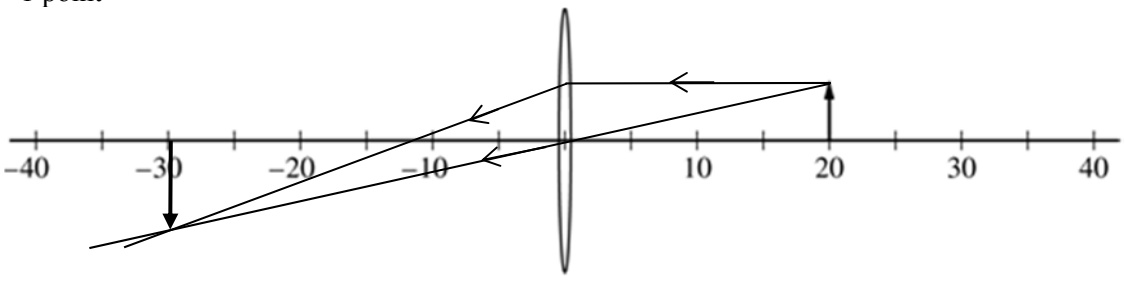
For correctly showing a calculation of the magnitude of the magnification (with or without sign) and a correct answer 1 point

$$M = d_i/d_o = 30\text{ cm}/20\text{ cm}$$

$$M = 1.5$$

(c)

i. 1 point



For two reasonably correctly drawn rays consistent with the calculated focal length, and inclusion of an inverted image 1 point

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 3 (continued)

Distribution of points

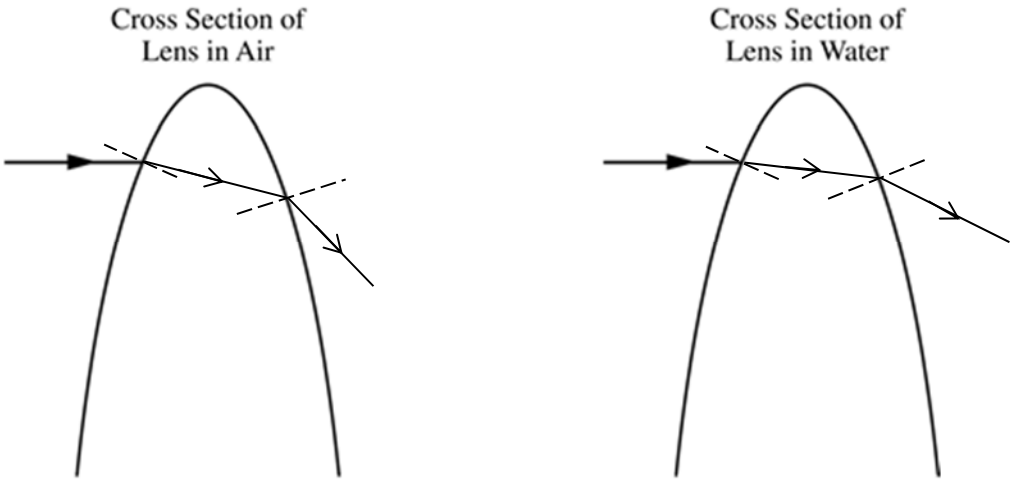
(c) (continued)

ii. 2 points

For a correct explanation of how the rays drawn relate to the focal length — 1 point
For a correct explanation of how the image relates to the magnification — 1 point
Example: The horizontal ray from the object bends to cross the axis at 12 cm from the middle of the lens, which is the focal length. The image arrow is about 1.5 times the height of the object, which is the magnification.

(d)

i. 2 points



For showing the downward refraction of the rays at each surface of the lens in air (i.e., toward the normal entering the lens and away from the normal leaving the lens) — 1 point
For the rays refracted by the lens in water at greater angles to the normal than the corresponding angles for the lens in air — i.e., less bending (can be earned even if first point was not, scoring is relative to whatever is drawn for the lens in air) — 1 point

ii. 3 points

For describing a greater focal length when the lens is in water or a comparison consistent with part (d)(i) — 1 point
For describing a larger image distance and image size or a comparison consistent with part (d)(i) — 1 point
For describing how the rays drawn in (d)(i) support the descriptions — 1 point
Example: The rays do not bend as much as they pass from water to glass as when they pass from air to glass (and vice versa). This means parallel rays coming into the lens will converge at a farther distance, so the focal length is longer. Rays from an object also will converge farther from the lens, so the new image is farther and larger.

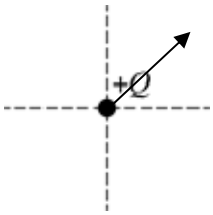
© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 4

10 points total **Distribution of points**

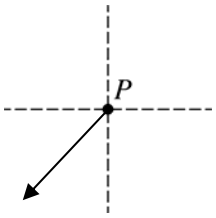
(a) 1 point



For an arrow pointing outward from the object, along a diagonal of the square and away from the object with charge $-2Q$, with no other arrows — 1 point

(b)

i. 3 points



For correctly determining magnitudes of the field from individual objects — 1 point

The fields from the $+2Q$ objects cancel. This can be implicit or explicit in the calculations.

For the $-2Q$ object, $E = 2kQ/d^2$

For the $+Q$ object, $E = kQ/d^2$

For correctly adding the individual fields — 1 point

$E = 3kQ/d^2$

For showing the correct direction on the diagram, along a diagonal of the square and toward the object with charge $-2Q$ — 1 point

ii. 1 point

For showing a correct scalar potential summation — 1 point

A final answer is not required; however, no credit is given if an incorrect final answer is included.

$V = (k/d)(+2Q + Q + 2Q - 2Q) = 3kQ/d$

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 4 (continued)

Distribution of points

(c) 5 points

For indicating that electric potential energy is the energy stored in a configuration of charged objects — 1 point

For indicating that the change in potential energy is equal to the work done by an external force to create a particular configuration — 1 point

For indicating that moving the object with $+2Q$ charge results in an increase in energy and indicating that moving the object with $+Q$ charge results in a decrease in energy (i.e., for showing understanding that moving charges of the same sign closer together increases the energy and/or moving charges of opposite sign closer together decreases the energy, with some support such as $U = kqQ/r$ or a description of doing work against forces) — 1 point

For indicating that the net result is an increase in the energy with some explanation — 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

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.