2018

AP CollegeBoard

AP Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

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Free Response Question 4

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AP® PHYSICS
2018 SCORING GUIDELINES

General Notes About 2018 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 1 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 Course and Exam Description* and the *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 the 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.

AP® PHYSICS 1
2018 SCORING GUIDELINES

Question 4

7 points total **Distribution of points**

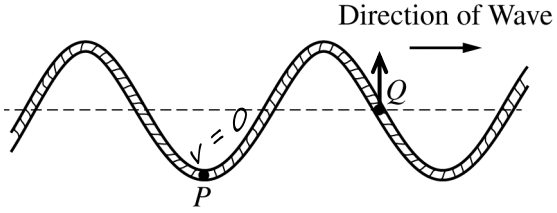
A transverse wave travels to the right along a string.

(a) LO / SP: 3.A.1.1 / 1.5; 6.A.1.2 / 1.2
4 points

Two dots have been painted on the string. In the diagrams below, those dots are labeled *P* and *Q*.

i. 2 points

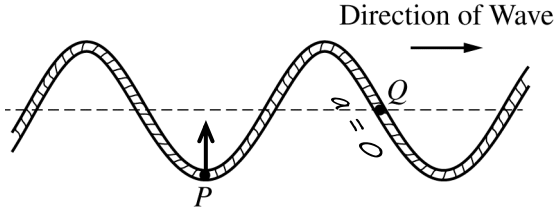
The figure below shows the string at an instant in time. At the instant shown, dot *P* has maximum displacement and dot *Q* has zero displacement from equilibrium. At each of the dots *P* and *Q*, draw an arrow indicating the direction of the instantaneous velocity of that dot. If either dot has zero velocity, write "$v = 0$" next to the dot.



For "$v = 0$" at point *P*		1 point
For an upward arrow at point *Q*		1 point

ii. 2 points

The figure below shows the string at the same instant as shown in part (a)(i). At each of the dots *P* and *Q*, draw an arrow indicating the direction of the instantaneous acceleration of that dot. If either dot has zero acceleration, write "$a = 0$" next to the dot.

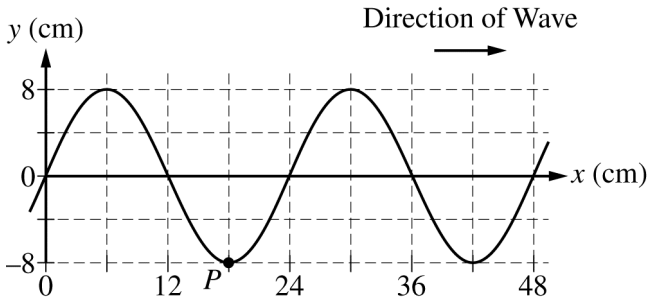


For an upward arrow at point *P*		1 point
For "$a = 0$" at point *Q*		1 point

Question 4 (continued)

Distribution of points

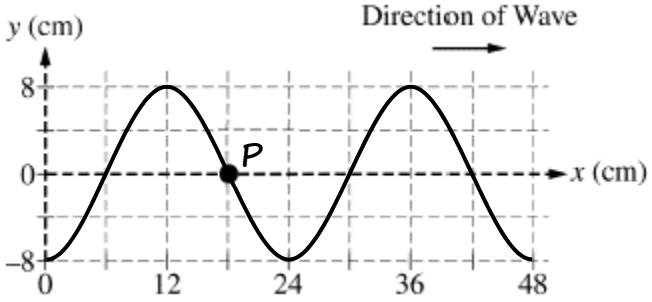
The figure below represents the string at time $t = 0$, the same instant as shown in part (a) when dot P is at its maximum displacement from equilibrium. For simplicity, dot Q is not shown.



(b) LO / SP: 3.A.1.1 / 1.5; 6.A.1.2 / 1.2
2 points

i. 1 point

On the grid below, draw the string at a later time $t = T/4$, where T is the period of the wave.
Note: Do any scratch (practice) work on the grid at the bottom of the page. Only the sketch made on the grid immediately below will be graded.



For a curve shifted to the right by 1/4 of a wavelength (1 gridline) with the same wavelength as the original wave (for example, as indicated by a negative minimum at $x = 0$)		1 point

ii. 1 point
On your drawing above, draw a dot to indicate the position of dot P on the string at time $t = T/4$ and clearly label the dot with the letter P.

For point P on the string and at the dot's original x position, 3/4 of a wavelength (3 grid units) to right of origin		1 point

Question 4 (continued)

Distribution of points

(c) LO / SP: 6.A.3.1 / 1.4
1 point

Now consider the wave at time $t = T$. Determine the distance traveled (not the displacement) by dot P between times $t = 0$ and $t = T$.

For the correct numerical answer: 32 cm		1 point

Learning Objectives (LO)

LO 3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practice 1.5]

LO 6.A.1.2: The student is able to describe representations of transverse and longitudinal waves. [See Science Practice 1.2]

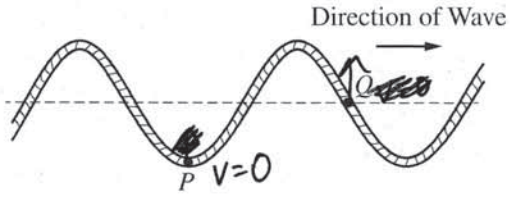
LO 6.A.3.1: The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave. [See Science Practice 1.4]

4. (7 points, suggested time 13 minutes)

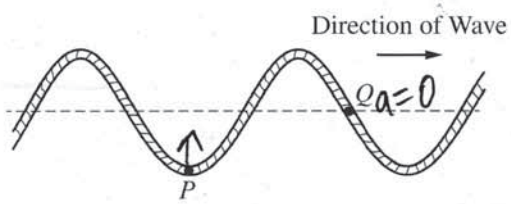
A transverse wave travels to the right along a string.

(a) Two dots have been painted on the string. In the diagrams below, those dots are labeled P and Q.

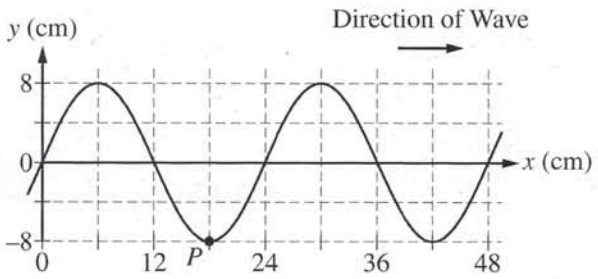
i. The figure below shows the string at an instant in time. At the instant shown, dot P has maximum displacement and dot Q has zero displacement from equilibrium. At each of the dots P and Q, draw an arrow indicating the direction of the instantaneous velocity of that dot. If either dot has zero velocity, write "$v = 0$" next to the dot.



ii. The figure below shows the string at the same instant as shown in part (a)i. At each of the dots P and Q, draw an arrow indicating the direction of the instantaneous acceleration of that dot. If either dot has zero acceleration, write "$a = 0$" next to the dot.



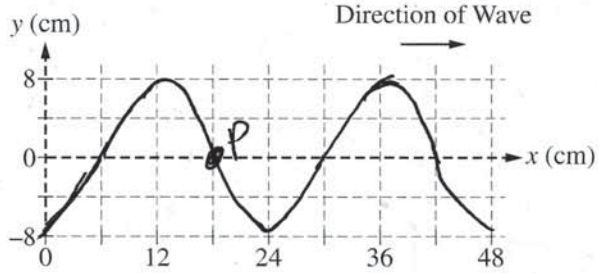
The figure below represents the string at time $t = 0$, the same instant as shown in part (a) when dot P is at its maximum displacement from equilibrium. For simplicity, dot Q is not shown.



(b)

i. On the grid below, draw the string at a later time $t = T/4$, where T is the period of the wave.

Note: Do any scratch (practice) work on the grid at the bottom of the page. Only the sketch made on the grid immediately below will be graded.



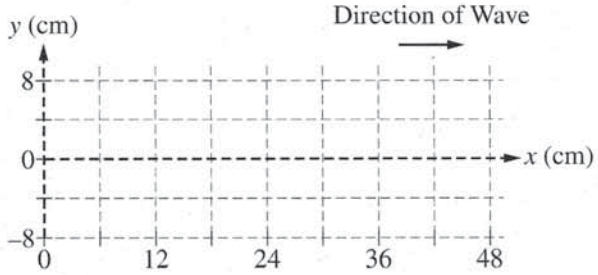
ii. On your drawing above, draw a dot to indicate the position of dot P on the string at time $t = T/4$ and clearly label the dot with the letter P.

(c) Now consider the wave at time $t = T$. Determine the distance traveled (not the displacement) by dot P between times $t = 0$ and $t = T$.

$-8 \rightarrow 8 \rightarrow -8$

$16 + 16 =$ 32 cm

The grid below is provided for scratch work only. Sketches made below will not be graded.



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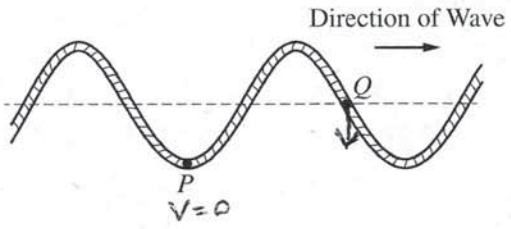
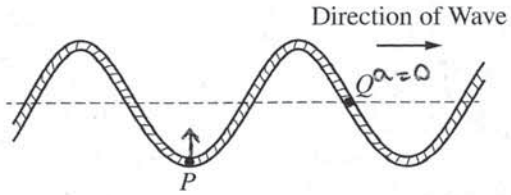
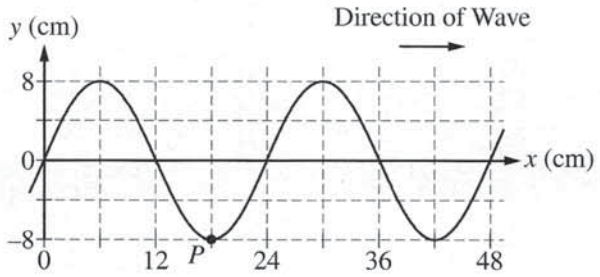


ii. The figure below shows the string at the same instant as shown in part (a)i. At each of the dots P and Q, draw an arrow indicating the direction of the instantaneous acceleration of that dot. If either dot has zero acceleration, write "$a = 0$" next to the dot.



The figure below represents the string at time $t = 0$, the same instant as shown in part (a) when dot P is at its maximum displacement from equilibrium. For simplicity, dot Q is not shown.



(b)

i. On the grid below, draw the string at a later time $t = T/4$, where T is the period of the wave.

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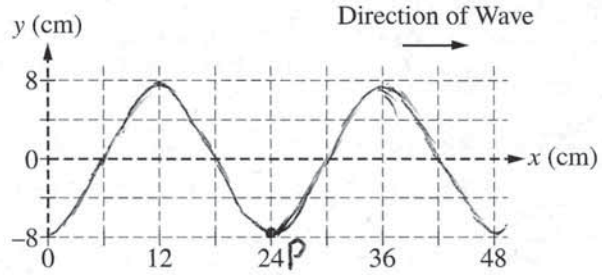
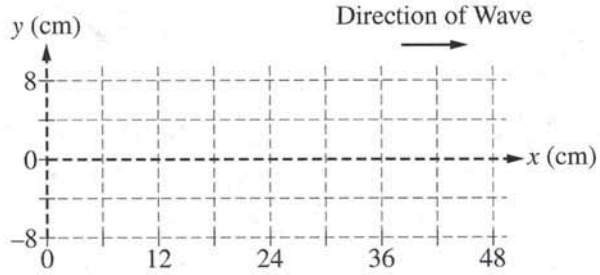


ii. On your drawing above, draw a dot to indicate the position of dot P on the string at time $t = T/4$ and clearly label the dot with the letter P.

(c) Now consider the wave at time $t = T$. Determine the distance traveled (not the displacement) by dot P between times $t = 0$ and $t = T$.

-6 cm is the distance dot P traveled

The grid below is provided for scratch work only. Sketches made below will not be graded.



4. (7 points, suggested time 13 minutes)

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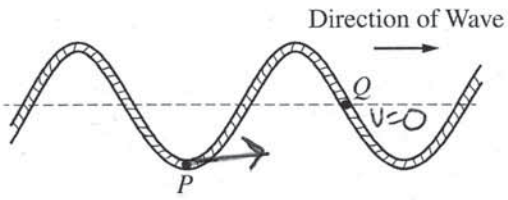
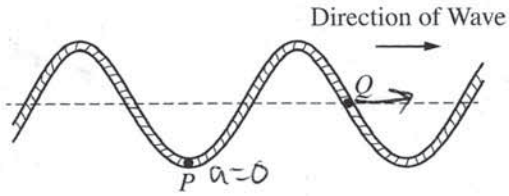
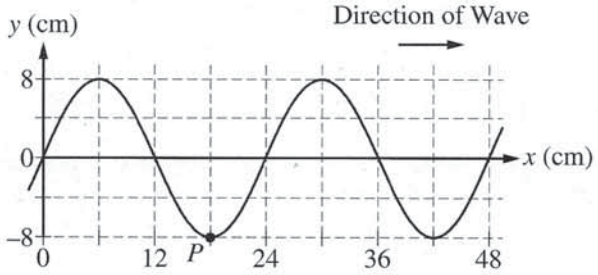


ii. The figure below shows the string at the same instant as shown in part (a)i. At each of the dots P and Q, draw an arrow indicating the direction of the instantaneous acceleration of that dot. If either dot has zero acceleration, write "$a = 0$" next to the dot.



The figure below represents the string at time $t = 0$, the same instant as shown in part (a) when dot P is at its maximum displacement from equilibrium. For simplicity, dot Q is not shown.



(b)

i. On the grid below, draw the string at a later time $t = T/4$, where T is the period of the wave.

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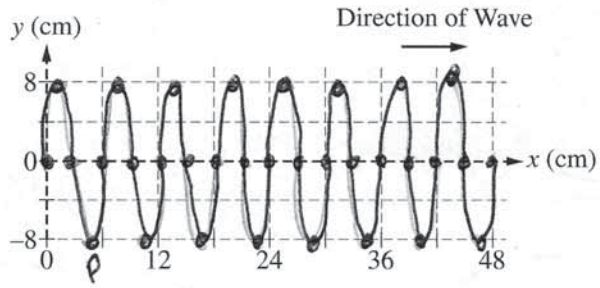
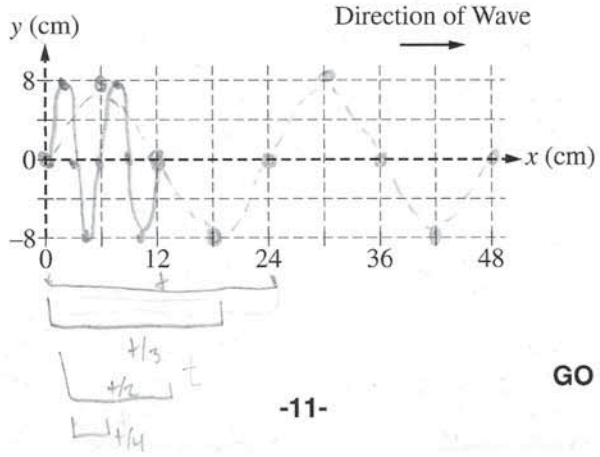


ii. On your drawing above, draw a dot to indicate the position of dot P on the string at time $t = T/4$ and clearly label the dot with the letter P.

(c) Now consider the wave at time $t = T$. Determine the distance traveled (not the displacement) by dot P between times $t = 0$ and $t = T$.

32cm

The grid below is provided for scratch work only. Sketches made below will not be graded.



AP® PHYSICS 1
2018 SCORING COMMENTARY

Question 4

Overview

This question assessed learning objectives 3.A.1.1, 6.A.1.2, and 6.A.3.1.

The responses to this question were expected to demonstrate the following:

- An understanding of the instantaneous velocity and acceleration of points in a medium that carries a transverse wave.
- An understanding of the forward motion of a transverse wave along a rope during an interval of time.
- The ability to demonstrate knowledge that the motion of individual points on a rope carrying a transverse wave is perpendicular to the direction of the wave's propagation.

Sample: P1 Q4 A
Score: 7

In part (a)(i) the response earned 2 points: 1 point for indicating that the velocity of dot *P* is zero and 1 point for indicating that the velocity of dot *Q* is upward. In part (a)(i) the response earned 2 points: 1 point for indicating that the acceleration of dot *P* is upward and 1 point for indicating that the acceleration of dot *Q* is zero. In part (b)(i) the response earned 1 point for a curve that is shifted to the right by 1/4th of a wavelength (1 gridline) with the same wavelength as the original wave. In part (b)(ii) the response earned 1 point for indicating dot *P* on the string and at the dot's original *x*-position. In part (c) the response earned 1 point for a correct answer of 32 cm.

Sample: P1 Q4 B
Score: 4

In part (a)(i) the response earned 1 of 2 points for indicating that the velocity of dot *P* is zero, and it did not earn 1 point for incorrectly indicating that the velocity of dot *Q* is downward. In part (a)(i) the response earned 2 points: 1 point for indicating that the acceleration of dot *P* is upward and 1 point for indicating that the acceleration of dot *Q* is zero. In part (b)(i) the response earned 1 point for a curve that is shifted to the right by 1/4th of a wavelength (1 gridline) with the same wavelength as the original wave. In part (b)(ii) the response earned no points because dot *P* is not at its original *x*-position. In part (c) the response earned no points for an incorrect answer of -6 cm.

Sample: P1 Q4 C
Score: 1

In part (a)(i) the response did not earn either of the 2 points for incorrectly indicating that the velocity of dot *P* is to the right and that the velocity of dot *Q* is zero. In part (a)(i) the response did not earn either of the 2 points for incorrectly indicating that the acceleration of dot *P* is zero and that the acceleration of dot *Q* is to the right. In part (b)(i) the response earned 1 point for a curve that is shifted to the right by 1/4th of a wavelength (1 gridline) with the same wavelength as the original wave. In part (b)(ii) the response earned no points because dot *P* is not at its original *x*-position. In part (c) the response earned 1 point for a correct answer of 32 cm.