AP® PHYSICS
2011 SCORING GUIDELINES

General Notes About 2011 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. 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 earned. 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.

3. Implicit statements of concepts normally earn credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still earned. 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 AP Physics 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 Course Description*.

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

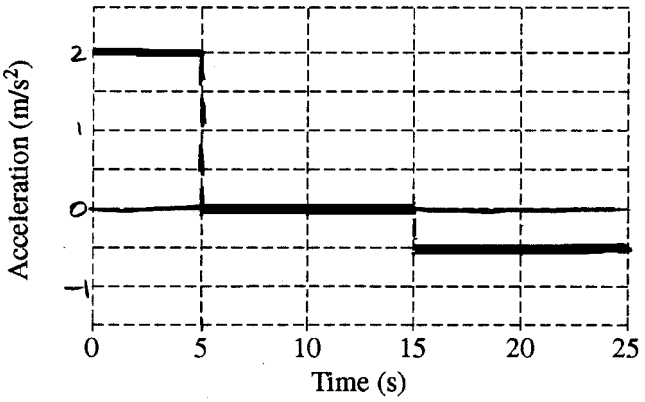
5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically earn 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 B
2011 SCORING GUIDELINES

Question 1

15 points total **Distribution of points**

(a) 3 points



For using a linear scale on the vertical axis 1 point
For showing horizontal lines in the three appropriate time frames 1 point
For having the correct acceleration values for segments *B* and *C* 1 point
(The correct value for segment *A* is accounted for in the answer point in part (d).)

$a = \Delta v/\Delta t$ (or the slope of the velocity versus time curve)

For segment *A*: $a = (10\,\text{m/s} - 0\,\text{m/s})/(5\text{ s} - 0\text{ s}) = 2\,\text{m/s}^2$

For segment *B*: slope is zero, so acceleration is zero

For segment *C*: $a = (5\,\text{m/s} - 10\,\text{m/s})/(25\text{ s} - 15\text{ s}) = -0.5\,\text{m/s}^2$

(b) 2 points

$x = x_0 + v_0 t + (1/2)at^2$, where $x_0 = 0$

For substituting $v_0 = 0$ and $t = 5$ s into the equation above 1 point

For substituting the value on the graph of the constant acceleration between 0 and 5 s or an explicit calculation of $2\,\text{m/s}^2$ 1 point

$x = (1/2)\left(2\ \text{m/s}^2\right)(5\text{ s})^2$

$x = 25$ m

Alternate solution *Alternate points*
Position is the area under the velocity versus time curve.
For correctly substituting into the expression for the area under the curve *1 point*
$x = (1/2)(10\,\text{m/s})(5\text{ s})$
For the correct answer *1 point*
$x = 25$ m

Question 1 (continued)

Distribution of points

(c) 2 points

For selecting segment B 1 point
For an appropriate justification 1 point
Example: $F_{net} = ma = m(\Delta v/\Delta t)$, the velocity is constant for this segment, so $\Delta v = 0$; therefore, $F_{net} = 0$.

(d) 2 points

For using Newton's second law 1 point
$F_{net} = ma$
$F_{net} = (0.40 \text{ kg})\left(2 \text{ m/s}^2\right)$
For the correct answer 1 point
$F_{net} = 0.80 \text{ N}$

(e) 2 points

For using the work-energy theorem 1 point
$W = F\Delta r\cos\theta$
To move in a straight line, the net force must be in the direction of motion, so $\theta = 0°$.
$W = F_{net}d$

For substituting the value of the position determined in from part (b), which is equal to the displacement, to determine the work done for segment A 1 point
For segment A, $W_A = (0.8 \text{ N})(25 \text{ m}) = 20 \text{ J}$
For segment B, $W_B = (0 \text{ N})(10 \text{ m/s})(10 \text{ s}) = 0 \text{ J}$
$W_{tot} = W_A + W_B = 20 \text{ J} + 0 \text{ J} = 20 \text{ J}$

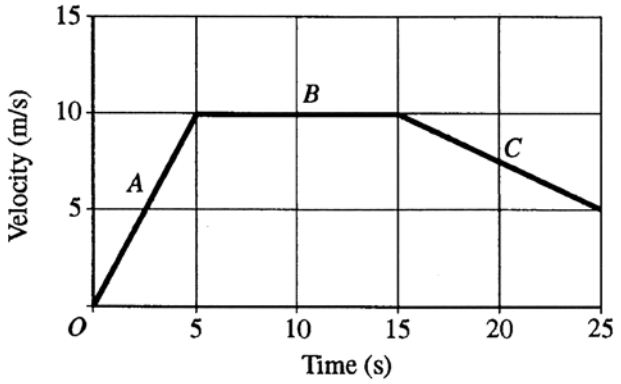
Alternate solution *Alternate points*
$W = \Delta K$
$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
For correct substitutions into the equation above *1 point*
$W = \frac{1}{2}(0.40 \text{ kg})(10 \text{ m/s})^2 - \frac{1}{2}(0.40 \text{ kg})(0 \text{ m/s})^2$
For the correct answer *1 point*
$W = 20 \text{ J}$

Question 1 (continued)

		Distribution of points
(f)	3 points	
	For selecting "Negative"	1 point
	For an appropriate explanation using kinematic or dynamic principles	1 point
	Examples: The velocity is decreasing, so the kinetic energy is also decreasing. The acceleration is negative; therefore, the direction of the net force is opposite to the direction of the displacement.	
	For connecting the explanation to the work done	1 point
	Units	1 point
	For correct units on at least two parts with a calculated numerical answer and no incorrect units	1 point

PHYSICS B
SECTION II
Time—90 minutes
6 Questions

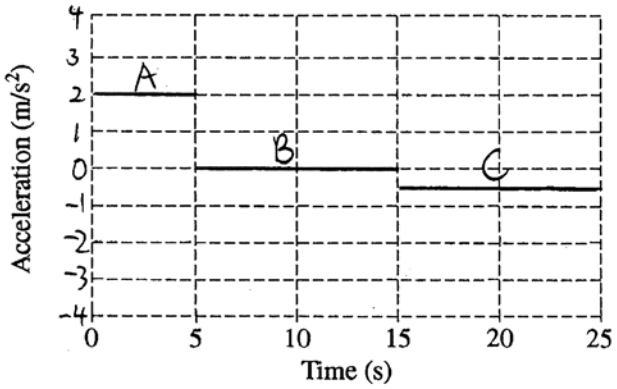
Directions: Answer all six questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1-3 and 5 and about 11 minutes for answering each of Questions 4 and 6. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



1. (15 points)

A 0.40 kg object moves in a straight line under the action of a net force. The graph above shows the velocity as a function of time for the object during a 25 s interval. At time $t = 0$, the object is at the position $x = 0$.

(a) On the grid below, sketch a graph of the acceleration as a function of time for the object. Label the scale for the acceleration.



(b) Calculate the position of the object at $t = 5.0$ s.

$x(5.0) = \frac{1}{2} \times 5 \times 10 =$ 25 m

GO ON TO THE NEXT PAGE.

(c) On which segment of the graph is the net force acting on the object zero?

___ A ✓ B ___ C

Justify your answer.

$F = ma$

m doesn't change

$a_B = 0$

$F_B = 0 \cdot m = 0$ N

(d) Calculate the net force on the object during the first 3.0 s of the motion.

$F = ma$

$= 0.4 \times 2$

$= 0.8$ N

(e) Calculate the amount of work done on the object by the net force during the first 15 s of the motion.

$W = Fd$

$= (ma)d$

$= (0.4 \times 2) \times (\frac{1}{2} \times 5 \times 10) + 0 \times 10 \times 10$

$= 20$ J

(f) For the interval $t = 15$ s to $t = 25$ s, is the work done on the object by the net force positive, negative, or zero?

___ Positive ✓ Negative ___ Zero

Justify your answer.

$15 \le t \le 25$ s, $a < 0$

$F = ma < 0$

$W = Fd < 0$

(distance traveled is positive)

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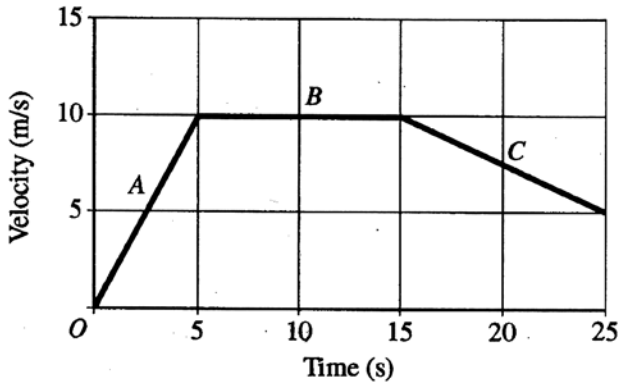
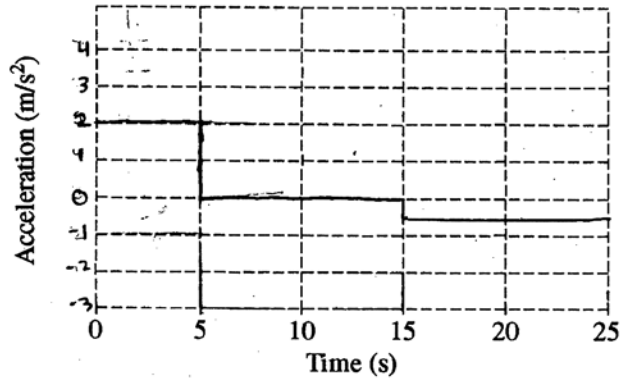


1. (15 points)

A 0.40 kg object moves in a straight line under the action of a net force. The graph above shows the velocity as a function of time for the object during a 25 s interval. At time $t = 0$, the object is at the position $x = 0$.

(a) On the grid below, sketch a graph of the acceleration as a function of time for the object. Label the scale for the acceleration.



(b) Calculate the position of the object at $t = 5.0$ s.

$d = rt$

$d = 10\ m/s\ (5\ s)$

$d = 50\ m$

(c) On which segment of the graph is the net force acting on the object zero?

___ A X B ___ C

Justify your answer.

$F = ma$

$F = m(0\ m/s^2)$

$F = 0$

(d) Calculate the net force on the object during the first 3.0 s of the motion.

$F = ma$

$F = (0.4\ kg)(2\ m/s^2)$

$F = 0.8\ N$

(e) Calculate the amount of work done on the object by the net force during the first 15 s of the motion.

$W = F \times d$

$\Sigma F = F_A + F_B$

$= 0.8N + 0$

$\Sigma F = 0.8N$

$d_t = (r_1 t_1) + (r_2 t_2)$

$d_t = (10\ m/s \cdot 5s) + (10\ m/s \cdot 10s)$

$d_t = 50m + 100m$

$d_t = 150\ m$

$W = (0.8\ N)(150\ m)$

$W = 144\ N \cdot m$

(f) For the interval $t = 15$ s to $t = 25$ s, is the work done on the object by the net force positive, negative, or zero?

___ Positive X Negative ___ Zero

Justify your answer.

$W = F \cdot d$

$F = ma$

$F = 0.4\ kg(-0.5\ m/s^2)$

$F = -0.2\ N$

$d = rt$

$d = 5\ m/s\ (10s)$

$d = 50\ m$

$W = (-0.2N)(50m)$

$W = -10\ N \cdot m$

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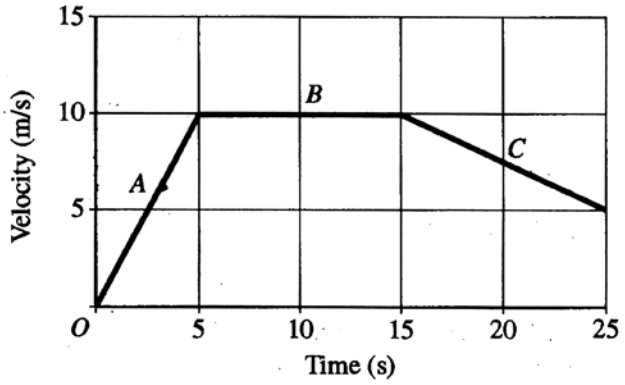
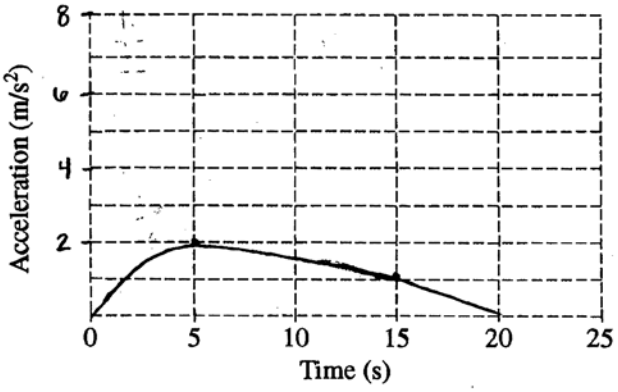


1. (15 points)

A 0.40 kg object moves in a straight line under the action of a net force. The graph above shows the velocity as a function of time for the object during a 25 s interval. At time $t = 0$, the object is at the position $x = 0$.

(a) On the grid below, sketch a graph of the acceleration as a function of time for the object. Label the scale for the acceleration.



(b) Calculate the position of the object at $t = 5.0$ s.

$v = \frac{x}{t}$ $\quad x = vt$

$x = 10\frac{m}{s}(5.0s)$

$x = 50\,m$

GO ON TO THE NEXT PAGE.

(c) On which segment of the graph is the net force acting on the object zero?

___ A ___√___ B ___ C

Justify your answer.

DURING SEGMENT B, THERE IS CONSTANT VELOCITY, THEREFORE THERE IS ZERO NET FORCE ACTING ON THE OBJECT.

(d) Calculate the net force on the object during the first 3.0 s of the motion.

$F_{NET} = ma$

$a = \frac{v}{t} = \frac{6\,m/s}{3s} = 2\,m/s^2$

$F_{NET} = .40kg\,(2\,m/s^2)$

$F_{NET} = .80N$

(e) Calculate the amount of work done on the object by the net force during the first 15 s of the motion.

$F_{NET} = ma$

$a = \frac{v}{t} = \frac{10\,m/s}{15s} = \frac{2}{3}\,m/s^2$

$F_{NET} = .40kg\,(\frac{2}{3}\,m/s^2)$

$F_{NET} = \frac{4}{15}N$

$x = vt$

$x = 10\,m/s\,(15s)$

$x = 150m$

$W = Fd$

$W = \frac{4}{15}N\,(150m)$

$W = 40J$

(f) For the interval $t = 15$ s to $t = 25$ s, is the work done on the object by the net force positive, negative, or zero?

___√___ Positive ___ Negative ___ Zero

Justify your answer.

$a = \frac{v}{t} = \frac{7.5\,m/s}{20s} = \frac{3}{8}\,m/s^2$

$F_{NET} = ma$

$F_{NET} = .40kg\,(\frac{3}{8}\,m/s^2)$

$F_{NET} = .15N$

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AP® PHYSICS B
2011 SCORING COMMENTARY

Question 1

Overview

This question assessed students' understanding of linear motion. Students were required to analyze the velocity versus time graph of an object's motion. They were also asked questions regarding the dynamics, work and energy involved in the object's motion.

Sample: B1A
Score: 15

The student does an excellent job of showing all the necessary work while keeping it simple. The justifications in parts (c) and (f) are clear, succinct statements using mostly equations.

Sample: B1B
Score: 11

The student earned all points in parts (a) through (d). In part (e) the student used the work formula incorrectly, adding the two forces in segments *A* and *B* and multiplying that by the total distance. Part (f) is incorrect and earned no points. The unit point was earned.

Sample: B1C
Score: 6

In part (a) the student earned the scaling point for the graph. Part (b) earned no points. All points were earned in parts (c) and (d). In part (e) there are no consistent or correct substitutions into the work equation. Part (f) is also incorrect, so no points were earned in parts (e) or (f). The unit point was earned.