AP® PHYSICS
2012 SCORING GUIDELINES

General Notes About 2012 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 awarded in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if the use of an equation expressing a particular concept is worth 1 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 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 AP Physics Exam equation sheets. 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 $g = 9.8\text{ m/s}^2$, but use of 10 m/s^2 is of course 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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 1

15 points total | **Distribution of points**

(a) 4 points

For writing a correct trigonometric equation for velocity as a function of time, including the negative sign — 1 point

$\upsilon(t) = -\upsilon_{max}\sin(\omega t) = -\upsilon_{max}\sin(2\pi t/T)$

For using $\omega = 2\pi f$ or $\omega = \dfrac{2\pi}{T}$ to solve for ω — 1 point

For using the correct period of 0.70 s from the graph — 1 point

$\omega = \dfrac{2\pi}{0.70\text{s}} = 9.0 \text{ rad/s}$

For using the correct value of the maximum speed from the graph (acceptable range of values for υ_{max}: 0.15 m/s to 0.17 m/s) — 1 point

$\upsilon(t) = (-0.16)\sin(9.0t)$

Note: One point is deducted if incorrect phase shift ϕ is used. Full credit is awarded for a correct answer with no work shown. Students are also given credit if the value of k from part (c) is used to calculate ω using $\omega = \sqrt{k/m}$.

(b) 2 points

Take the integral of the velocity determined in part (a)

$x(t) = \int \upsilon(t)\,dt = \int (-0.16 \text{ m/s})\sin((9.0 \text{ rad/s})t)\,dt$

For a correct trigonometric expression consistent with integrating the answer from part (a) — 1 point

For a correct x_{max} consistent with the integrating the answer from part (a) — 1 point

$x_{max} = (0.16 \text{ m/s})/(9.0 \text{ rad/s}) = 0.018 \text{ m}$

$x(t) = (0.018)\cos(9.0t)$

Question 1 (continued)

Distribution of points

(b) continued

Alternate solution — *Alternate points*

For solving for a maximum displacement consistent with the answer from part (a) — *1 point*

$$\upsilon_{max} = x_{max}\omega$$

$$x_{max} = \frac{\upsilon_{max}}{\omega} = \frac{(0.16\ \text{m/s})}{(9.0\ \text{rad/s})}$$

$$x_{max} = 0.018\ \text{m}$$

For a correct trigonometric expression consistent with the answer from part (a) — *1 point*

$$x(t) = (0.018)\cos(9.0t)$$

Note: Full credit is awarded for a correct answer with no work shown. One earned point is deducted for incorrect initial conditions (e.g., subtracting a constant from the cosine function).

(c) 2 points

For a correct relationship between the period and the spring constant — 1 point

$$T = 2\pi\sqrt{\frac{m}{k}}$$

For substituting correct values from previous parts into a correct expression — 1 point

$$k = \frac{4\pi^2 m}{T^2} = \frac{\left(4\pi^2\right)(0.30\ \text{kg})}{(0.70\ \text{s})^2}$$

$$k = 24\ \text{N/m}$$

Alternate solution #1 — *Alternate points*

For a correct expression relating angular frequency and the spring constant — *1 point*

$$\omega = \sqrt{\frac{k}{m}}$$

For substituting correct values from previous parts into a correct expression — *1 point*

$$k = m\omega^2 = (0.30\ \text{kg})(9.0\ \text{rad/s})^2$$

$$k = 24\ \text{N/m}$$

Question 1 (continued)

Distribution of points

(c) continued

Alternate solution #2 — *Alternate points*

For a correct statement of the conservation of energy, applied to the position of maximum displacement and the equilibrium position — *1 point*

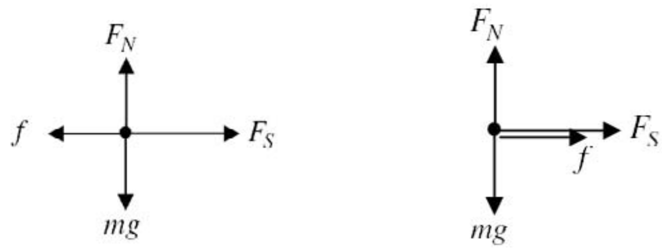
$$\frac{1}{2}kx_{\max}^2 = \frac{1}{2}mv_{\max}^2$$

For substituting correct values from previous parts into a correct expression — *1 point*

$$k = \frac{mv_{\max}^2}{x_{\max}^2} = \frac{(0.30\ \text{kg})(0.16\ \text{m/s})^2}{(0.018\ \text{m})^2}$$

$$k = 24\ \text{N/m}$$

(d) 4 points



Toward the equilibrium position — Away from the equilibrium position

For drawing and labeling F_N and mg correctly on both diagrams — 1 point

On diagram of the block moving toward the equilibrium position:

- For a correctly drawn and labeled spring force to the right — 1 point
- For a correctly drawn and labeled friction force to the left — 1 point

On diagram of the block moving away from the equilibrium position:

- For a correctly drawn and labeled spring force and friction force to the right — 1 point

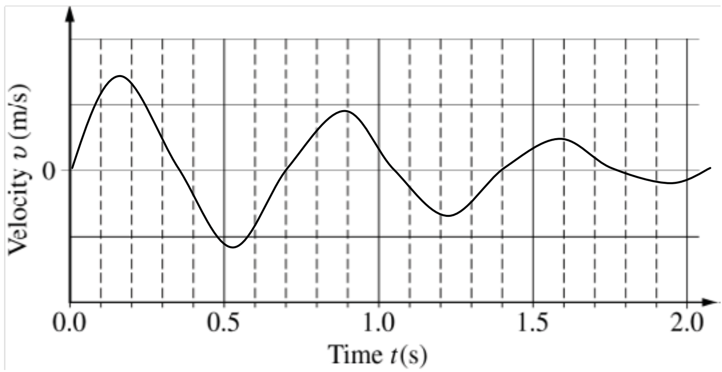
<u>Notes</u>

- Length of vectors is not considered, only direction.
- There is a 1-point maximum deduction for any vectors not touching (or at least almost touching) the dot or for any extraneous forces.Vectors can be drawn from the dot outward OR toward the dot, pointing inward and touching the dot.

Question 1 (continued)

Distribution of points

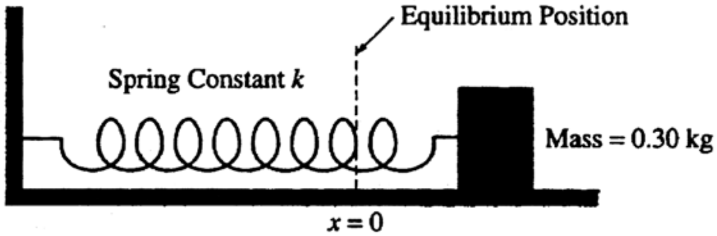
(e) 3 points



For a graph passing through equilibrium at 0.35 s intervals	1 point
For a graph displaying damped oscillations	1 point
For a graph that starts at zero with an increasing positive velocity	1 point

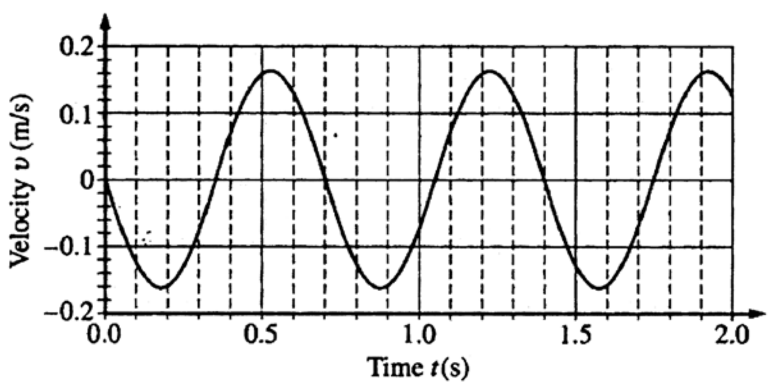
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



Mech. 1.

Experiment 1. A block of mass 0.30 kg is placed on a frictionless table and is attached to one end of a horizontal spring of spring constant k, as shown above. The other end of the spring is attached to a fixed wall. The block is set into oscillatory motion by stretching the spring and releasing the block from rest at time $t = 0$. A motion detector is used to record the position of the block as it oscillates. The resulting graph of velocity v versus time t is shown below. The positive direction for all quantities is to the right.



(a) Determine the equation for $v(t)$, including numerical values for all constants.

$x(t) = A\cos(\omega t)$ $\quad -A\omega = -.16 \, m/s$ (amplitude on graph)

$v(t) = -A\omega \sin(\omega t)$ $\quad \frac{2\pi}{\omega} = \text{Period} = .7 \, s$ (from graph)

$v(t) = -.16\sin(8.98t)$ $\quad \omega = \frac{2\pi}{.7} = 8.97598 \, \frac{rad}{s}$

(b) Given that the equilibrium position is at $x = 0$, determine the equation for $x(t)$, including numerical values for all constants.

$A = \frac{-.16}{-\omega} = .018 \, m$

$x(t) = \int_0^t v(t)\,dt$

$= A\cos(\omega t) = (.018\,m)\cos(8.98t)$

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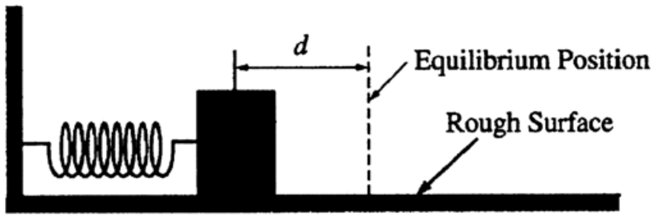
(c) Calculate the value of k.

$$\omega=\sqrt{\frac{k}{m}} = 8.98$$

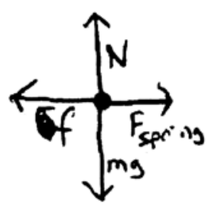
$$k = m(8.98)^2$$

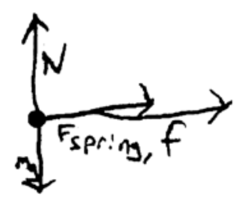
$$= (.3\,\text{kg})(8.98)^2 = 24.17\ \frac{N}{m}$$

Experiment 2. The block and spring arrangement is now placed on a rough surface, as shown below. The block is displaced so that the spring is compressed a distance d and released from rest.



(d) On the dots below that represent the block, draw and label the forces (not components) that act on the block when the spring is compressed a distance $x = d/2$ and the block is moving in the direction indicated below each dot.

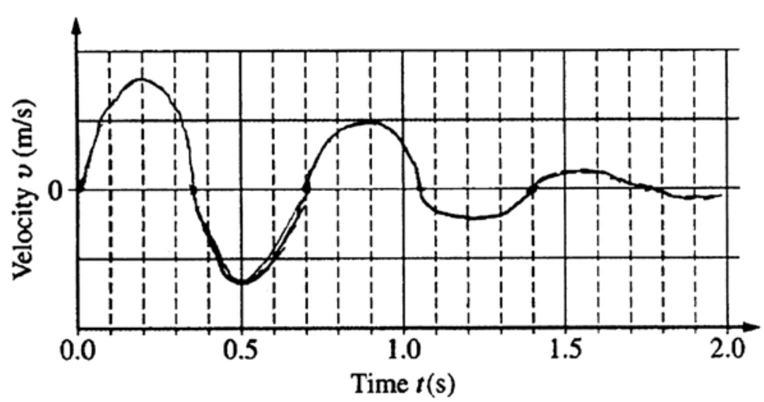




Toward the equilibrium position

Away from the equilibrium position

(e) Draw a sketch of v versus t in this case. Assume that there is a negligible change in the period and that the positive direction is still to the right.



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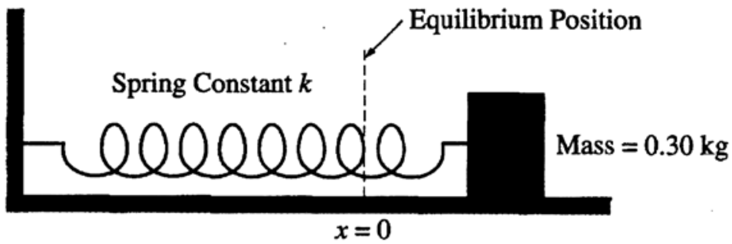
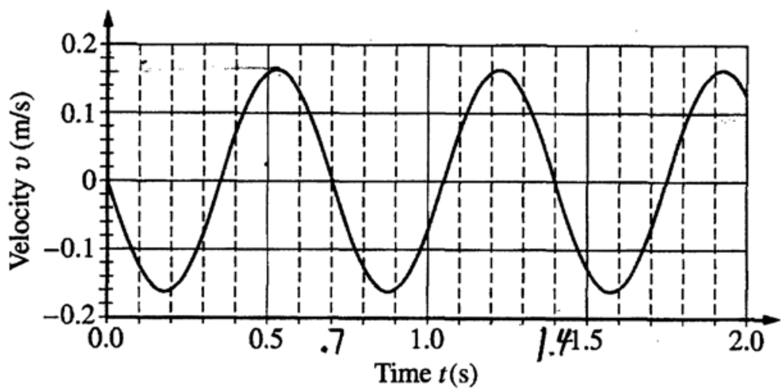


Mech. 1.

Experiment 1. A block of mass 0.30 kg is placed on a frictionless table and is attached to one end of a horizontal spring of spring constant k, as shown above. The other end of the spring is attached to a fixed wall. The block is set into oscillatory motion by stretching the spring and releasing the block from rest at time $t = 0$. A motion detector is used to record the position of the block as it oscillates. The resulting graph of velocity v versus time t is shown below. The positive direction for all quantities is to the right.



(a) Determine the equation for $v(t)$, including numerical values for all constants.

$v(t) = -A\sin(\omega t)$

where A is the amplitude and ω is $\frac{2\pi}{T}$.

$v(t) = -.16\sin(\frac{2\pi}{.7}t)$

$\boxed{v(t) = -.16\sin(8.976t)}$

$T = \frac{2\pi}{\omega}$

$T = .7$

(b) Given that the equilibrium position is at $x = 0$, determine the equation for $x(t)$, including numerical values for all constants.

$x(t) = \int v(t)\,dt$

$x(t) = .018\cos(8.976t) + C$

$0 = .018\cos(0) + C$

$C = -.018$

$\boxed{x(t) = .018\cos(8.976t) - .018}$

GO ON TO THE NEXT PAGE.

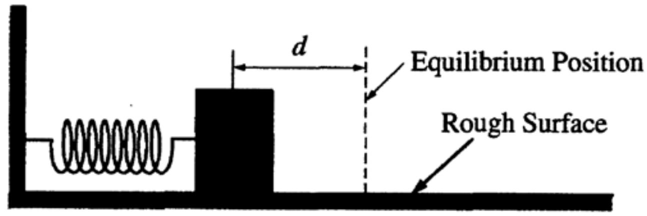
(c) Calculate the value of k.

$\omega = \sqrt{\frac{K}{m}}$

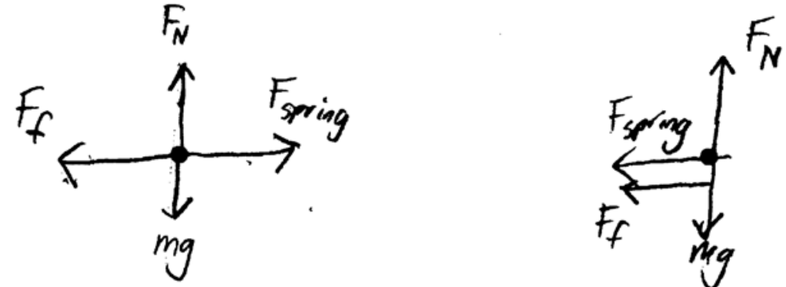
$8.976 = \sqrt{\frac{K}{3}}$

$\boxed{K = 24.17 \frac{N}{m}}$

Experiment 2. The block and spring arrangement is now placed on a rough surface, as shown below. The block is displaced so that the spring is compressed a distance d and released from rest.



(d) On the dots below that represent the block, draw and label the forces (not components) that act on the block when the spring is compressed a distance $x = d/2$ and the block is moving in the direction indicated below each dot.



Toward
the equilibrium position

Away from
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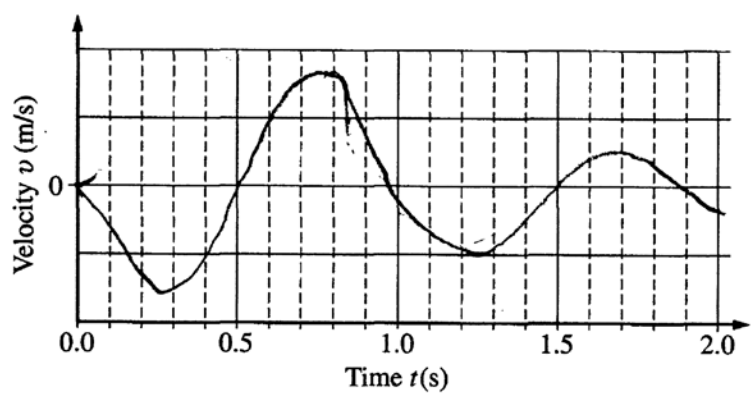
(e) Draw a sketch of v versus t in this case. Assume that there is a negligible change in the period and that the positive direction is still to the right.



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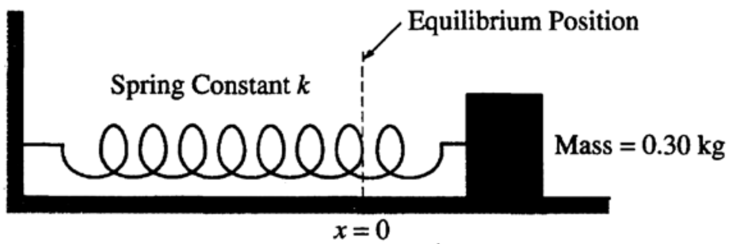

Mech. 1.

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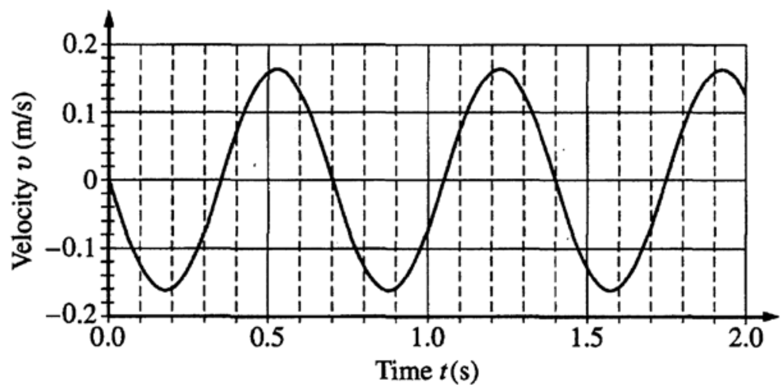


(a) Determine the equation for $v(t)$, including numerical values for all constants.

Amp = 1.4

Per. = $\frac{2\pi t}{0.7}$

$\boxed{v(t) = 1.4 \sin(8.98t)}$

$v(t) = -1.4 \sin\left(\frac{2\pi t}{0.7}\right)$

(b) Given that the equilibrium position is at $x = 0$, determine the equation for $x(t)$, including numerical values for all constants.

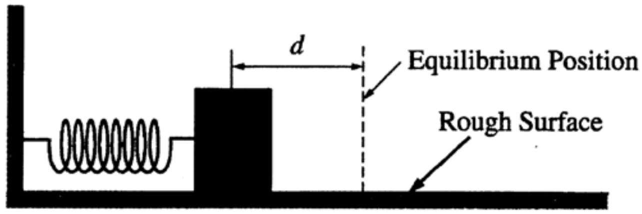
$x(t) = \int v(t)\,dt$

$\boxed{x(t) = 8.93 \cos(8.98t)}$

GO ON TO THE NEXT PAGE.

(c) Calculate the value of k.

Experiment 2. The block and spring arrangement is now placed on a rough surface, as shown below. The block is displaced so that the spring is compressed a distance d and released from rest.



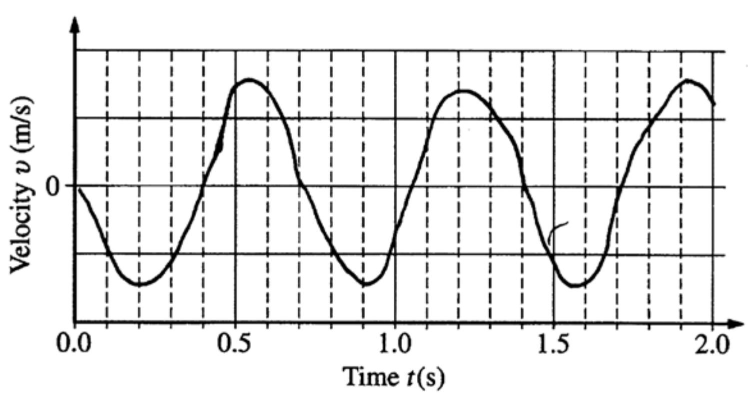
(d) On the dots below that represent the block, draw and label the forces (not components) that act on the block when the spring is compressed a distance $x = d/2$ and the block is moving in the direction indicated below each dot.

$F=k(\frac{d}{2})$ $F=k(\frac{d}{2})$

Toward the equilibrium position

Away from the equilibrium position

(e) Draw a sketch of v versus t in this case. Assume that there is a negligible change in the period and that the positive direction is still to the right.



Question 1

Overview

This question assessed students' understanding of simple harmonic motion for a spring/mass system and the damping effects of friction. Students were also tested on free-body diagrams and calculation of the spring constant.

Sample: M1-A
Score: 15

This response is typical of the stronger solutions for this question. The student correctly calculates the angular frequency for substituting into the negative sine function and even indicates that the initial velocity is obtained from reading the graph. The integral of the velocity function is correctly executed in part (b), and the spring constant is calculated in part (c). All of the forces start on the dots in the diagrams in part (d), and the student correctly indicates that the friction force reverses direction. The graph is carefully sketched to show the period, the sinusoidal nature of the displacement, and the decreasing amplitude.

Sample: M1-B
Score: 11

This response earned full credit in part (a). One point was deducted in part (b) for substituting the incorrect initial conditions into the integration. This was a common mistake, as some students misinterpreted the statement about the equilibrium position and took it to be a statement about the initial position. Full credit was earned in part (c). One point was lost in part (d) for the incorrect friction and spring force vectors on the "Away from the equilibrium" diagram. Only 1 of the 3 points was earned for the graph in part (e). One point was lost for the negative sine graph, and 1 point was forfeited for the incorrect period of the motion.

Sample: M1-C
Score: 6

In part (a) 3 points were earned; 1 point was lost for an incorrect maximum velocity. One point was lost in part (b) for an incorrect maximum displacement. Part (c) is left blank and thus earned no credit. One point was earned in part (d) for a correct spring force vector in the "Toward the equilibrium" diagram, but no other points were awarded. The friction, normal force, and weight vectors are missing from both diagrams. One point was earned in part (e) for the correct period of the motion, but the graph is a negative sine function, and the amplitude is not decreasing.