Question 2

15 points total | **Distribution of points**

(a)

i. 2 points

For selecting "Negative"	1 point
For a correct justification	1 point

<u>Examples</u>

- The spring pushes on the box in a direction opposite to the box's motion, therefore the work done is negative.
- The box slows down, so its kinetic energy decreases. Therefore the work done is negative.

ii. 3 points

For a correct expression relating work to change in kinetic energy — 1 point

$W = \Delta K$

$W = \frac{1}{2}m\left(v_2^2 - v_1^2\right) = -\frac{1}{2}mv_1^2$

For substituting the correct values — 1 point

$W = -\left(\frac{1}{2}\right)(20\ \text{kg})(4.0\ \text{m/s})^2$

For a correct answer — 1 point

$W = 160\ \text{J}$ (either positive or negative value acceptable)

(b) 2 points

For a correct expression of conservation of energy — 1 point

$K_1 = U_2$

$\frac{1}{2}mv_1^2 = \frac{1}{2}kx_2^2$

For correct substitution of values consistent with the answer from part (a) ii — 1 point

$(160\ \text{J}) = \left(\frac{1}{2}\right)k(0.50\ \text{m})^2$

$k = 1280\ \text{N/m}$

(c) 2 points

For a correct expression of the maximum acceleration — 1 point

$a = F_{max}/m = kx_{max}/m$

For correct substitution consistent with the answer from part (b) — 1 point

$a = (1280\ \text{N/m})(0.50\ \text{m})/(20\ \text{kg})$

$a = 32\ \text{m/s}^2$

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Question 2 (continued)

Distribution of points

(d) 2 points

For a correct expression of the frequency — 1 point

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

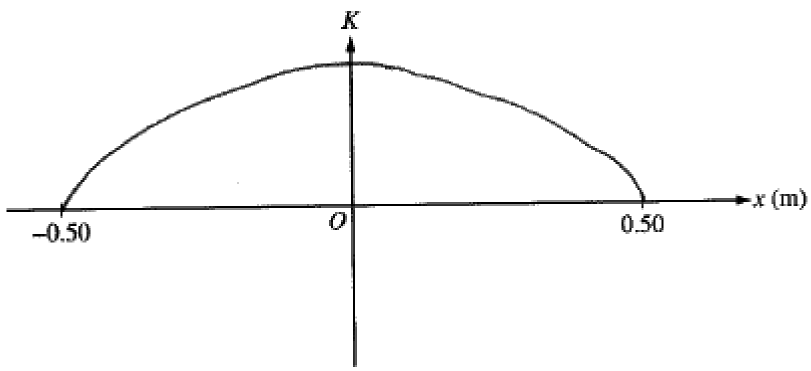
For correct substitution consistent with the answer from part (b) — 1 point

$$f = \left(\frac{1}{2\pi}\right)\sqrt{\frac{(1280\ \text{N/m})}{(20\ \text{kg})}}$$

$f = 1.27\ \text{Hz}$

(e)

i. 2 points



For a graph that shows positive kinetic energy values and zero kinetic energy at −0.50 m and +0.50 m — 1 point

For a smooth curve that is concave down — 1 point

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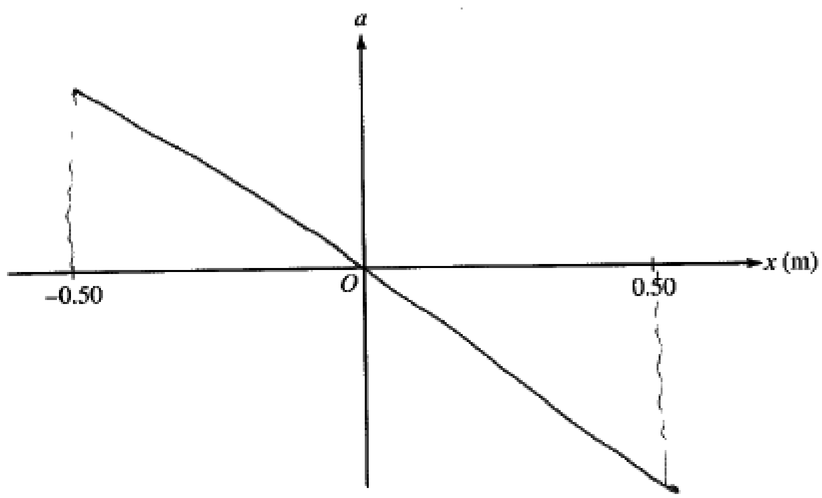
Question 2 (continued)

Distribution of points

(e) (continued)

ii. 1 point



For a straight line with negative slope that begins at −0.50 m, ends at +0.50 m, and passes through the origin — 1 point

Units 1 point

For correct units on three out of four calculated answers — 1 point

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B2 A1

2. (15 points)

A 20 kg box on a horizontal frictionless surface is moving to the right at a speed of 4.0 m/s. The box hits and remains attached to one end of a spring of negligible mass whose other end is attached to a wall. As a result, the spring compresses a maximum distance of 0.50 m, and the box then oscillates back and forth.

(a)

i. The spring does work on the box from the moment the box first hits the spring to the moment the spring first reaches its maximum compression. Indicate whether the work done by the spring is positive, negative, or zero.

____ Positive __✓__ Negative ____ Zero

Justify your answer.

The spring is applying force in opposition to the motion of the box.

ii. Calculate the magnitude of the work described in part i.

Work = energy

$W = \frac{1}{2}mv^2$

$W = \frac{1}{2}(20)(4)^2$

$W = 10(16)$

$W = 160J$

(b) Calculate the spring constant of the spring.

Cons of energy

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$160 = \frac{1}{2}k(.5)^2$

$160 = \frac{1}{8}k$

$k = 1280 \text{ N/m}$

(c) Calculate the magnitude of the maximum acceleration of the box.

$F_s = kx$

$F = ma$

$kx = ma$

$(1280)(.5) = (20)(a)$

$a = 32 \text{ m/s}^2$

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(d) Calculate the frequency of the oscillation of the box.

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

$T = 2\pi\sqrt{\frac{20}{1280}}$

$T = 2\pi(.125)$

$T = .785\,s$

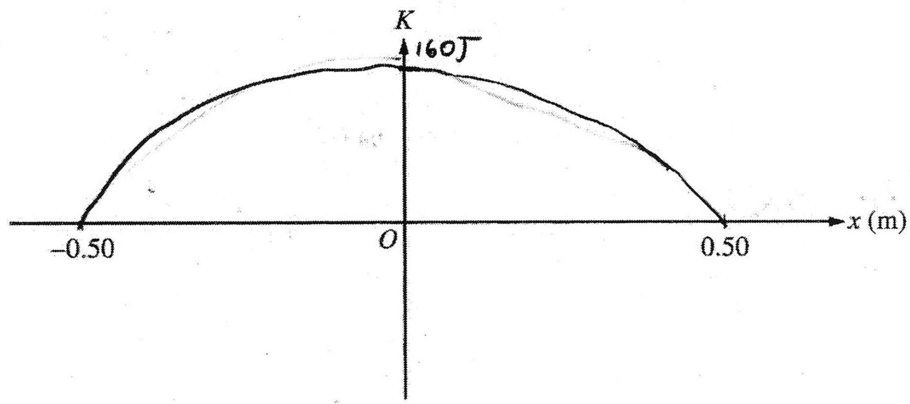
$f = \frac{1}{T}$

$f = \frac{1}{.785}$

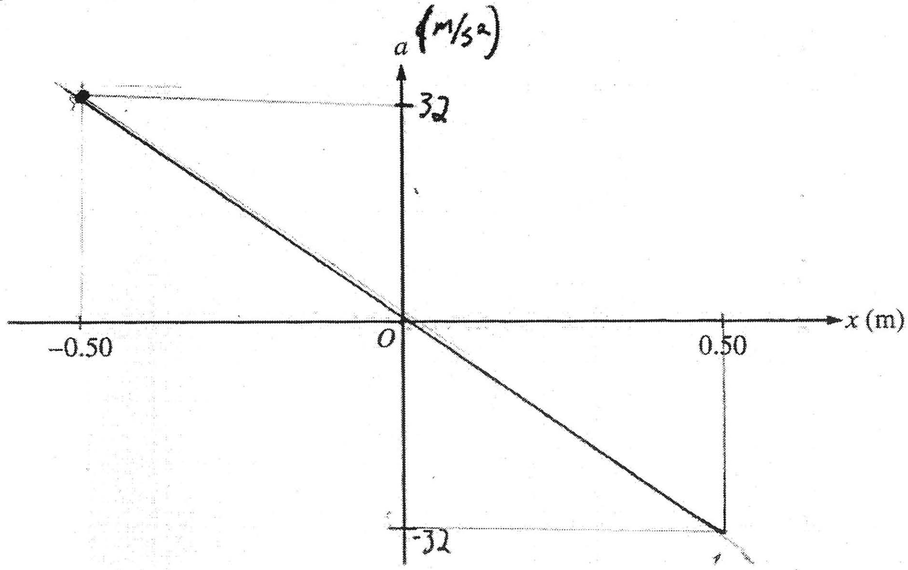
$f = 1.27\,Hz$

(e) Let $x = 0$ be the point where the box makes contact with the spring, with positive x directed toward the right.

i. On the axes below, sketch the kinetic energy K of the oscillating box as a function of position x for the range $x = -0.50$ m to $x = +0.50$ m.



ii. On the axes below, sketch the acceleration a of the oscillating box as a function of position x for the range $x = -0.50$ m to $x = +0.50$ m.



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2. (15 points)

A 20 kg box on a horizontal frictionless surface is moving to the right at a speed of 4.0 m/s. The box hits and remains attached to one end of a spring of negligible mass whose other end is attached to a wall. As a result, the spring compresses a maximum distance of 0.50 m, and the box then oscillates back and forth.

m v Δx

(a)

i. The spring does work on the box from the moment the box first hits the spring to the moment the spring first reaches its maximum compression. Indicate whether the work done by the spring is positive, negative, or zero.

__✓__ Positive ____ Negative ____ Zero

Justify your answer.

The work done on a system is always negative. Therefore, the work done by the spring must be positive.

ii. Calculate the magnitude of the work described in part i.

$W = \frac{1}{2}mv^2$

$W = \frac{1}{2}(20)(4)^2$

$\boxed{W = 160\ N}$

(b) Calculate the spring constant of the spring.

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$160 = \frac{1}{2}k(.5)^2$

$320 = k(.5)^2$

$\boxed{k = 1280\ N/m}$

(c) Calculate the magnitude of the maximum acceleration of the box.

$F = -kx \qquad F = ma$

$-kx = ma$

$-(1280)(.5) = (20)a$

$\boxed{a = -32\ m/s^2}$

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(d) Calculate the frequency of the oscillation of the box.

$(x)(v) = 1/t$

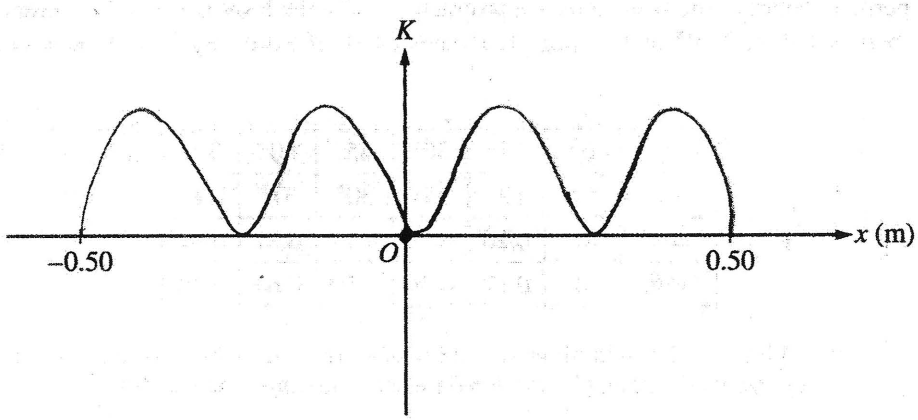
$(.5m)(4m/s) = 1/t$

$1/t = 2/s$

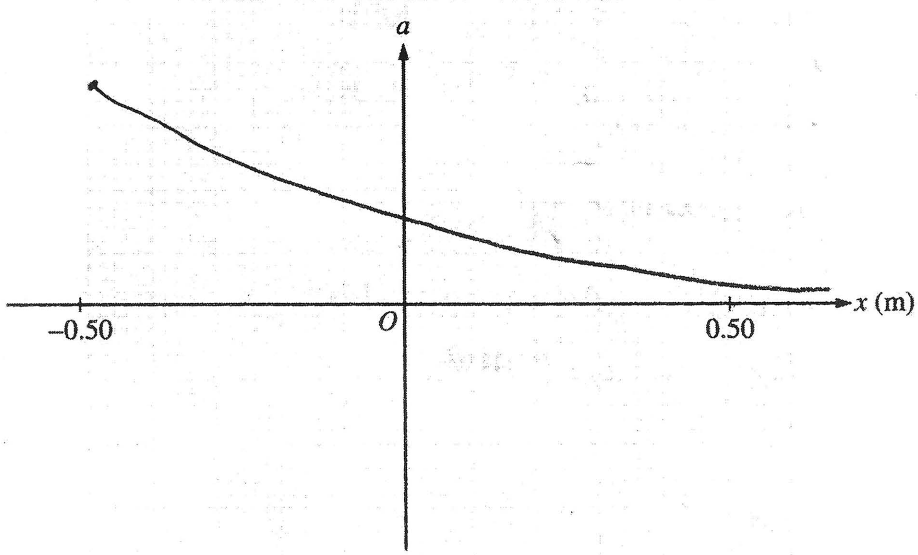
$f = 2Hz$

(e) Let $x = 0$ be the point where the box makes contact with the spring, with positive x directed toward the right.

i. On the axes below, sketch the kinetic energy K of the oscillating box as a function of position x for the range $x = -0.50$ m to $x = +0.50$ m.



ii. On the axes below, sketch the acceleration a of the oscillating box as a function of position x for the range $x = -0.50$ m to $x = +0.50$ m.



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(a)

i. The spring does work on the box from the moment the box first hits the spring to the moment the spring first reaches its maximum compression. Indicate whether the work done by the spring is positive, negative, or zero.

_✓_ Positive ____ Negative ____ Zero

Justify your answer.

$W = Fd$ F is constant and "d" distance is positive .5m $\Rightarrow W = +F(+d) = +$(positive)

ii. Calculate the magnitude of the work described in part i.

$W = Fd$ $W = (ma)d$

$W = (20 \cdot \quad).5$

(b) Calculate the spring constant of the spring.

$F_s = -kx$ $k = \frac{F}{x}$ $k = 2F$

$k = \frac{F}{.5}$ $k = 2($

(c) Calculate the magnitude of the maximum acceleration of the box.

$a = \frac{v_f - v_i}{t}$ $t = 2\pi\sqrt{\frac{m}{k}}$

$a = \frac{0 - 4}{2\pi\sqrt{\frac{20}{k}}}$

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B2 C2

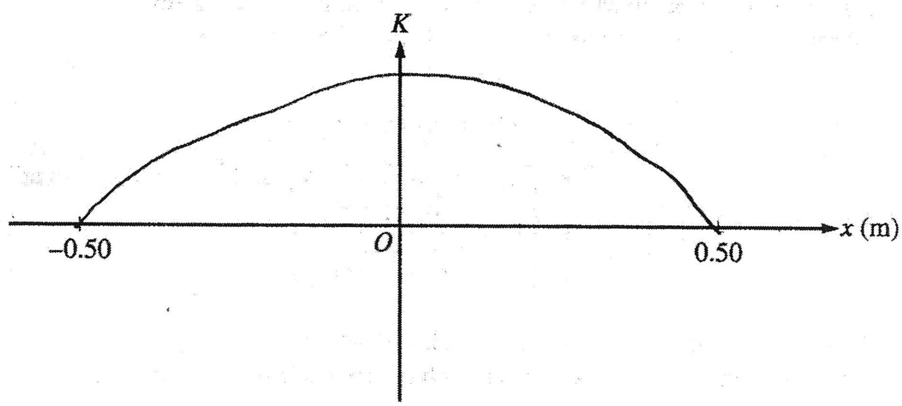
(d) Calculate the frequency of the oscillation of the box.

$$T_s = \frac{1}{f} \Rightarrow f = \frac{1}{T_s} \Rightarrow f = \frac{1}{2\pi\sqrt{\frac{m}{k}}}$$

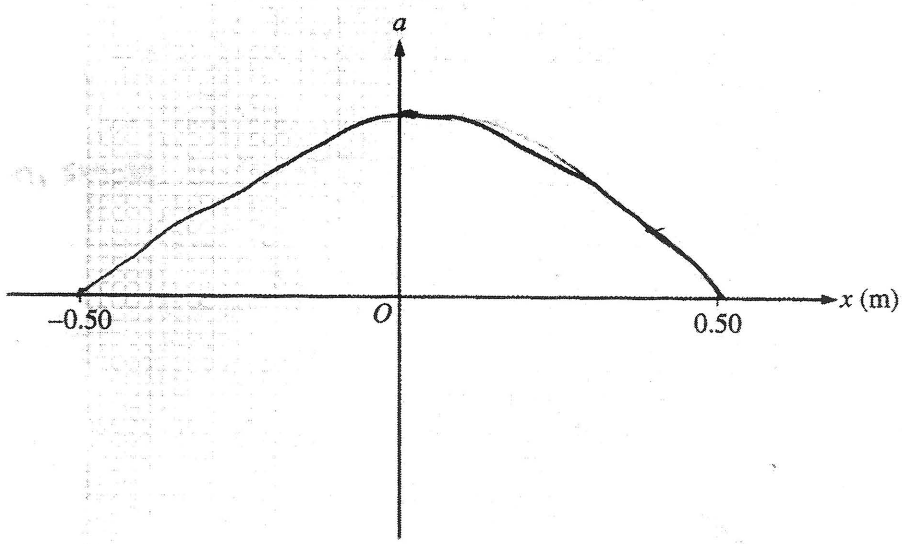
$$f = \frac{1}{2\pi\sqrt{\frac{20}{k}}}$$

(e) Let $x = 0$ be the point where the box makes contact with the spring, with positive x directed toward the right.

i. On the axes below, sketch the kinetic energy K of the oscillating box as a function of position x for the range $x = -0.50$ m to $x = +0.50$ m.



ii. On the axes below, sketch the acceleration a of the oscillating box as a function of position x for the range $x = -0.50$ m to $x = +0.50$ m.



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AP® PHYSICS B
2013 SCORING COMMENTARY

Question 2

Overview

The intent of this question was to demonstrate understanding of the work-kinetic energy theorem and the mechanics of simple harmonic motion. In part (a), the goal was to show negative work was done by a spring in stopping a block and to calculate the work done by the spring. In part (b), the goal was to demonstrate the relationship between the work done by the spring and the potential stored energy. In part (c), the intent was to demonstrate an understanding of the relationship between Hooke's law and Newton's second law. In part (d), the intent was to demonstrate an understanding of simple harmonic motion. And in part (e), the intent was to allow students to show their ability to relate mathematical functions to appropriate graphs.

Sample: B2-A
Score: 15

This response earned full credit. Part (a)(i) correctly identifies that the work done by the spring is negative and has a correct justification—that the work is negative because the spring is applying a force on the box in a direction opposite to the box's motion. Part (a)(ii) correctly identifies that the work is related to the change in kinetic energy and substitutes the correct values into the equation to obtain the correct answer. Part (b) determines a correct expression of conservation of energy in order to find the spring constant and substitutes correct values into the equation consistent with part (a)(ii). Part (c) determines the correct expression of the maximum acceleration and substitutes the correct values consistent with part (b). Part (d) determines the correct expression of the frequency and substitutes consistent with part (b). Part (e)(i) has a correct graph of kinetic energy versus position. Kinetic energy is zero at −0.50 m and +0.5 m, kinetic energy values are positive, and the graph is a smooth curve that is concave down. Part (e)(ii) has a correct graph of acceleration versus position. The graph is a straight line with negative slope that begins at −0.5 m, ends at +0.5 m, and passes through the origin. The units point was earned for correct units on all four calculated values.

Sample: B2-B
Score: 9

Credit was not earned in part (a)(i) for indicating that the work done by the spring is positive. Because the wrong selection was made, the justification is not considered (and was incorrect). Part (a)(ii) earned full credit. Full credit was earned in parts (b) and (c). No points were earned in part (d). Part (e)(i) earned 1 point for the graph of kinetic energy versus position. Kinetic energy is zero at −0.50 m and +0.5 m and kinetic energy values are positive; however, the graph is not a smooth curve that is concave down. Part (e)(ii) earned no credit as the graph is not a straight line and does not pass through the origin. The unit point was earned because three out of four units were correct.

Sample: B2-C
Score: 3

No credit was earned in parts (a), (b), and (c). The correct equation for the frequency of the system earned 1 point in part (d). However, no substitution consistent with part (b) was made. Part (e)(i) earned full credit for a correct graph of kinetic energy versus position. Part (e)(ii) did not earn credit and the units point was lost.

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