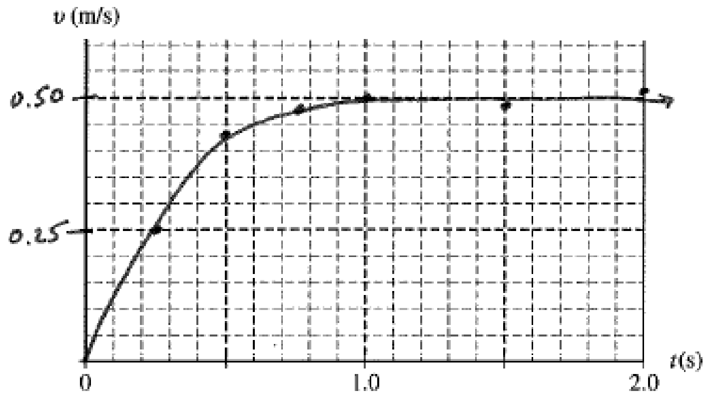
Question 1

15 points total | **Distribution of points**

(a) 3 points



For labeling the axes with appropriate values — 1 point
For a smooth curve that begins with increasing v and is concave down — 1 point
For a horizontal line near $v = 0.50$ m/s, beginning between $t = 0.79$ and 1.0 s — 1 point

(b)
i. 1 point

For a correct method of plotting position x as a function of time t — 1 point

Examples

Plot the area under the velocity curve from part (a) as a function of time.

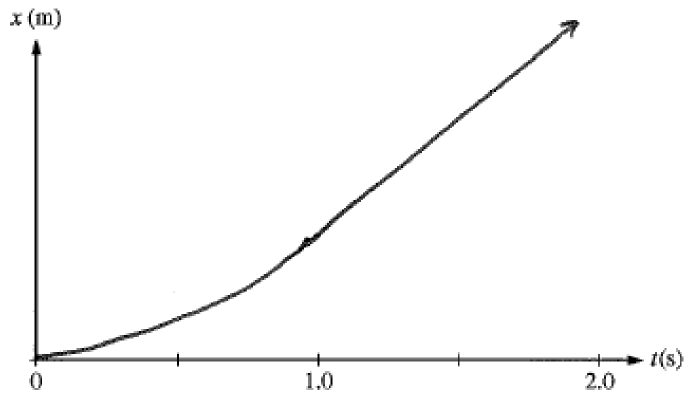
$x = \int v\,dt$

The slope of x as a function of t would yield the v versus t graph in part (a).

Question 1 (continued)

Distribution of points

ii. 3 points



For a smooth curve that begins with increasing x and is concave up for $t < 0.79$ s, ending between $t = 0.79$ s and 1.0 s	1 point
For a straight line with a positive slope, beginning between $t = 0.79$ s and 1.0 s	1 point
For a smooth transition of the curve from non-linear to linear in the region between $t = 0.79$ s and 1.0 s	1 point

(c) 3 points

For using the graph to determine the distance traveled during the first part of the motion, beginning at $t = 0$ and ending somewhere between 0.79 s (when the glider and spring lose contact) and 2 s (the maximum time shown on the velocity graph — 1 point

For calculating using the graph between 0 and 1.0 s,

$d_1 \approx (2.9 \text{ large grid squares})(0.125 \text{ m/square}) = 0.36 \text{ m}$

(1 square = 0.25 m/s × 0.5 s = 0.125 m)

For a correct expression indicating constant velocity during the last part of the motion — 1 point

$d_2 = v\Delta t = v(t - 1.0 \text{ s})$

For adding the two distances and solving for the time at which the glider hits the bumper — 1 point

$d_1 + d_2 = 2.0 \text{ m}$

$0.36 \text{ m} + (0.50 \text{ m/s})(t - 1.0 \text{ s}) = 2.0 \text{ m}$

$$t = \frac{(2.0 - 0.36) \text{ m}}{0.50 \text{ m/s}} + 1.0 \text{ s} = 4.3 \text{ s}$$

Question 1 (continued)

	Distribution of points
Alternate Solution	*Alternate Points*
For using the given information about the spring compression and the time at which the glider loses contact with the spring to arrive at $t_1 = 0.79\ \text{s}$ *at* $d_1 = 0.25\ \text{m}$	*1 point*
$d_2 = 2.0\ \text{m} - 0.25\ \text{m} = 1.75\ \text{m}$	
For a correct expression indicating constant velocity during the last part of the motion	*1 point*
$t_2 = d_2/v = 1.75\ \text{m}/0.50\ \text{m/s} = 3.5\ \text{s}$	
For adding the two times	*1 point*
$t = t_1 + t_2 = 0.79\ \text{s} + 3.5\ \text{s}$	
$t = t_1 + t_2 = 4.29\ \text{s}$	

(d) 2 points

For a correct expression of conservation of energy in terms of the spring constant k and the velocity v — 1 point

$$U_{S1} = K_2$$

$$\frac{1}{2}kx_1^2 = \frac{1}{2}mv_2^2$$

$$k = \frac{mv_2^2}{x_1^2}$$

$$k = \frac{mv_2^2}{x_1^2} = \frac{(0.40\ \text{kg})(0.50\ \text{m/s})^2}{(0.25\ \text{m})^2}$$

For a correct answer, with correct units — 1 point

$$k = 1.6\ \text{N/m}$$

Question 1 (continued)

Distribution of points

(e)

i. 1 point

For the correct amplitude — 1 point

$x_m = 0.25 \text{ m}$

ii. 2 points

For some work that uses a correct expression for the period of a spring — 1 point

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

For correct substitution of consistent values — 1 point

$T = 2\pi\sqrt{\frac{(0.40 \text{ kg})}{(1.6 \text{ N/m})}} = 3.1 \text{ s}$

Alternate Solution — *Alternate Points*

For recognizing that the 0.79 s of contact time is one quarter of a period — *1 point*

For giving the period as four times the contact time — *1 point*

$T = 4(0.79 \text{ s}) = 3.2 \text{ s}$

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.

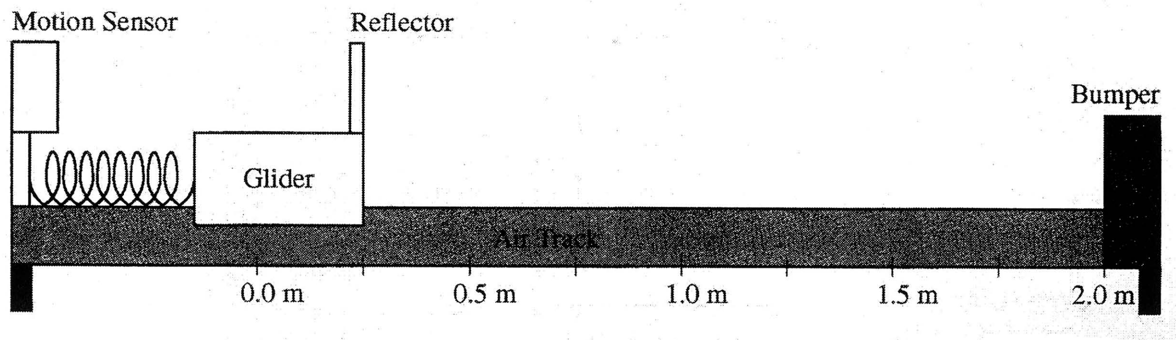


Figure 1

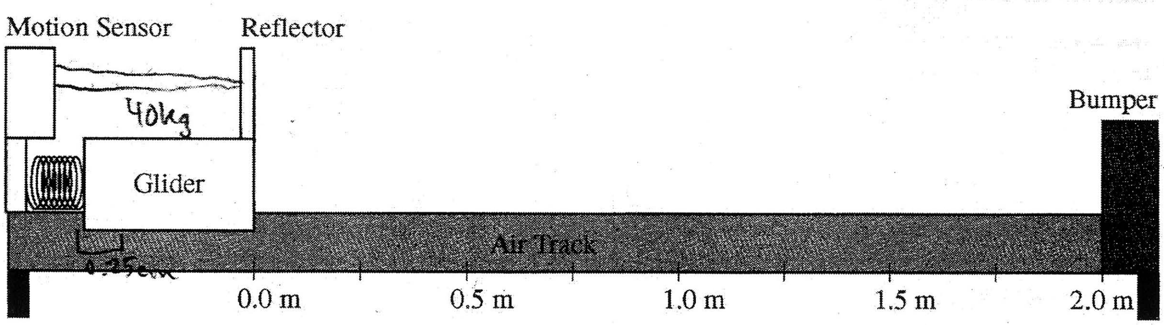


Figure 2

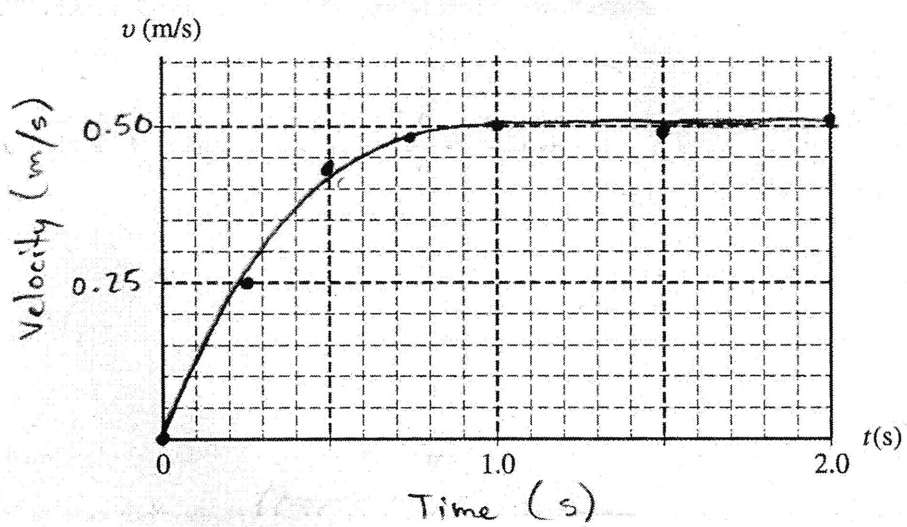
Mech 1.

A student places a 0.40 kg glider on an air track of negligible friction and holds it so that it touches an uncompressed ideal spring, as shown in Figure 1 above. The student then pushes the glider back to compress the spring by 0.25 m, as shown in Figure 2. At time $t = 0$, the student releases the glider, and a motion sensor begins recording the velocity of the reflector at the front of the glider as a function of time. The data points are shown in the table below. At time $t = 0.79$ s, the glider loses contact with the spring.

Time (s)	0	0.25	0.50	0.75	1.00	1.50	2.00
Velocity (m/s)	0	0.25	0.43	0.48	0.50	0.49	0.51

GO ON TO THE NEXT PAGE.

(a) On the axes below, plot the data points for velocity v as a function of time t for the glider, and draw a smooth curve that best fits the data. Be sure to label an appropriate scale on the vertical axis.

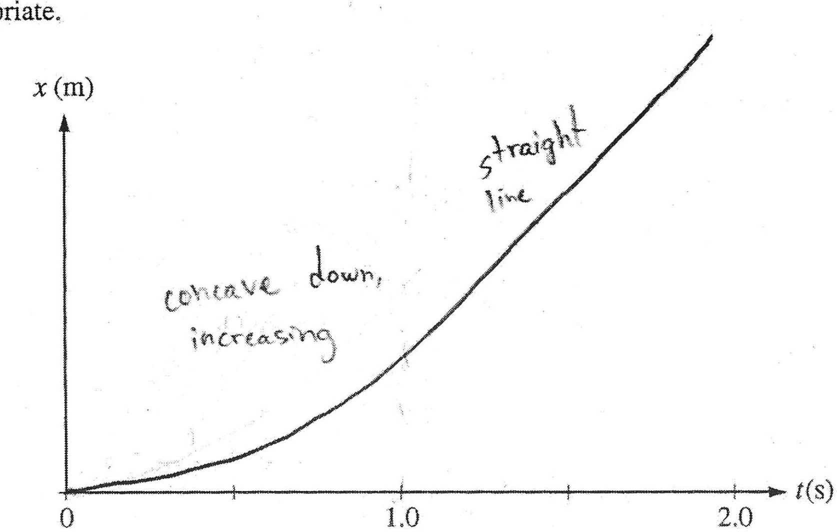


(b) The student wishes to use the data to plot position x as a function of time t for the glider.

i. Describe a method the student could use to do this.

The student could find the equation for the best fit line of the data for "v", velocity, using a graphing calculator. Then, he or she can integrate that equation with respect to get a position with respect to time equation, which can then be graphed. $x = \int_0^t v(t)\,dt$

ii. On the axes below, sketch the position x as a function of time t for the glider. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



GO ON TO THE NEXT PAGE.

(c) Calculate the time at which the glider makes contact with the bumper at the far right.

$t = ?$

$v = 0.50 m/s$

$x_0 = 0.25 m$

$d = 2.0 m$

$x = vt$; $x = (d - x_0)$

$d - x_0 = vt$

$t = \frac{d - x_0}{v}$

$t = \frac{((2.0) - (0.25))}{0.50}$; $t = 3.5 s$

(d) Calculate the force constant of the spring.

$k = ?$

$m = 0.40 kg$

$x_0 = 0.25 m$

$a = \frac{\Delta v}{\Delta t} \approx \frac{((0.25) - (0))}{((0.25) - (0))} = 1 m/s^2$

$F_s = ma = -kx$

$kx = ma$

$k = \frac{ma}{x}$

$k = \frac{(0.40)(1)}{(0.25)}$

$k = 1.6 N/m$

GO ON TO THE NEXT PAGE.

(e) The experiment is run again, but this time the glider is attached to the spring rather than simply being pushed against it.

i. Determine the amplitude of the resulting periodic motion.

$A = ?$

$x_o = 0.25\,m$

Since the spring is initially pressed 0.25 m, the amplititude of the periodic motion will likewise equal 0.25 m; $A = 0.25\,m$

ii. Calculate the period of oscillation of the resulting periodic motion.

$T = ?$

$m = 0.40\,kg$

$k = 1.6\,N/m$

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

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

$T = 2\pi\sqrt{\frac{(0.40)}{(1.6)}}$

$T = 3.1\,s$

GO ON TO THE NEXT PAGE.

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.

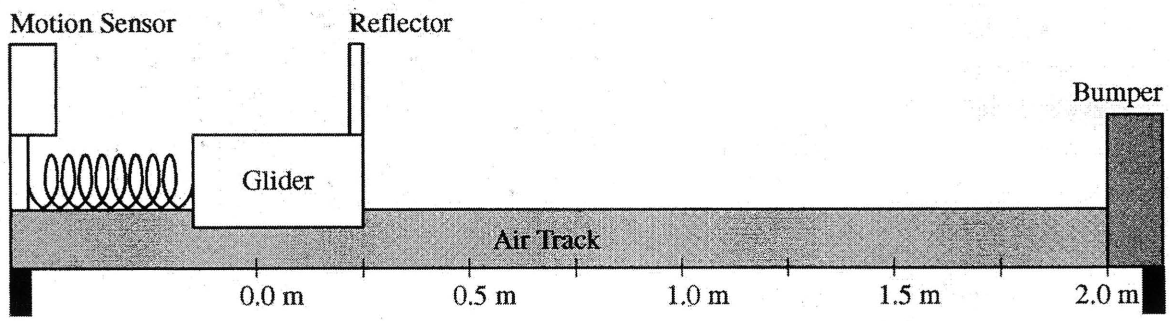


Figure 1

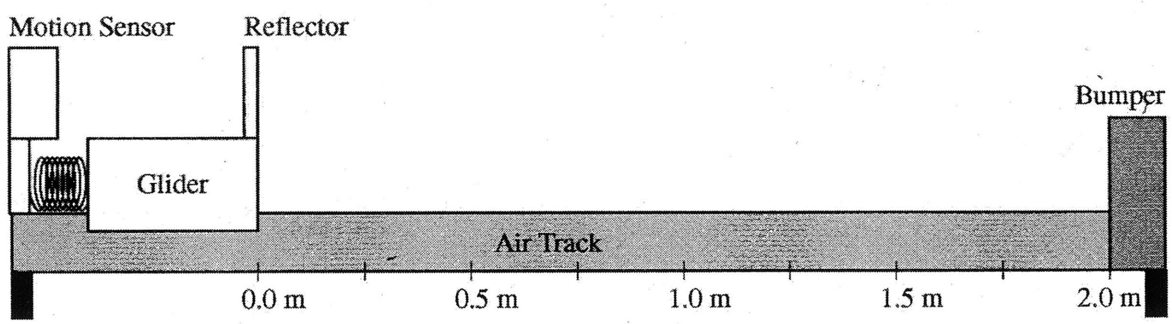


Figure 2

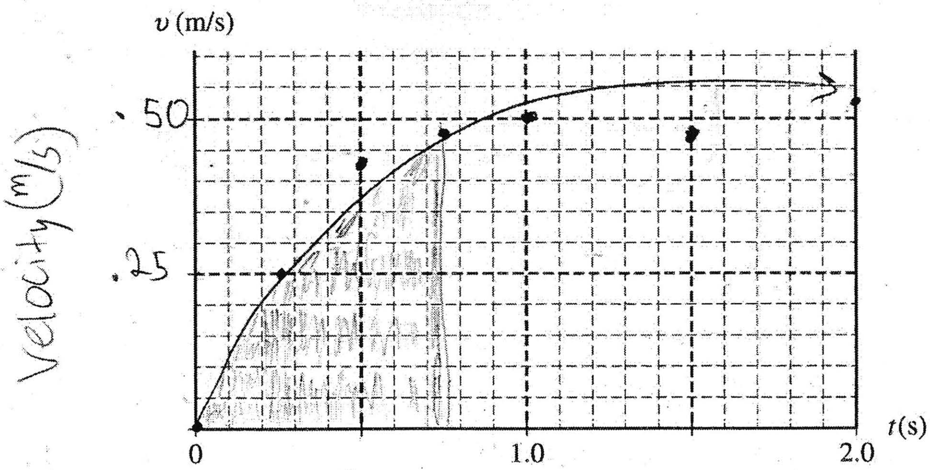
Mech 1.

A student places a 0.40 kg glider on an air track of negligible friction and holds it so that it touches an uncompressed ideal spring, as shown in Figure 1 above. The student then pushes the glider back to compress the spring by 0.25 m, as shown in Figure 2. At time $t = 0$, the student releases the glider, and a motion sensor begins recording the velocity of the reflector at the front of the glider as a function of time. The data points are shown in the table below. At time $t = 0.79$ s, the glider loses contact with the spring.

Time (s)	0	0.25	0.50	0.75	1.00	1.50	2.00
Velocity (m/s)	0	0.25	0.43	0.48	0.50	0.49	0.51

GO ON TO THE NEXT PAGE.

(a) On the axes below, plot the data points for velocity v as a function of time t for the glider, and draw a smooth curve that best fits the data. Be sure to label an appropriate scale on the vertical axis.



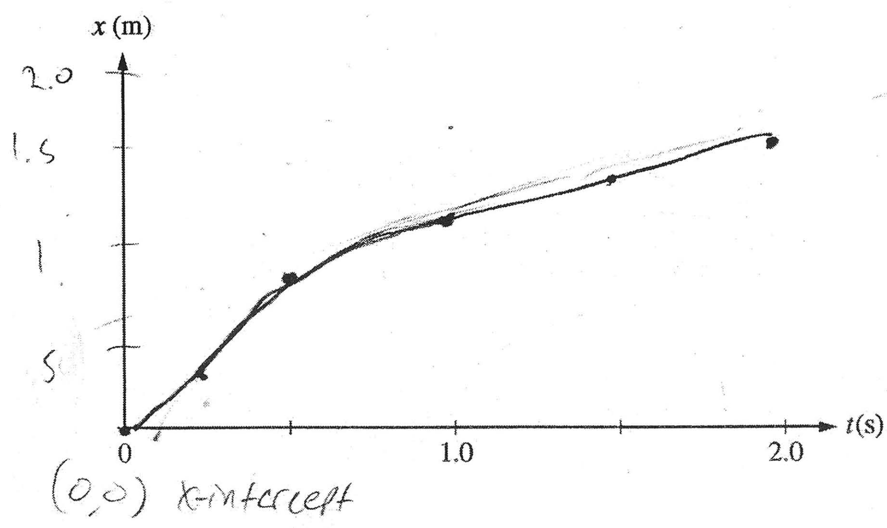
7·.05 = 7.5/100 = 35/100 = .035 16.5/100 = .8 21.5/100 = 105/1.05

(b) The student wishes to use the data to plot position x as a function of time t for the glider.

i. Describe a method the student could use to do this.

he could take the area under the curve at time t to solve for position at time t since $\int v(t)dx = X(t)$ with a C of -.25.

ii. On the axes below, sketch the position x as a function of time t for the glider. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



GO ON TO THE NEXT PAGE.

(c) Calculate the time at which the glider makes contact with the bumper at the far right.

$V_0 = .50 \text{ m/s}$

no accel

$\frac{2}{.5} =$ 4.0 seconds

(d) Calculate the force constant of the spring.

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

$\frac{1}{2}mv^2$ $\frac{1}{2}(.4)(.5^2) = \frac{1}{2}k(.25^2)$

$V = .5$ $\frac{2(.005)}{.25^2} = \frac{k(.25^2)}{.25^2}$

1.6 N/m

GO ON TO THE NEXT PAGE.

(e) The experiment is run again, but this time the glider is attached to the spring rather than simply being pushed against it.

i. Determine the amplitude of the resulting periodic motion.

.25 m

ii. Calculate the period of oscillation of the resulting periodic motion.

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

GO ON TO THE NEXT PAGE.

M1 C1

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.

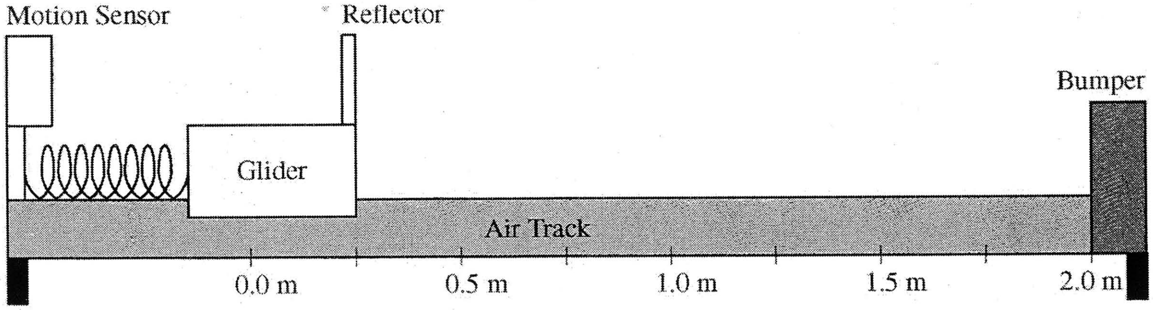


Figure 1

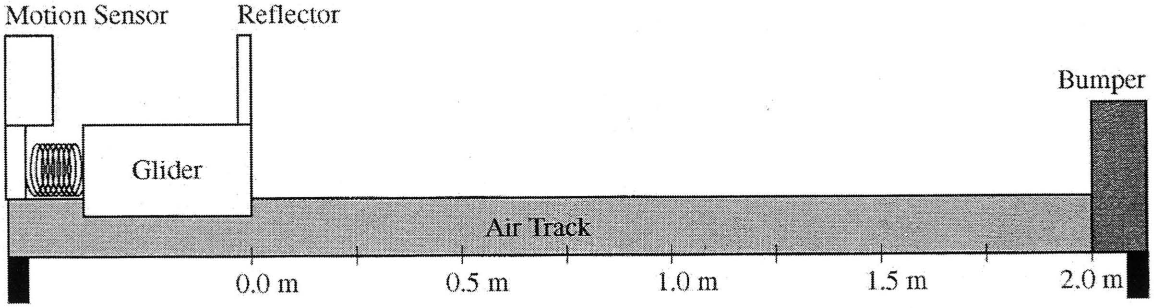


Figure 2

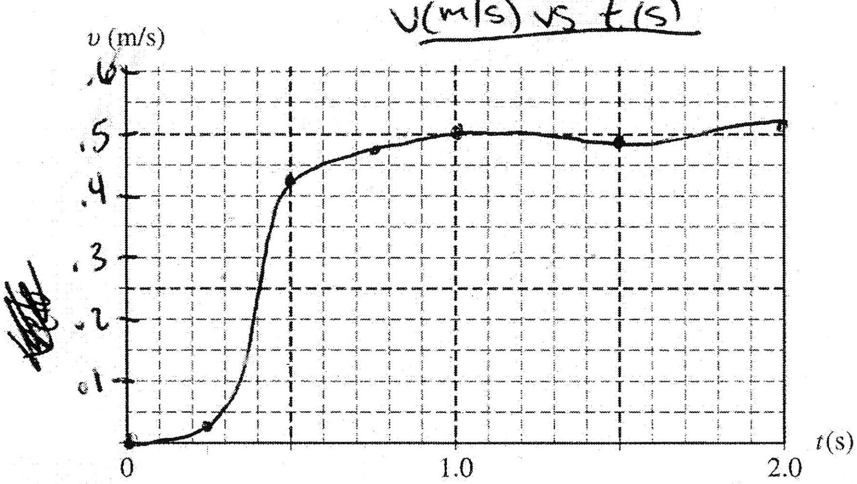
Mech 1.

A student places a 0.40 kg glider on an air track of negligible friction and holds it so that it touches an uncompressed ideal spring, as shown in Figure 1 above. The student then pushes the glider back to compress the spring by 0.25 m, as shown in Figure 2. At time $t = 0$, the student releases the glider, and a motion sensor begins recording the velocity of the reflector at the front of the glider as a function of time. The data points are shown in the table below. At time $t = 0.79$ s, the glider loses contact with the spring.

Time (s)	0	0.25	0.50	0.75	1.00	1.50	2.00
Velocity (m/s)	0	0.25	0.43	0.48	0.50	0.49	0.51

GO ON TO THE NEXT PAGE.

(a) On the axes below, plot the data points for velocity v as a function of time t for the glider, and draw a smooth curve that best fits the data. Be sure to label an appropriate scale on the vertical axis.

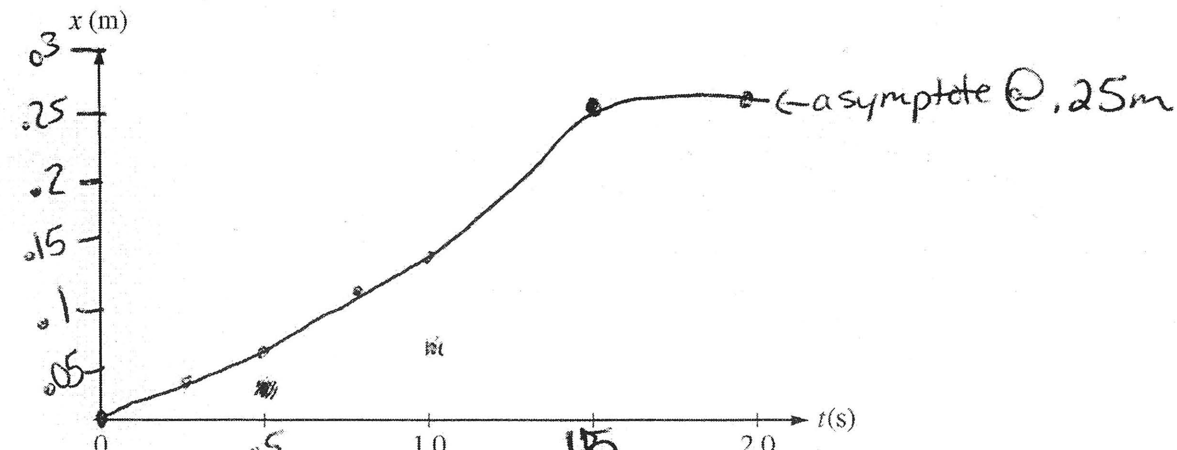


(b) The student wishes to use the data to plot position x as a function of time t for the glider.

i. Describe a method the student could use to do this.

The relationship between velocity and position is that the integral of velocity is position. Therefore, by finding the area under the graph at set intervals this would represent the position in that interval.

ii. On the axes below, sketch the position x as a function of time t for the glider. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.



Time	0	.25	.5	.75	1.00	1.5	2.0
position	0	.031	.054	.113	.125	.25	.25

GO ON TO THE NEXT PAGE.

(c) Calculate the time at which the glider makes contact with the bumper at the far right.

(d) Calculate the force constant of the spring.

$F_s = -kx$

$F = ma$

$F = (.4kg)(.2 m/s^2)$

$dv/dt = a$

Slope $= \frac{.48 - .43}{.75 - .5} = .2$

$F = .08$

$F_s = -kx$

$.08 = -k(.25m)$

$-k = .32$

$k = -.32 \text{ N/m}$

GO ON TO THE NEXT PAGE.

(e) The experiment is run again, but this time the glider is attached to the spring rather than simply being pushed against it.

i. Determine the amplitude of the resulting periodic motion.

$T_s = 2\pi\sqrt{m/k}$

$T_s = 2\pi\sqrt{.4\,kg/}$

ii. Calculate the period of oscillation of the resulting periodic motion.

$T_p = 2\pi\sqrt{\ell/g}$

$T_p = 2\pi\sqrt{\frac{2m}{10m/s^2}}$

$T_p = 2.81\,s$

GO ON TO THE NEXT PAGE.

Question 1

Overview

This question analyzed and interpreted simple harmonic motion with a variable force by graphical and analytical methods. Part (a) graphs the given data. Part (b)(i) describes how to determine the position-time graph from the graph/data in part (a). Part (b)(ii) is a sketch of the position as a function of time. Part (c) calculates the total time for both the accelerated motion and the constant velocity portion of the motion. Part (d) calculates the spring force constant. Part (e)(i) determines the amplitude of oscillation. Part (e)(ii) calculates the period of oscillation.

Sample: M1-A
Score: 13

Full credit was earned in part (a) for an exemplary graph. Full credit was also earned in part (b)(i) for a well described method for plotting position versus time. A correctly sketched graph of glider position versus time earned full credit in part (b)(ii). The student earned 1 point in part (c) for using constant velocity and determining the time for the cart to move from the end of the spring to the bumper at the 2 meter mark. The time interval during glider contact with spring was not determined and the total time was not calculated. The correct calculation of force constant with proper units earned full credit in part (d). Part (e)(i) earned full credit for realizing that the original displacement is equal to the amplitude. Part (e)(ii) earned full credit for correct calculation of the period.

Sample: M1-B
Score: 8

Part (a) earned two points for the correct axis scale and for the smooth curve with increasing velocity. The horizontal line is not a best fit with the data plotted. It should be closer to $v = 0.5\ \text{m/s}$. Part (b)(i) earned full credit for a correct method for plotting a graph of position versus time. Part (b)(ii) earned 1 point for the constant velocity segment of the graph and for the smooth transition from accelerated to non-accelerated motion near 0.79 seconds. The first portion of the graph representing the accelerated motion was drawn incorrectly. No credit was earned in part (c) for assuming constant velocity during the entire motion of the glider. Part (d) earned full credit for a correct calculation of the spring constant with proper units. Part (e)(i) earned full credit for the determination of the amplitude. No credit was earned in part (e).

Sample: M1-C
Score: 3

Part (a) earned 1 point for the correct axis scale. The second data point was incorrectly plotted and no credit was earned for the smooth curve illustrating the increasing velocity of the glider. The "dot-to-dot" nature of the curve for the constant velocity portion of the motion does not accurately reflect a best fit. Part (b)(i) earned full credit for a correct method of plotting a graph of position versus time. Part (b)(ii) earned 1 point for a curve representing the position of the glider during the accelerated portion of the motion. The horizontal line does not earn credit, as the glider leaves the spring with a constant velocity. The smooth transition does not occur near the 0.79 second time when the glider left contact with the spring. Part (c) is blank. Part (d) earned no credit for using an incorrect method of calculating the spring constant. Part (e)(i) earned no credit for incorrectly determining the amplitude. Part (e)(ii) earned no credit for attempting to use the period of a pendulum equation for a spring problem.