



AP[®] Physics C: Mechanics 2013 Scoring Guidelines

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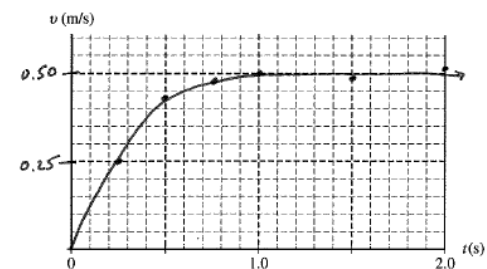
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Question 1

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.

$$x = \int v dt$$

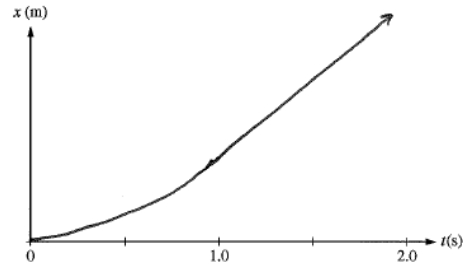
The slope of x as a function of t would yield the v versus t graph in part (a).

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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 = $0.25 \text{ m/s} \times 0.5 \text{ s} = 0.125 \text{ m}$)
- 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
- $d_1 + d_2 = 2.0 \text{ m}$
- $0.36 \text{ m} + (0.50 \text{ m/s})(t - 1.0 \text{ s}) = 2.0 \text{ m}$
- $t = \frac{(2.0 - 0.36) \text{ m}}{0.50 \text{ m/s}} + 1.0 \text{ s} = 4.3 \text{ s}$

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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 $t_1 = 0.79$ s at

1 point

$$d_1 = 0.25 \text{ m}$$

$$d_2 = 2.0 \text{ m} - 0.25 \text{ m} = 1.75 \text{ m}$$

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

$$U_{S1} = K_2$$

1 point

$$\frac{1}{2} k x_1^2 = \frac{1}{2} m v_2^2$$

$$k = \frac{m v_2^2}{x_1^2}$$

$$k = \frac{m v_2^2}{x_1^2} = \frac{(0.40 \text{ kg})(0.50 \text{ m/s})^2}{(0.25 \text{ m})^2}$$

For a correct answer, with correct units

1 point

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

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Question 1 (continued)

	Distribution of points
(e)	
i. 1 point	
For the correct amplitude $x_m = 0.25 \text{ m}$	1 point
ii. 2 points	
For some work that uses a correct expression for the period of a spring $T = 2\pi\sqrt{\frac{m}{k}}$	1 point
For correct substitution of consistent values $T = 2\pi\sqrt{\frac{(0.40 \text{ kg})}{(1.6 \text{ N/m})}} = 3.1 \text{ s}$	1 point
<i>Alternate Solution</i>	<i>Alternate Points</i>
<i>For recognizing that the 0.79 s of contact time is one quarter of a period</i>	1 point
<i>For giving the period as four times the contact time</i> $T = 4(0.79 \text{ s}) = 3.2 \text{ s}$	1 point

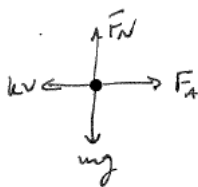
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 Last Saved By: Windows SOE Manager
 Total Editing Time: 10 Minutes
 Last Printed On: 7/10/2013 3:40:00 PM
 As of Last Complete Printing
 Number of Pages: 4
 Number of Words: 465 (approx.)
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Question 2

15 points total

(a) 4 points



For correctly showing and labeling the applied force directed to the right
For correctly showing and labeling the downward gravitational force
For correctly showing and labeling the upward normal force
For correctly showing and labeling the drag force directed to the left
One earned point was deducted for having any extraneous vectors

(b) 2 points

$$F_{\text{net}} = ma$$

For the correct substitution into Newton's second law

$$F_A - kv = ma$$

For a correct differential equation

$$F_A - kv = m \frac{dv}{dt}$$

(c) 1 point

Set $\frac{dv}{dt} = 0$ in the equation from part (b)

$$F_A - kv = 0$$

For the correct expression for the terminal velocity

$$v_T = \frac{F_A}{k}$$

**Distribution
of points**

1 point
1 point
1 point
1 point

1 point

1 point

1 point

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Question 2 (continued)

**Distribution
of points**

(d) 5 points

Use the differential equation from part (b)

$$F_A - kv = m \frac{dv}{dt}$$

For demonstrating separation of variables

$$\frac{1}{m} dt = \frac{1}{F_A - kv} dv$$

For demonstrating that the equation must be integrated

$$\int \frac{1}{m} dt = \int \frac{1}{F_A - kv} dv$$

For demonstrating substitution using initial and final values (or evaluating the constant of integration using the boundary conditions)

$$\int_0^t \frac{1}{m} dt = \int_0^{v(t)} \frac{1}{F_A - kv} dv$$

$$\left[\frac{t}{m} \right]_0^t = -\frac{1}{k} [\ln(F_A - kv)]_0^{v(t)}$$

For attempting to solve for $v(t)$

$$-\frac{kt}{m} = \ln\left(\frac{F_A - kv(t)}{F_A}\right)$$

$$e^{-kt/m} = \frac{F_A - kv(t)}{F_A} = 1 - \frac{kv(t)}{F_A}$$

$$\frac{kv(t)}{F_A} = 1 - e^{-kt/m}$$

For a correct answer

$$v(t) = \frac{F_A}{k} (1 - e^{-kt/m})$$

1 point

1 point

1 point

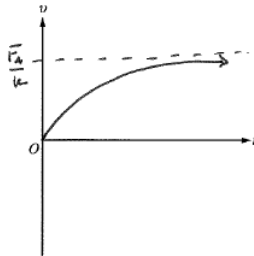
1 point

1 point

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Question 2 (continued)

(e) 3 points



**Distribution
of points**

For a graph that begins at the origin, with a non-negative slope everywhere,
and is concave downward
For a graph with a horizontal asymptote
For the correct label of the expression for the asymptote or maximum on the
vertical axis

1 point

1 point

1 point

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Total Editing Time: 1 Minute
Last Printed On: 7/10/2013 3:41:00 PM
As of Last Complete Printing
Number of Pages: 3
Number of Words: 268 (approx.)
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Question 3

15 points total

**Distribution
of points**

(a) 2 points

For a correct expression indicating that $F_{net} = 0$

$$2F_A - Mg = 0$$

$$F_A = Mg/2$$

$$F_A = (2.0 \text{ kg})(9.8 \text{ m/s}^2)/2$$

For a correct answer

$$F_A = 9.8 \text{ N} \quad (\text{or } 10 \text{ N using } g = 10 \text{ m/s}^2)$$

1 point

(b) 5 points

For a correct expression of Newton's second law for translational motion

$$F_{net} = Ma$$

$$F_A + T - Mg = Ma \text{ (equation 1)}$$

For using a correct expression of torque in Newton's second law for rotational motion

$$\tau = I\alpha$$

$$F_A R - TR = (MR^2/2)\alpha \quad \text{or} \quad F_A R - TR = I\alpha$$

For substituting for the angular acceleration in terms of the linear acceleration ($\alpha = a/R$)

$$F_A R - TR = (MR^2/2)(a/R)$$

$$F_A - T = Ma/2 \text{ (equation 2)}$$

For combining equations 1 and 2 to solve for the linear acceleration

Add the two equations

$$2F_A - Mg = (3/2)Ma$$

$$a = (2/3)((2F_A/M) - g)$$

$$a = (2/3)((2(12 \text{ N})/2.0 \text{ kg}) - 9.8 \text{ m/s}^2)$$

For a correct answer, with units

$$a = 1.47 \text{ m/s}^2 \quad (1.33 \text{ m/s}^2 \text{ using } g = 10 \text{ m/s}^2)$$

1 point

1 point

1 point

1 point

1 point

(c) 2 points

For using the relationship between linear and angular acceleration in the equation for angular speed

$$\omega = \omega_0 + \alpha t \quad \text{and} \quad \alpha = a/R$$

$$\omega_0 = 0, \text{ so } \omega = \alpha t/R$$

$$\omega = (1.47 \text{ m/s}^2)(3.0 \text{ s})/(0.10 \text{ m})$$

1 point

1 point

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Question 3 (continued)

**Distribution
of points**

For an answer with units, consistent with previous work

$$\omega = 44 \text{ rad/s} \quad (40 \text{ rad/s using } g = 10 \text{ m/s}^2)$$

(d) 4 points

Express the change in mechanical energy as the sum of the change in potential energy and the change in kinetic energy

$$\Delta E = \Delta U_g + \Delta K$$

For a correct expression for the change in kinetic energy including both translational and rotational kinetic energy

$$\Delta K = \frac{1}{2}M(v^2 - v_0^2) + \frac{1}{2}I(\omega^2 - \omega_0^2)$$

For a correct expression for the change in potential energy, including a correct expression of the height h in terms of the time

$$\Delta U_g = Mgh = Mg\left(\frac{1}{2}at^2\right)$$

$$v_0 \text{ and } \omega_0 \text{ are zero, so } \Delta E = Mg\left(\frac{1}{2}at^2\right) + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

For simplifying the expression using the relationship between linear velocity and angular velocity

$$\Delta E = Mg\left(\frac{1}{2}at^2\right) + \frac{1}{2}M(R\omega)^2 + \frac{1}{2}(MR^2/2)\omega^2$$

$$\Delta E = \frac{1}{2}Mgat^2 + \frac{3}{4}MR\omega^2$$

For correctly substituting given values and answers from previous parts into a correct expression

$$\Delta E = \frac{1}{2}(2.0 \text{ kg})(9.8 \text{ m/s}^2)(1.47 \text{ m/s}^2)(3.0 \text{ s})^2 + \frac{3}{4}(2.0 \text{ kg})(0.10 \text{ m})^2(44 \text{ rad/s})^2$$

$$\Delta E = 159 \text{ J} \quad (144 \text{ J using } g = 10 \text{ m/s}^2)$$

1 point

1 point

1 point

1 point

(e) 2 points

For selecting "Less than"

For a correct justification

1 point

1 point

Example

The rotational inertia of a hoop is greater than that of a solid disk of the same mass and radius, therefore the acceleration of the hoop would be less.

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