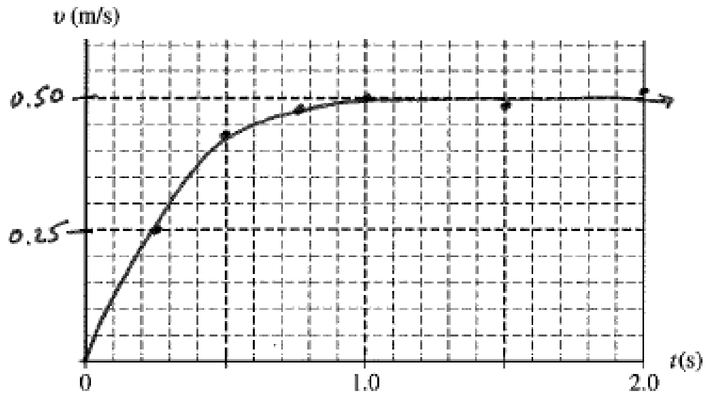
AP® Physics C: Mechanics
2013 Scoring Guidelines

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

<u>Examples</u>

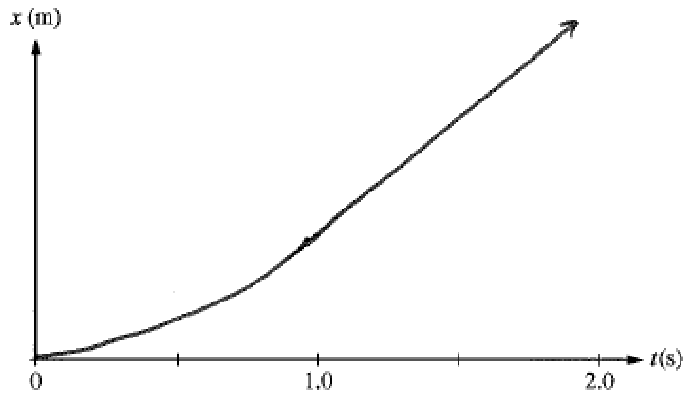
Plot the area under the velocity curve from part (a) as a function of time.

$x = \int v dt$

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*
$t_2 = d_2/\upsilon = 1.75\ \text{m}/0.50\ \text{m/s} = 3.5\ \text{s}$	
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 υ — 1 point

$$U_{S1} = K_2$$

$$\frac{1}{2}kx_1^2 = \frac{1}{2}m\upsilon_2^2$$

$$k = \frac{m\upsilon_2^2}{x_1^2}$$

$$k = \frac{m\upsilon_2^2}{x_1^2} = \frac{(0.40\ \text{kg})(0.50\ \text{m/s})^2}{(0.25\ \text{m})^2}$$

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 $x_m = 0.25\text{ m}$	1 point
ii. 2 points	
For some work that uses a correct expression for the period of a spring $T = 2\pi\sqrt{\dfrac{m}{k}}$	1 point
For correct substitution of consistent values $T = 2\pi\sqrt{\dfrac{(0.40\text{ kg})}{(1.6\text{ N/m})}} = 3.1\text{ s}$	1 point
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 $T = 4(0.79\text{ s}) = 3.2\text{ s}$	*1 point*

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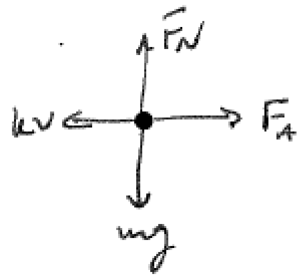
Question 2

15 points total | **Distribution of points**

(a) 4 points



For correctly showing and labeling the applied force directed to the right — 1 point
For correctly showing and labeling the downward gravitational force — 1 point
For correctly showing and labeling the upward normal force — 1 point
For correctly showing and labeling the drag force directed to the left — 1 point
One earned point was deducted for having any extraneous vectors

(b) 2 points

$F_{net} = ma$

For the correct substitution into Newton's second law — 1 point

$F_A - kv = ma$

For a correct differential equation — 1 point

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

(c) 1 point

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

$F_A - kv = 0$

For the correct expression for the terminal velocity — 1 point

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

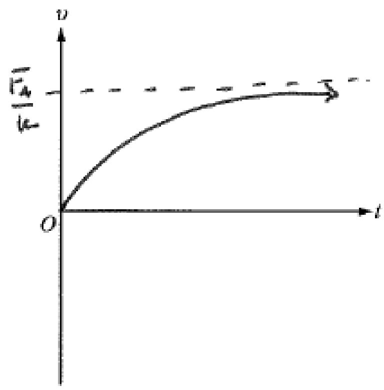
Question 2 (continued)

		Distribution of points
(d)	5 points	
	Use the differential equation from part (b)	
	$F_A - kv = m\dfrac{dv}{dt}$	
	For demonstrating separation of variables	1 point
	$\dfrac{1}{m}dt = \dfrac{1}{F_A - kv}dv$	
	For demonstrating that the equation must be integrated	1 point
	$\displaystyle\int \frac{1}{m}dt = \int \frac{1}{F_A - kv}dv$	
	For demonstrating substitution using initial and final values (or evaluating the constant of integration using the boundary conditions)	1 point
	$\displaystyle\int_0^t \frac{1}{m}dt = \int_0^{v(t)} \frac{1}{F_A - kv}dv$	
	$\left[\dfrac{t}{m}\right]_0^t = -\dfrac{1}{k}\left[\ln\left(F_A - kv\right)\right]_0^{v(t)}$	
	For attempting to solve for $v(t)$	1 point
	$-\dfrac{kt}{m} = \ln\left(\dfrac{F_A - kv(t)}{F_A}\right)$	
	$e^{-kt/m} = \dfrac{F_A - kv(t)}{F_A} = 1 - \dfrac{kv(t)}{F_A}$	
	$\dfrac{kv(t)}{F_A} = 1 - e^{-kt/m}$	
	For a correct answer	1 point
	$v(t) = \dfrac{F_A}{k}\left(1 - e^{-kt/m}\right)$	

Question 2 (continued)

Distribution of points

(e) 3 points



For a graph that begins at the origin, with a non-negative slope everywhere, and is concave downward	1 point
For a graph with a horizontal asymptote	1 point
For the correct label of the expression for the asymptote or maximum on the vertical axis	1 point

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Question 3

15 points total | **Distribution of points**

(a) 2 points

For a correct expression indicating that $F_{net} = 0$ — 1 point

$2F_A - Mg = 0$

$F_A = Mg/2$

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

For a correct answer — 1 point

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

(b) 5 points

For a correct expression of Newton's second law for translational motion — 1point

$F_{net} = Ma$

$F_A + T - Mg = Ma$ (equation 1)

For using a correct expression of torque in Newton's second law for rotational motion — 1 point

$\tau = I\alpha$

$F_AR - TR = \left(MR^2/2\right)\alpha$ or $F_AR - TR = I\alpha$

For substituting for the angular acceleration in terms of the linear acceleration $(\alpha = a/R)$ — 1 point

$F_AR - TR = \left(MR^2/2\right)(a/R)$

$F_A - T = Ma/2$ (equation 2)

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

Add the two equations

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

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

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

For a correct answer, with units — 1 point

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

(c) 2 points

For using the relationship between linear and angular acceleration in the equation for angular speed — 1 point

$\omega = \omega_0 + \alpha t$ and $\alpha = a/R$

$\omega_0 = 0$, so $\omega = at/R$

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

1 point

Question 3 (continued)

Distribution of points

For an answer with units, consistent with previous work

$\omega = 44 \text{ rad/s}$ (40 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 — 1 point

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

For a correct expression for the change in potential energy, including a correct expression of the height h in terms of the time — 1 point

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

v_0 and ω_0 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 — 1 point

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

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

For correctly substituting given values and answers from previous parts into a correct expression — 1 point

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

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

(e) 2 points

For selecting "Less than" — 1 point

For a correct justification — 1 point

<u>Example</u>

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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