AP® Physics C: Mechanics
2005 Scoring Guidelines

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AP® PHYSICS C MECHANICS
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General Notes About 2005 AP Physics Scoring Guidelines

1. The solutions contain the most common method(s) of solving the free-response questions and the allocation of points for these solutions. 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. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one 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.

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.

5. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. The exception is usually 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 lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

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Question 1

15 points total **Distribution of points**

(a) 2 points

For indicating that the magnitude of the acceleration decreases as the ball moves upward 1 point
For a correct, reasonable justification 1 point
For example: Since velocity is upward, air resistance is downward, in the same direction as gravity. The velocity will decrease, causing the force of air resistance to decrease. Therefore, the net force and thus the total acceleration both decrease.

(b) 3 points

For showing the expression $a = \frac{dv}{dt}$ 1 point

For any clear indication that the forces of air resistance and gravity are in the same direction, such as by showing an equation or a free-body diagram 1 point

$F_{\text{net}} = -Mg - kv$

For a correct differential equation with the correct signs 1 point

$M\frac{dv}{dt} = -Mg - kv$

(c) 3 points

For recognizing that at terminal speed $F_{\text{net}} = 0$ 1 point

For any clear indication that the forces of air resistance and gravity are now in opposite directions, such as by showing an equation or a free-body diagram 1 point

$F_{\text{net}} = -Mg + kv$

$0 = -Mg + kv_{\text{T}}$

For a correct expression for the terminal speed 1 point

$v_{\text{T}} = Mg/k$

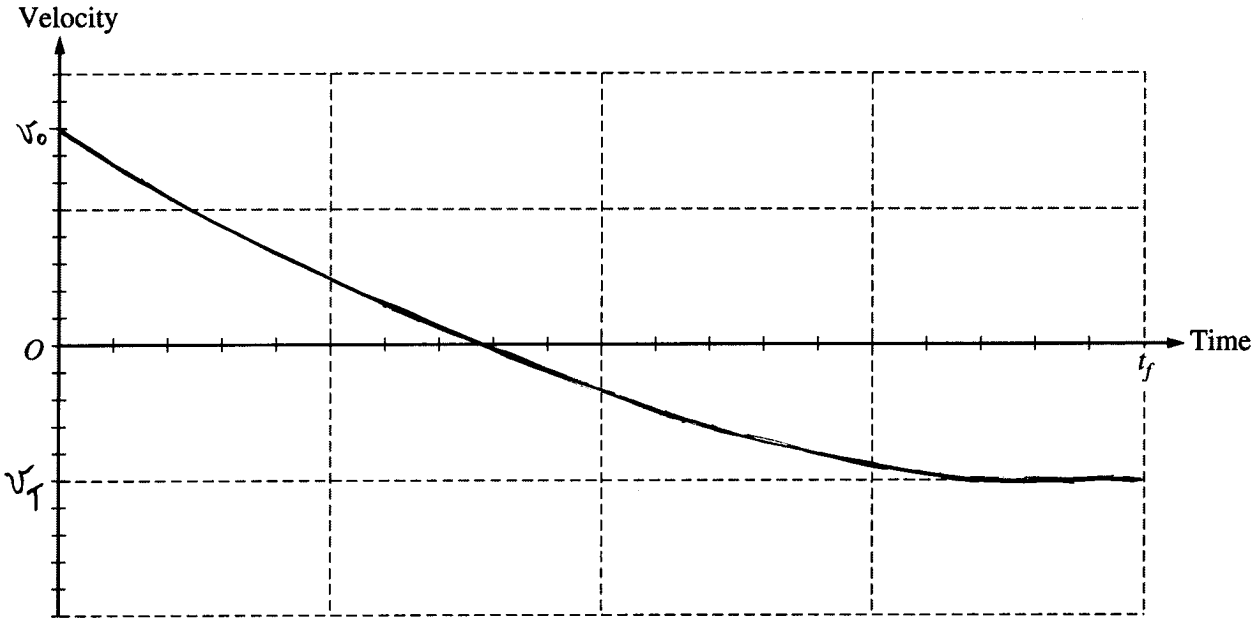
(d) 2 points

For indicating that it takes longer for the ball to fall 1 point
For a correct, reasonable justification 1 point
For example: The ball loses mechanical energy on the way up and on the way down. This means the average speed is greater on the way up than on the way down. Since the distance traveled is the same, the time must be longer on the way down.

Question 1 (continued)

Distribution of points

(e) 5 points



For an exponentially decreasing curve beginning with positive initial velocity v_0, crossing the time axis at t less than $t_f/2$, and having the final speed less than the initial speed — 5 points

One point partial credit was awarded for each of the following curve characteristics.

For showing that when $v = 0$, the curve is differentiable (i.e., no discontinuity in slope) and has a negative slope

For showing the curve to be concave upward both for when the ball is rising and when the ball is falling

For showing time intervals for when the ball is rising and when the ball is falling that are consistent with the answer to part (d)

For showing that the final velocity is negative and that the speed at t_f is less than v_0

Question 2

15 points total **Distribution of points**

(a) 1 point

For a correct expression of Newton's law of gravity containing the mass of Saturn, with or without the minus sign 1 point

$F = \frac{GM_S m}{R^2}$, where m is the mass of a moon

(b) 3 points

Circular orbit means the force is centripetal.

For equating Newton's law of gravity to the centripetal force 1 point

$\frac{GM_S m}{R^2} = \frac{mv^2}{R}$ OR $F_g = F_c$

For correctly relating the orbital speed and the period 1 point

$v = 2\pi R/T$ OR $v = \omega r$ and $\omega = 2\pi/T$

$\frac{GM_S m}{R^2} = \frac{m}{R}\left(\frac{2\pi R}{T}\right)^2$

For a correct relationship between T and R 1 point

$GM_S T^2 = 4\pi^2 R^3$ OR $T = \sqrt{\frac{4\pi^2}{GM_S}} R^{3/2}$

(c) 1 point

For any correct pair of quantities that would yield a straight line when graphed 1 point

For example, T^2 versus R^3 OR T versus $R^{3/2}$

(d) 3 points

For appropriate and correct table headings, i.e., powers of T and R consistent with answer to part (b) 1 point

For correct units in both columns 1 point

For correct numerical values in at least 75 percent of the table entries, provided that the table will yield a linear graph 1 point

Full credit was awarded for completing only one column containing $R^{3/2}$.

(Example data on next page.)

Question 2 (continued)

Distribution of points

(d) (continued)

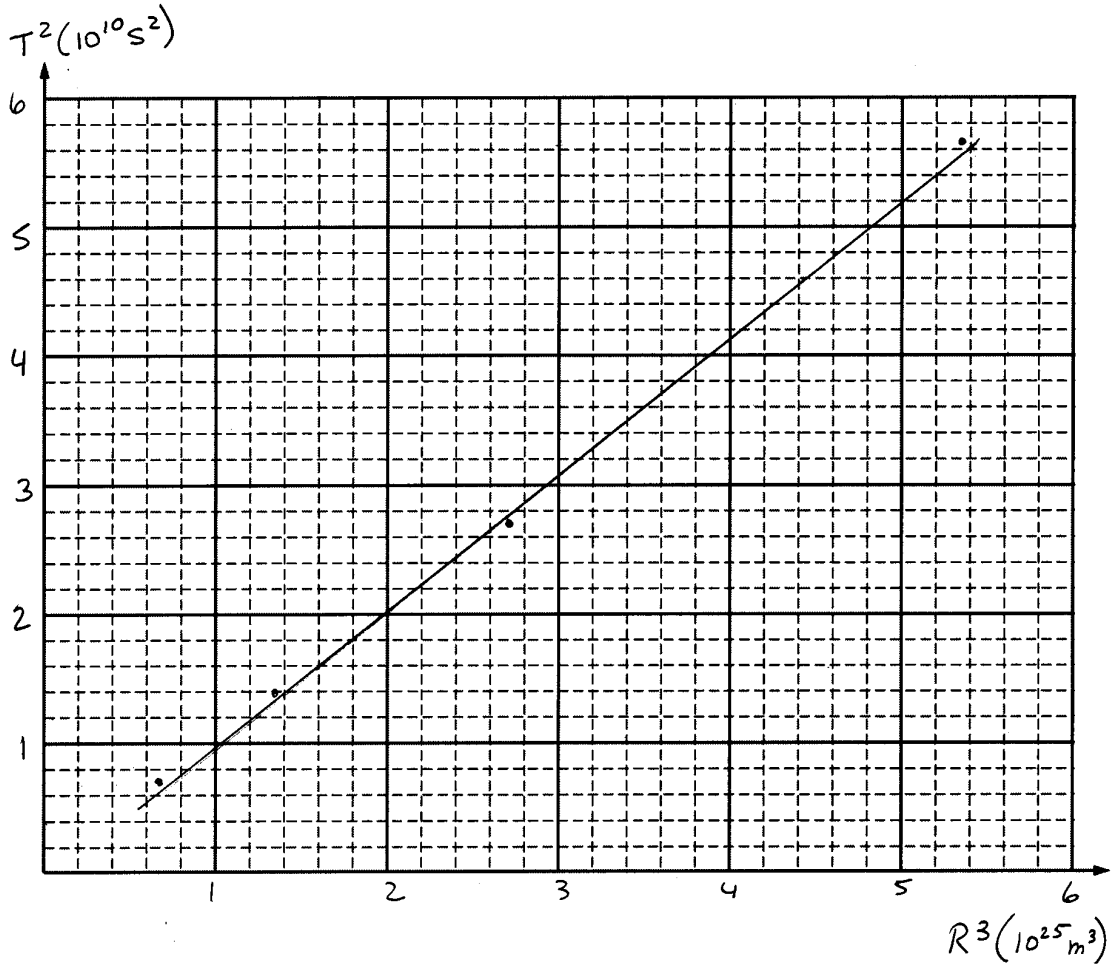
Example data

Orbital Period, T (seconds)	Orbital Radius, R (meters)	T^2 $\left(s^2\right)$	R^3 $\left(m^3\right)$
8.14×10^4	1.85×10^8	0.663×10^{10}	0.633×10^{25}
1.18×10^5	2.38×10^8	1.39×10^{10}	1.35×10^{25}
1.63×10^5	2.95×10^8	2.66×10^{10}	2.57×10^{25}
2.37×10^5	3.77×10^8	5.62×10^{10}	5.36×10^{25}

(e) 4 points

For axis labels consistent with the table and having correct units	1 point
For appropriate numbering of axes	1 point
For correctly plotting data from table (only awarded if numbering is correct)	1 point
For drawing a best-fit linear graph (only awarded if data define a linear graph)	1 point

Example response



Question 2 (continued)

Distribution of points

(f) 3 points

For correctly indicating a calculation of the slope of the graph (only awarded if graph is drawn) 1 point

From the graph shown here

$$\text{slope} = \frac{\left(5.6 \times 10^{10} - 1.4 \times 10^{10}\right)\text{m}^3}{\left(5.4 \times 10^{25} - 1.4 \times 10^{25}\right)\text{s}^2} = \frac{4.2 \times 10^{10}\ \text{m}^3}{4.0 \times 10^{25}\ \text{s}^2}$$

For relating the slope to the equation obtained in part (b) 1 point

In the example shown here, $T^2 = \frac{4\pi^2}{GM_S}R^3$.

$$\text{slope of line} = \frac{4\pi^2}{GM_S}$$

$$M_S = \frac{4\pi^2}{G\ (\text{slope})}$$

$$M_S = \frac{4\pi^2}{6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2}\ \frac{4.0 \times 10^{25}\ \text{s}^2}{4.2 \times 10^{10}\ \text{m}^3}$$

For the correct numerical answer 1 point

$$M_S = 5.64 \times 10^{26}\ \text{kg}$$

Solutions for which the slope yields Saturn's mass directly (e.g., table columns of $4\pi^2R^3$ versus GT^2) received full credit.

Question 3

15 points total **Distribution of points**

(a) 1 point

$L_r = I\omega$, where $I = (1/3)M_1d^2$

For the correct expression for angular momentum before the collision 1 point

$L_r = (1/3)M_1d^2\omega$

Note: An expression without an equation was acceptable. This point was not awarded if the expression was not given in terms of the given quantities.

(b) 4 points

For any indication of conservation of angular momentum 1 point

$L_b = L_r$

For the correct expression for L_b 1 point

For substitution for L_r consistent with part (a) 1 point

$M_2\upsilon d = \frac{1}{3}M_1d^2\omega$

For the correct final expression for υ 1 point

$\upsilon = \frac{1}{3}\frac{M_1}{M_2}d\omega$

(c) 4 points

For any indication of conservation of kinetic energy 1 point

No points were awarded for conservation of mechanical energy.

$K_b = K_r$

For the correct expressions for both kinetic energies 1 point

$\frac{1}{2}M_2\upsilon^2 = \frac{1}{2}I\omega^2$

$M_2\upsilon^2 = I\omega^2$

For correct substitutions for I and for υ consistent with part (b) 1 point

$M_2\left(\frac{1}{3}\frac{M_1}{M_2}d\omega\right)^2 = \left(\frac{1}{3}M_1d^2\right)\omega^2$

$M_2\frac{1}{9}\left(\frac{M_1}{M_2}\right)^2 d^2\omega^2 = \frac{1}{3}M_1d^2\omega^2$

$\frac{1}{9}\frac{M_1^2}{M_2} = \frac{1}{3}M_1$

For the correct final expression for the ratio 1 point

$M_1/M_2 = 3$ (3:1 was also acceptable)

Question 3 (continued)

Distribution of points

(d) 6 points

For the correct equation for conservation of angular momentum — 2 points

$M_1 \upsilon x = \frac{1}{3} M_1 d^2 \omega$

For solving this equation for υ — 1 point

$\upsilon = \frac{1}{3} \frac{d^2}{x} \omega$

For the correct equation for conservation of kinetic energy — 1 point

$\frac{1}{2} M_1 \upsilon^2 = \frac{1}{2} I \omega^2$

$M_1 \upsilon^2 = \left(\frac{1}{3} M_1 d^2 \right) \omega^2$

$\upsilon^2 = \frac{1}{3} d^2 \omega^2$

For the correct substitution of the above expression for υ from momentum conservation into the equation for conservation of kinetic energy — 1 point

$\left(\frac{1}{3} \frac{d^2}{x} \omega \right)^2 = \frac{1}{3} d^2 \omega^2$

$\frac{1}{9} \frac{d^4}{x^2} \omega^2 = \frac{1}{3} d^2 \omega^2$

$\frac{1}{x^2} = \frac{9}{3} \frac{1}{d^2}$

For the correct final answer — 1 point

$x = \frac{d}{\sqrt{3}}$