AP® Physics C: Mechanics
2007 Scoring Guidelines

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AP® PHYSICS C: MECHANICS
2007 SCORING GUIDELINES

General Notes About 2007 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. 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 1 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. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics exam equation sheet. See pages 21–22 of the *AP Physics Course Description* for a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each.

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. Solutions usually show numerical answers using both values when they are significantly different.

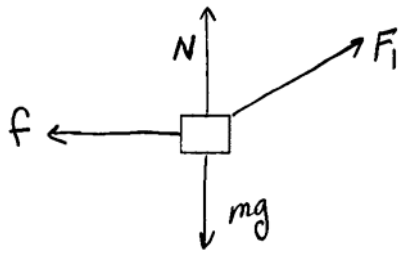
5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur 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.

AP® PHYSICS C: MECHANICS
2007 SCORING GUIDELINES

Question 1

15 points total **Distribution of points**

(a) 4 points



For each of the forces shown above with arrow correctly drawn and labeled, 1 point was awarded — 4 points

For each incorrect or extraneous vector, such as acceleration or velocity, a point was deducted, with the minimum possible score being 0.

(b) 2 points

$\sum F_y = 0$

For the correct y component of F_1 — 1 point

$N + F_1 \sin\theta - mg = 0$

For the correct answer — 1 point

$N = mg - F_1 \sin\theta$

(c) 3 points

$\sum F_x = ma$

For showing correct expressions for the horizontal forces and setting them equal to ma_1 — 1 point

$F_1 \cos\theta - \mu N = ma_1$

For substituting the expression for N from part (b) — 1 point

$F_1 \cos\theta - \mu(mg - F_1 \sin\theta) = ma_1$

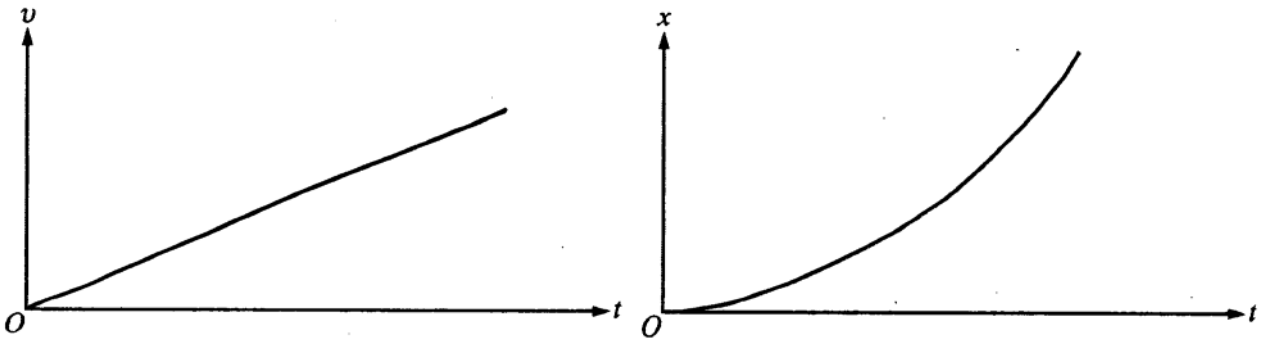
For the correct answer — 1 point

$\mu = \dfrac{F_1 \cos\theta - ma_1}{mg - F_1 \sin\theta}$

Question 1 (continued)

Distribution of points

(d) 3 points



For a linear relationship on the v versus t graph with positive slope and with $v = 0$ at $t = 0$ — 1 point

For a parabolic relationship on the x versus t graph that is concave upward, with $x = 0$ at $t = 0$ — 1 point

For the two graphs being consistent with each other — 1 point

(e) 3 points

For indicating that $N = 0$ is the condition for the maximum acceleration of the block before it loses contact — 1 point

For indicating that the friction force is zero — 1 point

$f = \mu N = 0$

$\sum F_x = F_{\max}\cos\theta = ma_{\max}$

$a_{\max} = \dfrac{F_{\max}\cos\theta}{m}$

$\sum F_y = F_{\max}\sin\theta - mg = 0$

$F_{\max} = \dfrac{mg}{\sin\theta}$

Substituting $F_{\max}$ into the expression for $a_{\max}$ above

$a_{\max} = \dfrac{mg}{\sin\theta}\dfrac{\cos\theta}{m}$

For the correct answer — 1 point

$a_{\max} = g\cot\theta$

Note: Since F_1 is a variable quantity in this problem and since the initial directions included F_1 as a quantity that could be used in expressions for the answers, the expression $a_{\max} = \dfrac{F_1\cos\theta}{m}$ was also acceptable for the answer point.

AP® PHYSICS C: MECHANICS
2007 SCORING GUIDELINES

Question 2

15 points total **Distribution of points**

(a) 2 points

For a correct expression of the relationship among T, R, and υ 1 point

$$T = \frac{2\pi R}{\upsilon}$$

$$R = \frac{\upsilon T}{2\pi}$$

$$R = \frac{\left(3.40 \times 10^3 \text{ m/s}\right)\left(7.08 \times 10^3 \text{ s}\right)}{2\pi}$$

For the correct numerical answer 1 point

$$R = 3.83 \times 10^6 \text{ m}$$

(b) 2 points

For correctly equating centripetal force and gravitational force 1 point

$$\frac{m_s \upsilon^2}{R} = \frac{G m_s M_M}{R^2}$$

$$M_M = \frac{\upsilon^2 R}{G}$$

For substituting the value of R from (a) into either the original equation or the simplified expression for M_M above 1 point

$$M_M = \frac{\left(3.40 \times 10^3 \text{ m/s}\right)^2 \left(3.83 \times 10^6 \text{ m}\right)}{6.67 \times 10^{-11} \text{ m}^3/\text{kg}\cdot\text{s}^2}$$

$$M_M = 6.64 \times 10^{23} \text{ kg}$$

Question 2 (continued)

Distribution of points

(c) 4 points

For a correct expression that equates E_{tot} to the sum of kinetic and gravitational potential energies — 1 point

$E_{tot} = K + U$

For a negative sign on a correct expression for U_G — 1 point

$$E_{tot} = \frac{1}{2}m_s v^2 - \frac{Gm_s M_M}{R}$$

For explicit substitution of the value of *R* from (a) and the value of M_M from (b) in the equation above or for correct numerical answer if worked as follows: — 1 point

From (b), $M_M = \frac{v^2 R}{G}$

$$E_{tot} = \frac{1}{2}m_s v^2 - \frac{Gm_s}{R}\frac{v^2 R}{G} = \frac{1}{2}m_s v^2 - m_s v^2 = -\frac{1}{2}m_s v^2$$

$$E_{tot} = -\frac{1}{2}(930 \text{ kg})\left(3.40 \times 10^3 \text{ m/s}\right)^2$$

For a negative sign on the final answer — 1 point

$E_{tot} = -5.38 \times 10^9$ J

(d) 3 points

For correct selection of "Less than" check space — 1 point

For a correct justification — 2 points

Example 1: From Kepler's third law ($r^3/T^2 = \text{constant}$), if *r* decreases, then *T* must also decrease

Example 2: Use relationships among *R*, v, and *T* with no incorrect physics such as the following: From (b), $M_M = \frac{v^2 R}{G}$, so as *R* decreases, v must increase. From (a), $T = \frac{2\pi R}{v}$, so both a decrease in *R* and an increase in v contribute to a decrease in *T*.

Note: 1 point partial credit was awarded for using only $T = \frac{2\pi R}{v}$, unless it was stated that v was constant, in which case no credit was awarded.

Question 2 (continued)

Distribution of points

(e) 2 points

For a correct expression of conservation of angular momentum 1 point
$m_s v_1 r_1 = m_s v_2 r_2$ or equivalent such as $I_1\omega_1 = I_2\omega_2$ or $v_1 r_1 = v_2 r_2$

$v_2 = v_1 \frac{r_1}{r_2} = v_1 \frac{R_C + R_M}{R_F + R_M}$, where R_C and R_F are the distances of closest and farthest approaches, respectively, and R_M is the radius of Mars

For explicit substitution of radii (not altitudes) into the equation or for the correct numerical answer 1 point

$$v_2 = \left(3.40 \times 10^3 \text{ m/s}\right)\frac{3.71 \times 10^5 \text{ m} + 34.3 \times 10^5 \text{ m}}{4.36 \times 10^5 \text{ m} + 34.3 \times 10^5 \text{ m}}$$

$$v_2 = 3.34 \times 10^3 \text{ m/s}$$

Alternatively, if the longer approach using conservation of energy was taken, 1 point was awarded for a correct statement of conservation of energy if explicitly written as $\frac{1}{2}m_s v_1^2 - \frac{Gm_s M_M}{r_1} = \frac{1}{2}m_s v_2^2 - \frac{Gm_s M_M}{r_2}$*, and 1 point was awarded for the explicit substitution of radii (not altitudes) or for a correct numerical answer.*

Units point

For including correct units on at least three numerical answers 1 point

Significant figures point

For including less than five significant digits on at least three numerical answers for which a calculation was shown 1 point

AP® PHYSICS C: MECHANICS
2007 SCORING GUIDELINES

Question 3

15 points total **Distribution of points**

(a) 2 points

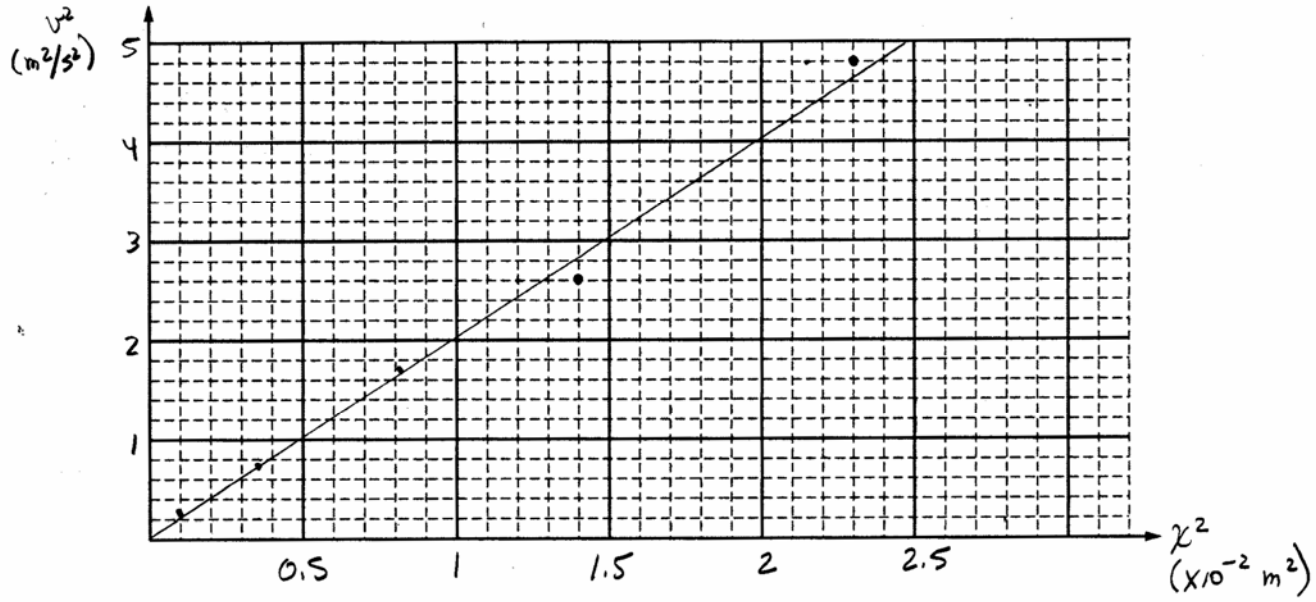
For a correct equation using conservation of energy 1 point

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

For a correct substitution of the numerical value of k in part (a) <u>or</u> in a subsequent part of the problem 1 point

$\frac{1}{2}mv^2 = \frac{1}{2}(40)x^2$

(b) and (c)



(b) 3 points

For correct axis labels and units on both axes 1 point

For correct linear scales on both axes 1 point

For plotting at least 4 of 5 points in the correct location 1 point

<u>Note:</u> Full credit was awarded if both axes were reversed from the graph shown above and everything else was correct.

Question 3 (continued)

Distribution of points

(c)

(i) 1 point

For a reasonable best-fit straight line — 1 point
Note: This point was awarded only if the axes had linear scales.

(ii) 3 points

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

$v^2 = \frac{k}{m}x^2$, so k/m is the slope of the graph of v^2 versus x^2

For use of a slope derived from the data — 1 point
For using two points in the calculation of the slope that are clearly on the best-fit line — 1 point
(Students using data points not on the line could not receive this second point.)

Example: Selecting the points (2.4×10^{-2}, 4.8) and (0.5×10^{-2}, 1.0), which are on the line shown in the graph

$$\text{Slope} = \frac{(4.8 - 1.0)\ \text{m}^2/\text{s}^2}{(2.4 - 0.5) \times 10^{-2}\ \text{m}^2} = 2.0 \times 10^2\ \text{s}^{-2} = \frac{k}{m}$$

$$m = \frac{k}{\text{slope}} = \frac{40\ \text{N/m}}{2.0 \times 10^2\ \text{s}^{-2}}$$

For a numerical answer in the range 0.18 kg to 0.22 kg — 1 point
$m = 0.20$ kg

(d)

(i) 4 points

For use of the correct energy types (K, U_g, and U_s) in a single equation — 1 point
For recognition that the difference in height is greater than h in the figure — 1 point
For a correct expression for U_g — 1 point
For substitution of U_g into a correct equation — 1 point

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 + mg(h + x\sin\theta)$

Note: Third and fourth points were awarded only if the first two points were awarded.

(ii) 2 points

For checking "No" — 1 point
For a clear justification explaining that v^2 varies with both x^2 and x. — 1 point