2017

AP® CollegeBoard

AP Physics C: Mechanics

Scoring Guidelines

General Notes About 2017 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. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. 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.

4. 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 embeds the application of that equation to the problem in other work, 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 exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Course and Exam Description*.

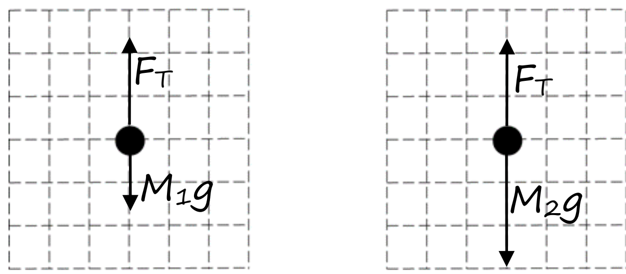
5. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. 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.

Question 1

15 points total **Distribution of points**

(a) 3 points



For correctly drawing and labeling the vectors for the weight of the block and the tension for block M_1 with the tension larger than the weight	1 point
For correctly drawing and labeling the vectors for the weight of the block and the tension for block M_2 with the weight larger than the tension	1 point
For correctly drawing tension on the two blocks as equal in magnitude	1 point

Note: If any extraneous vectors are drawn, only a maximum of two points may be earned.

(b) 3 points

For correctly applying Newton's second law to block 1 — 1 point

$F_T - M_1 g = M_1 a$

For correctly applying Newton's second law to block 2 — 1 point

$M_2 g - F_T = M_2 a$

For combining the two equations above in such a way that will lead to the correct equation — 1 point

$M_2 g - M_1 g = (M_1 + M_2) a$

$$a = \frac{(M_2 - M_1)}{(M_1 + M_2)} g$$

(c) 1 point

For indicating variables that will create a straight line whose slope can be used to determine g — 1 point

Example: Vertical axis: a

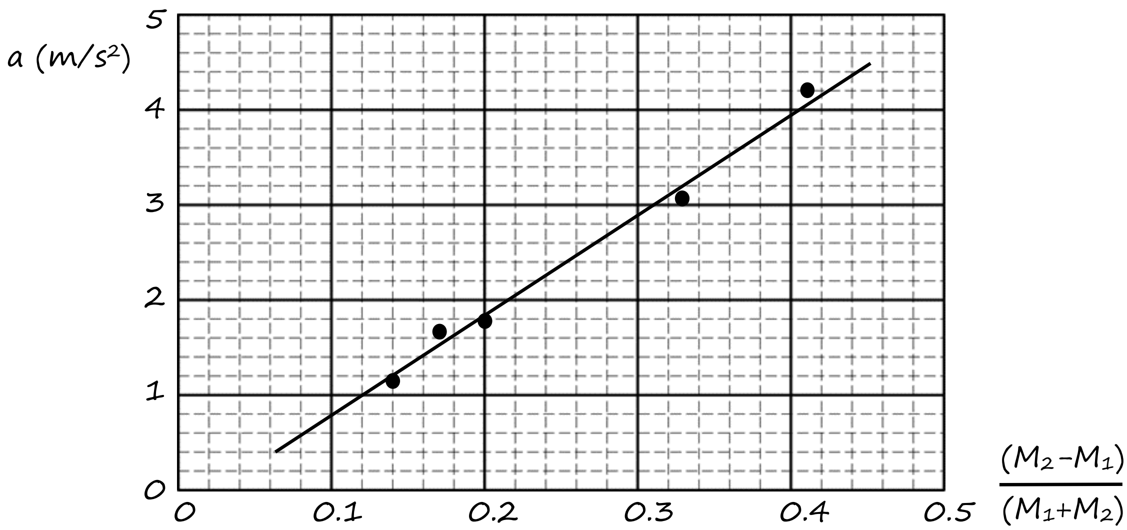
Horizontal axis: $\frac{(M_2 - M_1)}{(M_1 + M_2)}$

Note: Full credit is earned if axes are reversed, or if the student uses another acceptable combination.

Question 1 (continued)

Distribution of points

(d) 3 points



For using a correct scale that uses more than half the grid and for correctly labeling the axes, including units as appropriate — 1 point

For correctly plotting the data — 1 point

For drawing a straight best-fit line consistent with the plotted data — 1 point

(e) 2 points

For correctly calculating the slope using the best-fit line and not the data points, unless the points fall on the best-fit line — 1 point

(Note: Credit may be given for the linear regression only if the student states linear regression is used.)

$$\text{slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{(3.0 - 1.0)\ \text{m/s}^2}{(0.31 - 0.12)} = 10.5\ \text{m/s}^2$$

For correctly relating the slope to g — 1 point

$g = \text{slope} = 10.5\ \text{m/s}^2$ (using linear regression yields $10.1\ \text{m/s}^2$)

Question 1 (continued)

	Distribution of points
(f) 2 points	
Correct answer: "Lower"	
For including a correct statement about the acceleration of the blocks	1 point
For including a correct statement about the forces on the blocks	1 point
Example: Because the block M_1 is on the table, the net force on the system increases, and therefore the acceleration increases. Because the acceleration of M_2 increases, the net force on M_2 must increase. Therefore, there must be a greater difference in the magnitude of the two forces on M_2. Because the weight of block M_2 stays the same, the retarding force — the tension in the string — must decrease.	
(g) 1 point	
For a correct justification	1 point
Example: Block M_1 will experience friction with the table. The acceleration of the system will decrease and this will decrease the slope of the line; therefore, the value of g is determined by the experiment.	

Question 2

15 points total | **Distribution of points**

(a)

i. 2 points

For correctly using conservation of energy for the block moving down the incline — 1 point

$U_g = K$

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

For a correct answer — 1 point

$v = \sqrt{2gh}$

ii. 1 point

Correct answer: "Greater than"

For a correct justification — 1 point

Example: The speed is proportional to the square root of the change in height. So if the height is reduced by a factor of 2, the speed is reduced by a factor of $\sqrt{2} \approx 1.41$. Therefore, the speed halfway down the ramp is more than half the speed at the bottom of the ramp.

Note: If the incorrect selection is made, the justification cannot earn credit.

(b) 1 point

For correctly using conservation of energy, consistent with part (a), for the block compressing the spring — 1 point

$U_g = U_S$

$mgh = \frac{1}{2}kx_{max}^2$

$x_{max} = \sqrt{\frac{2mgh}{k}}$

(c) 2 points

For indicating a simple harmonic motion approach — 1 point

For a correct answer — 1 point

$t = \frac{1}{4}T = \left(\frac{1}{4}\right)\left(2\pi\sqrt{\frac{m}{k}}\right) = \frac{\pi}{2}\sqrt{\frac{m}{k}}$

Question 2 (continued)

Distribution of points

(d)

i. 3 points

For correctly applying Newton's second law for the horizontally sliding block — 1 point

For correctly indicating that the direction of F_{net} is opposite the direction of motion — 1 point

$F_{net} = ma$

$-\beta v^2 = ma$

For expressing the equation as a differential equation — 1 point

$$-\beta v^2 = m\frac{dv}{dt}$$

ii. 3 points

For correctly separating variables — 1 point

$$-\frac{\beta}{m}dt = \frac{1}{v^2}dv$$

For correctly integrating the equation above — 1 point

$$\int -\frac{\beta}{m}dt = \int \frac{1}{v^2}dv$$

$$-\frac{\beta}{m}[t] = \left[-\frac{1}{v}\right]$$

For using the correct limits or constant of integration — 1 point

$$-\frac{\beta}{m}[t]_0^t = \left[-\frac{1}{v}\right]_{v_0}^{v(t)}$$

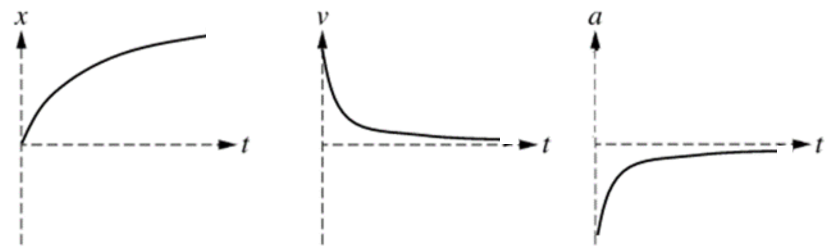
$$-\frac{\beta t}{m} = -\frac{1}{v(t)} - \left(-\frac{1}{v_0}\right)$$

$$\frac{1}{v(t)} = \frac{1}{v_0} + \frac{\beta t}{m}$$

Question 2 (continued)

Distribution of points

(e) 3 points



For a displacement curve that is concave down and approaching a horizontal asymptote	1 point
For a velocity curve that is concave up and has the horizontal axis as an asymptote	1 point
For an acceleration curve that is concave down and has the horizontal axis as an asymptote	1 point

Note: If an incorrect nonlinear velocity graph is generated, 1 point is earned if the position and acceleration graphs are consistent with the velocity graph.

Note: Full credit is earned if all three graphs are flipped vertically.

Question 3

15 points total | **Distribution of points**

(a) 2 points

For correctly applying conservation of energy to the cylinder rolling down the incline — 1 point

$U_{g\_top} = K_{table}$

$K_{table} = mgh = (0.50\ \text{kg})(9.8\ \text{m/s}^2)(1.0\ \text{m})(\sin 30)$

For a correct answer with units — 1 point

$K_{table} = 2.45\ \text{J}$ (or 2.5 J using $g = 10\ \text{m/s}^2$)

(b) 3 points

For correctly setting the kinetic energy of the cylinder equal to the sum of both the linear and rotational kinetic energy — 1 point

$K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

For correctly substituting into the above equation for the linear velocity and moment of inertia of the cylinder — 1 point

$K = \frac{1}{2}MR^2\omega^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\omega^2 = \frac{1}{2}M(R\omega)^2 + \frac{1}{4}M(R\omega)^2 = \frac{3}{4}M(R\omega)^2$

$\omega = \sqrt{\frac{4K}{3MR^2}} = \sqrt{\frac{(4)(2.45\ \text{J})}{(3)(0.50\ \text{kg})(0.10\ \text{m})^2}}$

For correct substitution into the equation above — 1 point

$\omega = 25.6\ \text{rad/s}$ (or $26.0\ \text{rad/s}$ using $g = 10\ \text{m/s}^2$)

(c) 2 points

For using a correct expression for the ratio of the rotational kinetic energy to the total kinetic energy of the cylinder — 1 point

$$\frac{K_{rot}}{K_{tot}} = \frac{\frac{1}{2}I\omega^2}{\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + mgh} = \frac{\frac{1}{4}M(R\omega)^2}{\frac{3}{4}M(R\omega)^2 + Mgh_{\text{table}}} = \frac{(R\omega)^2}{3(R\omega)^2 + 4gh_{\text{table}}}$$

For substituting into the above equation — 1 point

$$\frac{K_{rot}}{K_{tot}} = \frac{[(0.10\ \text{m})(25.6\ \text{rad/s})]^2}{(3)(0.10\ \text{m})^2(25.6\ \text{rad/s})^2 + (4)(9.81\ \text{m/s}^2)(0.75\ \text{m})}$$

$\frac{K_{rot}}{K_{tot}} = 0.133$ (or 0.135 using $g = 10\ \text{m/s}^2$)

Question 3 (continued)

Distribution of points

(c) (continued)

Alternate Solution — *Alternate Points*

For using a correct expression for the ratio of the rotational kinetic energy to the total potential energy of the cylinder — *1 point*

$$\frac{K_{rot}}{K_{tot}} = \frac{\frac{1}{2}I\omega^2}{U_{total}} = \frac{\frac{1}{4}M(R\omega)^2}{Mg(h+y)}$$

For substituting into the above equation — *1 point*

$$\frac{K_{rot}}{U_{total}} = \frac{\frac{1}{4}(R\omega)^2}{g(h+y)} = \frac{\frac{1}{4}[(0.10\text{ m})(25.6\text{ rad/s})]^2}{(9.81\text{ m/s}^2)\left((1.0\text{ m})\sin(30^\circ) + (0.75\text{ m})\right)}$$

$$\frac{K_{rot}}{U_{total}} = 0.13 \text{ (or } 0.135 \text{ using } g = 10\text{ m/s}^2\text{)}$$

(d) 2 points

For correctly using motion in the vertical direction to calculate the time for the cylinder to reach the floor — 1 point

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$$

$$y - y_0 = 0 - \frac{1}{2}gt^2$$

Determine the time for the cylinder to reach the floor

$$y - y_0 = -\frac{1}{2}gt^2$$

$$0 - y = -\frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{(2)(0.75\text{ m})}{(9.81\text{ m/s}^2)}} = 0.39\text{ s}$$

For correctly using the equation for constant speed in the horizontal direction — 1 point

$$x - x_0 = v_{0x}t$$

$$x - x_0 = R\omega t$$

$$x - x_0 = R\omega\sqrt{\frac{2y}{g}}$$

$$D = R\omega t = (0.10\text{ m})(25.6\text{ rad/s})(0.39\text{ s})$$

$$D = 1.0\text{ m}$$

Question 3 (continued)

	Distribution of points
(e)	
i. 2 points	
For selecting "Equal to" and attempting a relevant justification	1 point
For a correct justification	1 point
Example: Because the sphere falls the same height as the cylinder and because they have the same mass, the sphere-Earth system has the same initial potential energy and, therefore, the same total kinetic energy when it reaches the floor.	
ii. 2 points	
For selecting "Less than" and attempting a relevant justification	1 point
For a correct justification	1 point
Example: Because the rotational inertia of the sphere is less than the rotational inertia of the cylinder, the sphere will rotate faster and, because $v = r\omega$, will move with a greater linear speed. Because the mass is the same and the linear speed is greater, the sphere will have a greater linear kinetic energy. Because the total kinetic energies of the sphere and cylinder are the same, the sphere must have less rotational kinetic energy.	
iii. 2 points	
For selecting "Greater than" and attempting a relevant justification	1 point
For a correct justification	1 point
Example: Because the sphere has a greater linear speed as it leaves the table, it will travel a greater horizontal distance before it reaches the floor.	