AP® PHYSICS
2012 SCORING GUIDELINES

General Notes About 2012 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 in part (b). One exception to this practice may occur in cases where the numerical answer to a later part should easily be recognized as wrong, for example, a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if the use of an 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 sheets. 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 Course Description*.

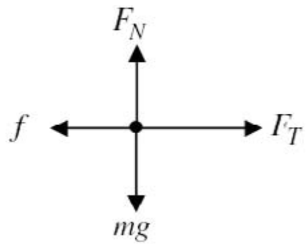
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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 owing 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 eliminate the level of accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 1

15 points total — **Distribution of points**

(a) 2 points



For showing a complete vector diagram in the horizontal direction with proper labels and vectors pointing in the correct directions — 1 point

For showing a complete vector diagram in the vertical direction with proper labels and vectors pointing in the correct directions — 1 point

(b) 3 points

For any use of Newton's second law to sum the forces in the horizontal direction — 1 point

$$F_T - f = ma$$

$$a = \frac{F_T - f}{m}$$

For a correct expression for, or value of, the frictional force — 1 point

$$a = \frac{F_T - \mu mg}{m} = \frac{(15\text{ N}) - (0.25)(2.0\text{ kg})\left(9.8\text{ m/s}^2\right)}{(2.0\text{ kg})}$$

For a correct answer, with units — 1 point

$a = 5.1\text{ m/s}^2$ (or 5.0 m/s^2 using $g = 10\text{ m/s}^2$)

(c) 4 points

For a proper summation of forces on block A in the x-direction — 1 point

$$\sum F_{m_A} = m_A a = F_T - f$$

For a proper summation of forces on block B in the y-direction — 1 point

$$\sum F_{m_B} = m_B a = m_B g - F_T$$

For a reasonable attempt to combine these two relationships — 1 point

$$(m_A + m_B)a_{system} = m_B g - f$$

$$a_{system} = \frac{m_B g - f}{(m_A + m_B)} = \frac{(1.5\text{ kg})\left(9.8\text{ m/s}^2\right) - (0.25)(2.0\text{ kg})\left(9.8\text{ m/s}^2\right)}{(3.5\text{ kg})}$$

For a correct answer with units — 1 point

$a = 2.8\text{ m/s}^2$ (or 2.9 m/s^2 using $g = 10\text{ m/s}^2$)

Question 1 (continued)

Distribution of points

(c) (continued)

Alternate solution — *Alternate points*

Treating the two blocks as one system with a total mass of $M_T = m_A + m_B$

For a correct statement of the net force on the system — *1 point*

For a correct expression for total mass of the system — *1 point*

$m_B g - f = (m_A + m_B)a$

For agreement between the sign of the net force and the direction of acceleration — *1 point*

$$a = \frac{m_B g - \mu m_A g}{(m_A + m_B)} = \frac{(1.5\text{ kg})(9.8\text{ m/s}^2) - (0.25)(2.0\text{ kg})(9.8\text{ m/s}^2)}{(2.0\text{ kg} + 1.5\text{ kg})}$$

For a correct answer — *1 point*

$a = 2.8\text{ m/s}^2$ (or 2.9 m/s^2 using $g = 10\text{ m/s}^2$)

(d) 2 points

For a correct expression of the summation of forces on either block A or block B — 1 point

$F_T - \mu m_A g = m_A a$ or $m_B g - F_T = m_B a$

For correct substitution of the acceleration determined in part (c) and the given masses — 1 point

$F_T = m_A(a + \mu g)$
$= (2.0\text{ kg})(2.8\text{ m/s}^2 + (0.25)(9.8\text{ m/s}^2))$

or

$F_T = m_B(g - a)$
$= (1.5\text{ kg})(9.8\text{ m/s}^2 - 2.8\text{ m/s}^2)$

$F_T = 10.5\text{ N}$

(e) 2 points

For any proper kinematic approach to determine the displacement of block B — 1 point

$$\Delta y = \frac{1}{2}at^2$$

For a correct substitution of the acceleration found in part (c) into the kinematic relationship — 1 point

$$\Delta y = \frac{1}{2}(2.8\text{ m/s}^2)(0.40\text{ s})^2$$

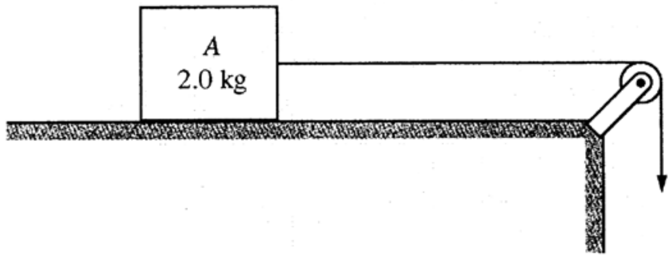
$\Delta y = 0.22\text{ m}$

Question 1 (continued)

	Distribution of points
(f) 2 points	
For any reasonable statement of a physical factor that would alter the measured value of the acceleration	1 point
The following are some common acceptable responses: • The pulley has an appreciable amount of friction in the bearings. • The string has an appreciable mass. • The pulley has an appreciable rotational inertia. • A small uphill incline exists in the horizontal surface. Note: If a response contains both correct and incorrect factors, this point can be earned only if a correct justification for a correct factor is given.	
For a proper justification of how the physical factor listed causes the measured value of the acceleration to be smaller than the theoretical value of the acceleration	1 point
The following are examples of some common correct justifications: • The friction in the bearings of the pulley does negative work on the system, leaving less energy available for the system's kinetic energy. This will result in a slightly smaller final velocity and therefore a slightly smaller acceleration than the theoretical value. • The slightly inclined surface creates a small downward component of gravity, which works in opposition to the acceleration. This small opposing force will create a smaller net force and a decrease in the measured acceleration of block *B*.	

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 2, 3, 4, 6, and 7 and about 17 minutes for answering each of Questions 1 and 5. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



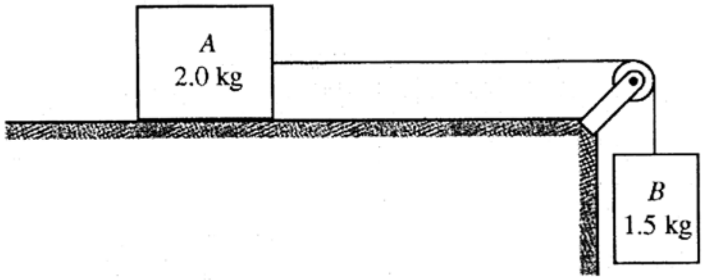
1. (15 points)

Block *A* of mass 2.0 kg is pulled along a horizontal table by a force of 15 N, which is applied by a light string that passes over a light frictionless pulley, as shown above. The coefficient of kinetic friction between the block and the surface is 0.25.

(a) On the dot below, which represents the block, draw and label the forces (not components) that act on the block as it is pulled across the table.

(b) Calculate the magnitude of the acceleration of the block.

$F_{net_y} = \emptyset$
$F_N = mg$
$F_{net_x} = 15N - F$
$ma = 15N - (0.25)(mg)$
$2a = 15N - (0.25)(19\frac{3}{5}N)$
$2a = 10\frac{1}{10}N$
$a = 5\frac{1}{20}\ m/s^2$



The applied force is removed. Block *B* of mass 1.5 kg is now attached to the string, as shown above. The system is released from rest so that the 1.5 kg box descends and the 2.0 kg block is again pulled across the table.

(c) Calculate the acceleration of the 1.5 kg block as it descends.

$f_A \leftarrow (3.5) \rightarrow m_B g$, $\uparrow F_N$, $\downarrow m_A g$

$F_N = m_A g$

$F_{net_x} = m_B g - f_A$

$m_T a = 1.5 \cdot 9.8 - \mu(2 \cdot 9.8)$

$3.5a = 14\frac{7}{10}\,N - 4\frac{9}{10}\,N$

$a = 2\frac{4}{5}\,m/s^2$

(d) Calculate the tension in the string connecting the two blocks.

$\uparrow F_T$, (B), $\downarrow m_B g$

$F_{net} = m_B a$

$m_B a = m_B g - F_T$

$1.5 \cdot 2\frac{4}{5} = 1.5 \cdot 9.8 - F_T$

$F_T = 10.5\,N$

(e) Calculate the distance that the 1.5 kg block descends in 0.40 s.

$V_{iy} = 0$

$a_y = 2\frac{4}{5}\,m/s^2$

$t = 4s$

$\Delta y = ?$

$\Delta y = \frac{1}{2}at^2$

$= \frac{1}{2}(2\frac{4}{5})(4)^2$

$= 22.4\,m.$

(f) If this system is set up in a laboratory and the acceleration of the 1.5 kg block is experimentally determined, the experimental value is found to be smaller than the value calculated above. If the given value for the coefficient of friction is correct and air resistance is negligible, explain briefly, but specifically, why the experimental value of the acceleration is smaller.

The pulley itself ~~has~~ exerts friction

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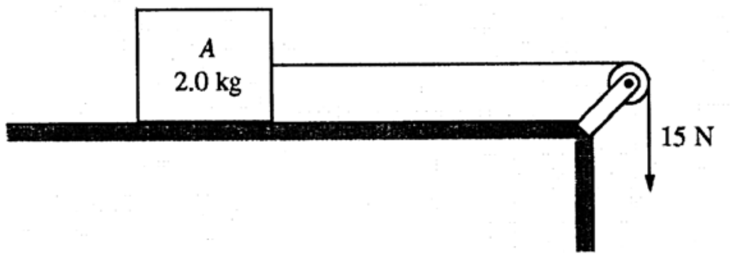
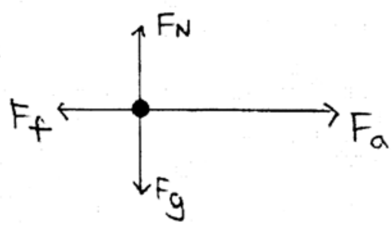


1. (15 points)

Block *A* of mass 2.0 kg is pulled along a horizontal table by a force of 15 N, which is applied by a light string that passes over a light frictionless pulley, as shown above. The coefficient of kinetic friction between the block and the surface is 0.25.

(a) On the dot below, which represents the block, draw and label the forces (not components) that act on the block as it is pulled across the table.



(b) Calculate the magnitude of the acceleration of the block.

$F_f = \mu F_N$ $\quad F_N = F_g$

$F_f = \mu mg$ $\quad F_N = mg$

$F_f = 0.25 \times 2 \times 9.8$

$F_f = 4.9\,N$

$\Sigma F = ma$

$(F_a - F_f) = ma$

$(15 - 4.9) = 2a$

$\frac{10.1}{2} = a$

$5.1\,m/s^2 = a$

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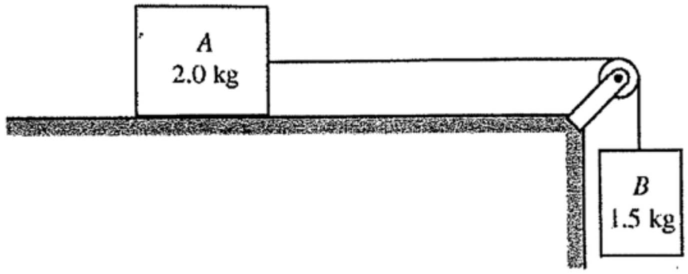

The applied force is removed. Block *B* of mass 1.5 kg is now attached to the string, as shown above. The system is released from rest so that the 1.5 kg box descends and the 2.0 kg block is again pulled across the table.

(c) Calculate the acceleration of the 1.5 kg block as it descends.

$F_B = 1.5 \times 9.8$ $F_B = ma$

$F_B = 14.7\ N$

$\Sigma F = ma$ $(14.7 - 5.1) = 1.5a$

$(F_B - F_f) = ma$

$\frac{9.6}{1.5} = a$

$a = 6.4\ m/s^2$

(d) Calculate the tension in the string connecting the two blocks.

Tension is force

$F_f = T$

$\mu FN = T$ $T = 4.9\ N$

$\mu mg = T$

$0.25 \times 2 \times 9.8 = T$

(e) Calculate the distance that the 1.5 kg block descends in 0.40 s.

$V_i = 0$ $t = 0.4$ $a = 9.8$ $d = ?$

$d = V_i t + \frac{1}{2}at^2$ $d = 0.5\ m$

$d = 0 + \frac{1}{2}(6.4)(0.4)^2$

(f) If this system is set up in a laboratory and the acceleration of the 1.5 kg block is experimentally determined, the experimental value is found to be smaller than the value calculated above. If the given value for the coefficient of friction is correct and air resistance is negligible, explain briefly, but specifically, why the experimental value of the acceleration is smaller.

The table maybe slightly tilted toward left

The location of laboratory may have gravitational force less than 9.8

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PHYSICS B

SECTION II

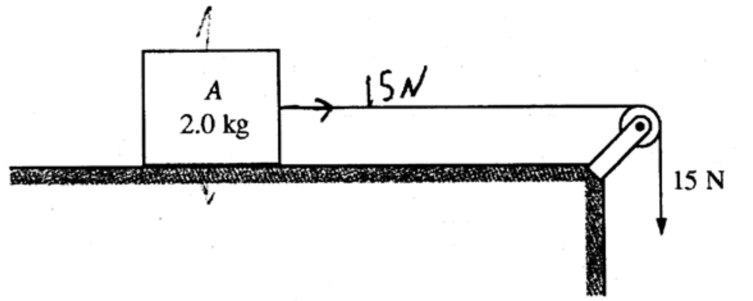
Time—90 minutes

7 Questions

B1-C

1 of 2

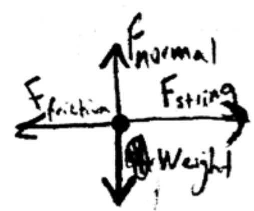
Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 2, 3, 4, 6, and 7 and about 17 minutes for answering each of Questions 1 and 5. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



1. (15 points)

Block A of mass 2.0 kg is pulled along a horizontal table by a force of 15 N, which is applied by a light string that passes over a light frictionless pulley, as shown above. The coefficient of kinetic friction between the block and the surface is 0.25.

(a) On the dot below, which represents the block, draw and label the forces (not components) that act on the block as it is pulled across the table.



(b) Calculate the magnitude of the acceleration of the block.

$\sum F = F_{net} = ma$

+15 N

-20N = Normal

+20N weight

-5 = $F_{friction}$

$\frac{10}{2} = \frac{2a}{2}$

$a = 5 m/s^2$

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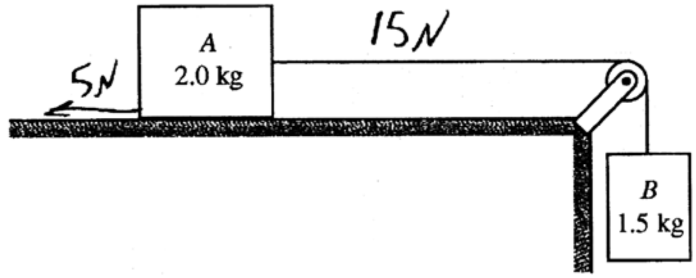

The applied force is removed. Block B of mass 1.5 kg is now attached to the string, as shown above. The system is released from rest so that the 1.5 kg box descends and the 2.0 kg block is again pulled across the table.

(c) Calculate the acceleration of the 1.5 kg block as it descends.

$a = ?$

(d) Calculate the tension in the string connecting the two blocks.

$15N - 5N = \boxed{10N}$

(e) Calculate the distance that the 1.5 kg block descends in 0.40 s.

$t = .4\,s$ $\quad v_i = 0\,m/s$

$d = ?$

$m = 1.5\,kg$

(f) If this system is set up in a laboratory and the acceleration of the 1.5 kg block is experimentally determined, the experimental value is found to be smaller than the value calculated above. If the given value for the coefficient of friction is correct and air resistance is negligible, explain briefly, but specifically, why the experimental value of the acceleration is smaller.

The experimental value is smaller because the given value is theoretical but we know that these results only occur in the best of conditions, and there has to be room for human trial error.

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Question 1

Overview

This question assessed students' understanding of Newton's second law for two cases: a single moving object and a two-object system. Students were asked to draw free-body diagrams and to analyze processes involving friction and motion of coupled objects. They were also asked to conceptually identify experimental error sources.

Sample: B1-A
Score: 14

This response earned full credit in parts (a), (b), (c), and (d). Notice that part (c) is an excellent example of the alternate solution provided in the scoring guidelines, which was very popular with students. Part (e) has the incorrect answer because of a computational error, but the full 2 points were earned because the scoring guidelines do not require a specific answer. The student uses the proper kinematic approach and also substitutes in the acceleration from part (c). In part (f) only 1 of the 2 points was earned, as the student does not explain the effect of friction on the system's acceleration.

Sample: B1-B
Score: 10

Full credit was earned in both parts (a) and (b). In part (c) only 2 of the 4 points were earned: 1 point for the net force exerted on the system and 1 point for the sign of the forces and acceleration being in alignment. No credit was earned in part (d). Part (e) shows the correct kinematic relationship, and the student substitutes the acceleration from part (c) into the expression and thus earned both points. In part (f) the student identifies one valid physical factor (a "tilted" or inclined surface) but does not explain how it would affect the acceleration and thus earned only 1 point.

Sample: B1-C
Score: 5

In parts (a) and (b) full credit was earned. Parts (c), (d), and (e) are essentially blank, so no points were awarded. In part (f) the student writes a general statement about "human trial error" and thus earned no credit.