General Notes About 2006 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.

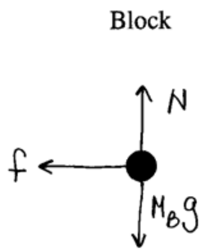
4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

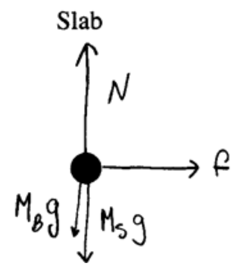
5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences 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.

Question 1

15 points total **Distribution of points**

(a) 4 points





For the block force diagram:

For correctly labeled horizontal force (friction to the left, no other forces or vectors) — 1 point

For correctly labeled vertical forces (normal up <u>and</u> weight down; gravity alone not accepted) — 1 point

For the slab force diagram:

For correctly labeled horizontal force (friction to the right, no other forces or vectors) — 1 point

For correctly labeled vertical forces (normal up <u>and</u> combined weight down; combined weight can be shown with two arrows <u>or</u> identifying weight as $W_S + W_B$ or $M_S g + M_B g$; gravity alone not accepted) — 1 point

(b) and (c)

These two parts were scored together because of the different approaches that could be used to answer them.

<u>Momentum approach to part (b); Newton's second law and kinematics approach to part (c)</u>

(b) 3 points

For any statement of conservation of momentum — 1 point

No net external forces act on the two-block system, so linear momentum is conserved.

For a correct momentum equation — 1 point

$M_B \upsilon_0 = (M_B + M_S)\upsilon_f$

$$\upsilon_f = \frac{M_B}{M_B + M_S}\upsilon_0 = \frac{0.50 \text{ kg}}{0.50 \text{ kg} + 3.0 \text{ kg}} 4.0 \text{ m/s}$$

For the correct answer — 1 point

$\upsilon_f = 0.57 \text{ m/s}$

Question 1 (continued)

Distribution of points

Momentum approach (continued)

(c) 6 points

For a correct expression for the friction force (awarded if found in the solution to any of parts (a) through (d)) — 1 point

$f = \mu mg$ or $f = \mu N$

For correct substitution of $m = M_B$ for the friction force on the block — 1 point

$f = \mu M_B g$

For recognizing that the friction force on the slab is equal in magnitude to the friction force on the block and for an equation relating this force to the acceleration of the slab — 1 point

$f = M_S a_S$

For a correct expression for the acceleration of the slab or its numerical value — 1 point

$$a_S = \frac{\mu M_B g}{M_S} = 0.33 \text{ m/s}^2$$

For a correct kinematic equation for the slab — 1 point

$\upsilon_f^2 = \upsilon_0^2 + 2a_S x$, where $\upsilon_0 = 0$

$$x = \frac{\upsilon_f^2}{2a_S} = \frac{\upsilon_f^2}{2}\frac{M_S}{\mu M_B g}$$

For correct substitutions consistent with earlier values — 1 point

$$x = \frac{(0.57 \text{ m/s})^2}{2}\frac{3.0 \text{ kg}}{0.20(0.50 \text{ kg})\left(9.8 \text{ m/s}^2\right)}$$

$x = 0.49$ m or 0.50 m, depending on use of $g = 9.8$ or 10 m/s^2 and where substitution and rounding took place

Question 1 (continued)

Distribution of points

<u>Newton's second law and kinematics approach to part (b); kinematics approach to part (c)</u>

(b) 7 points

For a correct expression for the friction force (awarded if found in the solution to any of parts (a) through (d)) — 1 point

$f = \mu mg$ or $f = \mu N$

For correct substitution of $m = M_B$ — 1 point

$f = \mu M_B g$

For recognizing that the friction force on the slab is equal in magnitude to the friction force on the block and for an equation relating this force to the acceleration of the slab — 1 point

$f = M_S a_S$

For a correct expression for the acceleration of the slab or its numerical value — 1 point

$$a_S = \frac{\mu M_B g}{M_S} = 0.33 \text{ m/s}^2$$

For a correct expression for the acceleration of the block or its numerical value — 1 point

$$a_B = \frac{\mu M_B g}{M_B} = \mu g = 2.0 \text{ m/s}^2$$

For a solution of the following simultaneous kinematic equations for the block and the slab, such as by setting the times equal and solving for v_f — 1 point

$v_f = v_0 - a_B t$ for the block

$v_f = a_S t$ for the slab

$$v_f = \frac{a_S v_0}{a_S + a_B} = \frac{\left(0.33 \text{ m/s}^2\right)(4.0 \text{ m/s})}{0.33 \text{ m/s}^2 + 2.0 \text{ m/s}^2}$$

For the correct answer — 1 point

$v_f = 0.57 \text{ m/s}$

(c) 2 points

For a correct kinematic equation for the slab — 1 point

$v_f^2 = v_0^2 + 2a_S x$, where $v_0 = 0$

$$x = \frac{v_f^2}{2a_S} = \frac{v_f^2}{2}\frac{M_S}{\mu M_B g}$$

For correct substitutions consistent with earlier values — 1 point

$$x = \frac{(0.57 \text{ m/s})^2}{2}\frac{3.0 \text{ kg}}{0.20(0.50 \text{ kg})\left(9.8 \text{ m/s}^2\right)}$$

$x = 0.49$ m or 0.50 m, depending on use of $g = 9.8$ or 10 m/s^2 and where substitution and rounding took place

Question 1 (continued)

Distribution of points

(d) 2 points

For a correct expression for the work done — 1 point

$W = Fd = \mu M_B g x$ OR $W = \Delta K = \frac{1}{2} M_S v_f^2$

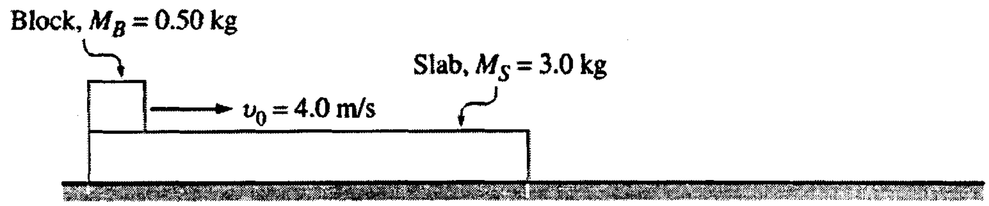
For consistent substitution from parts (b) and (c) — 1 point

$W = 0.20(0.5\ \text{kg})\left(9.8\ \text{m/s}^2\right)(0.50\ \text{m})$ OR $W = \frac{1}{2}(3.0\ \text{kg})(0.57\ \text{m/s})^2$

$W = 0.49$ J (or $W = 0.50$ J using $g = 10\ \text{m/s}^2$)

PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.

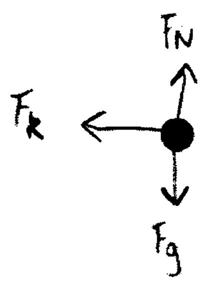


Mech 1.

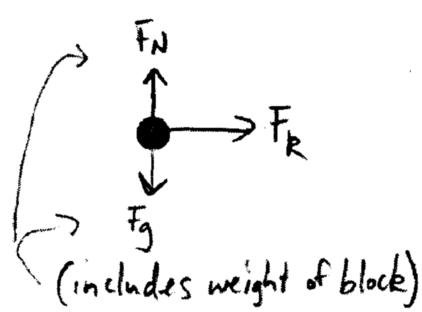
A small block of mass $M_B = 0.50$ kg is placed on a long slab of mass $M_S = 3.0$ kg as shown above. Initially, the slab is at rest and the block has a speed v_0 of 4.0 m/s to the right. The coefficient of kinetic friction between the block and the slab is 0.20, and there is no friction between the slab and the horizontal surface on which it moves.

(a) On the dots below that represent the block and the slab, draw and label vectors to represent the forces acting on each as the block slides on the slab.

Block



Slab



At some moment later, before the block reaches the right end of the slab, both the block and the slab attain identical speeds v_f.

(b) Calculate v_f. conservation of momentum

$$M_B v_0 = (M_B + M_S) v_f$$

$$(.5\,kg)(4\,m/s) = (.5\,kg + 3\,kg)\,v_f$$

$$v_f = .5714\,m/s$$

(c) Calculate the distance the slab has traveled at the moment it reaches v_f.

~~conservation of energy~~

$\cancel{\frac{1}{2}M_B v_0^2 = \mu M_B g d + \frac{1}{2}(M_B + M_S)v_f^2}$

$\cancel{\frac{1}{2}(.5kg)(4 m/s)^2 = (.2)(.5kg)(9.8 m/s^2)d + \frac{1}{2}(.5kg + 3kg)(.5714 m/s)^2}$

$\cancel{d = 3.499m}$

$v_f^2 = v_0^2 + 2ad \qquad a = \frac{F_k}{M_S} = \frac{\mu M_B g}{M_S}$

$(.5714 m/s)^2 = 2\left[\frac{.2(.5kg)(9.8 m/s^2)}{(3kg)}\right]d \qquad d = .499m$

(d) Calculate the work done by friction on the slab from the beginning of its motion until it reaches v_f.

$W = F_k d = \mu M_B g d = .2(.5kg)(9.8 m/s^2)(.499m) =$

$\boxed{.489 J}$

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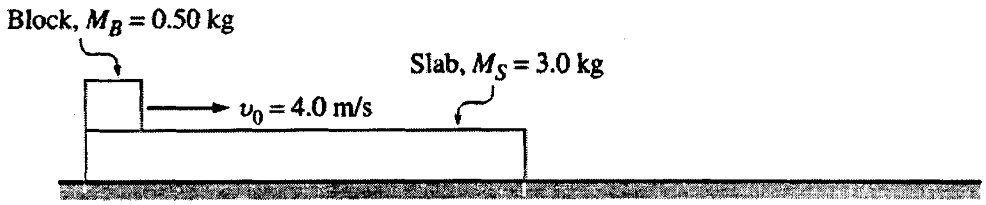
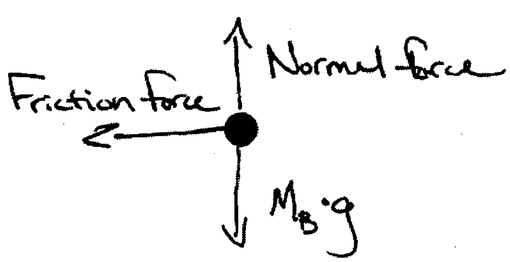


Mech 1.

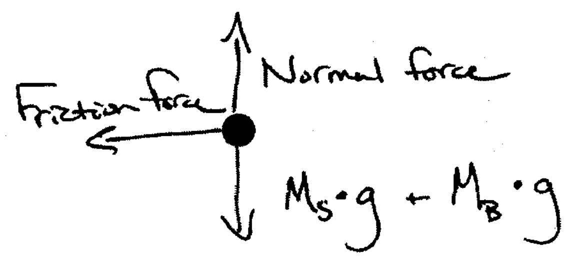
A small block of mass $M_B = 0.50$ kg is placed on a long slab of mass $M_S = 3.0$ kg as shown above. Initially, the slab is at rest and the block has a speed v_0 of 4.0 m/s to the right. The coefficient of kinetic friction between the block and the slab is 0.20, and there is no friction between the slab and the horizontal surface on which it moves.

(a) On the dots below that represent the block and the slab, draw and label vectors to represent the forces acting on each as the block slides on the slab.

Block



Slab



At some moment later, before the block reaches the right end of the slab, both the block and the slab attain identical speeds v_f.

(b) Calculate v_f.

$.5 \cdot 9.8 \cdot .2 = \text{Friction} = .98 = ma = .5 \cdot a$

$a = 1.96 \text{ m/s}^2$

$\cancel{4 - 1.96t + 1.96t}$

$4 - 1.96t = V_{f_B}$ $\quad V_{f_S} = 1.96t$

$\cancel{V_f = 4}$

$V_f = 1.96 \cdot \frac{4}{1.96 \cdot 2} = 2 \text{ m/s}$

$4 - 1.96t = 1.96t$

$t = \frac{4}{3.92} \approx 1.020$

(c) Calculate the distance the slab has traveled at the moment it reaches v_f.

$a = 1.96 \text{ m/s}^2$

$x = x_0 + v_0 t + \frac{1}{2} a t^2$

$x = 0 + 0 \cdot t + \frac{1}{2}(1.96) \cdot \left(\frac{4}{3.92}\right)^2$

$x = 1.02 \text{ m}$

(d) Calculate the work done by friction on the slab from the beginning of its motion until it reaches v_f.

$W = \int F \cdot dx$

$W = .5 \cdot 1.96 \cdot 1.02$

~~W=~~ $W = 1 \text{ J}$

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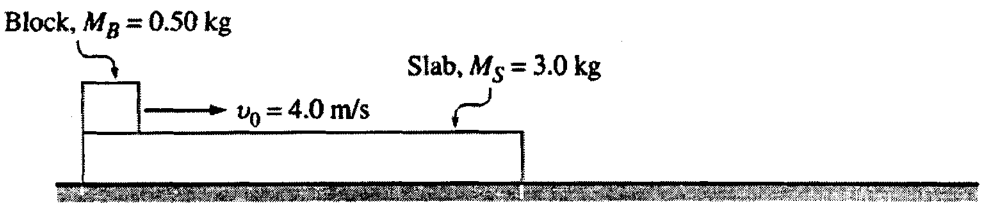
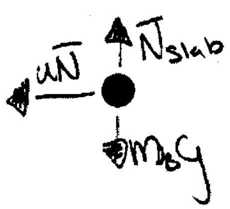


Mech 1.

A small block of mass $M_B = 0.50$ kg is placed on a long slab of mass $M_S = 3.0$ kg as shown above. Initially, the slab is at rest and the block has a speed v_0 of 4.0 m/s to the right. The coefficient of kinetic friction between the block and the slab is 0.20, and there is no friction between the slab and the horizontal surface on which it moves.

(a) On the dots below that represent the block and the slab, draw and label vectors to represent the forces acting on each as the block slides on the slab.

Block



Slab

At some moment later, before the block reaches the right end of the slab, both the block and the slab attain identical speeds v_f.

(b) Calculate v_f.

$$\tfrac{1}{2} m_B V_0^2 - W_{ext} = \tfrac{1}{2} m_B V_f^2 + \tfrac{1}{2} m_S V_f^2$$

$$\tfrac{1}{2} m_B V_0^2 - u\bar{N} = \tfrac{1}{2}(m_B + m_S) V_f^2$$

$$\tfrac{1}{2}(.5)(4)^2 - u\bar{N} = \tfrac{1}{2}(.5 + 3) V_f^2$$

$$V_f^2 = \frac{16 - .98}{.5(.5+3)}$$

$$\boxed{V_f = 2.93\, m/s}$$

$$\Sigma F_y = m_B g - \bar{N}$$

$$\bar{N} = m_B g$$

$$W_{ext} = u\bar{N} = .2(.5)(9.8)$$

$$= .98$$

GO ON TO THE NEXT PAGE.

(c) Calculate the distance the slab has traveled at the moment it reaches v_f.

$x = V_0 t + \frac{1}{2} a t^2$

$V_f^2 = V_0^2 + 2ax$

$V_f = V_0 + at$

(d) Calculate the work done by friction on the slab from the beginning of its motion until it reaches v_f.

$W = fx \cos\theta$

$W = umgx \cos\theta$

$W = .98x$

AP® PHYSICS C: MECHANICS
2006 SCORING COMMENTARY

Question 1

Overview

This question probed students' understanding of Newtonian dynamics and kinematics, along with conservation laws. A block with a given initial velocity slid on a slab that was initially at rest, with friction between the two objects. There was no friction between the slab and the supporting surface. In part (a) students were asked to analyze the forces acting on the block and slab. In part (b) students could use conservation of momentum or a kinematic approach to determine a common final speed for the block and slab. In part (c) students were asked to determine the distance the slab traveled to reach that speed. In part (d) they were asked to find the work done by friction on the slab.

Sample: M1A
Score: 15

This response earned full credit on all parts. On part (a), 1 point would have been lost for the downward force on the lab if it had not been clearly specified that the force included the weight of the block. The student correctly uses the conservation of momentum for part (b). Part (c) is started incorrectly, but the student wisely crosses it out (so it was not graded) and then correctly answers parts (c) and (d).

Sample: M1B
Score: 11

This response lost 1 point in part (a) for showing both friction forces in the same direction. In part (b), which used the Newton's second law and kinematics approach, 2 points were awarded for the expression for the friction force and the correct substitution of the mass of the block to find the acceleration of the block. However, the student assumes that the accelerations are the same and thus failed to get the point for the correct equation for the acceleration of the slab or the point for the final expression or value of the slab's acceleration. The student then earned another point by correctly solving the two simultaneous velocity-versus-time equations by setting the final velocities equal and solving for time but failed to earn the point for the correct final answer. Full credit was then awarded in parts (c) and (d) for the correct approach substituting values for quantities that are consistent with the answers in part (b).

Sample: M1C
Score: 7

Part (a) earned 3 points, losing only the point for showing the friction force on the slab. In part (b) the student incorrectly attempts a conservation of energy approach and earned nothing for this effort. But the student did correctly calculate the friction force, with the intent of accounting for the work done by friction, and this earned 2 points. Part (c) earned 1 point for recognizing that kinematics is needed and for including a correct kinematic equation. Part (d) earned 1 point for a correct expression for the work, but the final substitution point was not given.