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 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. However, when students are asked to derive and 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. 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 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.

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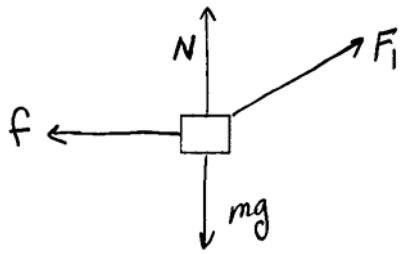
Question 1

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

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

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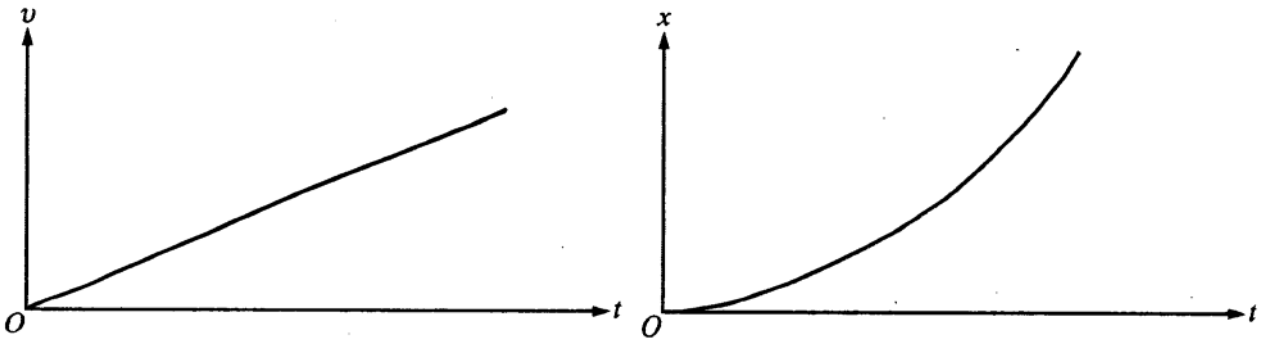
Question 1 (continued)

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

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

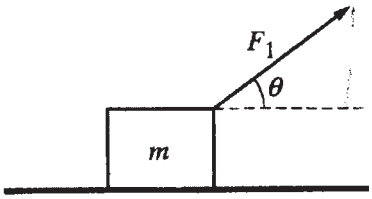
For the correct answer — 1 point

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

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.*

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

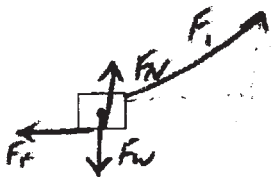
Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



Mech. 1.

A block of mass m is pulled along a rough horizontal surface by a constant applied force of magnitude F_1 that acts at an angle θ to the horizontal, as indicated above. The acceleration of the block is a_1. Express all algebraic answers in terms of m, F_1, θ, a_1, and fundamental constants.

(a) On the figure below, draw and label a free-body diagram showing all the forces on the block.



(b) Derive an expression for the normal force exerted by the surface on the block.

$F_N = F_w - F_1 \sin\theta$

$F_N = mg - F_1 \sin\theta$

GO ON TO THE NEXT PAGE.

(c) Derive an expression for the coefficient of kinetic friction μ between the block and the surface.

$\mu F_N = F_{fric}$

$\mu(mg - F\sin\theta) = F\cos\theta - ma$

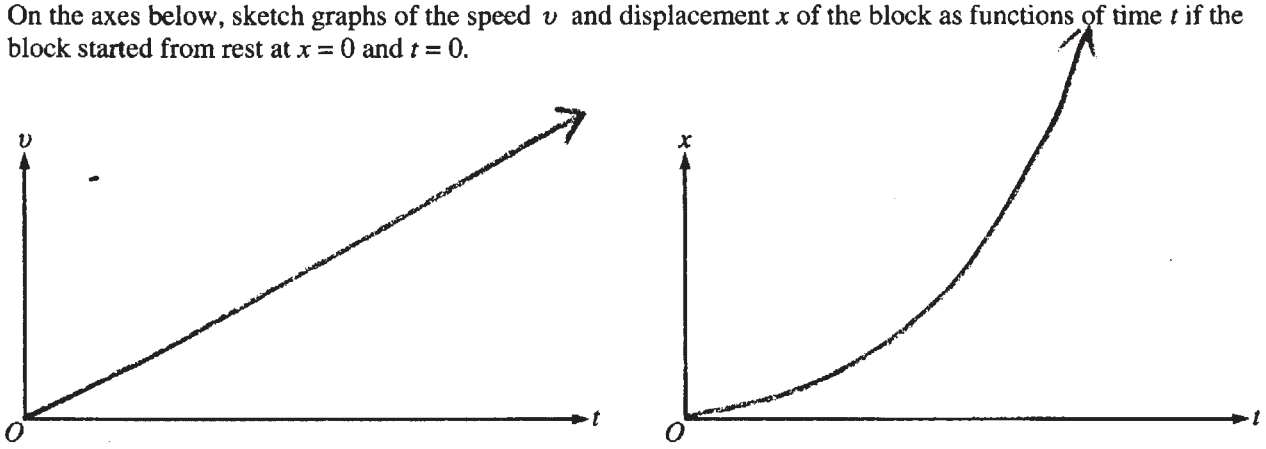
$\mu = \dfrac{F\cos\theta - ma}{mg - F\sin\theta}$

$F_{net} = ma$

$F\cos\theta - F_{fric} = ma$

$F\cos\theta - ma = F_{fric}$

(d) On the axes below, sketch graphs of the speed v and displacement x of the block as functions of time t if the block started from rest at $x = 0$ and $t = 0$.



(e) If the applied force is large enough, the block will lose contact with the surface. Derive an expression for the magnitude of the greatest acceleration a_{max} that the block can have and still maintain contact with the ground.

$F_N = 0 = mg - F\sin\theta$

$F\sin\theta = mg$

$F = \dfrac{mg}{\sin\theta}$

$F_{net} = ma_{max}$

$F\cos\theta = ma_{max}$

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

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

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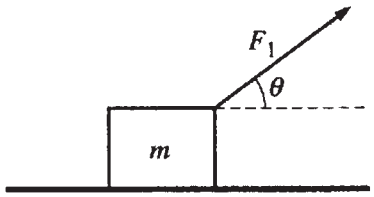

Mech. 1.

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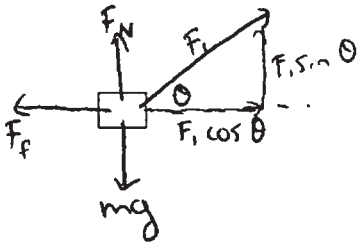


(b) Derive an expression for the normal force exerted by the surface on the block.

$\Sigma F_y = ma_y$, 0

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

$F_N = mg - F_1 \sin\theta$

GO ON TO THE NEXT PAGE.

(c) Derive an expression for the coefficient of kinetic friction μ between the block and the surface.

$\mu = \frac{F_f}{F_N}$

$\Sigma F_x = ma_x$

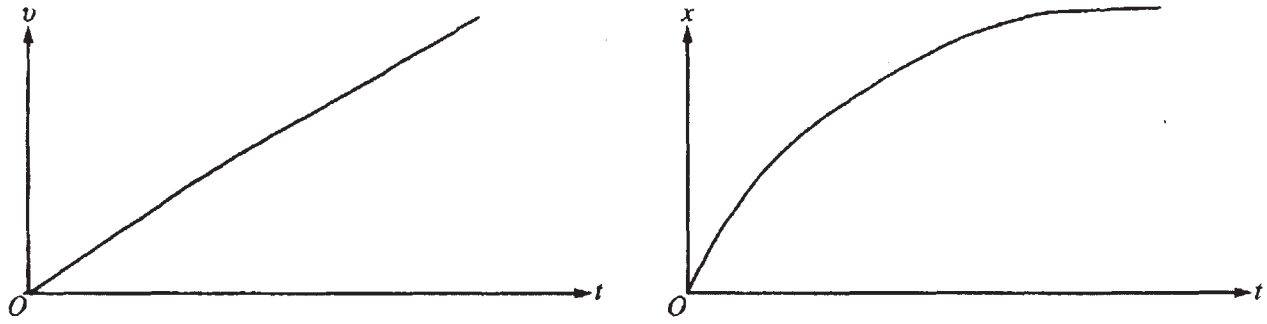
$-F_f + F_1 \cos\theta = ma_x$

$F_f = F_1 \cos\theta - ma_1$

$F_N = mg - F_1 \sin\theta$

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

(d) On the axes below, sketch graphs of the speed v and displacement x of the block as functions of time t if the block started from rest at $x = 0$ and $t = 0$.



(e) If the applied force is large enough, the block will lose contact with the surface. Derive an expression for the magnitude of the greatest acceleration a_{max} that the block can have and still maintain contact with the ground.

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

they have to remain $= 0$

$\Sigma F_x = ma_x$

$-F_f + F_1 \cos\theta = ma_x$

$a_{max} \leq \frac{F_1 \cos\theta - F_f}{m}$

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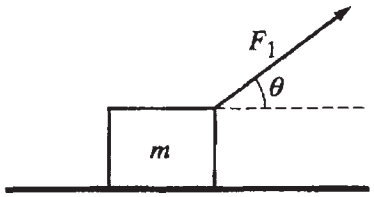

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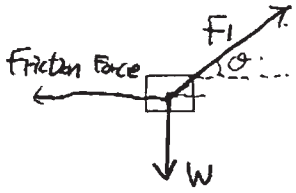


(b) Derive an expression for the normal force exerted by the surface on the block.

$\Sigma F = F_{net} = ma$.

the acceleration of the block is a_1.
the block of mass is m.
the angle is θ.

~~$F = ma_1 \sin\theta$.~~

$F = ma_1 \cos\theta$. N.

GO ON TO THE NEXT PAGE.

(c) Derive an expression for the coefficient of kinetic friction μ between the block and the surface.

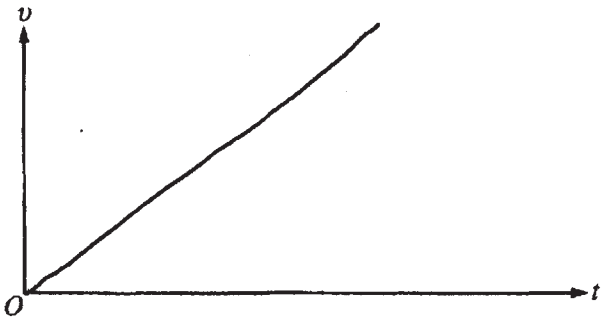
the coefficient of kinetic friction is μ.

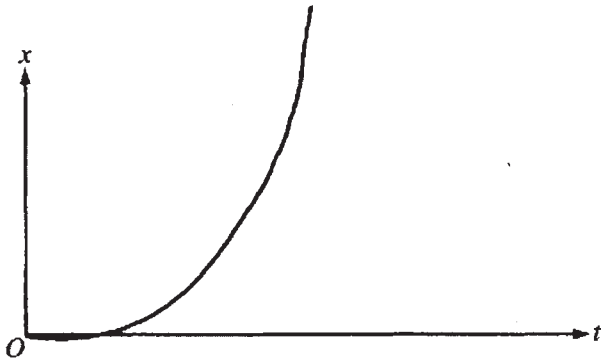
$F_{friction} = \mu \cdot m \cdot a_1$

$\mu \cdot m \cdot a_1 = m a_1 \cos\theta$

$\boxed{\mu = \cos\theta}$

(d) On the axes below, sketch graphs of the speed v and displacement x of the block as functions of time t if the block started from rest at $x = 0$ and $t = 0$.





(e) If the applied force is large enough, the block will lose contact with the surface. Derive an expression for the magnitude of the greatest acceleration a_{max} that the block can have and still maintain contact with the ground.

$F = m a_{max} \cos\theta$

$F = m a_{max} \cos\theta > \mu \cdot m \cdot a_{friction}$

$\cos > \mu$

$\boxed{a_{max} = \frac{a_1 \cdot \mu}{\cos\theta}}$

AP® PHYSICS C: MECHANICS
2007 SCORING COMMENTARY

Question 1

Overview

This question was designed to assess students' understanding of Newton's second law, kinetic friction, and basic kinematics. The system in question was a block being pulled across a rough horizontal surface by an applied force directed at an angle to the horizontal. (The horizontal acceleration a_1 was specified, and answers were to be expressed in terms of a_1 and other given quantities.) Part (a) asked students to draw and label a free-body diagram for the block. Part (b) instructed them to derive an expression for the normal force exerted by the surface, while part (c) told them to derive an expression for the coefficient of kinetic friction between the block and the surface. In part (d) they were required to sketch graphs of the block's speed and displacement. Part (e) stated that if the applied force was large enough, the block would lose contact with the surface, and then asked students to derive an expression for the magnitude of the greatest acceleration the block could have and still maintain contact with the ground.

Sample: M1A
Score: 15

This response received full credit on all parts. Although the label for the normal force vector is somewhat ambiguously placed on the page, the student correctly makes use of the normal force in the work that follows. The work is clearly presented and demonstrates a good understanding of the concepts involved.

Sample: M1B
Score: 10

Parts (a), (b), and (c) received full credit. In part (a) the components of the applied force are shown in addition to the applied force vector, but since they are identified as components and correctly used in succeeding parts of the problem, no deductions were made. Part (d) earned only the point for the correct speed versus time graph; the displacement versus time graph is curved in the wrong direction and is inconsistent with the speed graph. Part (e) received no credit since there is no recognition that the normal force and the friction force had to be zero.

Sample: M1C
Score: 6

Part (a) received 3 points for the three correct forces shown, but the normal force is missing. Part (d) earned 3 points for the correct graphs, but the other parts of the problem received no credit.