General Notes About 2008 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. 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*.

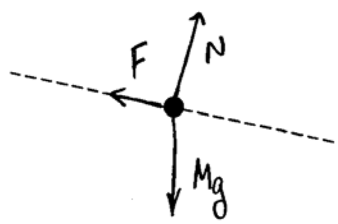
4. The scoring guidelines typically show numerical results using the value $g = 9.8\ \mathrm{m/s^2}$, but use of $10\ \mathrm{m/s^2}$ is, of course, also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

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) 3 points



For a correctly drawn and labeled weight vector, originating on the dot and with an arrowhead (Alternatively, correctly drawn and labeled components <u>instead</u> of the total weight vector was acceptable.) — 1 point

For a correctly drawn and labeled normal force vector, originating on the dot and with an arrowhead — 1 point

For a correctly drawn and labeled drag-force vector, originating on the dot and with an arrowhead — 1 point

One point was deducted if there were any extra vectors on the point, including components drawn with arrowheads.

(b) 4 points

For any expression of $F = Ma$ or any dimensionally correct application of $F = Ma$ — 1 point

For correctly expressing the component of the weight parallel to the plane as $Mg\sin\theta$ — 1 point

For correctly expressing the drag force as $-kx$ — 1 point

$Ma = Mg\sin\theta - bv$

For a dimensionally correct differential equation, including dv/dt and expressions for the drag force and the component of the weight parallel to the plane — 1 point

$M\dfrac{dv}{dt} = Mg\sin\theta - bv$

One point was deducted if the algebraic signs of the weight component and the drag force were not opposite somewhere in the solution, OR if only one of these two terms was included.

(c) 2 points

For an indication that $F_{\text{net}} = 0$, $a = 0$, or the parallel component of the weight $= bv_T$ — 1 point

$0 = Mg\sin\theta - bv_T$

$bv_T = Mg\sin\theta$

For the correct expression for the terminal velocity (or one consistent with part (b)) — 1 point

$v_T = Mg\sin\theta/b$

Question 1 (continued)

Distribution of points

(d) 3 points

For taking the differential equation from part (b) and correctly separating the variables in preparation for integration (definite or indefinite integral) — 1 point

$$M\frac{dv}{dt} = Mg\sin\theta - bv$$

$$\frac{dv}{Mg\sin\theta - bv} = \frac{dt}{M}$$

For correct integration of both sides of equation — 1 point

For example, using a method involving an indefinite integral

Letting $u = Mg\sin\theta - bv$, so $du = -b\,dv$

$$-\frac{1}{b}\frac{du}{u} = \frac{dt}{M}$$

$$\int\frac{du}{u} = -\frac{b}{M}\int dt$$

$$\ln u = -\frac{b}{M}t + \ln C$$

$$u = Ce^{-bt/M}$$

$$Mg\sin\theta - bv = Ce^{-bt/M}$$

Using $v = 0$ at $t = 0$

$$Mg\sin\theta = C$$

$$Mg\sin\theta - bv = Mg\sin\theta\, e^{-bt/M}$$

$$-bv = Mg\sin\theta\, e^{-bt/M} - Mg\sin\theta$$

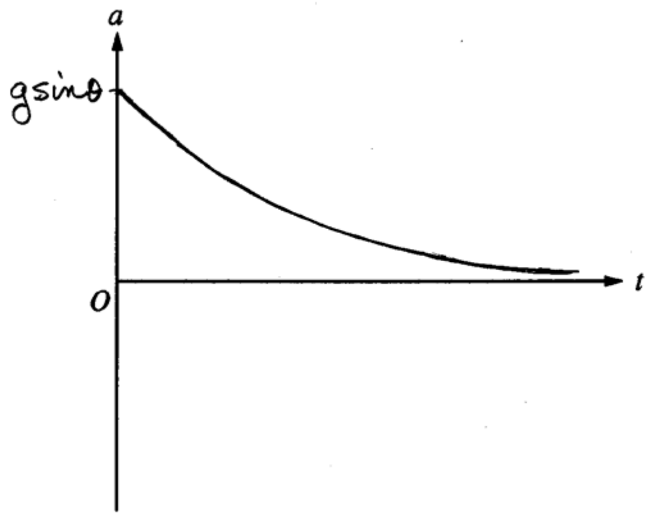
For a correct final expression for $v(t)$ — 1 point

$$v = (Mg\sin\theta/b)\left(1 - e^{-bt/M}\right)$$

Question 1 (continued)

Distribution of points

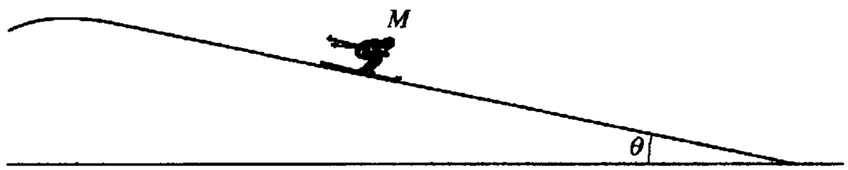
(e) 3 points



For the correct initial value of *a* (or a value consistent with part (b))	1 point
For a negatively sloped curve, concave up	1 point
For a curve asymptotic to the *t* axis	1 point
(This point was awarded even if the curve was not otherwise correct.)	

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

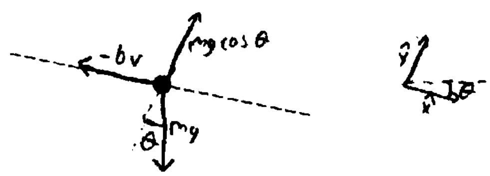
Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



Mech. 1.

A skier of mass M is skiing down a frictionless hill that makes an angle θ with the horizontal, as shown in the diagram. The skier starts from rest at time $t = 0$ and is subject to a velocity-dependent drag force due to air resistance of the form $F = -bv$, where v is the velocity of the skier and b is a positive constant. Express all algebraic answers in terms of M, b, θ, and fundamental constants.

(a) On the dot below that represents the skier, draw a free-body diagram indicating and labeling all of the forces that act on the skier while the skier descends the hill.



(b) Write a differential equation that can be used to solve for the velocity of the skier as a function of time.

$$m\frac{dv}{dt} = mg\sin\theta - bv$$

$$\frac{dv}{dt} = g\sin\theta - \frac{bv}{m}$$

(c) Determine an expression for the terminal velocity v_T of the skier.

$$0 = mg\sin\theta - bv_T$$

$$bv_T = mg\sin\theta$$

$$v_T = \frac{mg\sin\theta}{b}$$

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(d) Solve the differential equation in part (b) to determine the velocity of the skier as a function of time, <u>showing all your steps</u>.

$$\frac{dv}{dt} = g\sin\theta - \frac{bv}{m}$$

$$= -\frac{b}{m}\left(v - \frac{mg\sin\theta}{b}\right)$$

$$\int \frac{dv}{v - \frac{mg\sin\theta}{b}} = -\frac{b}{m}\int dt$$

$$\ln\left|v - \frac{mg\sin\theta}{b}\right| = -\frac{bt}{m} + C$$

$$v - \frac{mg\sin\theta}{b} = Ce^{-bt/m}$$

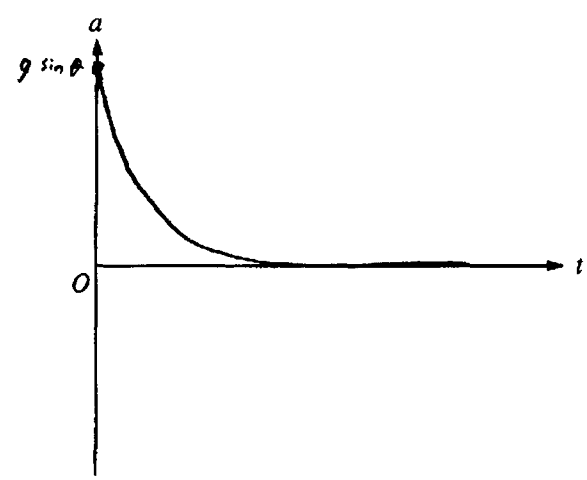
$$v(t) = Ce^{-bt/m} + \frac{mg\sin\theta}{b}$$

$$0 = C + \frac{mg\sin\theta}{b}$$

$$C = -\frac{mg\sin\theta}{b}$$

$$v(t) = \frac{mg\sin\theta}{b}\left(1 - e^{-bt/m}\right)\hat{x}$$

(e) On the axes below, sketch a graph of the acceleration a of the skier as a function of time t, and indicate the initial value of a. Take downhill as positive.



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CM1B

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

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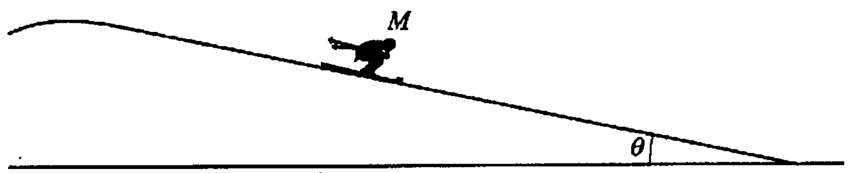
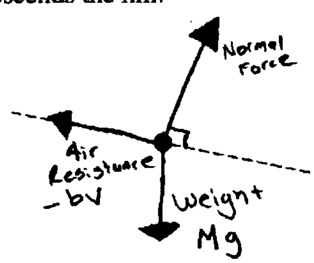


Mech. 1.

A skier of mass M is skiing down a frictionless hill that makes an angle θ with the horizontal, as shown in the diagram. The skier starts from rest at time $t = 0$ and is subject to a velocity-dependent drag force due to air resistance of the form $F = -bv$, where v is the velocity of the skier and b is a positive constant. Express all algebraic answers in terms of M, b, θ, and fundamental constants.

(a) On the dot below that represents the skier, draw a free-body diagram indicating and labeling all of the forces that act on the skier while the skier descends the hill.



(b) Write a differential equation that can be used to solve for the velocity of the skier as a function of time.

$V = V_0 + a t$

$V = a t$

$V = \frac{g \sin\theta - bv}{M} \cdot t$

$F = MA$ – Newton's Second Law

$A = \frac{F}{M}$

$A = \frac{g \sin\theta - bv}{M}$

(c) Determine an expression for the terminal velocity v_T of the skier.

$F = g \sin\theta$

$-bv = g \sin\theta$

$V_T = \frac{g \sin\theta}{b}$

g is negative so the final answer is positive

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CM1B2

(d) Solve the differential equation in part (b) to determine the velocity of the skier as a function of time, showing all your steps.

$$V = \frac{g\sin\theta - bv}{M} \cdot t$$

$$VM = g\sin\theta t - bvt$$

$$\frac{VM}{t} = g\sin\theta - bV$$

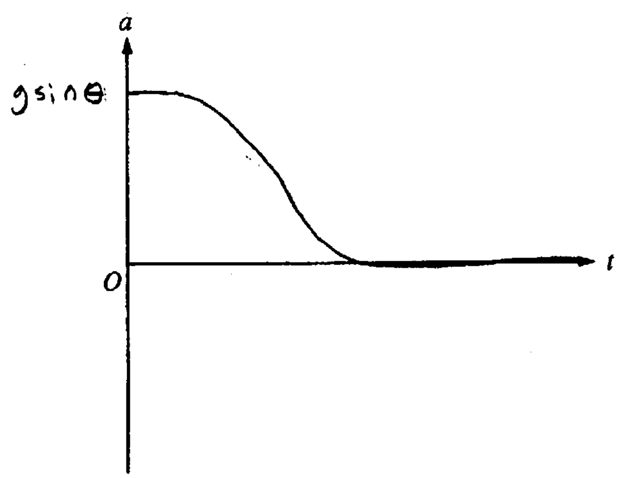
$$\frac{VM}{t} + bv = g\sin\theta$$

$$v\left(\frac{M}{t} + b\right) = g\sin\theta$$

$$V = \frac{g\sin\theta}{\frac{M}{t} + b}$$

$$V = \frac{g\sin\theta t}{M + b}$$

(e) On the axes below, sketch a graph of the acceleration a of the skier as a function of time t, and indicate the initial value of a. Take downhill as positive.



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CM1C

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

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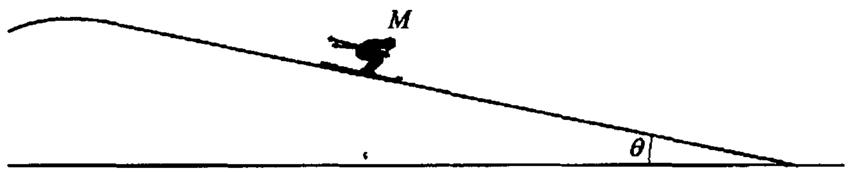
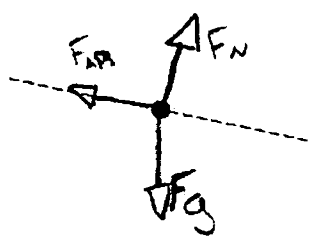


Mech. 1.

A skier of mass M is skiing down a frictionless hill that makes an angle θ with the horizontal, as shown in the diagram. The skier starts from rest at time $t = 0$ and is subject to a velocity-dependent drag force due to air resistance of the form $F = -bv$, where v is the velocity of the skier and b is a positive constant. Express all algebraic answers in terms of M, b, θ, and fundamental constants.

(a) On the dot below that represents the skier, draw a free-body diagram indicating and labeling all of the forces that act on the skier while the skier descends the hill.



(b) Write a differential equation that can be used to solve for the velocity of the skier as a function of time.

$x(t) = V_0 t + \frac{1}{2} a t^2$ $\qquad x'(t) = v(t)$

$x'(t) = V_0 + at$

$v(t) = \cancel{V_0}^{0} + at$ $\qquad v(t) = at$

(c) Determine an expression for the terminal velocity v_T of the skier.

$F = ma = 0$

$F_{g_x} - F_{AR} = 0$

$mg\cos\theta + bv = 0$

$mg\cos\theta = -bv$

$v = -\frac{mg\cos\theta}{b}$

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(d) Solve the differential equation in part (b) to determine the velocity of the skier as a function of time, showing all your steps. CM1C 2

$x(t) = v_0 t + \frac{1}{2} a t^2$ $\qquad \frac{dx}{dt} = v$

$\frac{dx}{dt} = v_0 + at$ $\qquad v_0 = 0$

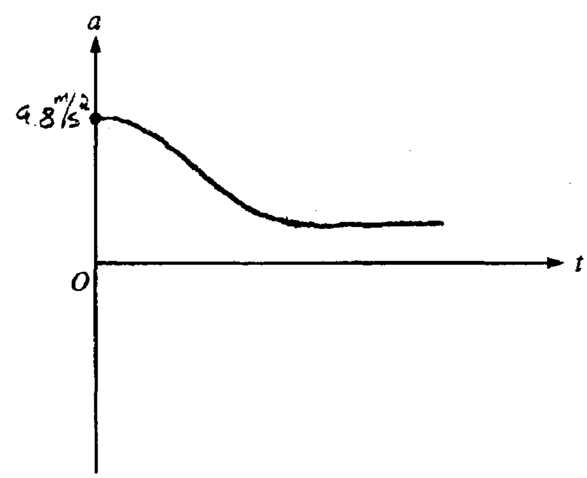
$v = \cancel{v_0}^{0} + at$

$v(t) = at$

(e) On the axes below, sketch a graph of the acceleration a of the skier as a function of time t, and indicate the initial value of a. Take downhill as positive.

$a = \frac{F_{net}}{m}$

$a = \frac{mg\cos\theta - kv}{m}$



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AP® PHYSICS C: MECHANICS
2008 SCORING COMMENTARY

Question 1

Overview

This question was intended to evaluate students' understanding of velocity-dependent drag forces and of the dynamics and mathematics required to set up and solve Newton's second law for a skier moving down a frictionless slope under the influence of a linear drag force. Part (a) asked students to draw a free-body diagram showing the forces acting on the skier. Part (b) required them to write a differential equation that could be used to find the velocity of the skier as a function of time. Part (c) asked students to write an expression for the terminal velocity of the skier. Part (d) required them to solve their differential equation from part (b) to determine the velocity of the skier as a function of time. Finally, in part (e) students had to draw a graph representing the acceleration of the skier as a function of time and to indicate the initial value of the acceleration.

Sample: CM1A
Score: 15

The student labels the normal force with its magnitude in terms of the weight. The integration in part (d) is straightforward and easy to follow. Technically, the right-hand side of the fourth line should contain $\ln C$ to be strictly consistent with the next line. However, this slight carelessness in notation does not affect the correctness of the integration or the final answer and was not penalized.

Sample: CM1B
Score: 9

Full credit was earned in part (a). In part (b) the expression for the component of weight is incorrect, and the equation is not written in differential form, so only 2 points were earned. In part (c) full credit was earned for correctly using the expression from part (b). No points were earned in part (d), but 2 points were earned in part (e) for the initial value and the asymptote.

Sample: CM1C
Score: 4

Full credit was earned in part (a). No points were earned in part (b). One point was earned in part (c) for indicating the sum of the forces is zero. No points were earned in parts (d) and (e).