

2005 AP[®] PHYSICS C: MECHANICS FREE-RESPONSE QUESTIONS

PHYSICS C

Section II, MECHANICS

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 the pink booklet in the spaces provided after each part, NOT in this green insert.

Mech. 1.

A ball of mass M is thrown vertically upward with an initial speed of v_0 . It experiences a force of air resistance given by $\mathbf{F} = -k\mathbf{v}$, where k is a positive constant. The positive direction for all vector quantities is upward. Express all algebraic answers in terms of M , k , v_0 , and fundamental constants.

- (a) Does the magnitude of the acceleration of the ball increase, decrease, or remain the same as the ball moves upward?

_____ increases _____ decreases _____ remains the same

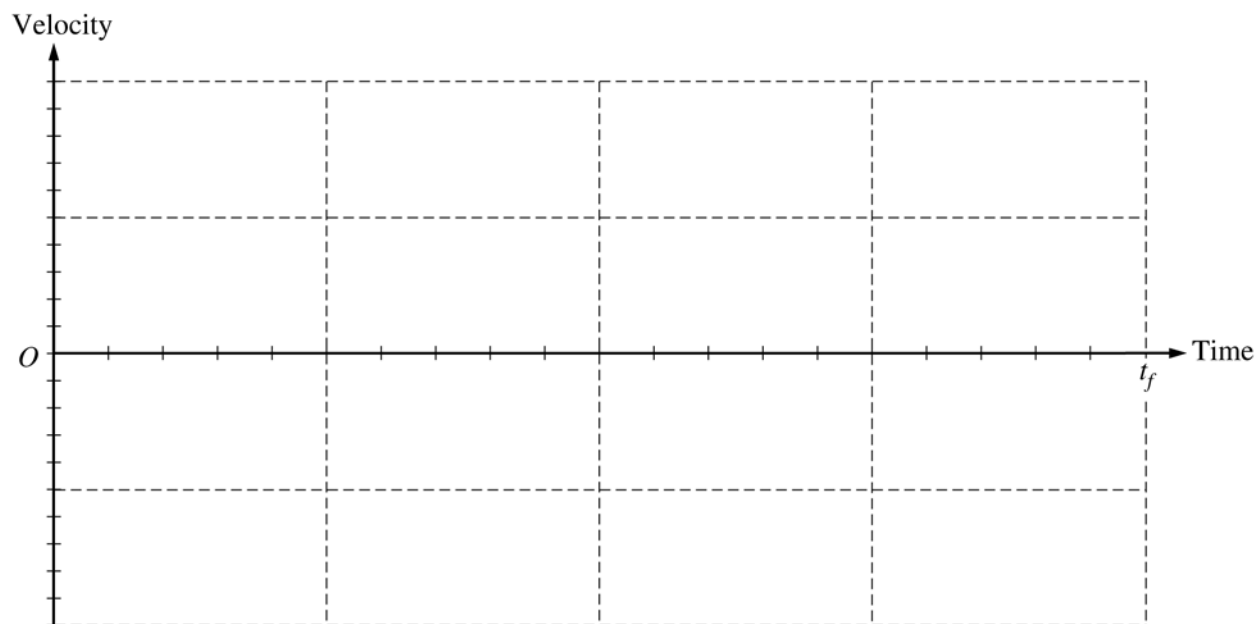
Justify your answer.

- (b) Write, but do NOT solve, a differential equation for the instantaneous speed v of the ball in terms of time t as the ball moves upward.
- (c) Determine the terminal speed of the ball as it moves downward.
- (d) Does it take longer for the ball to rise to its maximum height or to fall from its maximum height back to the height from which it was thrown?

_____ longer to rise _____ longer to fall

Justify your answer.

- (e) On the axes below, sketch a graph of velocity versus time for the upward and downward parts of the ball's flight, where t_f is the time at which the ball returns to the height from which it was thrown.



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Question 1

15 points total

**Distribution
of points**

(a) 2 points

For indicating that the magnitude of the acceleration decreases as the ball moves upward
 For a correct, reasonable justification
 For example: Since velocity is upward, air resistance is downward, in the same direction as gravity. The velocity will decrease, causing the force of air resistance to decrease. Therefore, the net force and thus the total acceleration both decrease.

1 point
1 point

(b) 3 points

For showing the expression $a = \frac{dv}{dt}$

1 point

For any clear indication that the forces of air resistance and gravity are in the same direction, such as by showing an equation or a free-body diagram

1 point

$$F_{\text{net}} = -Mg - kv$$

For a correct differential equation with the correct signs

1 point

$$M \frac{dv}{dt} = -Mg - kv$$

(c) 3 points

For recognizing that at terminal speed $F_{\text{net}} = 0$

1 point

For any clear indication that the forces of air resistance and gravity are now in opposite directions, such as by showing an equation or a free-body diagram

1 point

$$F_{\text{net}} = -Mg + kv$$

$$0 = -Mg + kv_T$$

For a correct expression for the terminal speed

1 point

$$v_T = Mg/k$$

(d) 2 points

For indicating that it takes longer for the ball to fall

1 point

For a correct, reasonable justification

1 point

For example: The ball loses mechanical energy on the way up and on the way down.

This means the average speed is greater on the way up than on the way down.

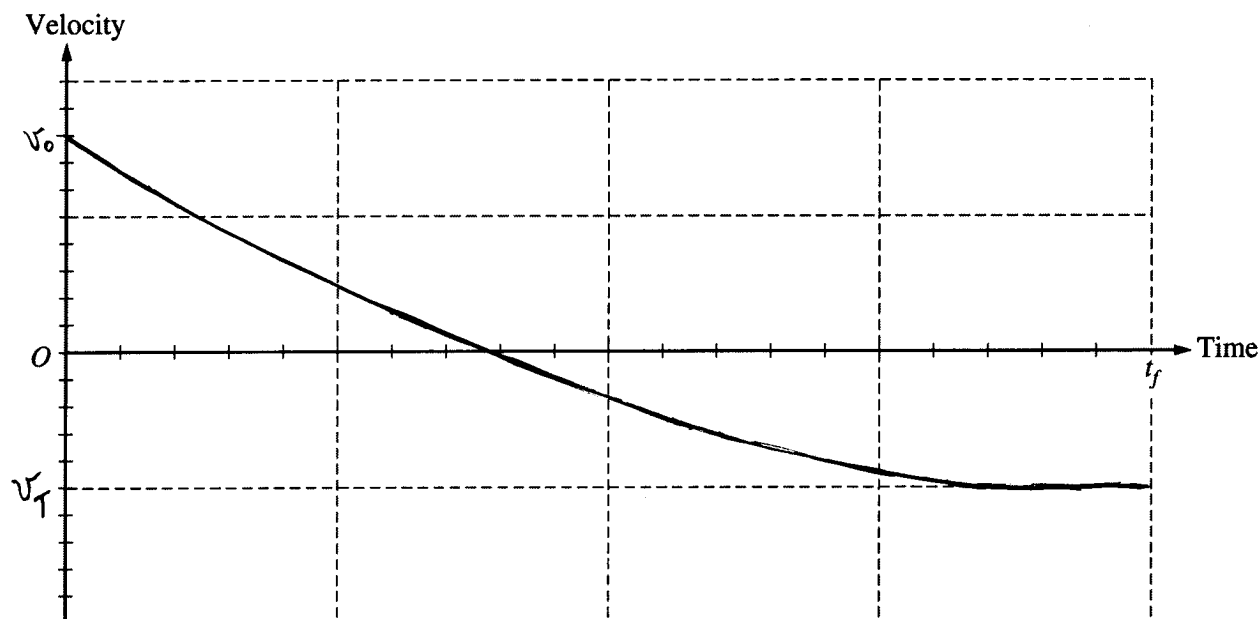
Since the distance traveled is the same, the time must be longer on the way down.

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Question 1 (continued)

Distribution
of points

(e) 5 points



For an exponentially decreasing curve beginning with positive initial velocity v_0 , crossing the time axis at t less than $t_f/2$, and having the final speed less than the initial speed 5 points

One point partial credit was awarded for each of the following curve characteristics.

For showing that when $v = 0$, the curve is differentiable (i.e., no discontinuity in slope) and has a negative slope

For showing the curve to be concave upward both for when the ball is rising and when the ball is falling

For showing time intervals for when the ball is rising and when the ball is falling that are consistent with the answer to part (d)

For showing that the final velocity is negative and that the speed at t_f is less than v_0