Freefall with Air Resistance

Pre-Lecture Questions

Problem Set #15(due next time)

Lecture Outline

1. The Force of Air Resistance
2. The Equations of Motion
3. A Summary of the Course to Date

Pre-Class Summary:

To understand freefall with air resistance, we followed our usual method to understand the motion of an object.

1. Find the forces acting on the object.
2. Use Newton's Laws of Motion to find the acceleration of the object.
3. Use the definition of acceleration and the definition of velocity to find the equations of motion.

The force of air resistance is proportional to the velocity, $F_d = bv$, where b is the coefficient of air resistance which depends upon the size and shape of an object as well as the properties of the fluid through which it is moving.

As objects speed up, the force increases eventually equaling the gravitational force. At which point, the speed becomes constant at the "terminal speed."

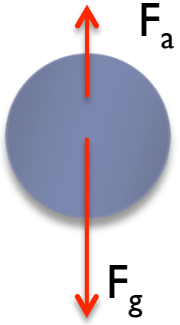
The Definition of the Terminal Speed $v_t \equiv \frac{mg}{b}$

The equations of motion for an object falling with air resistance can be written in terms of the terminal speed,

$$a(v) = \frac{b}{m}\left(v_t - v\right) \qquad v(t) = v_t\left(1 - e^{-\frac{b}{m}t}\right) \qquad x(t) = x_o + v_t t + v_t \frac{m}{b}\left(e^{-\frac{b}{m}t} - 1\right)$$

1. *For an object falling with air resistance, the force of air resistance grows as the _____ grows. One way to write this mathematically is $F_a = bv$.*

2. *Since the object is falling, the other force on it must be the force of _____ usually written as F_g = _____ .*



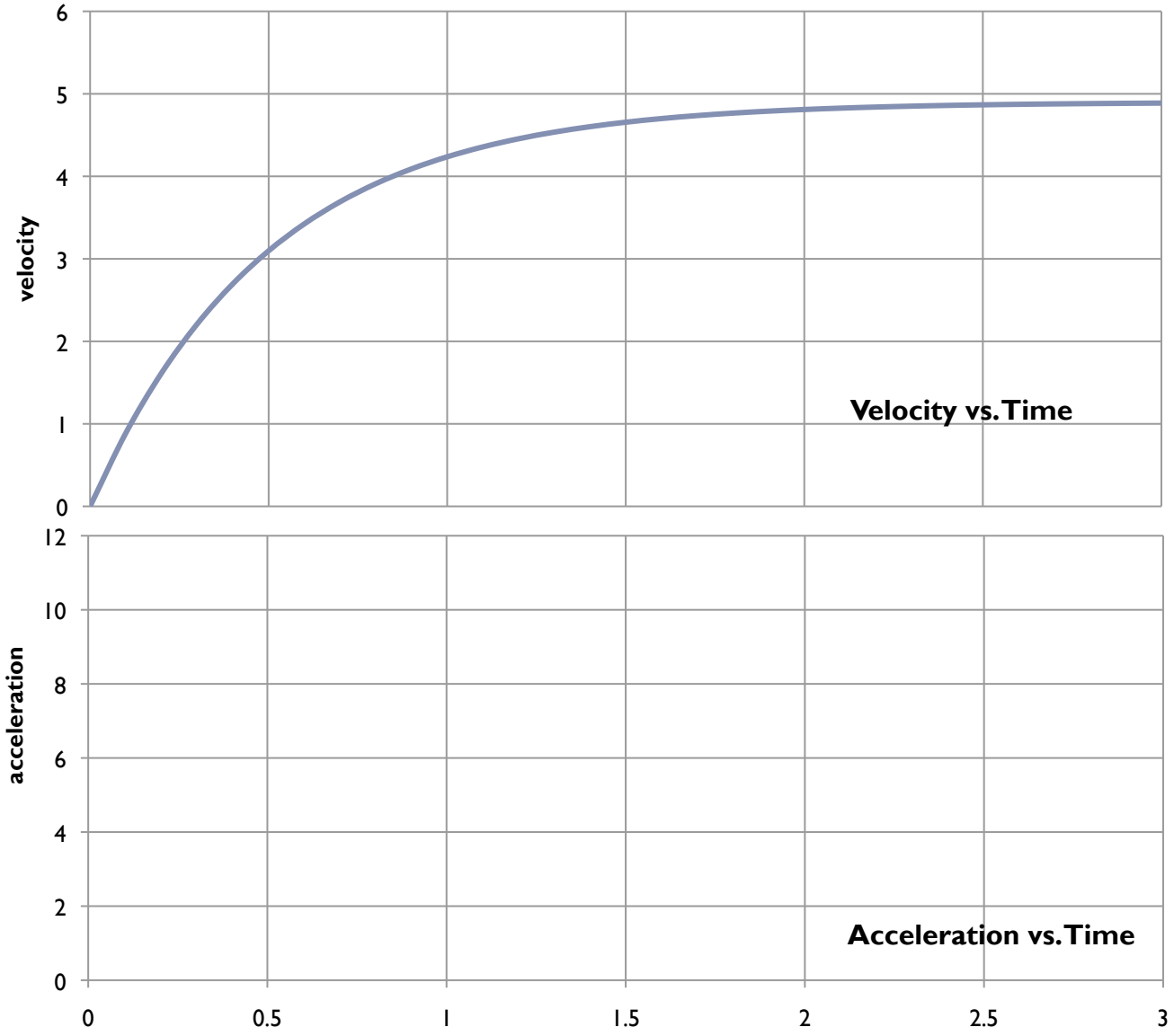
3. *Write the Second Law using F_g and F_a. Then substitute for each force:*

4. *Initially, since the object is released from rest the initial velocity is _____ . At rest, the only force on it is _____ , therefore the initial acceleration is _____.*

5. *As the object speeds up, eventually the force of _____ is exactly equal to the force of _____. Therefore, the acceleration is _____ and the velocity stops changing.*

6. *Use the Second Law equation above to find this "terminal velocity:"*

At the left is the velocity vs. time curve for an object falling with air resistance. Sketch the acceleration vs. time curve.



Example 1: A 2.7g ping pong ball dropped from a substantial height reaches a maximum speed of 20m/s. Find (a)the terminal speed and (b)the air resistance coefficient, b.

Six balls are all the same size, but have different masses as indicated. They are all dropped off the top of a tall cliff. Rank the balls according to:

a)the gravitational force they feel from greatest to least.

b)their acceleration just after being released from greatest to least.

c)their terminal velocity from greatest to least.

d)the order in which they hit the ground.

A. 50g B. 100g C. 150g D. 200g E. 350g F. 500g

Example 2: A 2.7g ping pong ball dropped from a substantial height reaches a maximum speed of 20m/s. Find (a)the time to reach terminal velocity and (b)the velocity it would have acquired in that time if there were no air resistance.

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Summary of the Course to Date