CHAPTER 3 PRACTICE PASSAGE

When an object is falling through air, it experiences a drag force due to the frictional effects of the air. The drag force is always directed opposite the direction of motion of the object. For a spherical object, the drag force can be calculated using Stokes' law:

$$F_D = 6\pi\eta r v$$

Equation 1

where F_D is the drag force, η is the coefficient of viscosity of the air, r is the radius of the sphere, and v is the velocity of the sphere.

Since the drag force is related to the velocity of the sphere, as the sphere's velocity increases, so does the drag force. After a certain time, the drag force will be large enough that the net force acting on the sphere is zero. At this point, the sphere falls with a constant velocity, known as the terminal velocity, v_T.

A student experiments with different spherical objects falling on Earth in order to test Stokes' law. The experiment involves dropping a variety of spheres from the balcony of a building. The relative mass and radius for each sphere are listed in Table 1.

Object	Mass	Radius
Beach ball	m	$20r$
Bowling ball	$20m$	$10r$
Golf ball	m	r
Ping pong ball	$0.25m$	r

Table 1 Mass and radius of spheres

1. Ignoring air resistance, which ball will hit the ground first?

A) The beach ball, since it has the largest radius.
B) The bowling ball, since it has the largest mass.
C) The golf ball, since it has the smallest radius and more mass than the ping pong ball.
D) All the balls will hit at the same time.

2. Considering air resistance, which ball will take the longest time to reach the ground when dropped, assuming none of the balls reaches its terminal velocity?

A) Beach ball
B) Bowling ball
C) Golf ball
D) Ping pong ball

3. For the experiment conducted, let v_1 be the velocity of the golf ball after 10 seconds when dropped from height, h. Let v_2 be the velocity of the ping pong ball after 10 seconds when dropped from the same height, h. How do v_1 and v_2 compare?

A) $v_1 < v_2$
B) $v_1 = v_2$
C) $v_1 > v_2$
D) It cannot be determined without information on the drag force.

4. How does the drag force on the beach ball compare to the drag force on the bowling ball when the velocities of the two balls are the same?

A) The drag force on the beach ball is 20 times the drag force on the bowling ball.
B) The drag force on the beach ball is 2 times the drag force on the bowling ball.
C) The drag force on the beach ball is $\frac{2}{3}$ the drag force on the bowling ball.
D) The drag force on the beach ball is $\frac{1}{2}$ the drag force on the bowling ball.

5. Which of the following gives an equation for terminal velocity for the balls?

A) $v_T = mg - 6\pi\eta r$

B) $v_T = mg + 6\pi\eta r$

C) $v_T = \frac{mg}{6\pi\eta r}$

D) $v_T = \frac{6\pi\eta r}{mg}$

6. Which ball has the greatest terminal velocity?

A) Beach ball
B) Bowling ball
C) Golf ball
D) Ping pong ball

7. Which of the following changes would result in the greatest time difference between the time the first ball hits the ground and the time the last ball hits the ground?

I. Increasing the coefficient of viscosity, thus increasing the drag force.
II. Increasing the radius by a factor of 2, thus increasing the drag force.
III. Increasing the height from which the balls are dropped so that each ball reaches its terminal velocity before hitting the ground.

A) I and II
B) II and III
C) III only
D) None of the options will result in a time difference.