Acceleration of Falling Objects CWA

The Acceleration of Falling Objects CWA is an open argument. The overarching question is: Which of the two objects do you predict would have the greater acceleration when dropped in air? The following handouts are included:

- Prompt
- Sample student response

Students should be provided the prompt, which includes the question as well as data necessary to answer the question. A sample student response is included. Either the CWA Common Scoring Rubric or the Old Science CWA Rubric can be used to score the responses.

Name_____ Date_____

Falling Objects

Claim-Evidence-Reasoning (CER) Writing Assignment

Directions: Read the following Prompt. Then construct a scientific argument, using the Claim-Evidence-Reasoning (CER) framework, that answers the Scientific Question below. Use what you learned in class about falling objects.

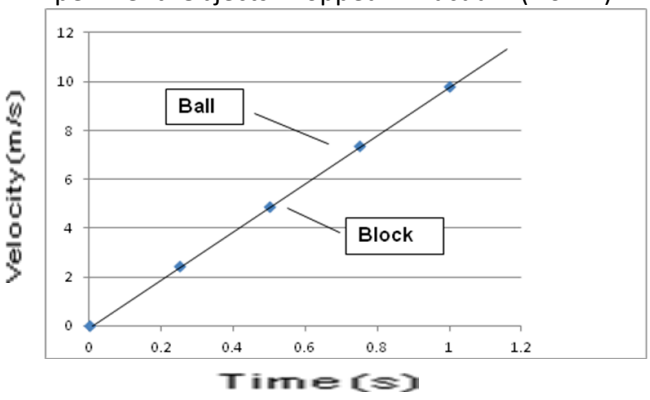
Prompt: A group of students performed an experiment to investigate the acceleration of different falling objects on Earth. In the experiment, the students dropped each object from a height of 5.0 meters, and carefully measured the speed (in meters per second) and the time (in seconds), using electronic sensors. The objects included a small round ball (3-inch diameter round plastic ball) and a large rectangular block (5-inch cube shaped Styrofoam block). The Styrofoam block's weight was four times the amount of weight of the plastic ball.

Table 1.
Data resulting from an investigation in which objects inside a large vacuum tube were dropped after removing the air inside the tube.

Time (s)	Speed (m/s)	
	Small ball	Large block
0	0	0
.25	2.45	2.45
.50	4.9	4.9
.75	7.35	7.35
1.00	9.8	9.8

The students created the following velocity (speed) vs. time graph of the data for the experiment. After plotting the data points, they drew the best fit line through the points, as shown below.

Experiment: Objects Dropped in Vacuum (No Air)



The students used the slope of the best fit line to determine the acceleration ($\Delta v/\Delta t$) of each object. After looking at the results, one of the students remarked, "Wow, both objects had an acceleration of 9.8 m/s^2. That's exactly the acceleration due to the force of gravity on the surface of the Earth. I wonder what the accelerations of the objects would be if they were falling through air."

Scientific Question: Which of the two objects do you predict would have the greater acceleration when dropped in air?

Falling Objects: Sample Student Response

Claim:

a) I predict that the ball will have greater acceleration than the block when dropped in air.

b) I predict that the block will have greater acceleration than the ball when dropped in air.

Evidence:

The plastic ball is 3 inches in diameter and round (spherical) shaped. The Styrofoam block is 5 inches on a side and cube shaped. The block's weight is four times the weight of the plastic ball.

Reasoning:

We learned in physics class that the downward acceleration of falling objects due to the force of gravity alone (when no other forces are acting) is the same for all objects (9.8 m/s^2 on the surface of the Earth) regardless of the objects' masses. This explains why both the ball and the block accelerated at 9.8 m/s^2 in the experiment, when no forces like air resistance were acting on the objects (since there was no air).

As we know from Newton's Second Law of Motion, an object's acceleration = net force ÷ mass. In this case, the net force is the force of gravity (or, the object's weight). To calculate weight (wt) for a given mass (m), we multiply mass times the acceleration due to gravity, g. So, to find acceleration, a:

$a = wt/m = mg/m = g$

For the block, which has four times the weight (and thus, 4 times the mass): $a = 4mg/4m = g$. It's the same acceleration result, g.

When the objects are dropped in air, they are subject to air resistance. Air resistance is a force that acts in the direction opposite to the direction of the object's motion. In this case, air resistance would act in an upward direction, which would reduce the net force on the object, and thus the acceleration of the object. So, whichever object has the least air resistance relative to its mass will have the greatest acceleration.

The math looks this: $a = g - (F_{Air}/m)$ (where F_{Air} is force of air resistance)

For the ball: $a = g - (F_{Air\text{-}ball}/m_{ball})$

For the block: $a = g - (F_{Air\text{-}block}/m_{block}) = g - (F_{Air\text{-}block}/4 \text{ X } m_{ball})$

This means that if the air resistance acting on the block happened to be four times the amount of the air resistance acting on the ball, the reduction in the acceleration due to gravity alone (g, or 9.8 m/s^2) would be the same exact amount for both objects. If the air resistance on the block is less than four times the air resistance on the ball, then the block will have greater acceleration than the ball (since it will reduce the acceleration due to gravity by a lesser amount than the ball). If the air resistance on the block is more than four times the air resistance on the ball, the block will have less acceleration than the ball.

So, how do we determine the amount of air resistance acting on each object? The amount of air resistance depends on the shape and size of an object. The round shape of the ball should produce less air resistance than the flat sides of the cube-shaped block, especially if the block is oriented so that a flat side is facing downward. The size, or cross-sectional area that pushes against the air, of the ball is less than that of the block, so that will contribute to the ball experiencing less air resistance, also. The area of each object is:

Ball: $A = \pi r^2 = 3.14\ (1.5\ \text{in.})^2 = 7\ \text{inches}^2$

Block: $A = L \times W = 5\ \text{in.} \times 5\ \text{in.} = 25\ \text{inches}^2$

The block's area is 25/7 or 3.6 times the area of the ball.

a) The block's area is less than four times the ball's area, which would seem to indicate that the block's air resistance would be less than four times that for the ball. However, the round shape of the ball would offset this, further reducing the ball's air resistance enough so that the block's air resistance would be more than four times that for the ball. This would support the ball having a greater acceleration as it falls than the block.

b) The block's area is less than four times the ball's area, which would seem to indicate that the block's air resistance would be less than four times that for the ball. Although the round shape of the ball would offset this by some amount, it might not reduce the ball's air resistance enough to result in the block's air resistance being more than four times as much. Moreover, if the block were oriented with an edge facing downward, or if it were rotating as it fell, its shape relative to the air would actually reduce the air resistance it experienced compared to it falling with one flat side facing downward. This would support the block having a greater acceleration as it falls than the ball.