Flipping Physics Lecture Notes:

2016 #2 Free Response Question - AP Physics 1 - Exam Solution
http://www.flippingphysics.com/ap1-2016-frq2.html

This Experimental Design question also works as a part of the AP Physics C: Mechanics curriculum.

A new kind of toy ball is advertised to "bounce perfectly elastically" off hard surfaces. A student suspects, however, that no collision can be perfectly elastic. The student hypothesizes that the collisions are very close to being perfectly elastic for low-speed collisions but that they deviate more and more from being perfectly elastic as the collision speed increases.

(a) Design an experiment to test the student's hypothesis about collisions of the ball with a hard surface. The student has equipment that would usually be found in a school physics laboratory.

i. What quantities would be measured?
ii. What equipment would be used for the measurements, and how would that equipment be used?
iii. Describe the procedure to be used to test the student's hypothesis. Give enough detail so that another student could replicate the experiment.

(b) Describe how you would represent the data in a graph or table. Explain how that representation would be used to determine whether the data are consistent with the student's hypothesis.

You should get all the way here in the problem before you begin answering any of these questions. Without knowing what will go on the x and y axes of a graph, you cannot answer the question "What quantities would be measured?". In other words, think all the way through your hypothetical lab before answering these questions. And now, on to my answers:

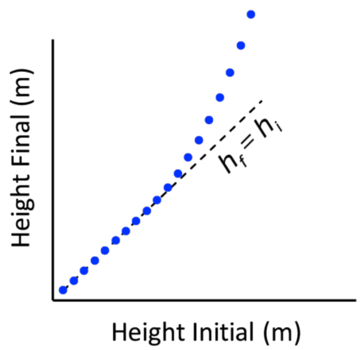
i. *Drop the ball from various heights and measure the initial drop height, h_i, and the maximum rebound height which I will call height final, h_f.*
ii. *A video camera and a meter stick. Orient the meter stick vertically next to where the ball is dropped. Film the motion of the ball and use the video to measure h_i and h_f.*
iii. *Orient a meter stick vertically above a hard surface. Drop the toy ball 10 times from various heights such that the initial height is always measurable using the meter stick. Use the video camera to video the motion of the ball from initial drop to maximum height of the first bounce. Review the video to measure initial and final heights.*

(b) On our graph plot height final as a function of height initial. If the collision is perfectly elastic, the speeds of the ball right before and after the collision will be the same. If those two speeds are the same, because mechanical energy is conserved, the initial and final heights will be the same. Therefore, if the collision is perfectly elastic, the data should show a linear relationship with a slope of 1 and a y-intercept of zero. This is because $h_f = h_i$ in an elastic collision. In order for our data to be consistent with the hypothesis, for small initial heights the data should have a best-fit line near a slope of 1, for large initial heights the data should be below the $h_f = h_i$ line.

Point about grading: One of the "sample student responses" includes measuring data which was unnecessary. For example, there is no need to measure the mass of the ball or the time the ball is in the air. The student did not gain full points because their response included extraneous measurements. So please, only include measurements you know need to be collected. This is an example where writing more simply to fill space is not helpful.

(c) A student carries out the experiment and analysis described in parts (a) and (b). The student immediately concludes that something went wrong in the experiment because the graph or table shows behavior that is elastic for low-speed collisions but appears to violate a basic physics principle for high-speed collisions.

i. Give an example of a graph or table that indicates nearly elastic behavior for low-speed collisions but appears to violate a basic physics principle for high-speed collisions.
ii. State one physics principle that appears to be violated in the graph or table given in part (c)i. Several physics principles might appear to be violated, but you only need to identify one. Briefly explain what aspect of the graph or table indicates that the physics principle is violated, and why.



i. The dotted line represents expected behavior if the collision is perfectly elastic. The blue dots represent data collected which appears to violate basic physics principles.

ii. Conservation of Energy appears to be violated because the height final appears to be greater than the height initial, therefore there appears to be more mechanical energy, in the form of gravitational potential energy, after the collision than before the collision. The final mechanical energy of the system cannot be greater than the initial mechanical energy.

And one last comment about grading. Be aware that part (c)ii is only worth 1 point and, if you do not give any explanation to your answer, you get zero points. In other words, if you wrote only "Conservation of Energy is the physics principle which appears to be violated." You would garner zero points even though your answer is correct, however, you did not explain your answer. Always explain your answer when asked to on the exam.