PHYS 220 – FREE FALL

Materials and equipment: motion detector mounted to or held at ceiling and a football.

Under EXPERIMENT then DATA COLLECTION adjust the sampling rate to 30 samples per second and duration to 3 seconds.

Note: Logger Pro will determine the slope of a graph if you select ANALYZE and then LINEAR FIT.

I. Falling body

1. What does the slope of a velocity versus time graph represent?
2. When a body is in free fall, what is its acceleration?
3. Drop a football below the motion detector so that you get nice clean graphs of the position versus time and the velocity versus time.
   a. Print the graphs and carefully label each portion of these two graphs explaining what is happening in each section.
   b. How long was the football in free fall? Explain how you figured this out.
   c. Determine the acceleration of the football from your experimental results and explain and show how you figured this out.
   d. Use the percent error calculation described in the appendix to compare your experimental acceleration to the expected value of 9.8 m/s^2.

II. Vertical Jump

In your homework this week you analyzed the vertical jump of the African bush baby. It is able to jump 2.3m into the air. You determined that while pushing off the ground, it undergoes an acceleration of approximately 13g's!

Today you will analyze a person's vertical jump.

1. First pull out a meter stick and determine how high the bush baby jumps? Do you think you can jump this high?
2. What would you estimate for a person's acceleration while pushing off the ground?
3. Collect nice clean graphs of a human jumper.

(The jumper must stand directly below the sonic ranger and jump vertically upward with their hands at their sides. When the jumper lands, they should return to their original stance before the jump and stand there until the detector has stopped "ticking". The jumper should practice the jump until they can generate smooth graphs.)

(a) Print the graphs and carefully label each portion of these two graphs explaining what is happening in each section.

(b) Over what distance was the jumper accelerating while extending their legs before their feet left the ground? How did you determine this from your graphs?

(c) How long was the jumper in freefall? Explain how you figured this out.

(d) How high did the jumper jump? Clearly explain how you determined this.

(e) Convert this distance to feet and make sure it is reasonable!

(f) At the top of the jump, what is the jumper's velocity and acceleration?

(g) Use your experimental results to determine the acceleration of the jumper at the following times:

- While pushing off the floor.
- While going up after their feet left the floor.
- While coming down before their feet touch the floor.

(h) How close was your estimate in 2. above for the acceleration of a human jumper while pushing off the ground?

(i) Use the percent error calculation described in the appendix to compare your two experimentally determined accelerations of free fall to the expected value of 9.8 m/s^2 where appropriate.

4. Compare the human jump to that of the African bush baby.
5. What is/are the limitations of this lab setup for analyzing your vertical jump?

Appendix: Percent Error and Percent Difference

When reporting your experimental result, you will compare it to either an accepted value or an experimental value measured using a different procedure to check for consistency.

A. Comparing an experimental value to a theoretical value

Percent error is used when comparing an experimental result E with a theoretical value T that is accepted as the "correct" value.

$$\text{percent error} = \frac{|T-E|}{T} \times 100\%$$

For example, if you are comparing your measured value of 10.2 m/s^2 with the accepted value of 9.8 m/s^2 for the acceleration due to gravity g, the percent error would be

$$\text{percent error} = \frac{|9.81-10.2|}{9.81} \times 100\% = 4\%$$

Often, fractional or relative uncertainty is used to quantitatively express the precision of a measurement.

B. Comparing two experimental values

Percent difference is used when comparing two experimental results E_1 and E_2 that were obtained using two different methods.

$$\text{percent difference} = \frac{|E_1-E_2|}{\frac{E_1+E_2}{2}} \times 100\%$$

Suppose you obtained a value of 9.95 m/s^2 for g from a second experiment. To compare this with the result of 10.2 m/s^2 from the first experiment, you would calculate the percent difference to be

$$\text{percent difference} = \frac{|9.95-10.2|}{\frac{9.95+10.2}{2}} \times 100\% = 2.5\%$$