HINT for Hang Time lab report

The following items need to be concerned in each section.

1. Introduction
- What is motivation? What is the meaning of this experiment?
- What do you expect to learn from this experiment?

2. Procedure
- Tell me exactly what you did.

3. Data
- Raw data should be in this section. In this experiment, raw data have 5 numbers in each jump (4 timing data and 1 vertical jump data).
- Don't forget units.
- Make sure you're using the identical units (m or cm? Be careful for g:$9.8m/s^2 = 980cm/s^2$).

4. Analysis
- All the calculations after data taking should be written in this section.
- Show the formula you used.
- For the instruction, see "Step by step calculation" below.

5. Conclusion
- Answer to the questions in the lab manual.
- Discuss the result **quantitatively** (This is a fun part of physics experiment!).
- How was your measurement? If you think it's failure, write the reason **qualitatively**. (Is the difference within the errors or not? If not, what kind of errors do you expect other than minimal and random uncertainty?)
- What did you learn about your running from this measurement?
- The averaged vertical jump is about 45cm for male and 35cm for female. You can discuss the result using these numbers.

If you have comments/suggestions on lab report, lab itself, and/or me, please do not hesitate to write after the conclusion.

Step by step calculation

In this experiment, we measured hang-time (t) and vertical jump (h) simultaneously. Between these two variables, there is a relationship, $t = 2\sqrt{\frac{2h}{g}}$ (t: hang-time, h: vertical jump, and g: gravity) from Newton's law of motion. We compare the calculated hang-time from the vertical jump measurement to the direct hang-time measurement to check this relationship. The errors to be considered are minimal uncertainty and random uncertainty.

1. **Vertical jump measurement**

In terms of vertical jump data, you don't need to calculate minimal uncertainty. Therefore, you have already 10 jumps data without errors. Calculate the average, which is your final vertical jump data. To calculate the random uncertainty, calculate the difference between the average and each vertical jump. Then maximum difference is the random uncertainty. (Strictly speaking, you need to calculate standard deviation. To make it simpler, I just take the maximum difference. If you can calculate standard deviation, do it. I'll give you extra points.)

> **Example**) 10 vertical jumps: 0.58m, 0.58m, 0.64m, 0.60m, 0.60m, 0.60m, 0.60m, 0.60m, 0.60m, 0.60m.
>
> The average is $h = \frac{0.58+0.58+0.64+0.60+0.60+0.60+0.60+0.60+0.60+0.60}{10} = 0.60m$
>
> The maximum difference is $\Delta h = 0.64 - 0.60 = 0.04m$
>
> Therefore, the vertical jump is $0.60 \pm 0.04m$

2. **Calculate hang-time from the vertical jump measurement**

Using the formula, $t = 2\sqrt{\frac{2h}{g}}$, hang-time is calculated. The error is also calculated from this formula. Because the parameters other than h are all constant, just plug in the error into this formula.

> **Example**) The vertical jump is $0.60 \pm 0.04m$.
>
> $t = 2\sqrt{\frac{2h}{g}} = 2\sqrt{\frac{2\times 0.60m}{9.8m/s^2}} = 0.70m$
>
> $\Delta t = 2\sqrt{\frac{2\Delta h}{g}} = 2\sqrt{\frac{2\times 0.04m}{9.8m/s^2}} = 0.18m$
>
> Therefore, the hang-time is $0.70 \pm 0.18m$

3. **Direct hang-time measurement**

For the jump starting time, you have two numbers, t_{1i} and t_{1f}. For the jump end time, you have two numbers, t_{2i} and t_{2f}. The starting time (T_1) is the average of these two numbers, namely: $T_1 = \frac{t_{1i} + t_{1f}}{2}$. Then minimal uncertainty (ΔT_1) for the starting time is $\Delta T_1 = T_1 - t_{1i} = \frac{t_{1i} + t_{1f}}{2} - t_{1i}$. From the same calculation, you can get the end time with the minimal uncertainty ($T_2 \pm \Delta T_2$). Then the hang-time $t = T_2 - T_1$. The error of the hang-time is $\Delta t = \sqrt{\Delta T_1^{\ 2} + \Delta T_2^{\ 2}}$ because this is subtraction (See exp #1 lab manual.).

Example) $t_{1i} = 0.98\,\text{sec}, t_{1f} = 1.02\,\text{sec}, t_{2i} = 1.70\,\text{sec}, t_{2f} = 1.76\,\text{sec}$

$$T_1 = \frac{t_{1i} + t_{1f}}{2} = \frac{0.98 + 1.02}{2} = 1.00, \Delta T_1 = T_1 - t_{1i} = 1.00 - 0.98 = 0.02$$

$$T_2 = \frac{t_{2i} + t_{2f}}{2} = \frac{1.70 + 1.76}{2} = 1.73, \Delta T_2 = T_2 - t_{2i} = 1.73 - 1.70 = 0.03$$

$$t = T_2 - T_1 = 1.73 - 1.00 = 0.73\,\text{sec}, \Delta t = \sqrt{\Delta T_1^2 + \Delta T_2^2} = \sqrt{0.02^2 + 0.03^3} = 0.036$$

Therefore, hang-time is $0.73 \pm 0.04\,\text{sec}$

Using the obtained 10 hang-time data, calculate the average and random error just like vertical jump calculation. You have 10 minimal uncertainties and 1 random uncertainty. For the final error, take maximum uncertainty.

4. Comparison between direct-measured and calculated hang-time

In the analysis section, compare the obtained numbers from direct hang-time measurement and calculated hang-time from vertical jump measurement. The discussion should be in the conclusion.