Summary
This week, we were given measurements of the volume of liquid in a syringe interacting with the pressure in the syringe. We had to calculate the interaction, that is, the product, for 6 datapoints. We then calculated mean and standard deviation of the data. Finally, we did a measurement I wasn't previously familiar with, the standard deviation divided by the mean as a percentage.

Data

P (KPa)	V (mL)	PV (KPa.mL)
100.101	21	2102.121
110.834	19	2105.846
122.562	17	2083.554
137.700	15	2065.5
157.720	13	2050.36
184.088	11	2024.968

Average PV = 2072.058167 (see equation 3 page 74)

rms (root-mean-square) deviation (σ) = 28.60317 (see equation 4 page 74)

% rms deviation of the PV products = 1.380423344 (see equation 5 page 74)

Calculations

```
>>> 100.101 * 21
2102.121
>>> 110.834 * 19
2105.846
>>> 122.562 * 17
2083.554
>>> 137.7 * 15
```

```
2065.5
>>> 157.72 * 13
2050.36
>>> 184.088 * 11
2024.9679999999998
>>> PVs = [100.101 * 21, 110.834 * 19, 122.562 * 17, 137.7 * 15,
157.72 * 13, 184.088 * 11]
>>> def mu(xs: list) -> float:
...     return sum(xs) / len(xs)
...
>>> def sigma(xs: list) -> float:
...     from math import sqrt
...     return sqrt(sum((x - mu(xs))**2 for x in xs) / len(xs))
...
>>> mu(PVs)
2072.058166666667
>>> sigma(PVs)
28.603174639753277
>>> 100 * sigma(PVs) / mu(PVs)
1.3804233442812748
>>>
```

Analysis

Given Boyle's Law, I expected the deviation to be quite a bit lower. It'd be interesting to see what the standard deviation would be on centered data, that is, data linearly adjusted to have mean zero. Maybe that's what the ratio of deviation to mean measures! Boyle's Law says that the product of pressure with volume is a constant, that when volume changes pressure interactively changes with with it to maintain the same product. With a standard deviation as high as we got, there must be sources of error. The syringe must be imperfect, the volume markers on it and the instrument we used to measure pressure must be imperfect. Also, the law only holds in closed system, and this system could have been imperfectly closed!

Question

I saw nothing on wikipedia suggesting that Boyle's Law breaks down in edge cases like very very high or very very low temperatures. However, if temperature is extreme enough to cause a phase transition to a different form of matter, there may be no analogue of Boyle's Law to non-gaseous substances. I think pressure could be low or high enough that it would be extremely difficult to demonstrate a closed system in a lab, but that doesn't mean Boyle's Law isn't at play it just means that we would fail to create a closed system. I think if the difference between volume and pressure got extreme enough, Boyle's Law would appear differently, because the scale of the smaller quantity might either shift or fail to shift to a more logarithmic scenario at extremes. There's more learning to be done here.