# More Error

## 1 Tor...what now?

There exists a quantity called torque, whose formula is $\tau = FR$ where F is a force and R is the distance from the point the force is applied to the center of the wheel.

You have a wheel with an exactly known diameter $D$ and you apply a force $F + \Delta F$ to the rim of the wheel:

1. What is the error in the torque $\Delta\tau$ (in terms of things given in the problem)?
2. What is the relative error in the torque $\frac{\Delta\tau}{\tau}$ (in terms of things given in the problem)?

## 2 A train

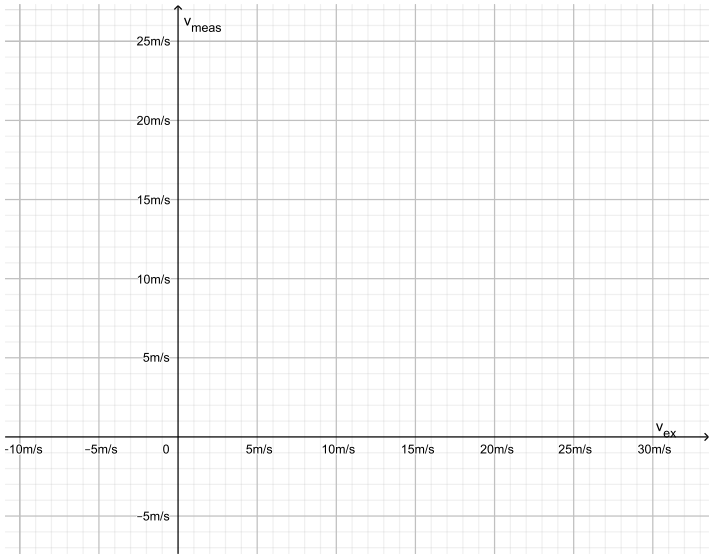
You want to measure the speed of a train moving with constant velocity. You have a perfectly accurate way to measure time and want to use one of these two methods:

1. Measure a 1 km displacement with an accuracy of ±10 m and use that to calculate velocity.
2. Measure the velocity of the train directly using a speedometer on the train with an accuracy of $\pm 5 \frac{\text{m}}{\text{s}}$.

How fast would the train need to be traveling for the methods to produce about the same error in velocity?

# 3 Error Bars

Given an actual speed of $v_{ex} = 20\ \frac{\text{m}}{\text{s}}$, if the speedometer is accurate to $\pm 2\ \frac{\text{m}}{\text{s}}$, what values could the measured speed be? Plot a point on the graph with an appropriate error bar representing this.




# 4 Caution! (non-testable)

I've been lying by omission about error propagation.
Since we have seen that error terms multiply by numbers the way we expect, we might expect them to add nicely also. Alas we cannot actually add error terms in the way we might expect. This is because the error terms are actually random variables, not deterministic values. It's tempting if we see $\Delta y + \Delta x$ to add the two together, but we can't! If we really need to add them, the correct way is $\sqrt{\Delta x^2 + \Delta y^2}$ when the values are completely independent. If the values aren't completely independent, we need the laws of statistical correlation to add them. Terms that look like $\Delta x \Delta y$ are problematic also, but since errors are usually small compared to the value being measured, we don't need to worry about that weirdness here. You will never have to add error terms in this class.