

Random and Systematic Errors

Definitions

All experimental uncertainty is due to either *random errors* or *systematic errors*. Random errors are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device.

Random errors usually result from the experimenter's inability to take the same measurement in exactly the same way to get exact the same number.

Systematic errors, by contrast, are reproducible inaccuracies that are consistently in the same direction. Systematic errors are often due to a problem which persists throughout the entire experiment.

Note that systematic and random errors refer to problems associated with making measurements. Mistakes made in the calculations or in reading the instrument are not considered in error analysis. It is assumed that the experimenters are careful and competent!

How to minimize experimental error: some examples

Type of Error	Example	How to minimize it
Random	You measure the mass of a ring three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g	Take more data. Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.
Systematic	The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all of your length measurements were too long.) The electronic scale you use reads 0.05 g too high for all your mass measurements.	Systematic errors are difficult to detect and cannot be analyzed statistically, because all of the data is off in the same direction (either too high or too low). Spotting and correcting for systematic error takes a lot of care. Add or subtract known error.