CP1 & honors (not AP®)

Random *vs.* Systematic Error

Unit: Laboratory & Measurement

NGSS Standards/MA Curriculum Frameworks (2016): SP3

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): SP3.C

Mastery Objective(s): (Students will be able to…)

- Correctly use the terms "random error" and "systematic error" in a scientific context.
- Explain the difference between random and systematic errors.

Success Criteria:

- Be able to recognize situations as accurate/inaccurate and/or precise/imprecise.

Language Objectives:

- Be able to describe the difference between random errors and systematic errors.

Tier 2 Vocabulary: random, systematic, accurate, precise

Notes:

Science relies on making and interpreting measurements, and the accuracy and precision of these measurements affect what you can conclude from them.

Random vs. Systematic Errors

random errors: are natural uncertainties in measurements because of the limits of precision of the equipment used. Random errors are assumed to be distributed around the actual value, without bias in either direction.

systematic errors: occur from specific problems in your equipment or your procedure. Systematic errors are often biased in one direction more than another, and can be difficult to identify.

"Accuracy" *vs.* "Precision"

The words "accuracy" and "precision" are not used in science because these words are often used as synonyms in everyday English. However, because some high school science teachers insist on using the terms, their usual meanings are:

accuracy: the amount of systematic error in a measurement. A measurement is said to be accurate if it has low systematic error.

precision: either how finely a measurement was made or the amount of random error in a set of measurements. A single measurement is said to be precise if it was measured within a small fraction of its total value. A group of measurements is said to be precise if the amount of random error is small (the measurements are close to each other).

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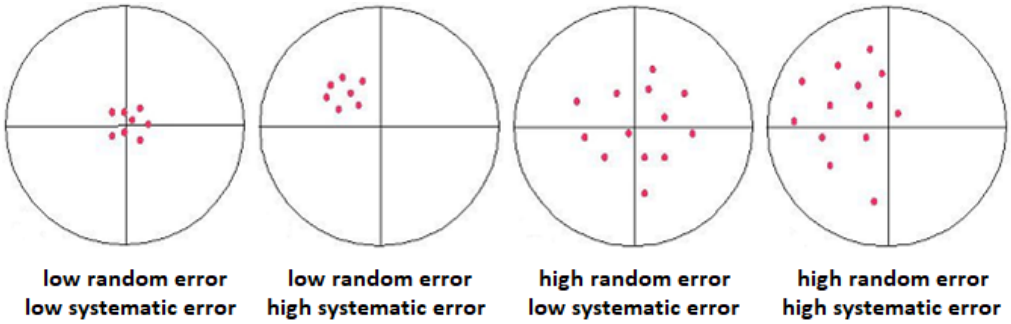
Examples:

Suppose the following drawings represent arrows shot at a target.



low random error low systematic error	low random error high systematic error	high random error low systematic error	high random error high systematic error

The first set has *low random error* because the points are close to each other. It has *low systematic error* because the points are approximately equally distributed about the expected value.

The second set has *low random error* because the points are close to each other. However, it has *high systematic error* because the points are centered on a point that is noticeably far from the expected value.

The third set has *low systematic error* because the points are approximately equally distributed around the expected value. However, it has *high random error* because the points are not close to each other.

The fourth set has *high random error* because the points are not close to each other. It has *high systematic error* because the points are centered on a point that is noticeably far from the expected value.

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For another example, suppose a teacher is 55 years old, and two of their classes estimate their age.

High Systematic Error

The first class's estimates are 72, 73, 77, and 78 years old. These measurements have low random error because they are close together, but high systematic error (because the average is 75, which is far from the expected value of 55).

When there is a significant amount of systematic error, it often means there is some problem with the way the experiment was set up or performed (or a problem with the equipment) that caused all of the numbers to be off in the same direction.

In this example, the teacher may have gray hair and very wrinkled skin, and may appear much older than they actually are.

High Random Error

The second class's estimates are 10, 31, 77 and 98. This *set* of data has low systematic error (because the average is 54, which is close to the expected value), but high random error because the individual values are not close to each other.

When there is a significant amount of random error, it can also mean a problem with the way the experiment was set up or performed (or a problem with the equipment). However, it can also mean that the experiment is not actually measuring what the scientist thinks it is measuring.

If there is a lot of random error, it can look like there is no relationship between the manipulated variables and the responding variables. If there is no relationship between the manipulated variables and the responding variables, it can look like there is a lot of random error. Scientists must consider both possibilities.

In this example, the class may have not cared about providing valid numbers, or they may not have realized that the numbers they were guessing were supposed to be the age of a person.

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