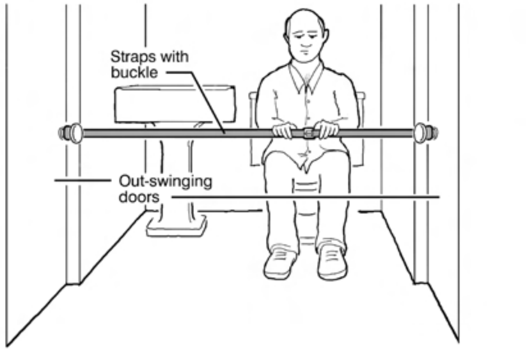


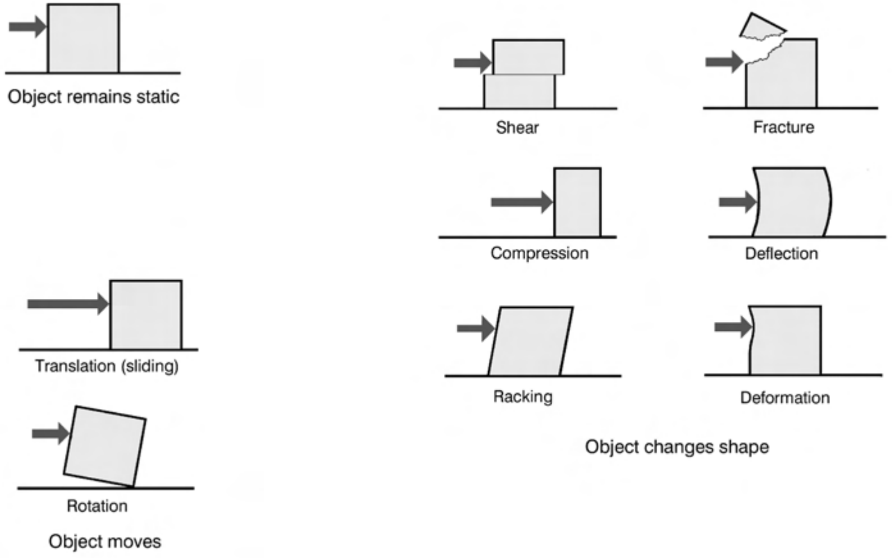
How the former Hotel Louis XIV in Quebec prevented guests
from locking each other out of the shared bathrooms

With regards to Ralph Caplan, *By Design*

5

Every problem is unique.

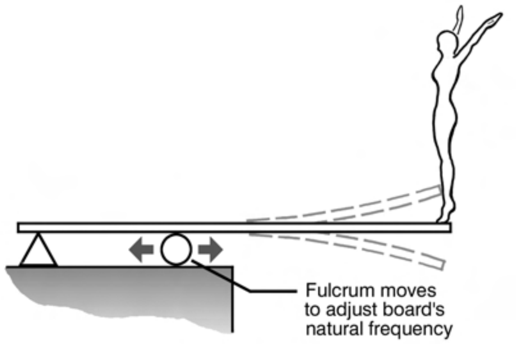
Engineering problems rely on the familiar, but invention is also called for. Some problem solving tools are developed through rote and repetition; some emerge intuitively; some rote-learned tools become intuitive over time; and some come out of nothing other than necessity and even desperation. Add the tools you develop from solving each problem to your toolbox to use on future problems. More importantly, add to your toolbox the methods by which you *discovered* the new tools.



9

When a force acts on an object, only three things can happen.

An object that receives a force will remain stationary, move, or change shape—or a combination. Mechanical engineering generally seeks to exploit movement, while structural engineering seeks to prevent or minimize it. Nearly all engineering disciplines aim to minimize changes in the shape of the end product.



With each bounce, a diver stores energy in the board. By coordinating each landing with the board's natural frequency, the height of the takeoff is increased.

Soldiers shouldn't march across a bridge.

Structural members vibrate in response to normal impacts, in the manner of a plucked guitar string. The **natural frequency** or resonant frequency of an object is the time it takes to complete one cycle of movement (fully back and forth or up and down) upon disturbance.

When a force acts on a structural member repeatedly and at a rate that matches its natural frequency, the member's response is enhanced on every cycle. The effects range from loud humming (such as when vibrations from mechanical equipment coincide with a beam's natural frequency) to uncomfortable oscillation to occasional collapse. Many relatively small earthquakes have induced significant damage when their wave frequency has matched that of affected buildings. In 2000, thousands of pedestrians celebrating the opening of the London Millennium Footbridge inadvertently induced oscillation when their walking rhythms matched the structure's natural frequency. As they swayed in response to the unanticipated movement, they inadvertently increased the harmonic resonance. The bridge was closed following the event and the structural system was repaired.

π = 3.14

Accurate and imprecise

π = 3.1415926535

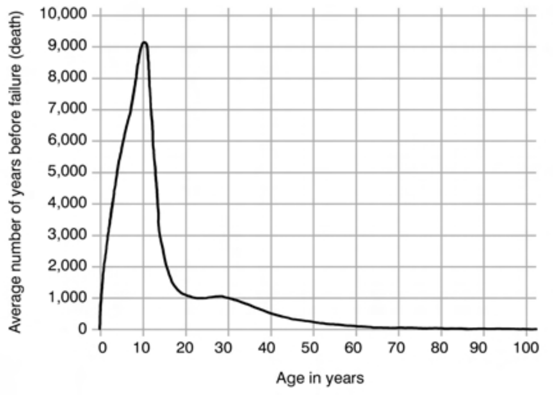
Accurate and precise

π = 3.4566289441

Inaccurate and precise

Accuracy and precision are different things.

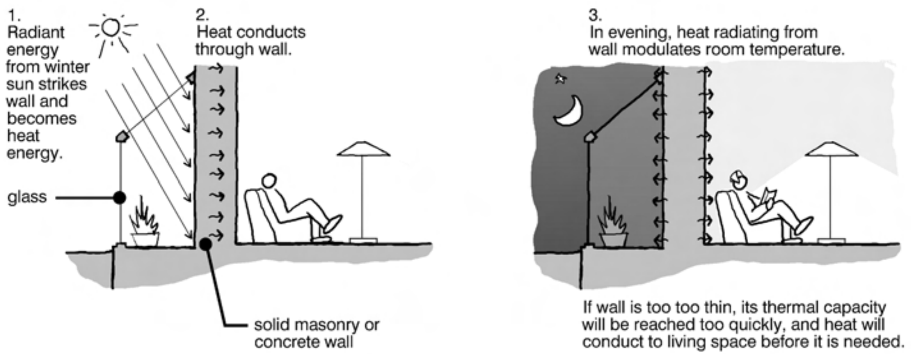
Accuracy is the absence of error; **precision** is the level of detail. Effective problem solving requires always being accurate, but being only as precise as is helpful at a given stage of problem solving. Early in the problem solving process, accurate but imprecise methods, rather than very exact methods, will allow consideration of all reasonable approaches and minimize the tracking of needlessly detailed data.



Human Mean Time Before Failure

Human time to failure is 1,000 years.

Mean Time Before Failure is the inverse of the expected failure rate of a device or system. A 25-year-old person has a MTBF of about 1,000 years, because the annual rate of death (failing) for a person that age is 1 in 1,000, or 1/1000. As we age and near the end of our **service life**, our MTBF decreases. There is no direct correlation between service life and failure rate. A rocket is designed to have a MTBF of several million hours, because failure would be critical. However, it is intended to last only a few minutes, such as during the launch of a space ship.



A thermal storage wall

Available solar energy is 50,000 times our energy need.

At least 100 watts of energy strike each square foot of the earth's surface in a fully sunlit hour. Most areas of the U.S. receive the equivalent of 4 hours full sunlight per day, translating into about 1.5 trillion twh (terawatt hours) of energy per year—many times the 28,000 twh used in the U.S.

However, solar collectors currently capture only about 15 to 20% of the sun's energy (and are limited to a theoretical maximum of about 33%). And as the percentage of land that feasibly can be covered with solar collectors is small, it is difficult to meet all our energy demands through solar power. At present levels, the U.S. would need a continuous field of solar collectors covering the entire land area of Indiana. If the world used energy at the per capita rate of the US, a field the size of Venezuela would be required.