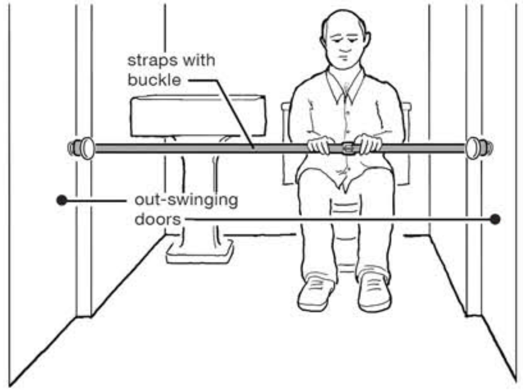
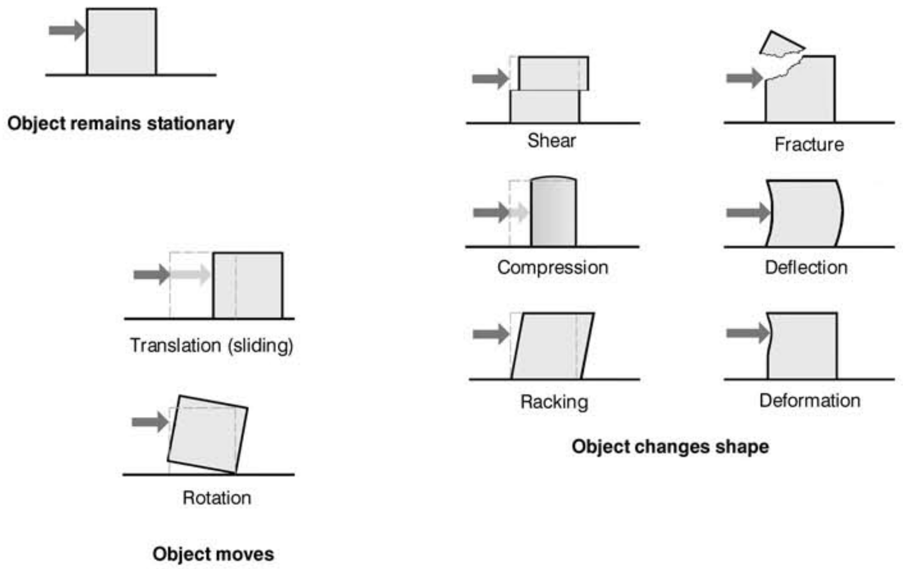


How the former Hotel Louis XIV in Quebec prevented guests from locking each other out of the shared bathrooms

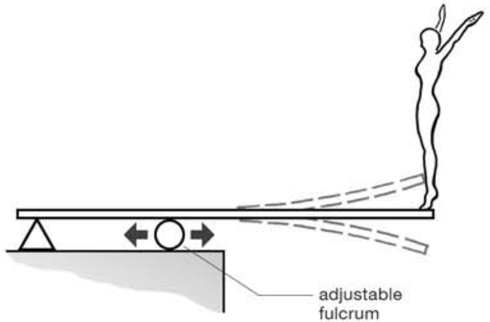
Every problem is unique.

Engineering problem solving relies 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 necessity and even desperation. Add the tools you develop while solving each problem to your toolbox, to use on future problems. More important, add to your toolbox the methods by which you *discovered* the new tools.



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

An object that receives a force will remain stationary, move, or change shape—or undergo a combination of these reactions. Mechanical engineering generally seeks to exploit movement, while structural engineering seeks to prevent or minimize it. Most engineering disciplines aim to minimize changes in the shape of a designed object.



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.

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A structural member vibrates in response to normal loads and impacts, in the manner of a plucked guitar string. The **natural** 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 repeatedly on a structural member, and at a rate that matches its natural frequency, the member's response is enhanced with every cycle. The effects range from loud humming (such as when vibrations from a building's 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 it. The bridge was closed following the event and the structural system was repaired.

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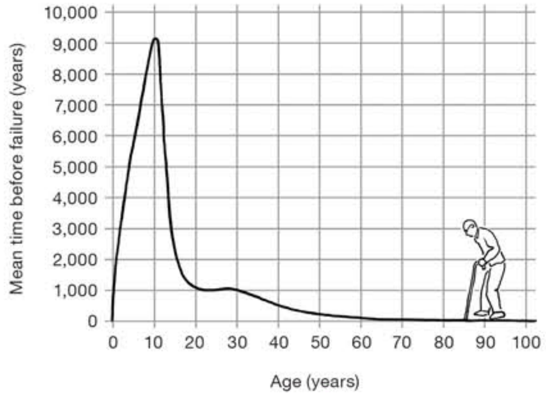
Accuracy and precision are different things.

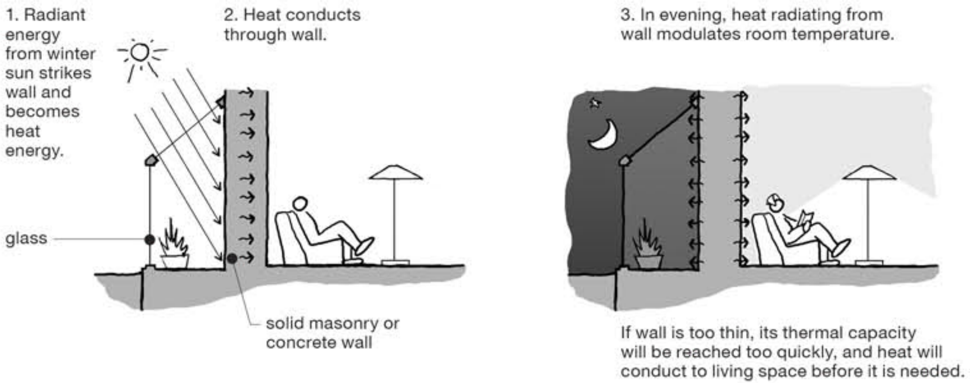
Accuracy is the absence of error; **precision** is the level of detail. Effective problem solving requires always being accurate, but being only as precise as is helpful at a given stage of problem solving. Early in the problem-solving process, accurate but imprecise methods, rather than very exact methods, will facilitate design explorations while minimizing the tracking of needlessly detailed data.



Human MTBF

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 an MTBF of about 1,000 years, because the annual rate of death (failure) for a person that age is 1 in 1,000, or 1/1,000. 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 an MTBF of several million hours, because failure would be catastrophic. However, its intended service life is only a few minutes, such as during the launch of a spaceship.



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 cells today can capture only about 20% of the sun's energy that strikes them and are subject 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 U.S., a field the size of Venezuela would be required.