

## Physics Integration Lesson 10 – What is Optimal?

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During your first semester of calculus you were introduced to a valuable application of the derivative, extrema (minima/maxima). If a particular design goal can be expressed in the form of a mathematical function, an extrema can be found by setting the first derivative to zero and solving for the location. To determine the difference between minima and maxima, a second derivative is required. This technique is useful in physics because it appears that in many situations the creation operates in an optimal manner. Although most of the interesting problems in physics cannot be completely modeled mathematically, they can be effectively approximated near their extrema.

Some will take exception to the prior statement, “the creation operates in an optimal manner.” This hints at the notion of a good design and possibly an intelligent designer. In response they will point out biological features that appear to be purposeless or have bad design. The example that comes up most often is the human spine. Many people suffer from back pain at some point in their life and this is due to the S-shaped curvature of the spine. If the spine were curved as a bow, as found in most mammals, back problems would be greatly reduced, but humans would then travel as quadrupeds.

This example points out an important aspect of design. If something operates in an optimal manner it is due to a tradeoff between competing design goals. If you design an animal for speed, you make design choices found in a cheetah. If you design for height, you add features found in a giraffe’s neck. If good design is equated to being the best in everything, then there will always be grounds for rejecting any design as good. This is equivalent to a customer expecting an engineer to design a universal tool that works better than a hammer, screwdriver, saw and pliers combined.

1. The human spine is cited as an example of bad design. Assuming the design is good, what might be the competing design goals that go into the function of the spinal column?
2. Whether it is in the design of a machine, electrical circuit or computer program, there is a temptation to expand the scope of a project so the product has 101+ features. List at least two problems that arise from this view of a successful project. Describe why these problems fight against the project’s success.