A person trying to explain a difficult concept will often say, “Well, the analogy is ... .” The use of analogies in everyday life aids in understanding and makes everyone better communicators. Mechatronic systems depend on the interactions among mechanical, electrical, magnetic, fluid, thermal, and chemical elements, and most likely combinations of these. They are truly multidisciplinary, and the designers of mechatronic systems are from diverse backgrounds. Knowledge of physical system analogies can give design teams a significant competitive advantage.

Consider the exhaust system of a motorcycle and its heat shield. Temperatures have to be controlled through design for performance but also to protect the rider. Being able to model this system as a network of thermal resistances and capacitances, just like an electrical circuit, is a powerful design tool. It allows the engineer to visualize the flow of heat and the storage of thermal energy and specify key temperatures by selection of materials and geometries that vary the network thermal resistances (conduction, convection, and radiation) and capacitances. Improving performance happens with understanding—not by trial and error—and quickly.

To explore in some depth the nature of physical system analogies, let’s use the common electrical-mechanical analogy. These systems are modeled using combinations of pure (only have the characteristic for which they are named) and ideal (linear in behavior) elements: resistor (R), capacitor (C), and inductor (L) for electrical systems, and damper (B), spring (K), and mass (M) for mechanical systems. The variables of interest are voltage (e) and current (i) for electrical systems and force (f) and velocity (v) for mechanical systems. Figure 1 shows the model structures for these systems. The analogy is obvious!

We can use this analogy to explain the flow of current and the changes in voltages in an LC (inductor-capacitor) electrical circuit—difficult to envision for most mechanical engineers and even for some electrical engineers—by comparing it with a spring-mass mechanical system. Figure 2 is color-coded: Colored diagrams for each system correspond to each other. By comparing the motion of the mass—its changing potential energy corresponding to energy stored in the electric field of the
capacitor and its changing kinetic energy corresponding to energy stored in the magnetic field of the inductor—one can better understand how electrical capacitors and inductors function.

For enhanced multidisciplinary engineering system design and better communication and insight among the design team members, the use of analogies is a powerful addition to an engineer’s toolbox.