Welding is perhaps the most complex of materials processing technologies. This might be surprising to hear, given that even highly qualified welders seldom have advanced studies. What happens is that issues of technology and metallurgy are dealt with by engineers before the welder touched the torch. Engineers must select the materials and welding parameters the welder will use, and must also design the welding machine. The physics involved in machine design and selection of parameters are so complex that very few general rules available. In arc welding, the temperature of the plasma in an arc is about three times the temperature of the surface of the sun. The velocity of the plasma in the arc is faster than a jet airliner. Even questions such as “what is the size of the molten bead?” have not even an approximate answer based on fundamentals. An additional motivation is that particular answers that had been obtained for steel through trial and error now need to be extended to a much broader diversity of materials for additive manufacturing. In this presentation I will describe the work we are doing at the Canadian Centre for Welding and Joining to generate general rules for welding. A formal methodology of analysis will be described, and its application to heat transfer in the base metal will be used as an example. Overall, I will show how the numerous and diverse challenges in welding bring also opportunities for interdisciplinary collaborations and make a difference that multiplies at the national level.