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# Preface

The use of microwaves as a heat source for modern technological processes has recently become a topic of considerable research. These processes range from drying wood and curing rubber, to sintering and joining of advanced ceramic materials. The underlying physical principle that makes microwaves attractive for these applications is volumetric heating which causes, in general, rapid heating rates.

Along with the benefit of rapid heating, the use of microwaves as a heat source for industrial applications poses several challenges. The first is the control of the electromagnetic fields to produce temperature distributions that are required for a particular process. For example, uniform heating is highly desirable for sintering ceramics, curing polymers, and cooking foods, while focused heating is necessary for joining ceramics in an efficient way. The second challenge relates to the heating of certain materials that absorb more microwave energy as their temperature increases. For these applications there is the distinct possibility that thermal runaway may occur with destructive consequences. Clearly the control of this phenomenon is important. Finally, and not unrelated, there are other materials that do not absorb efficiently microwaves at room temperature. These are usually placed in a highly resonant cavity where large electric fields produce required heating rates. In some applications, all three challenges must be simultaneously met.

The mathematical description of a microwave-heating processes usually takes the form of an initial-boundary-value problem involving a diffusion equation for the temperature, the time-harmonic Maxwell equations, and the necessary boundary conditions. The elliptic form of the electromagnetic equations occurs because the microwave period is ten to twelve orders of magnitude smaller than the thermal time scales. Quite often, the mathematical problem is nonlinear. Nonlinearities can arise from at least three physical mechanisms. In the first, radiative losses are important at elevated temperatures and these give rise to nonlinear, and sometimes even nonlocal, boundary conditions on the surface of the heated material. In the second, the electrical and thermal properties of the material may be temperature-dependent. The former will couple the partial equations together in a nonlinear fashion. In the third, changes of state can produce moving fronts that must be tracked; this is a Stefan problem with a source. Finally, there are heating scenarios where all three of these effects may occur and interplay.

The mathematical problems described are inherently interesting and challenging from both a modeling and a computational perspective. The papers presented in this issue focus on the former approach, although all have a computational component. These models range from a provocative circuit analogy, to understand cavity detuning and potential self-sustained temperature oscillations, to the design of a microwave applicator to insure uniform heating. The mathematical techniques employed range from asymptotic methods, such as homogenization theory, to control theory. The papers represent a snapshot of current applied mathematical research in microwave heating. The editor hopes the reader will find them interesting.

Finally, there is much exciting and interesting work that is focused on numerical simulations, large-scale computations, of complicated and realistic microwave-heating experiments. These methods can yield important information and insight into the heating process. Perhaps a future special of JEM will be dedicated to this approach.

Gregory A. Kriegsmann