Fundamentals and Applications of Machine Learning in Thermal Management and Heat Transfer Technologies

March 9th, 2026 (9 AM to 1 PM)
at ASTFE TFEC2026 Conference in person at Arizona State University and online virtual in Whova/Zoom

www.astfe.org/courses/famltmht2026/

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Distinguished Professor of Mechanical Engineering

SHORT COURSE ABSTRACT

The first part of this short course will focus on fundamentals of machine learning tools. It will first summarize the features and uses of data-science-based machine learning tools that may be relevant to researchers with interests in heat transfer, thermophysics, thermal management or energy technology development. Principles behind genetic algorithms and diWerent neural network models will be discussed together with the features of heat transfer and associated energy technologies that can dictate the types of data science tools that are most useful. Pathways to access open-source python machine learning computational tools will be described, with recommendations on how novices can get started. Typical computer program algorithm structures will be described.

Several aspects of using machine learning tools relevant to thermophysics and thermal management will be described, including: strategies to achieve a synergistic combination of physics-based modeling and machine learning tools that yield more than the sum of the parts, the key role of custom loss functions for integrating physical modeling in training neural networks, the conceptual framework for PINNs modeling of physical systems behavior, machine-learning-based energy system adaptive control, and how developments in computing software and hardware are enhancing the usefulness of machine learning tools.

The second half of this short course (~ 1.75 hours) will focus on applications. It will begin with a discussion of strategies for framing the modeling and organizing data for use of machine learning for modeling in an application. This will be followed by a presentation of specific examples of ways machine learning can be used to enhance research and development for thermal management and heat transfer technologies. The examples may include: machinelearning-enhanced modeling of complex boiling processes, use of machine learning to enhanced heat pipe design for electronics cooling, machine-learning-enhanced adaptive thermal storage for thermal control applications, and PINN's modeling of thermal transport in applications.

The final 20 minutes or so of the course will be dedicated to some closing remarks and an opportunity for participant questions and discussion. Topics discussed may include how AI and machine learning can stimulate rethinking approaches to research and development, how AI and machine leaning are aWecting leading industries in this field, how education and technical training could be changed to best prepare engineers and scientists working on thermophysics research and technology development for optimal use of machine learning tools.

DATE AND TIME

Can be partially online virtual and in person at ASTFE conference site. Parts 1 and 2 will each be 1.75 hours long, with a 30-minute break between. Including the break between Parts 1 and 2, this short course would fit in 4-hour time window.

WHO SHOULD ATTEND

The short course will aim to provide information that can be used to initiate research use of machine learning tools, with the target audience being young engineers or researchers who want to grow their knowledge of machine learning tools, or more senior technical staW who may want to provide a path to increase machine learning expertise of researchers in their group.

COURSE MATERIALS

PDF copies of the slides for the short course can be made available for duplication so a copy could be provided for each registered course participant.

REGISTRATION

- **Fee: $100**
- **Registration will be limited to 50 participants**
- **A certificate will be given upon completion of the course**

INSTRUCTOR BIO

VAN P. CAREY

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Professor Carey is widely recognized for his research on near-interface micro/nanoscale thermophysics and transport in liquid-vapor systems, and computational modeling and simulation of energy conversion and transport processes. His research has frequently included modeling at multiple scales, ranging from the molecular level (molecular dynamics simulation of thermophysics) to the device and system level (multidevice system models). His more recent research has been exploring the use of machine learning strategies to enhance performance of energy conversion and transport in applications and to create energy technologies that can autonomously adapt to maximize their performance and reduce their environmental impact.

Since joining the Berkeley faculty in 1982, Professor Carey's research has spanned a variety of applications areas, including high performance solar thermal power systems, building and vehicle air conditioning, smelting and casting of aluminum, phase change thermal energy storage, heat pipes for aerospace applications, high heat flux cooling of electronics, data center thermal management, and energy eWiciency of digital information systems. His research has also contributed to developing advanced heat rejection technologies for electronics cooling, building AC systems and power plants. He has also developed performance models for Tesla turbine expanders for green energy conversion technologies and thermionic power generation technologies for space applications.

Carey's current research emphasizes development of strategies to use machine learning tools to better understand and model the physics of boiling heat transfer at surfaces covered with hydrophilic nanostructured coatings. This includes exploring innovative ways to combine advanced instrumentation data and machine learning image analysis to understand the physics of boiling processes. He is also using machine learning tools to enhance performance modeling of energy conversion devices, and developing machine-learningbased adaptive energy conversion systems that can autonomously adjust their operation to simultaneously maximize energy eWiciency and meet operating requirements for the application of interest.

Carey is a Fellow of the American Society of Mechanical Engineers (ASME) and the American Association for the Advancement of Science, and he has also served as the Chair of the Heat Transfer Division of ASME. Carey received the James Harry Potter Gold Medal in 2004 for his eminent achievement in thermodynamics, and the Heat Transfer Memorial Award in the Science category (2007) from the ASME. Carey is also a three-time recipient of the Hewlett Packard Research Innovation Award for his research on electronics thermal management and energy eWiciency (2008, 2009, and 2010), and he received the 2014 Thermophysics Award from the American Institute of Aeronautics and Astronautics.

SHORT COURSE OUTLINE

This short course will be presented as two segments with a break between them (Monday morning 3/9/26) with each segment being about 1.75 hours each.

PART 1

The first half of this short course will focus on fundamentals of machine learning tools including:

- A summary of the features and uses of data-science-based machine learning tools that may be relevant to researchers with interests in heat transfer, thermophysics, thermal management or energy technology development.
- Principles behind genetic algorithms and diWerent neural network models will be discussed together with the features of heat transfer and associated energy technologies that can dictate the types of data science tools that are most useful.
- Pathways to access open-source python machine learning computational tools will be described, with recommendations on how novices can gain more experience. Typical computer program algorithm structures will be described.

Several aspects of using machine learning tools relevant to thermophysics and thermal management will be described in more detail, including:

- Physics based models and data science models of system behavior – benefits of creating models that incorporate both perspectives.
- Strategies to achieve a synergistic combination of physics-based modeling and machine learning tools that yield more than the sum of the parts.
- Custom loss functions for training neural networks – why they can be key to integrating physical modeling and data science modeling.
- PINNs modeling of physical systems behavior, and specific adaptations of this methodology to thermophysics modeling.
- Use of machine learning tools for energy component/system design optimization.
- Machine-learning-based energy system adaptive control.
- Use of machine learning tools to make strategic choices in research experiments or device performance tests.
- How developments in computing software and hardware are enhancing the usefulness of machine learning tools.

After the first portion of the short course exploring fundamentals, there will be a break of 20-30 minutes.

PART 2

The second portion of this short course (~ 1.75 hours) will focus on applications. It will begin with a discussion of strategies for framing the modeling and organizing data for use of machine learning in an application. That initial discussion will be followed by a presentation of specific examples of ways machine learning can be used to enhance research and development for thermal management and heat transfer technologies. The examples may include:

- Machine-learning-enhanced modeling of complex boiling processes.
- Use of machine learning to enhanced heat pipe design for electronics cooling.
- Machine-learning-enhanced adaptive thermal storage for thermal control applications.
- Machine learning performance modeling for thermionic energy conversion.
- Enhancing the performance of CFD modeling for electronics cooling.
- Adaptive thermal control of electronics using infrared camera image analysis.

CLOSING DISCUSSION

The final 20 minutes or so of the course will be dedicated to some closing remarks and an opportunity for participant questions and discussion. This closing discussion will focus on:

- Challenges associated with eWective use of machine learning tools for thermal engineering and thermophysics research.
- How AI and machine learning can stimulate rethinking approaches to research and development.
- How AI and machine leaning aWecting leading industries in this field.
- The challenges of changing undergraduate and graduate education to prepare engineers and scientists working on thermophysics research and technology development for optimal use of machine learning tools.
- Best strategies to guide how thermal engineering research and technology development adapt to this wave of technology.