

## IEEE-EDS Japan Joint Chapter\*

### IEEE-EDS Distinguished Lecture of the Electron Devices Society

## [Ohm to Arora: A New Paradigm for Nanoscale Devices and Circuits](#)

\* The lecture is downloadable by clicking the link above and expanding it to full screen by clicking on double arrows in the corner and press the central arrow to start the lecture.

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A newfangled paradigm through deployment of the nonequilibrium Arora's distribution function (NEADF) for resistance surge in low-dimensional nano-resistors is presented, with applications to carbon-based devices. The key outcome is that the Ohm's Law with linear I-V characteristics cannot be used for devices approaching micro- and nano-scale. A nano-resistor, in addition to having ohmic resistance, also necessitates the value of the critical voltage for its complete description. This critical voltage is proportional to the length of the resistor. In macro resistors of yesteryears, the critical voltage is much larger than the applied voltage, with infinity as the default value. However, as devices are scaled down to the nanometer dimensions, the critical voltage is much lower than the applied voltage, including the traditional 5 V or even 1 V as the higher logic level for VLSI devices. As the applied voltage becomes larger than the critical voltage, Arora's Law predicts current saturation due to velocity saturation. The random velocity vectors in equilibrium transform to streamlined velocity vectors in a high electric field that is necessarily high in scaled down dimensions. The saturation current is thus limited by the intrinsic velocity vectors that become streamlined and hence ballistic in the sense that scattering does not play any active role in saturation. As I-V characteristics become nonlinear, the distinction between direct and differential resistance takes on an increasing importance due to dramatic rise in the differential resistance. The experimental nonlinear I-V characteristics, when voltage across the length of a resistor is higher than its critical value, defy ohmic and ballistic transmission through a nano-resistor. Arora's Law embraces well the Ohm's Law when applied voltage is smaller than the critical voltage. It is shown that the smaller-length resistor becomes more resistive in a circuit where two resistors of the same ohmic value are used in series or parallel configuration. Transit time delay gives way to enhanced RC time delay and is the major limiting factor for signal propagation in ultra-large scale integration (ULSI) on a chip. Inductive L/R time constants are suppressed. The lecture will cover landscape from basic sciences to engineering with a touch of liberal arts that is talk of the day for an outcome-based education (OBE) making Engineering an Art in the Application of the Liberal Arts kindling STEAM (Science, Technology, Engineering, Arts, and Mathematics).

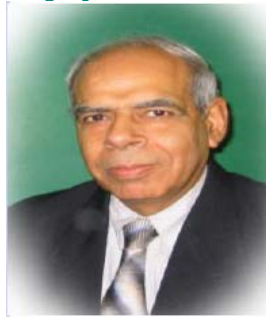
**When: October 27, 2017, 4:00-5:00 PM**

**Where: Center for Innovative Integrated Electronic Systems (CIES) Tohoku University**

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## BIOGRAPHICAL SKETCH

### Vijay K. Arora



**Vijay K. Arora**, a tenured Professor of Electrical Engineering and Physics at Wilkes University with Ph. D. from the University of Colorado, held distinguished visiting appointments at the University of Illinois, the University of Tokyo, National University of Singapore, Nanyang Technological University, the University of Western Australia, Universiti Malaysia Sabah, and Universiti Teknologi Malaysia (UTM). At UTM, he was honored as Brain Gain Fellow of the Academy of Sciences Malaysia for research at UTM Ibnu Sina Institute of Fundamental Sciences. In addition to his long-term visiting appointments, Professor Arora has visited several international institutions on short-term consulting assignments and enjoys the privilege of knowing the cultures and educational methods being practiced around the globe. In recognition of his research, he is invited to give presentations at several international scientific gatherings. His research interests include nanoelectronics, engineering management and global educational paradigms. Professor Arora has authored or co-authored over 250 papers on scientific, educational, and management issues. He chaired EScienceNano2012, NanoTechMalaysia2010 NanoSingapore2006, and ASEE Mid-Atlantic Conference1996. Professor Arora is on the Distinguished Lecturer Program of the IEEE Electron Devices Society and APS Forum on Industrial and Applied Physics. Compendium of his distinguished lectures appears in his book *[Nanoelectronics: Quantum Engineering of Low-Dimensional Nanoensembles](#)*. As a researcher in Operations Research, he practices project- and problem-based learning with integration across the boundaries of disciplines with deliverable outcomes. He is listed in a number of Who's Who biographies, including the Leading Educator of the World 2005. His Final Word lecture on [Engineering a Quality Person in You](#) with Manuscript, PowerPoints, and Notable Quotes is downloadable by clicking on the link or log on to <http://web.wilkes.edu/vijay.arora> and click on the Final Word.