PURDUE UNIVERSITY | Elmore Family School of Electrical and Computer Engineering

Engineering Faculty Document No. EFD 40-22
January 18, 2022

Memorandum

To: The College of Engineering Faculty

From: The Elmore Family School of Electrical and Computer Engineering

Re: new Quantum Technology Concentration

The faculty of the Elmore Family School of Electrical and Computer Engineering has approved the following new concentration from the College of Engineering. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Description: The Quantum Technology Concentration will introduce students to the fundamental concepts and engineering challenges of various emerging technologies, including quantum computers, quantum communication systems, and quantum sensors. Students will also gain further training on classical engineering topics that will prepare them to understand and work with emerging quantum technologies.

Reasons: Quantum technologies provide a new way for computing, communication, and sensing to occur that has the potential to surpass the performance of any classical alternative for certain applications. To continue to advance these exciting quantum technologies, it is necessary for more engineers to become trained in this highly multidisciplinary field. This concentration will provide students with the knowledge and skills needed to understand simple quantum systems and effects that are instrumental in the operation of quantum technologies. These skills are sought after for any engineer entering the growing quantum economy, even if their role primarily focuses on designing classical peripherals for quantum systems. Completing this concentration will also provide students with a firm foundation to pursue a graduate education focused on quantum technology and engineering, which will open further opportunities for them in the quantum economy.

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Concentration in
Quantum Technology
for the Bachelor of Science in Electrical Engineering

What is the topic focus of the concentration?

Since the beginning of the 21st century, explosive advancement in the realization of quantum technologies has occurred. These quantum technologies provide a new way for computing, communication, and sensing to occur that has the potential to surpass the performance of any classical alternative for certain applications. To continue to advance these exciting quantum technologies, it is necessary for more engineers to become trained in this highly multidisciplinary field.
Students who complete this concentration will be introduced to the fundamental concepts and engineering challenges of various emerging technologies, including quantum computers, quantum communication systems, and quantum sensors. Students will also gain further training on classical engineering topics that will prepare them to understand and work with emerging quantum technologies.
This concentration will provide students with the knowledge and skills needed to understand simple quantum systems and effects that are instrumental in the operation of quantum technologies. These skills are sought after for any engineer entering the growing quantum economy, even if their role primarily focuses on designing classical peripherals for quantum systems. Completing this concentration will also provide students with a firm foundation to pursue a graduate education focused on quantum technology and engineering, which will open further opportunities for them in the quantum economy.

Proposing [Sub]area

Faculty from the FO and MN areas have collaborated in preparing this concentration. Feedback was gathered from the full FO and MN areas via email and area meetings and incorporated into this proposal. This concentration was subsequently approved by area votes in the FO and MN areas.

Target Degree

It will apply to the BSEE degree.

Concentration Requirements

Selectives: Must choose 1 (3-4 credits)

- ECE 30412 Electromagnetics II (3 credits)

- ECE 30500 Semiconductor Devices (3 credits) or
  ECE 59500 Fundamentals of Current Flow (1 credit) and
  ECE 59500 Introduction to Quantum Transport (1 credit) and
  ECE 59500 Boltzmann Law: Physics to Computing (1 credit)

- ECE 44000 Transmission of Information (4 credits)

Electives: (6 credits)

- ECE 39595 Fundamentals of Quantum Technology (3 credits)

- ECE 39595 Introduction to Nanotechnology and Quantum Science and Technology (3 credits)

- ECE 59500 Fundamentals of Current Flow (1 credit) and
  ECE 59500 Introduction to Quantum Transport (1 credit) and
  ECE 59500 Boltzmann Law: Physics to Computing (1 credit)

- ECE 59500 Introduction to Quantum Science and Technology (3 credits)

- ECE 59500 Applied Quantum Computing I: Fundamentals (1 credit) and
  ECE 59500 Applied Quantum Computing II: Hardware (1 credit) and
  ECE 59500 Applied Quantum Computing III: Algorithm and Software (1 credit)

- ECE 59500 Quantum Optics (3 credits)

- With approval of the Associate Head of Undergraduate Programs or Associate Head of Teaching and Learning, can include up to 3 hours of:
  - VIP 37920 (2 credits)
  - VIP 47920 (2 credits)
  - ECE 49600 (1-3 credits)

Note: The ECE 59500 Sequence of Fundamentals of Current Flow, Introduction to Quantum Transport and Boltzmann Law: Physics to Computing may be used to satisfy the Selective or Elective requirement, but not both.

The advanced EE selective requirement helps inform students which classical EE courses are most relevant to understanding emerging quantum technologies. Advanced undergraduate electromagnetics courses are included because most quantum technologies to date rely significantly on electromagnetic effects at some level. These courses also provide background in wave physics and solving partial differential equations, which can be relevant for a more detailed understanding of certain advanced quantum technologies. Semiconductor and nanoelectronic devices also play a significant role in many quantum technologies. Developing an increased understanding of the engineering and physics of these devices can be crucial in working with quantum technologies that utilize semiconductor platforms.

The remaining elective requirements focus specifically on establishing fundamental understanding of quantum technologies, while providing enough flexibility to allow students to focus on specific technologies they are most interested in. The 300-level courses provide a broad introduction to many important concepts in the engineering of quantum technologies and are complementary to the more advanced 500-level courses included in the concentration. Enough classes are included so that students can complete this concentration without requiring them to take a 500-level course, although it is highly recommended that they complete at least one 500-level course.

The 500-level courses are ideal for inclusion in an undergraduate quantum concentration. Many of these courses are included in the quantum micro-master's program that was designed to provide engineers with the knowledge needed to participate in the growing quantum economy. Further, these courses were designed so that undergraduates can take them without any prior exposure to quantum technology.