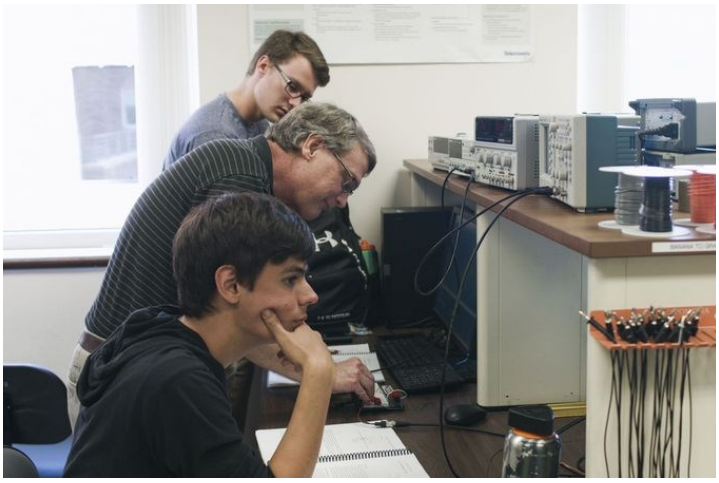
PHYSICS FOCUS

Bethel Launches Electrical Engineering Major

Bethel is proud to announce the addition of a Bachelor of Science in Electrical Engineering degree.

The field of electrical engineering has long been a strong emphasis in Bethel's widely-recognized physics and engineering department. Previously, students could begin a pathway toward electrical engineering fields through the dual-degree program, where they would complete undergraduate work at Bethel and in their engineering field of choice at an approved university, graduating with two bachelor's degrees in five years. A second popular path started with students earning an applied physics major at Bethel followed by two years in a second school's graduate program, resulting in a master's degree in electrical engineering in six years. Countless alumni have followed their research interests and aptitudes shaped at Bethel into successful careers and professional networks.



Professor Brian Beecken working with Electronics students in one of the foundational lab courses of the EE major.

While the dual-degree and applied-physics-to-grad-school options remain ap-

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Two New Professors Join Dept. of Physics & Engineering

Karen Rogers, associate professor of engineering, working with students in the Analog Electronics course

The Physics & Engineering department is excited to welcome two new professors, Dr. Karen Rogers and Dr. Julie Hogan! The following is a brief introduction to each of them.

Karen Rogers

Dr. Karen Rogers comes to Bethel with 22 years of experience teaching Electrical Engineering courses at Kettering University in Flint, Michigan. While at Kettering she taught a

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Compiled by Alyssa Hamre

Bethel Launches Electrical Engineering Major *(continued)*

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pealing pathways for a number of engineering specialties, electrical engineering students will now have the option to further specialize their undergraduate focus and take a more direct path toward employment or graduate school in this high-demand field.

Preparations for this new major have been underway for some time, with significant summer renovations in the department's space to make way for dedicated electrical engineering-focused lab space and equipment and cosmetic upgrades throughout. While many universities separate physics and engineering programs, Bethel has made a conscious effort to keep the programs intertwined spatially as well as programmatically. Physics and engineering students—and faculty from the various programs—will work side-by-side and learn from one another.

This summer, Karen Rogers also joined the department as associate professor of engineering, one of two new full-time faculty members in the Department of Physics and Engineering. She received her bachelor's degree in electrical engineering from the General Motors Institute and her master's and doctorate in mechanical engineering from the Massachusetts Institute of Technology—making her an ideal choice for adding cross-functional expertise in the rapidly-growing department.

"God prepares us for the jobs He has in store for us. As I look back over my 22 years at my previous university, I see the many ways God was preparing me for launching the electrical engineering program at Bethel," says Rogers, who first settled in to campus in the midst of construction dust and within days was installing equipment and making plans for her courses. She's taking all the changes in stride, bringing her expertise and winsome character to her new team and home at Bethel. "I am excited to get started, to meet the students, and to help prepare them academically for the jobs God has in store for them."

She had a 22-year teaching career at Kettering University in Flint, Michigan, during which she served as interim department head for electrical and computer engineering. As Bethel looks to the future and expanding on its already-stellar reputation in the sciences, Rogers' leadership, teaching, and program development and accreditation experience will be invaluable. Rogers joins six other full-time department faculty who hope to build on recent National Science Foundation (NSF) and other grants, valuable internship and research placements, and positive national reputation to attract and serve increasing numbers of students interested in STEM careers.

"Our commitment to preparing students to tackle the world's most challenging problems to God's glory and for our neighbors' good drives the programmatic decisions that we make. Well-educated, highly skilled, ethical leaders in science, technology, engineering, and math are in high demand in our world," says Executive Vice President and Provost Deb Harless. "We have a long history of preparing students for competitive graduate programs in the sciences and high level technical and scientific positions in the marketplace. God's hand has been evident in providing the resources for this program, and I'm excited to see how He works in the lives of our engineering students."

Article first appeared at bethel.edu/news, courtesy of Monique Kleinhuizen.

Physics & Engineering students Gabe Segura and Ben Harker work on Electronics in the facilities updated to accommodate the Electrical Engineering major.

Two New Professors join Dept. of Physics & Engineering *(continued)*

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wide variety of courses within the EE discipline, and she is using that breadth to teach Bethel undergraduates pursuing their EE degrees. In the Fall, she taught Analog Electronics; she is teaching Introduction to Engineering during Interim, and will teach Digital Electronics in the Spring.

Dr. Rogers received her bachelor's degree in Electrical Engineering from General Motors Institute in Flint, Michigan, and her master's degree and doctorate in Mechanical Engineering from Massachusetts Institute of Technology. As a faculty member at Kettering, she was the Interim Department Head for Electrical & Computer Engineering for one and a half years. During that time, she shepherded that department through an ABET accreditation visit, program reviews, and the reconstitution of an Industry Advisory Board. She expects to draw on that experience as Bethel will be seeking ABET accreditation for its engineering programs in a few years.

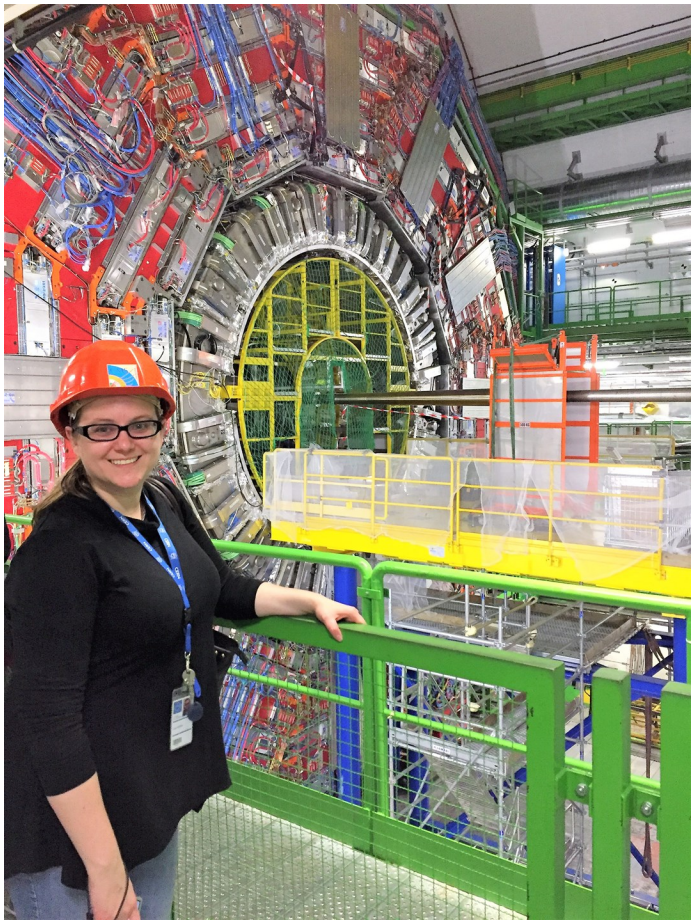
Dr. Rogers' professional interests include biomechanics, feedback control systems, and designing projects for developing countries. Other interests include bicycling, quilting and knitting. In the past few months, she has become quite experienced at unpacking boxes, as she and her husband settle into their Coon Rapids home.

Julie Hogan

Dr. Julie Hogan is fascinated by fundamental particles, high energy phenomena, and the mysteries they can answer about the universe. Her high school chemistry teacher did physics research during the summer and his classes got her excited about modern physics principles, such as light being a particle as well as a wave and electrons behaving like waves as well as particles.

She majored in physics at Vanderbilt University in Nashville, TN, and then pursued an M.S. and Ph.D. in physics at Rice University in Houston, TX. She did her doctoral research at Fermilab, outside Chicago, where the Tevatron accelerator collided protons with their anti-particles ("anti-protons") at very high energies. If you've ever been shocked by a 9V battery, imagine being shocked by a charge from a *trillion* volt battery – that's how much energy these particles have! Her group at the Tevatron was interested in questions like "why is our universe made out of only matter, without much antimatter?" They were looking for evidence of matter and antimatter particles interacting at different rates to try and answer this question.

After receiving her doctorate, she began a post-doc working at the Compact Muon Solenoid experiment (CMS), situated on the Large Hadron Collider (LHC) at the Conseil Européen pour la Recherche Nucléaire (CERN), or the European Council for Nuclear Research. At the LHC they collide protons with protons to create a hot, dense collision environment with 13 trillion electron-Volts of energy. With this much energy , collisions could produce heavy particles that have never been discovered, if they exist in nature.



Dr. Julie Hogan in front of the detector at CERN in Switzerland, which she uses to obtain data for her research.

Students who do CMS research at Bethel will join Dr. Hogan in searching for high-mass exotic new physics particles. To perform these searches, they will explore collision events that leave massive "jets" of particles in the CMS detector, and study new software for classifying these jets using deep machine learning algorithms. They will also help develop and test new silicon-semiconductor microstrip detector elements for CMS upgrades to be installed starting in 2023. With all the data collected by CMS over the next decade they are sure to learn important new truths about the universe. It's an exciting time to do particle physics!

Bios courtesy of Dr. Karen Rogers and Dr. Julie Hogan.

Ten Bethel students attend National Division of Laser Science (DLS) Conference

Ten Bethel students presented research at the Symposium on Undergraduate Research in Washington, D.C. on 17 September 2017. The 17th annual Symposium, co-organized by Harold Metcalf and Bethel Associate Professor of Physics Chad Hoyt, was sponsored by the Division of Laser Science (DLS) of the American Physical Society and was co-located with the 34th annual meeting of the DLS and the Frontiers in Optics meeting of the Optical Society (formerly Optical Society of America).

Bethel students Kallai Hokanson, Josh Kolbow, and Joe Nelson presented posters of their work from Dr. Nathan Lindquist's Nanolab. Nate Wahlberg and Keith Vollendorf presented posters of their work from Dr. Keith Stein's fluid dynamics lab. Greyson Stocker and Daniel Upcraft presented posters of their work from Dr. Chad Hoyt's atomic, molecular and optical physics lab. Anna Slattery presented a poster of her Bose-Einstein condensate work from the previous summer in the lab of Dr. Nicholas Bigelow at The Institute of Optics at the University of Rochester. Ella Johnson gave a talk about her optical atomic clock work the previous summer at the National Institute of Standards and Technology (NIST) in Boulder, CO. Max Werner also gave a talk about his work on ion atomic clocks at NIST, Boulder.

Attending a national conference as an undergraduate is an important experience for these students. Associate Professor of Physics Nathan Lindquist, who heads Bethel's NanoLab, says of the conference, "Sending students to a conference like this gives them a good idea about how the scientific community operates on a larger scale. Beyond one-on-one discussions with a professor in the lab, or working alongside a student partner, or presenting to the department, the scientific community needs to share what they've found and how they found it with a broad audience. That is how science advances. Our students were presenting their research to peers, professors from other institutions around the country, graduate students, and other scientists. One commented to me that even though they felt intimidated by the whole concept, it was still a 'fantastic learning experience.' They had to field questions from professors and graduate students, defend and explain our work, and have some back-and-forth with experts. It's a little different than studying for just another exam. Another commented that it was fun to share some of our ideas with folks and to hear them respond by saying "so *that's* how you can do that!" These kinds of events show our students that, yes, other scientists from around the country really are interested in what they are working on."

As noted earlier, a few of the students were presenting work done in national summer internships, but most of

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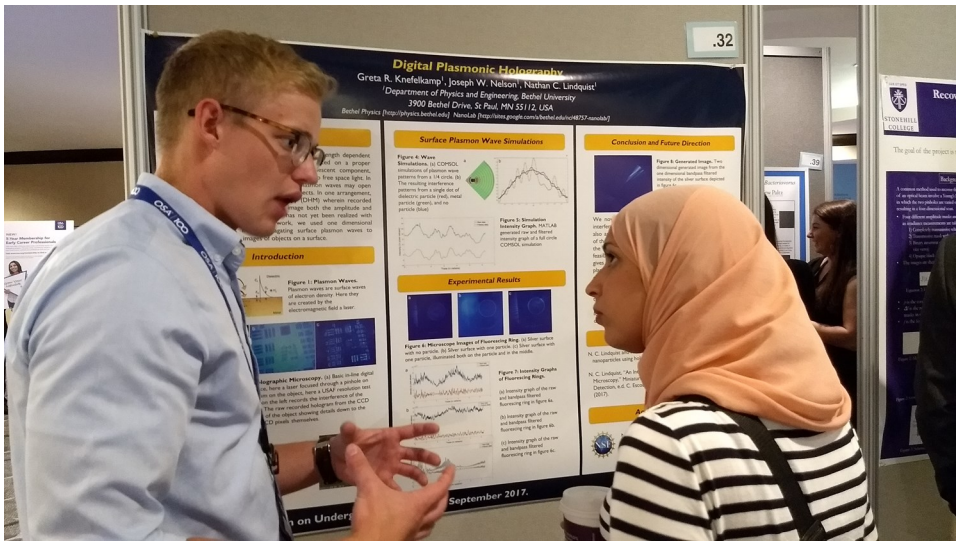
DLS Attendees Back row from left: Greyson Stocker, Josh Kolbow, Joe Nelson, Nate Wahlberg, Max Werner, Dan Upcraft. Front row from left: Kallai Hokanson, Anna Slattery, Ella Johnson, Keith Vollendorf.

the students attending had done work in one of Bethel's labs. Students from Dr. Lindquist's nanotechnology lab presented work on nano-sized "tractor beams" used to manipulate viruses, using plasmons to take pictures of cells "edge-on," and methods for simultaneously imaging cells both optically and chemically.
From Dr. Chad Hoyt's Optical, Molecular, and Atomic Physics lab, students presented work on fiber laser comb development and ultracold lithium atomic experiments with a hollow laser beam, based in the magneto-optical trap (MOT).
Students who worked in Dr. Keith Stein's Fluids lab presented on Schlieren and Mach-Zehnder interferometer techniques to image high-speed recordings of compressible flows. This combined qualitative (visual) and quantitative methods provide a holistic analysis of gas dynamics.

What do students think of the conference? Student attendee Max Werner '18 says of the OSA conference, "The OSA conference was an amazing opportunity to connect with students and researchers while also learning about cutting-edge research being conducted in the field of optics. Additionally, it provided a broader view of the opportunities and careers available in optics."
Joe Nelson '19 says, "This year's OSA/APS-DLS conference was a great experience for me. Not only was it fun to travel with my classmates, I was also able to meet physics and engineering students from across the country. I gained experience both from presenting my research and from listening to other students' research. "
As a positive learning and networking experience for students, we hope and anticipate that Bethel Physics & Engineering students will continue to attend this conference for years to come.

Written by Chad Hoyt and Nathan Lindquist

Nate Wahlberg '18 points out part of his poster presentation to a fellow DLS attendee while his colleague Keith Vollendorf '18 looks on.



Joe Nelson '19 explains his poster to a fellow DLS conference attendee.

Bethel DLS attendees take a break to visit monuments on the National Mall

Physics Student Receives Prestigious Internship with American Association for Physics Teachers (AAPT) in Washington, D.C.

When Justine Boecker ’17 was in high school, she knew God was calling her to work with children. But she could also tell that she wasn’t supposed to give up her dream of becoming a physicist. So when she got to Bethel, she was determined to make a double major of physics and elementary education work.

Boecker remembers sitting down with her advisor and professor of science education, Patricia Paulson, during her freshman year. After two hours they had figured it out: If everything worked out perfectly, she could do both majors and finish in four years. “She doesn’t let things discourage or stop her,” reflects Paulson. “She keeps persevering. She’s persistent to be able to move in the direction God’s calling her. And she interacts very kindly and respectfully to make that happen.”

All those skills came into play a few months ago, when Boecker applied for an undergraduate internship with the American Association of Physics Teachers (AAPT) to help design and revise resources for K-12 physics teachers. The internship combines physics with K-12 education and curriculum development—exactly what interests Boecker the most. “I’m really passionate about getting science in elementary schools,” Boecker says. “I see how people develop in science from preschool to high school. I see how it should work and how it can be developmentally appropriate.”

Since her freshman year at Bethel, Boecker has worked in the toddler room at the university’s Child Development Center, and for the past three years she has also worked as a birthday party coordinator at the Science Museum of Minnesota. Both jobs have provided opportunities to teach science lessons to children, adjusting the lesson to their ages—from 16 months to 12 years.

“The idea for kids is that they are more exploring science than digesting it,” Boecker explains. “I believe that kids are naturally curious and always trying to understand what’s going on around them. We need to do STEM [science, technology, engineering, and math] earlier when they want to learn about the world around them.”

Paulson recognizes how well Boecker understands the learning progressions for children and science, and that her understanding is a gift. STEM programs that are designed only for grades K-5 or grades 5-8 can lead to misunderstandings among teachers about what should be taught and when, Paulson explains. “Justine knows what it should look like and she’ll provide support to help those things happen,” Paulson says. “She’s an ambassador now for what science education should look like in the future and she’s only going to get stronger with the AAPT internship this summer.”

The internship provides an opportunity to learn and contribute to federal education policy on physics education. Boecker will live in Washington, D.C., for 10 weeks with others in the Society of Physics Students. She will also attend AAPT’s Summer Meeting in Cincinnati and have a chance to interact directly with teachers and students.

Justine Boecker ‘17 works with students at Bethel’s Child Development Center (CDC)

University Professor of Physics Emeritus Richard Peterson had passed information about the internship to Boecker and wrote her a letter of recommendation for the position. “I was delighted with her application and optimistic because of Justine's background. Still there was only one slot of this sort in the U.S., and there are nationally many universities more visible in physics education than Bethel,” Peterson says. “It worked because of Justine's enthusiastic track record along with high-quality STEM education mentors at Bethel.”

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Boecker counts being part of the physics department as the best part of her Bethel experience. She recalls spending many hours in help sessions during her freshman year and later in the electronics lab building circuits. In 2015, Boecker and her friend Morgan Wittner '17 co-founded the Women in Physics and Engineering club at Bethel. The goal was to build community between women studying physics as well as with their male classmates. "There is a large possibility that you will be the only woman in your class, but the guys are really great and they don't treat us any differently," Boecker says. "They value us as people and as physicists."

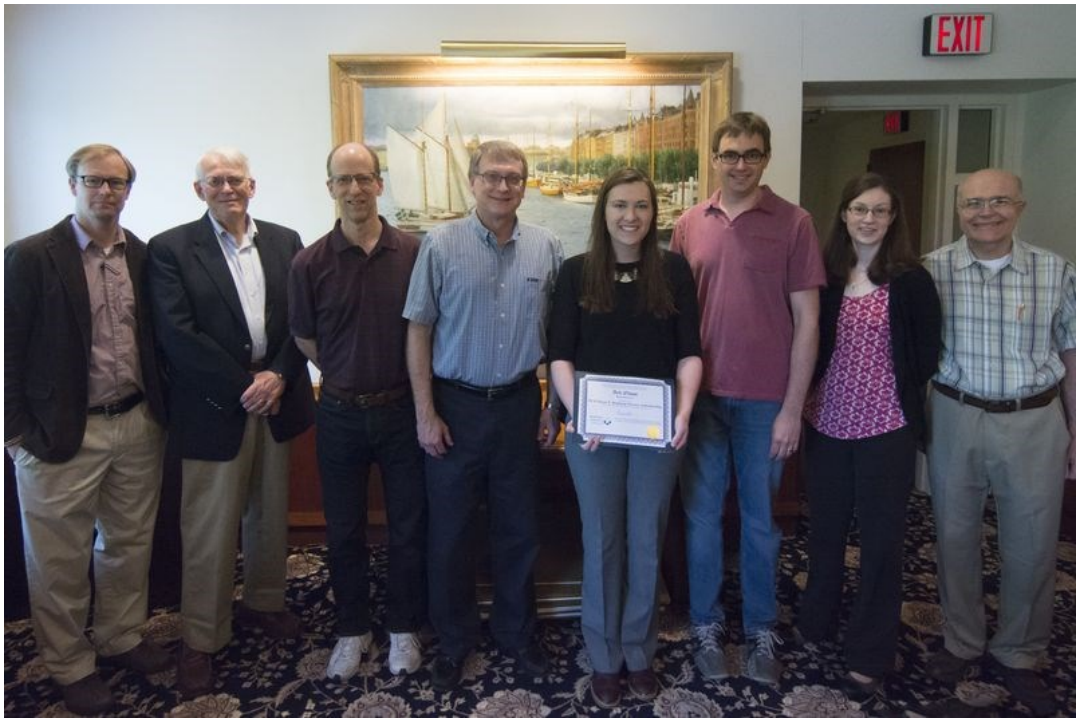
Boecker's many accomplishments garnered her a 2016 STEM Scholarship from the Minnesota High Tech Association Foundation and also helped with her AAPT summer internship application. Rebecca Vieyra, K-12 program manager for AAPT, recognized Boecker's unique qualifications and background with expertise in elementary education and physics. "It is extremely rare to find an aspiring teacher—especially in elementary education—who so whole-heartedly embraces physics," says Vieyra. "The nation desperately needs teachers like Justine."

After the summer internship, Boecker hopes to return to the Twin Cities and get a classroom teaching job. Eventually she would love to work as a STEM specialist in an elementary school, but those jobs are rare and she doesn't expect to get one as a first-year teacher. Paulson has no doubt that Boecker will become a STEM specialist one day. In fact, she could see Boecker coordinating STEM education for the whole state, not just one school.

Article first appeared at bethel.edu/news, use courtesy of Suzanne McInroy

Physics Student Wins Seaborg Award and Participates in Nobel Week

At the end of the spring semester, Aeli Olson '17 headed to the president's office for a meeting. President Jay Barnes had requested to talk with her before she graduated to hear her Bethel story. As she was shown to his office, she remembers hearing a lot of voices.



Aeli Olson '17 (center, with certificate) surrounded by her physics professors.

Instead of scheduling a one-on-one meeting, Barnes had asked Olson's professors to join him in presenting her with the Glenn T. Seaborg Science Scholarship from the Swedish Council of America (SCA), an annual award given to one outstanding student within the natural sciences selected through nominations made by the college presidents of six Swedish heritage institutions. Fourteen of Olson's professors showed up for the 8 a.m. surprise party to honor her. Olson was moved by the large show of support. "It was really touching," she says. "It goes to show that Bethel professors are really high quality, and they care about what they do."

Olson describes herself as "the easiest case" for the Bethel admissions office four years ago. She was familiar with the university because her two older siblings had already graduated from Bethel—Amalia Olson '12 and Christian Olson '13—and she felt called to study physics, a top major at Bethel.

During her senior year in high school, Olson discovered a field called medical physics, which as its name suggests, applies physics concepts, theories, and methods—such as quantum mechanics, nuclear physics, and radiation—to the biological and medical areas. As a Bethel student, Olson began taking courses

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in those areas and attended a conference at the Mayo Clinic on medical physics. By her sophomore year she knew she was on the right path.

During her sophomore and junior years as well as the summer between, she worked as a student researcher in Professor of Physics Nathan Lindquist's lab. During the summer between her junior and senior years, she worked as a student researcher at the Mayo Clinic. All of these research opportunities—plus a published paper—helped her as she applied to graduate programs during her senior year. Now, Olson is pursuing a Ph.D. in biomedical sciences at the University of Wisconsin-Madison—studying nuclear medicine.

As the recipient of the SCA's Seaborg Science Scholarship, Olson traveled to Sweden to present her research at the Stockholm International Youth Science Seminar. She is among 25 other high-achieving young scientists from around the world participating in Nobel Week. Participants also tour universities and research institutes in Stockholm, and meet Nobel laureates. She then attends the Nobel Awards Ceremonies and Banquet on December 10.

Olson feels blessed with how Bethel has prepared her for the next chapter in her life, not just academically, but in terms of her faith as well. She credits the biblical and theological studies department at Bethel for helping her understand her Christian faith better and the range of views within Christianity. "I feel well prepared to present Christianity to a logical audience," she says.

As she forges ahead, she will continue to let her faith in God guide her. "I've really stepped through the doors as they open and I don't see myself as trying to force anything I've done," she says. "I don't think I've done anything cool. I've just been living and doing my work. But I look back and see that He's given me a really cool resume. He's definitely blessed me. I try to keep working hard for Him and He keeps pushing me."

Article first appeared at bethel.edu/news, courtesy of Suzanne McInroy

Physics Alumna in Forbes' *30 under 30* in Energy, wins Cyclotron Road Fellowship

Lauren Otto '12 is a pioneer, developing materials that could enable the devices and technologies of tomorrow. And in November she made *Forbes'* list of 30 Under 30 in Energy, individuals described as "fueling a more sustainable future."

Lauren Otto '12, founder and CEO of tech firm Laminera

Her niche interests were sparked by a realization she had very early in her career. While working as an intern at HGST (formerly Hitachi Global Storage Technologies and now part of Western Digital Corporation), Otto learned about materials challenges with metals in emerging hard drive technologies. She realized there could be solutions to these challenges in conductive ceramics, but that traditional methods for creating these materials were not compatible with the tight manufacturing requirements of the hard drive industry.

So Otto launched a company, Laminera, whose goal is to create conductive ceramics through atomic layer deposition (ALD), a process that can coat a surface of arbitrary shape and substance equally, one atomic layer at a time. Otto and her team at Laminera have been awarded a prestigious place among Cohort Three of Cyclotron Road: an elite group of hard science innovators whose projects are supported by Activation Energy and the Department of Energy-funded Lawrence Berkeley National Laboratory. Being named to Cyclotron Road is a highly competitive feat, with just nine entrepreneurial projects funded this year. As a member of Cohort Three, Otto is granted access to tools and funds to

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explore the possibilities of the technique she's been developing with scientists at Berkeley.

Though ALD of some conductive ceramics already exists in research-scale environments, Otto believes Laminera's technique will be better suited for higher-quality materials and the industrial-scale manufacturing of hard disk drives or other upcoming technologies. She's excited about the possibilities of this technique and for the future of Laminera: "There's a lot to explore, lots of potential," she says. "If I can make the surface of something conductive, then I can use this not only in the hard disk drive industry where I got started, but also potentially elsewhere in semiconductor fabrication, like in integrated circuits or solid state data storage, with batteries or solar technology, or high surface area electrodes for supercapacitors and water desalination devices."

None of this innovation would have happened, though, if Otto had given up two years earlier. Otto was working on her Ph.D. in electrical engineering at the University of Minnesota and was grappling with a lack of advisory support. Without it, Otto faced the possibility of having to start over with her research, as her own access to materials and resources were limited. "I decided that I wasn't going to let that stop me from pursuing what I'm passionate about. I found another way," she said. "My colleague from HGST told me about Berkeley Lab's Molecular Foundry and suggested I submit a proposal. This could solve my access-to-resources issue. He introduced me to his connections there, and over the course of a few weeks, a collaboration came together both in Berkeley and at the U of M." She submitted her proposal and was quickly accepted to do research at the Molecular Foundry. Additionally, Otto was awarded a prestigious National Science Foundation Graduate Research Fellowship, worth $46,000 per year for three years.

All of these factors, along with the support of key mentors, came together for Otto to complete her Ph.D. "I also credit God's faithfulness and provision as I walked through this unusual route to completing my degree and journeying on to what was next," she says.

As a follower of Jesus and a scientist, Otto is grateful for the educational opportunities and the "faith home" she found at Bethel. "Bethel kick-started the journey to where I'm at in my faith right now. Dr. Beecken's 'Great Controversies in Science and Technology' class was one of the first things that really got me thinking about faith's relationship to science." In the course, Department Chair and Professor of Physics Brian Beecken demonstrates how Christianity and science are not in conflict with one another.

"I tell students on the first day that my real, hidden goal is to get them to think and not just believe what they hear," Beecken says. "I want them to understand there are two sides to every issue or controversy and that they should never decide one way without first checking out the other side."

Otto graduated from Bethel as a first-generation college student, double majoring in physics and mathematics. "Getting to this point has been very difficult, and I've often struggled with what's referred to as 'impostor syndrome,' or just a lack of confidence," admits Otto. "But I'm much stronger now for the challenges I've faced. I've had to learn that humility isn't discounting who you are, it's more about knowing who you are."

Article first appeared at bethel.edu/news, courtesy of Ava Bergen

Physics Alumnus receives NSF Fellowship for Geosciences from an Engineering Perspective

The Mackenzie Dike Swarm, an ancient geological feature covering an area more than 300 miles wide and 1,900 miles long beneath Canada from the Arctic to the Great Lakes, is the largest dike swarm on Earth. Formed more than one billion years ago, the swarm's geology discloses insights into major magmatic events and continental breakup.

The Mackenzie Dike Swarm and the roughly 120 other known giant dike swarms located across the planet may also provide useful information about efficient extraction of oil and natural gas in today's modern world. To explore how naturally-occurring dike swarms can lead to improved methods of oil and gas reservoir stimulation, the National Science Foundation (NSF) Division of Earth Sciences awarded a $310,000 award to Andrew Bunger '00, assistant professor in the Departments of Civil and Environmental Engineering and Chemical and Petroleum Engineering at the University of Pittsburgh's Swanson School of Engineering.

Dike swarms are the result of molten rock (magma) rising from depth and then driving cracks through the Earth's crust. Dike swarms exhibit a self-organizing behavior that allows hundreds of individual dikes to fan out across large distances. Although petroleum engineers desire to achieve the same effect when creating hydraulic fractures for stimulation of oil and gas production, the industrial hydraulic fractures appear far more likely to localize to only one or two dominant strands. This localization leaves 30-40 percent of most reservoirs in an unproductive state, representing an inefficient use of

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resources and leading to unnecessary intensity of oil and gas development.

In the study, "Self-Organization Mechanisms within Magma-Driven Dyke and Hydraulic Fracture Swarms," Bunger will take a novel approach to understanding the mechanics of fluid-driven cracks, which he refers to as "geosciences-inspired engineering." Like the growing field of biologically-inspired engineering, Bunger will be looking to processes in the natural world to better understand the constructed or engineered world.

"I would like to challenge myself and the geoscience community to look at naturally occurring morphologies with the eye of an engineer," says Bunger. "The first part of the study will involve developing a mechanical model to explain the behavior of the dike swarms. We are borrowing from a theoretical framework developed in biology called 'swarm theory,' which explains the self-organizing behavior of groups of animals."

Swarm theory, or swarm intelligence, refers to naturally and artificially occurring complex systems with no centralized control structure. The individual agents in the system exhibit simple or even random behavior, but collectively the group achieves emergent, or "intelligent," behavior.

"One of the hallmarks of self-organizing behavior within swarms was recognized by swarm theory's earliest proponents, who were actually motivated by developing algorithms to simulate flocks and herds in computer animation," Bunger explains. "They proposed that all swarming behavior can be tied to the presence of three basic forces. One of these leads to alignment of the members with each other – it is what makes a flocking bird fly in the same direction as its neighbors. A second force is associated with repulsion – it keeps birds within a flock from running into each other and knocking each other out of the air. The third force is attraction – an often instinctive desire of certain animals to be near other animals of their own species, typically for protection from predators."

"If you look at dike swarms," Bunger continues, "They have been called 'swarms' for decades, but there has never been an effort to identify the mechanical origins of the three forces that are known to be present any place that swarming morphology is observed. When we view dikes in this way, we see that the alignment and repulsive forces have been recognized for years, although never placed in the broader context of their role in swarming. However, the origin of the attractive force is problematic. Why do all these dikes have any mechanical impetus to grow near each other? Because the mechanical origin of the attractive force has not been known, it is unclear why natural fluid-driven cracks – dikes – tend to exhibit swarming behavior while such an outcome is far less commonly observed in man-made fluid-driven cracks associated with hydraulic fracturing of oil and gas reservoirs."

"We will use computational models and analogue experiments, which use artificial materials to simulate the Earth's processes, to develop a new theory of fluid-driven crack swarms," says Bunger. "Through this advance, we would like to improve the stimulation methods used for oil and gas production. This will be a win-win for both industry and our society that depends upon the energy resources they produce. Industry will benefit from more efficient methods, and society will benefit from lower energy costs and a decreased environmental footprint associated with resource extraction."

In addition to a deeper understanding of the geological process that occur throughout Earth's history, Bunger also sees his research impacting planetary research of Mars and Venus. Both rocky planets contain a large number of giant dike swarms. Understanding how the geometry of dike swarms relates to the conditions in the Earth's crust at the time of emplacement will lead to a new method for ascertaining the little-known geological structure and history of Mars and Venus though analysis of the geometry of their many giant dike swarms.

Courtesy of Matthew Cichowicz

Physics alumnus Andrew Bunger '00 in his research lab at the University of Pittsburgh

Physics & Engineering Alumna helps repair Bethel sinkhole

"Bethel University—what city is that located in?" When Rachel Hagen '14 overheard that question posed near her desk in fall 2016, she couldn't help but chime in with a hearty "Arden Hills!" The physics alum—and a new Civil Engineer in Training (CEIT) at Minneapolis-based BKBM Engineers—had already been assigned to her share of projects, working on drainage and infrastructures "from the ground down," as she explains her field. But the die-hard Royal jumped at the chance to get back to campus and serve her alma mater.

The project? Fix a sinkhole that was caused by significant underground erosion, leaving an unsightly pit in front of the Lundquist Community Life Center (CLC) and Benson Great Hall. As a violinist in Bethel's Philharmonic Orchestra—and the 2016 Festival Orchestra—she was intimately familiar not only with Bethel's campus and community, but also the urgency of preparing for one of Bethel's signature events, Festival of Christmas.

"That was stressful—we kept saying, 'We *have* to get this done in time,'" Hagen recalls, noting that a sinkhole brings a lot of unknowns, with constant reassessment as the scope of erosion is explored. "To not be able to decorate for Christmas—for Festival? Not okay. We needed it to be done on time and look nice." Hagen, BKBM Principal Tom Cesare, and Project Manager Joel Maier worked with Bethel's facilities and grounds teams to quickly design and install an updated stormwater system, with new culverts in a material that would work long term with the unique soil and challenges in that part of campus.

Timely success with that project led to BKBM helping design a natural stone retaining wall along the creek through campus during summer 2017 improvements. Now, they've

Physics alumna and civil engineer Rachel Hagen '14 in front of one of the projects she's helped complete on campus.

almost completed design of a brand-new Bethel Drive thoroughfare through campus. That project, which will be completed in summer 2018, will include new sidewalks, shoulders, gutters, crosswalks, signage, and drainage. Along the way, Hagen has used her experience as an alumna to help prioritize purchases, providing insight about what spaces students would or wouldn't use, where to splurge or save money on the project, and how pedestrian traffic tends to flow on campus.

"[Rachel] gets the Bethel culture and what students care about," says Mike Lindsey, associate director of planning and projects in Bethel's Office of Facilities Management. "She represents everything that Bethel would hope graduates would be: excellent in their field, professional, teachable, and focused on customer service and solid values. Plus, she has this big smile and bubbly, friendly personality—she's really a delightful person."

Hagen wasn't sure at first where she wanted to go to college, much less where she wanted to end up after she was done. She saw a Welcome Week video on an overnight campus visit in high school, and she was sold on the kind of place Bethel was and the type of high-quality science programs she could find here. She declared biochemistry and chemistry majors but quickly learned they weren't for her. Once she took a few more courses, she landed on a path toward engineering, completing a B.A. in Engineering Science at Bethel and a Bachelor of Science in Civil Engineering at the University of Minnesota through the dual-degree engineering program. She loves the unique way civil engineering brings together different materials and processes, providing the foundation for so many spaces people know and love.

Now, as the only female and one of the youngest members of her team,

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she spends a lot of time using AutoCAD and HydroCAD stormwater modeling software, developing several projects at a time for diverse sites across the greater Twin Cities area. Hagen says Bethel's top-quality academic experiences, tailored mentoring and advising from physics faculty, being on Welcome Week teams, and playing violin on a music scholarship all shaped who she's turned out to be as a person and a professional. But on this particular jobsite, she's tapping into a whole new level of experience that's helping to bring a tangible project to fruition.

"It's cool having all this knowledge that I never thought would be useful—being able to recognize areas of campus that are underutilized or that aren't worth investing in," says Hagen. "I know where students hang out, where freshmen cross the roads. You never know what experiences you're having that are going to play a huge role in your life or career a few years down the road. Bethel really helped lay the groundwork for my values and the type of person I want to be—outside of what I want to do. And it's so cool to be a part of the work that's going on here—it's a blessing to work on this campus, just to *be* back on this campus."

Article first appeared at bethel.edu/news, courtesy of Monique Kleinhuizen

Dr. Tom Greenlee Retires

After 38 years of full-time service to Bethel University and the Physics Department, the most consecutive years of service by any current faculty member, Dr. Tom Greenlee began a well-deserved phased retirement in Fall, 2017. In phased retirement, we are pleased to have Dr. Greenlee continuing to teach one course per academic year for the next few years.

Tom Greenlee has played a huge role in the growth and success of the Physics Department for four decades. His ability to lead upper-level classes through difficult, puzzling theoretical physics—challenging the best students and yet still finding ways to simultaneously reach the struggling students—has truly been an inspiration. At the same time, Tom has demonstrated a remarkable range in his teaching style by touching the lives of non-science majors in classes like Astronomy.

Despite having received his Ph.D. as an experimentalist, Tom has served as our resident theoretical physicist. As a department, we have benefited greatly from having a "go-to-guy" who helps us with those difficult mathematical and theoretical questions. We have always appreciated and benefitted from Tom's willingness to apply his time and effort on problems that we encounter in our research.

Dr. Tom Greenlee (left) with 2017 inductees into the Sigma Pi Sigma physics honor society, a part of the annual Society of Physics Students (SPS) Banquet.

Every department needs someone who is willing to step up and get things done, regardless of whether or not the task fits their interests or furthers their career. No one could do that better than Dr. Greenlee. In the 1980's, Bethel devised a General Education curriculum that required every student to take laboratory science, so Tom taught himself to teach Astronomy. He spent over twenty years representing the Physics Department to the NASA Minnesota Space Grant Consortium. He has advised the Society of Physics Students for as long as it's existed. Tom has served faithfully and quietly for decades on essential tasks when no one else was willing or able. Tom's last sabbatical was centered entirely on working behind the scenes to improve our department by writing lab manuals that will be used for many years to come by other professors—selfless, and typical of Tom.

In addition to all that Tom does for the department, Tom has been a great example of integrity and dedication to Biblical Christianity. For example, many of his former students think Modern Physics simply cannot be taught without first hear-

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ing one of the letters from C.S. Lewis' *Screwtape* read. His integrity and honesty are almost legendary. Both students and colleagues speak of how they cherish his commitment to Christ.

Thank you, Tom, for 38 years of dedicated, humble service that has been an inspiration to all of us.

Written by Dr. Brian Beecken

Physics & Engineering Department Renovation

As we looked forward to expanding from a Physics Department with an Engineering Program (known as "Dual-Degree") to a Physics & Engineering Department that includes full majors in both fields, we knew that it would be necessary to add more lab space to accommodate the new Electrical Engineering major (see article on page 1). In addition, we anticipate continuing to add engineering majors in the future, which will also require increased space. In order to prepare for the space requirements of the new major plus possible future majors, we started by repurposing, re-organizing, and renovating some of the current space in the department, as well as expanding into some renovated spaces near the department.

Contents of the old storage room in the General Physics lab during construction

This was not a small task—most of the labs in the department underwent some renovation during summer of 2017. For some labs, this involved refurbishing existing space, while for other labs, it meant tearing down walls and moving equipment to completely new locations.

The most immediately obvious changes took place in the space that was formerly the "entrance hallway" to the department. What used to be the science division office and the faculty lounge were completely gutted to create two new labs. The outermost lab, with a full glass-paneled wall, is now home to the Carlsen Electrical Design Lab, named in honor of Emeritus Physics Professor R.A. Carlsen. The lab will be used for some of the upper-level Electrical Engineering courses and promotes high visibility for the hands-on work involved in those courses. Between the Design lab and the former entrance to the department is a new Modern Physics lab. The Modern Physics lab was moved to the new location so that the physics and engineering labs would be fully integrated together in the department, rather than having the two disciplines split into different areas. The former Modern Physics lab then became another new Electrical Engineering lab to provide space for the number of lab courses in the new major.

While the two new labs expand the square footage of the department, a significant amount of the renovation occurred in space already within the department. The most significant of these was the three-way switching of the Fluids lab, storage room, and Carlsen Analysis Center.

The Fluids lab, which has always been a fairly small space for very large equipment, moved into the former Carlsen Analysis Center with a few modifications to that room. The increased space for equipment will allow more room for students and faculty in research and fluids projects.

In order to replace some of the project and study space formerly housed by the Carlsen Analysis Center, the storage room was completely emptied and renovated with study tables, benches, an optics table, markerboards, and a sink. The room also has a window into the General Physics lab—hopefully revealing to General Physics students all the exciting things that happen in the back of the department! Because the room is intended as a study and project space, it has been named the Peter-

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son Project Center, in honor of University Professor of Physics Emeritus Richard (Dick) Peterson.

When renovating for the new Fluids lab (former Carlsen Analysis Center), the wall between that room and the machine shop was knocked down moved outwards, increasing the size of the machine shop and also adding a window between the shop and the Fluids lab. The additional space and visibility will increase the safety for those making use of the machine shop for projects or research.

The Nanotechnology Lab and smaller Lasers Lab, which often both housed nanotechnology research, were combined by knocking down the wall between the two in order to create one larger Nanotechnology lab. The spaces were also renovated to integrate them into a single room.

Since access to most of the Physics & Engineering labs is mainly through the General Physics lab, that lab was given a 'facelift' as well, being significantly brightened by the addition of whiteboards and new ceiling tiles and lighting.

The new Carlsen Electrical Design lab

Now that the dust from all of the renovation and remodeling has settled, and we look forward to many years of use in updated spaces with increased functionality. We invite you to stop by the department and check it out!

Bethel's Leadership in "Lighting the Future"

Bethel faculty and students again played a leading role in the 3rd annual "Optics and Photonics Winter School and Workshop: Lighting the Future" held January 4-8, 2018 at the College of Optical Science (COS) of the University of Arizona, Tucson. Each of the major national centers for graduate work in optical science and engineering (including University of Rochester, COS, CREOL, and others) were represented with speakers, and dozens of undergraduates were present from colleges and universities nationwide.

The Winter School portion of the program opened with two days largely devoted to helping undergraduates see the full breadth of optical science and engineering – including a focus on crucial optical advances in astronomy and space science. A centerpiece of the program included student re-


Physics student Max Werner '18 (left) presents his poster to other Workshop attendees, including alumnus Seth Erickson '17 (center)

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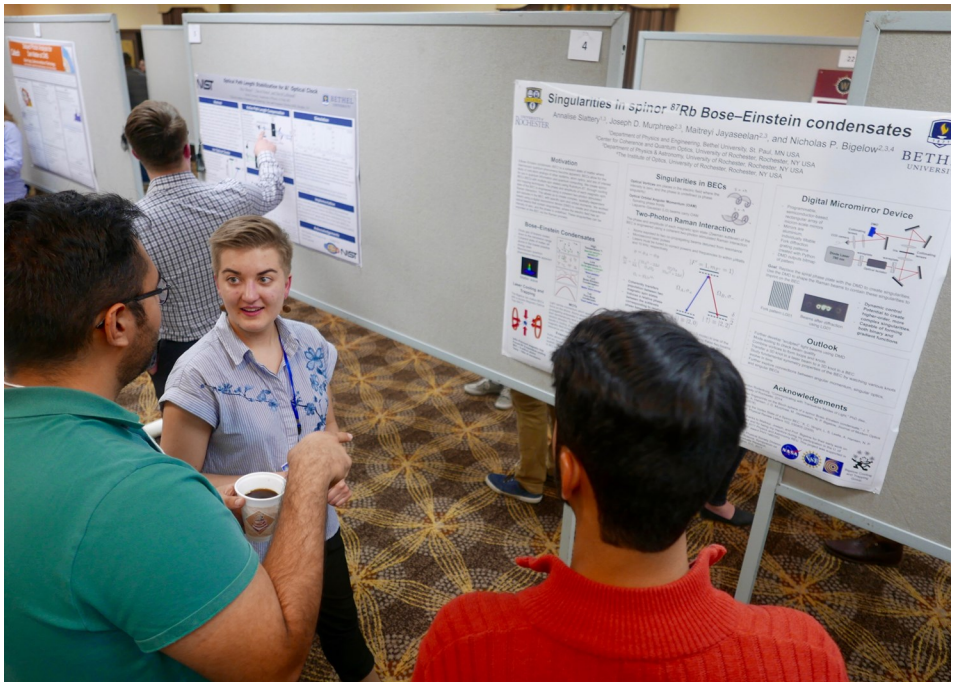
search, and over 20 poster papers were presented by undergraduates on Friday night. A Workshop program followed during the weekend, and it concluded with an experimental "Immersion Day" that encouraged participants to directly become very "hands-on" familiar with building and operating an advanced lab optical system.

For three years, Bethel's Dr. Chad Hoyt '94 has teamed up with Dr. Jason Jones '94 (University of Arizona COS faculty member and Bethel alumnus) in helping organize these national exposures to optical science and engineering. This year Hoyt led one of the concluding immersion experiments on his NSF supported, erbium-doped femtosecond fiber laser for use in advanced teaching laboratories. Bethel students led the nation in presenting the highest number of posters from their undergraduate research. These included: Ella Johnson, "Frequency-doubled source for atomic state lifetime measurements;" Anna Slattery, "Singularities in spinor 87Rb Bose–Einstein condensates;" and Max Werner, "Optical Path Length Stabilization for Al+ Optical Clock." Bethel's Dr. Richard Peterson presented the workshop's concluding keynote address, "On the Joys of Teaching Experimental Optics."



Physics student Anna Slattery '18 discusses her poster with other Workshop attendees

Written by University Professor of Physics Emeritus Richard Peterson

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Do you find yourself eagerly awaiting the next *PhysicsFocus* newsletter, wishing that you could keep up with Bethel Physics & Engineering department news as it happens?

Now you can! Read department news, see pictures of recent department events, and get your regular dose of general physics & engineering silliness at our Facebook page: https://www.facebook.com/BethelPhysicsEngineering/ .

Picture at right: Physics & Engineering Department students and professors at the annual Christmas party

Spring 2017 Graduates

Back row from left: Spencer Seiler, Seth Erickson, Nick Stone, Jacob Heppner, Tylor Cromer, Austin Riedeman. Middle row from left: Robbie Hanson, Chris Auer, Chris Gill, Andrew Acker, Andrew Thomas. Front row from left: Krista Johnson, Abby Rankila, Morgan Wittner, Matt Larson, Alissa Montzka, Justine Boecker, Preston Huft, Aeli Olson.

Fall 2017 Graduates

From left: Prof. Alyssa Hamre, Dr. Keith Stein, Dr. Brian Beecken, Joey Gronseth, JT Thweatt, Izzi Rich, Rachel Stephan, Dr. Julie Hogan, Dr. Karen Rogers