Detailed Course Outline with Required Readings
Fall 2017

Power and Energy, onshore and afloat

Course Number: CNIT 58100 (CRN: 19642)
3 credit hours; every Monday (3:30-6:20 pm) starting August 21, 2017
Materials and Electrical Engineering Building (MSEE) Room #B010
More Information:
http://www.purdue.edu/discoverypark/energy/programs/navy-programs/power-and-energy-course.php

Tentative

August 21 (3:30-4:45 PM)
Introduction to Course, Projects and Field Trips
Instructors and TA

August 21 (4:45-6:20 PM)
Energy Challenge
Rakesh Agrawal and Caleb Miskin, Chemical Engineering

Abstract
Earth's population is expected to approach 10 billion by 2050, with an accompanying unprecedented growth in the demand for energy—the lifeblood of modern economies. The grand challenge before us is to meet that growing energy need, while improving the quality of life for earth's inhabitants and decreasing our impact on the environment. Simply stated, we will need more energy, less CO_2. In fact, it has been estimated that by ~2050, carbon-neutral power sources in excess of 30 TW are needed to stabilize atmospheric CO2 at 350 ppm. As *total* global energy consumption is currently around 17 TW, a herculean challenge and marvelous opportunity for innovation lies before us. Current renewable technologies such as solar, wind, and biomass will need to be implemented at a scale far beyond their current market penetration and at a much lower cost.

After listening to these lecture students should understand:
- understand what is meant by the 'terawatt challenge'
- understand the sheer magnitude of the energy market
- understand the challenges and opportunities associated with transitioning to a renewable energy economy

Required Readings
1. Future Global Energy Prosperity: The Terawatt Challenge
   http://journals.cambridge.org/download.php?file=%2FMRS%2FMRS30_06%2FS0883769400013014a.pdf&code=58e070b0185609c9ff41ae708a1ef5e1

2. Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet http://www.sciencemag.org/cgi/doi/10.1126/science.1072357
3. Solar energy in the context of energy use, energy transportation and energy storage http://rsta.royalsocietypublishing.org/content/371/1996/20110431.long

August 28 (3:30-4:45 PM)
Navy Onboarding/Culture/Mission/Customs
Allen Garner, Nuclear Engineering and Commander US Navy

Abstract
Given its history and tradition, the Navy has a unique culture and provides excellent opportunities for professional growth and development for its officers and enlisted whether they pursue Naval or civilian careers. This talk will first summarize the Navy core values of honor, courage, and commitment and their role as the foundation of the Navy. It will then outline different Navy career paths with a focus on the initial officer routes of serving on board surface ships, submarines, or aircraft, as well as more technical opportunities with Naval Reactors, which manages the design and operation of the nuclear power plants onboard submarines and aircraft carriers, and Naval Sea Systems Command, which manages ship maintenance, construction, and the purchasing of major weapons systems. Finally, I will draw upon my own experience as a nuclear power trained submarine officer and a Reserve Engineering Duty Officer to discuss important leadership and technical skills that I developed that have helped me throughout both my civilian and military careers.

Required Readings
1. Navy Traditions, Customs, and Core Values: https://www.navy.com/about/tradition.html
2. Navy Careers: https://www.navy.com/careers.html

August 28 (4:45-5:20 PM)
Transition from Army to Civilian Career
Wayne Leuthold
EP Investor Nuclear Tech Supt, Caterpillar

August 28 (4:45-5:20 PM)
Grid System
Tom Adams, NSWC Crane

August 28 (4:45-5:20 PM)
Team Projects Discussion
Tom Adams

September 4 (no class – Labor Day)

September 11 (3:30 – 5:30 PM)
Nuclear Power and Navy
Robert Bean, Nuclear Engineering, Purdue
Thomas Adams, Naval Surface Warfare Center, Crane Division, IN

Abstract

About 8% of total US energy comes from nuclear sources and it provides carbon free energy. There are currently over 500 nuclear reactors either operating or being fabricated globally. Nuclear power is different than other power generating systems. The main focus of this lecture is to introduce fundamentals of nuclear energy and its applications to navy operations. A comparison will be discussed among various sources of energy and challenges in associated using nuclear power for peaceful as well combat operations.

After listening to this lecture, students should
- understand the basic concepts of nuclear energy
- be able to understand various types of nuclear reactors
- learn application of nuclear power in navy operations

Required Readings
(1) Fundamental of Nuclear Power
http://www.purdue.edu/discoverypark/energy/assets/pdfs/SUFG/publications/SUFG%20nuclear%20report.pdf
(2) "Nuclear Marine Propulsion.pdf," M. Ragheb, Naval Postgraduate School, October 15, 2015.
http://mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/Nuclear%20Marine%20Propulsion.pdf

September 11 (4:45 AM – 6:20 PM)
Emergency Stationary Power
Wayne Leuthold
EP Investor Nuclear Tech Supt, Caterpillar

Tour: Purdue University Nuclear Reactor
Electrical Engineering (Basement/Room #?)
Robert Bean
Nuclear Engineering

September 18 (3:30-4:45 PM)
Introduction to Rechargeable Batteries
Vilas Pol, Chemical Engineering

Abstract
The main focus of this lecture is to introduce electro-chemical energy storage systems, particularly rechargeable Li-ion batteries. Working principle of current state of the art Li-ion batteries that are in your cell phones, laptops and electric vehicles will be explained. Today's main challenges (cycle life, safety, high cost etc.) in the development of high energy density batteries will be discussed. Advanced materials for anodes, cathodes, separators, electrolytes and their engineering to produce high energy density batteries will be highlighted.

After listening to this lecture, students should

- understand the **basic physical concepts** involved in electrochemical energy storage
- be able to ***critically evaluate*** the utility and viability of technological claims in popular and scientific literature

Required Readings

1) The Li-Ion Rechargeable Battery: A Perspectives
   http://pubs.acs.org/doi/abs/10.1021/ja3091438
2) Challenges in the development of advanced Li-ion batteries: a review
   http://pubs.rsc.org/en/content/articlelanding/2011/ee/c1ee01598b#!divAbstract

September 18 (4:45-6:20 PM)
Battery Safety
Vikas Tomar
Professor, School of Aeronautics and Astronautics

Investigation of Dynamic Loading Effect on Performance and Safety of Lithium- ion Batteries using Nanomechanical Raman Spectroscopy
Lithium- ion battery (LIB) has been well accepted in industry as one of the most mature yet promising rechargeable batteries. However, there still exists safety flaws in LIBs, with one main hazard being dynamic load generated defects during transportation. In order to understand the effect of dynamic loading and temperature on battery safety, impulse and vibration impact tests are being performed at the Interfacial Multiphysics Lab at Purdue University as a function of battery operation temperature. An analytical technology referred to as Nanomechanical Raman Spectroscopy is being used to observe change in battery electrode properties under dynamic loading. Emphasis is on understanding how battery electrode change their properties as under a combination of impact and temperature induced electrode changes that can lead to catastrophic battery failure. Reported work also involves in-situ Raman coin cell development and new electrode materials preparation.

References:

- NAVY. Navy Lithium Battery Safety Program Responsibilities and Procedures; 2010.
- Zhao, W.; Luo, G.; Wang, C.-Y. Modeling Nail Penetration Process in Large-Format Li-Ion Cells. J. Electrochem. Soc. 2014, 162 (1), A207–A217.
- Gan, M., Samvedi, V., and Tomar, V., "A Raman Spectroscopy Based Investigation of Thermal Conductivity of Stressed Silicon Micro-Cantilevers". *AIAA Journal of Thermophysics and Heat Transfer, DOI: 10.2514/1.T4491*, 2014.
- Gan, M. and Tomar, V., "An in-situ platform for the investigation of Raman shift in micro-scale silicon structures as a function of mechanical stress and temperature increase". *AIP Rev. Scientific Instruments*, 2014. **85**: p. 013902 (10 pp).
- Love, C., "Perspective on the mechanical interaction between lithium dendrites and polymer separators at low temperature", ASME J Electrochemical Energy Conversion and Storage, 2016, 13: p. 031004 (5 pp).

****Introduction to Missile Batteries****

Sam Stuart, NSWC Crane

Abstract

The focus of this lecture is to provide an introduction to reserve batteries used in missile applications. Reserve batteries are designed for long storage time without losing energy to operate as specified upon demand. In reserve batteries are inert while stored; in some types, the electrolyte is separated from the electrodes or cells to prevent self-discharge. When power is needed, a gas generator is activated and forces electrolyte into cells. There are several types of reserve batteries: gas activated, water activated, electrolyte activated and heat activated. These batteries are made in various shapes and sizes; it is usually the last component designed into the system. Since the quantities of batteries made for missile applications is relatively small compared with commercial, there are many challenges in obtaining materiel, fabrication, and reliability.

After listening to this lecture, students should understand the reserve battery technology and the challenges and difficulty in maintaining operational readiness.

Required Readings

1) Handbook of Batteries, by David Linden and Thomas Reddy: Part 3 – Reserve batteries http://www.etf.unssa.rs.ba/~slubura/diplomski_radovi/Zavrsni_rad_MarkoSilj/Literatura/Handbook%20Of%20Batteries%203rd%20Edition.pdf
2) Reserve battery, https://en.wikipedia.org/wiki/Reserve_battery

September 25 (3:00-4:45 PM)

Students to make short presentations (e.g. solar, thermal, hydro, wind, fuel cells)

September 25 (4:45-6:20 PM)
Electricity System, Micro Grid
Paul Roege, P.E.
Colonel (Retired) Army

October 2 (3:30-4:45 PM)
Power Electronics
Peter Bermel
Electrical and Computer Engineering
Peter Peide
Electrical and Computer Engineering

October 2 (4:45-6:20 PM)
Tour – Birck Nanotechnology Center
Zhiguang Zhou
Electrical and Computer Engineering

October 9 (no class – October break)

October 16 (3:30-4:45 PM)
Midterm Exam/Take Home Exam
Field Trip to Battery Innovation Center and Naval Surface Warfare Center, Crane, IN
Thomas Adams
Naval Surface Warfare Center, Crane Division, IN
Pankaj Sharma, Purdue

October 23 (3:30-4:45 PM)
Basics of Thermal Barrier Coatings for Gas Turbines and Impurity Interactions
Rodney Trice, Materials Engineering

Abstract
Thermal barrier coatings are used extensively in gas turbines engines, enabling operating temperatures 100-200oC higher than possible with superalloys alone. TBCs are typically composed of a low thermal conductivity 7wt.% Y2O3-ZrO2 topcoat, and a MCrAlY bondcoat that improves bonding between the topcoat and superalloy. New gas turbines are being operated at temperatures in excess of 1200oC, making new corrosion threats real. One of these threats involves the melting of particulate or sand into the topcoat, which can cause delamination and cracking of this protective layer. In addition, biofuels also have impurities intrinsic to how the biomass is harvested. In this short lecture, I will review TBC basics and discuss potential corrosion hazards.

Required Readings
Chapter 11 from Turbine Aerodynamics, Heat Transfer, Materials, and Mechanics, edited by Tom I-P. Shih and Vigor Yang, AIAA Press. (chapter is available as hard copy)

October 23 (4:45 – 6:20 PM)
Midterm Project Review

October 30 (3:30-4:45 PM)
Manufacturing of Nanocomposite for High Density /Power Batteries
Gary Cheng
Industrial Engineering
Kejie Zhao
Mechanical Engineering

October 30 (4:45-6:20 PM)
Tour – Laser Manufacturing (Potter B35)
Gary Cheng
Industrial Engineering
Nanocomposites (ME Gatewood Wing 3141)
Kejie Zhao
Mechanical Engineering

November 6 (3:30-4:45 PM)
Thermal Management of Electronics
Justin Weibel
Mechanical Engineering

Abstract
Heat must be effectively removed from electronic components to prevent the deterioration of electrical performance and reliability at high operating temperatures. Efficient thermal management of electronics is critical to operation of transportation, renewable energy, data centers, and other energy systems. The lecture this week will review the electronics cooling and packaging challenges currently faced by industry, as well as to introduce modeling techniques that allow evaluation of the performance of several alternative cooling strategies.

Required Readings

1. Sauciuc, R. Prasher, J.-Y. Chang, H. Erturk, G. Chrysler, C.-P. Chiu, R. Mahajan, Thermal Performance and Key Challenges for Future CPU Cooling Technologies, (2005) 353–364. https://doi.org/10.1115/IPACK2005-73242
2. S.V. Garimella, T. Persoons, J. Weibel, L.-T. Yeh, Technological drivers in data centers and telecom systems: Multiscale thermal, electrical, and energy management, Applied Energy. 107 (2013) 66–80. https://doi.org/10.1016/j.apenergy.2013.02.047

November 6 (4:45-6:20 PM)
Tour: Electronics Cooling and Thermal Microsystems Labs
Website: https://engineering.purdue.edu/CTRC/
Room # MEG063 (Mechanical Engineering Building)
Justin Weibel
Mechanical Engineering

November 13 (3:30-4:45 PM)
The billion-ton bioeconomy
Maureen McCann
Biological Sciences

While the use of inexpensive liquid hydrocarbon transportation fuels has been an unparalleled achievement and enabler of economic prosperity for many nations, singular dependence upon crude oil has given rise to systemic vulnerabilities in climate, energy, economic, and national security. Lignocellulosic biomass, a renewable and carbon-neutral resource, has the potential to displace an estimated annual equivalent of three billion barrels of oil in the U.S. alone. However, biomass has only one-third the energy density of crude oil and lacks petroleum's versatility as a feedstock for fuels and chemicals. This lecture explores various research pathways to produce biofuels such as ethanol, biodiesel, and liquid hydrocarbons, and the potential of future biorefineries to produce fuels, biorenewable chemicals, polymers and materials in the emerging bioeconomy.

Suggested Readings:

Dale et al. (2014) Take a Closer Look: Biofuels Can Support Environmental, Economic and Social Goals. Environ. Sci. Technol. 48, 7200−7203 [10.1021/es5025433].

November 13 (4:45-6:20 PM)
Alternative Aviation Fuels
Gozdem Kilaz
Aviation Technology

Abstract
The focus of this lecture will be to introduce the alternative aviation fuels that are utilized as "drop-in" replacements for the fossil based aviation fuel – kerosene.
The need for shifting towards biofuels will be discussed. Students will gain knowledge on the fuel manufacturing technologies, ASTM approval standards and fuel sustainability measurements.

After listening to this lecture, students should;
- Understand and compare the basic steps of alternative fuel production from various feedstocks

- Learn the technical, economic, and social parameters involved in utilizing sustainable aviation fuels
- Evaluate the challenges involved in deployment of biofuels in civil and military aircraft in the U.S.

Required Readings:

Aviation Gas Turbine Alternative Fuels: A review
http://www.sciencedirect.com/science/article/pii/S1540748910003950

November 20 (3:30-4:45 PM)
Metal Combustion for Energy and Energetic Material Applications
Steve Son, Mechanical Engineering

Abstract

The main focus of this lecture is to introduce metal as an energy storage medium, as well as its use in chemical looping reactors. Applications to energetic material (propellants, explosives, and pyrotechnic) applications will also be introduced. The basic physical concepts of metal combustion will be presented. In addition, state of the art approaches to improving metal combustion will be presented.

After listening to this lecture and the readings, students should

• Understand the **basic physical concepts** involved in metal combustion, and applications to energy and energetic materials applications
• Be able to ***critically evaluate*** the utility and viability of technological claims in popular and scientific literature

Required Readings

Direct combustion of recyclable metal fuels for zero-carbon heat and power
http://dx.doi.org/10.1016/j.apenergy.2015.09.037

Optional Readings (not available online)

Encapsulated Nanoscale Particles and Inclusions in Solid Propellant Ingredients by S. Son et al., In Energetic Nanoparticles by Vladimir Zarko and Alexander Gromov (2016)

November 20 (4:45-6:20 PM)
Hydrogen Storage: Status, Perspectives, and Industrial Applications
Timothy Pourpoint
Aeronautics and Astronautics Engineering

Abstract

The lecture will cover following topics: Applications for hydrogen storage; The good and "less good" news; Hydrogen storage options; Matching application with options - Chemical hydrides and Aerospace applications; Conclusions.

Required Readings

1. Puru Jena (2011), Materials for Hydrogen Storage – Past, Present and Future, The Journal of Physical Chemistry Letters, 2(2011)206-211 (printed copy available)

November 27 (3:30-4:45 PM)
High Energy and Pulsed Power
Allen Garner
Nuclear Engineering

Abstract

Pulsed power, which involves accumulating electrical energy over a relatively long period of time and then using specifically designed switches to apply it to a load over periods of time that can be as short as hundreds of picoseconds. These unique capabilities to deliver electric pulses of various durations and intensities leads to multiple commercial and military applications. Pulsed power is an enabling technology for high power microwave sources, which are used in military radar systems nonlethal defense technologies, such as Tasers. Pulsed power is also a critical component of the Navy's railgun program, in which electromagnetic forces replace conventional chemical propellants for ordnance. Ongoing research explores the application of pulsed power for biomedical applications, including athermal sterilization of milk, water, and juices, cancer treatment, permeabilization of cells and tissues for drug delivery, and even wound healing. This lecture will provide a general overview of these topics from a technical perspective and the relationship to military applications.

Required Readings

1. Barnes, Julian E. (2016). "Faster Than a Speeding Bullet: A First Look at America's Supergun" Wall Street Journal http://www.wsj.com/articles/a-first-look-at-americas-supergun-1464359194 .
2. Mankowski, J. and Kristiansen, M. (2000). "A Review of Short Pulse Generator Technology," IEEE Transactions on Plasma Science, vol.28, no.1, pp.102-108. http://dx.doi.org/10.1109/27.842875

November 27 (4:45-6:20 PM)
*Tour: Zucrow Lab (*500 Allison Road, West Lafayette, IN 47907
Steve Son
Mechanical Engineering
Timothy Pourpoint
Aeronautics and Aeronautics

December 4 (3:30-4:45 PM) and (4:45-6:20 PM)
Project Presentations

December 11 (3:30—4:45 PM and 4:45-6:20 PM)
Final exam

Field Trip
TENTATIVE

Naval Surface Warfare Center
300 Highway 361, Crane, IN 47522

Battery Innovation Center
7970 S Energy Dr, Newberry, IN 47449

0700 – 1730; October 16, 2017

Visitors: Professor Eric Dietz, Dr. Pankaj Sharma, ~20-25 Undergraduate/Graduate students in the Power and Energy Course at Purdue: Power and Energy, onshore and afloat

Purpose: The course is part of Purdue's Military Research Initiative and is funded by the Office of Naval Research to inspire leadership in Science and Technology for the workforce of the future fleet.

Visitors will be escorted by Tom Adams

Important Instructions to participants: Two forms of acceptable ID's (listed in the instructions for completing the SECNAV 5512/1 form) and completed SECNAV 5512/1 form are required before a pass will be issued (ID's must be legible). If driving; a valid driver's license, proof of insurance and current/valid vehicle registration is required.

*****A printed document needs to be signed before August 28*****

Visitors: Professor Eric Dietz -Director of the Purdue Homeland Security Institute and Professor in Computer and Information Technology Department
Dr. Pankaj Sharma - Associate Professor of Engineering Technology (courtesy)
Managing Director, Energy Center, Discovery Park
Cell# 765-412-1158
Dr. Tom Adams - Instructor

15 Purdue University Graduate Students plus three staff members

Purpose: Students visiting NSWC Crane are completing their Power and Energy Course at Purdue. The course is part of Purdue's Military Research Initiative and is funded by the Office of Naval Research to inspire leadership in Science and Technology for the workforce of the future fleet.

Vehicle: Private Bus and Car

Uniform: Military – Khakis; Civilian – Casual Business Attire

Visitor will be escorted by: Tom Adams and Sue Wagonner

Monday, 11 September 2016 UNCLASSIFIED

* Tom Adams will meet visitors Battery Innovation Center.

6:45 AM **Gather in front of PMU East/Hotel entrance (look for Lafayette Limo)**

7:00 AM **Depart by Lafayette Limo**
Refreshment

10:00-10:30 **Battery Innovation Center - WestGate**
7970 S Energy Dr. Newberry, IN 47449
Presenter –*** Casey Butler***

10:40 AM **Depart for WestGate Academy**
13598 E. WestGate Drive, Odon, Indiana 47962

11:00-12:15 **Working lunch at WestGate Campus**
Navy contractors and other local industry leaders

12:20-12:35 **Arrive at Visitor Center**
103 Furlong Street, Crane, IN 47522
Will be escorted on base by Tom Adams

13:00-13:30 **Expeditionary Department – B3235**
Power and Energy Systems Division; Lithium batteries and Safety testing
Presenter: Mark Tisher

13:45-14:15 **Expeditionary Department – B3287E**
Power and Energy Systems Division; Reserve battery testing and evaluation
Presenter: Sam Stuart

14:30-15:00 **Expeditionary Department – B3287W**

Power and Energy Systems Division; Rechargeable and stationary battery, and alternative power and energy testing and evaluation
Presenter: To be decided

15:00 PM **Depart NSWC Crane**
Refreshment

17:30 PM **Arrive at Purdue - PMU**

Points of Contact
Pankaj Sharma, Purdue Energy Center
765-412-1158 Cell

Tom Adams – Research Engineer, Expeditionary Power and Energy Branch, Code JXMR
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Sue Waggoner – Electronics Engineer, Science & Technologies Engagement Branch, Code JXML
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McKean Defense
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