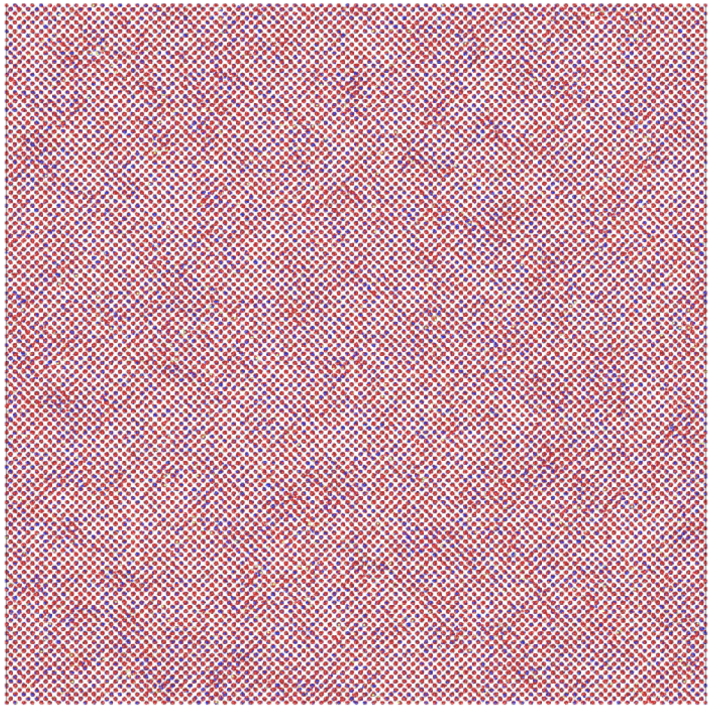
Introduction and Overview

NE 591: Nuclear Fuel Performance

Dr. Benjamin Beeler

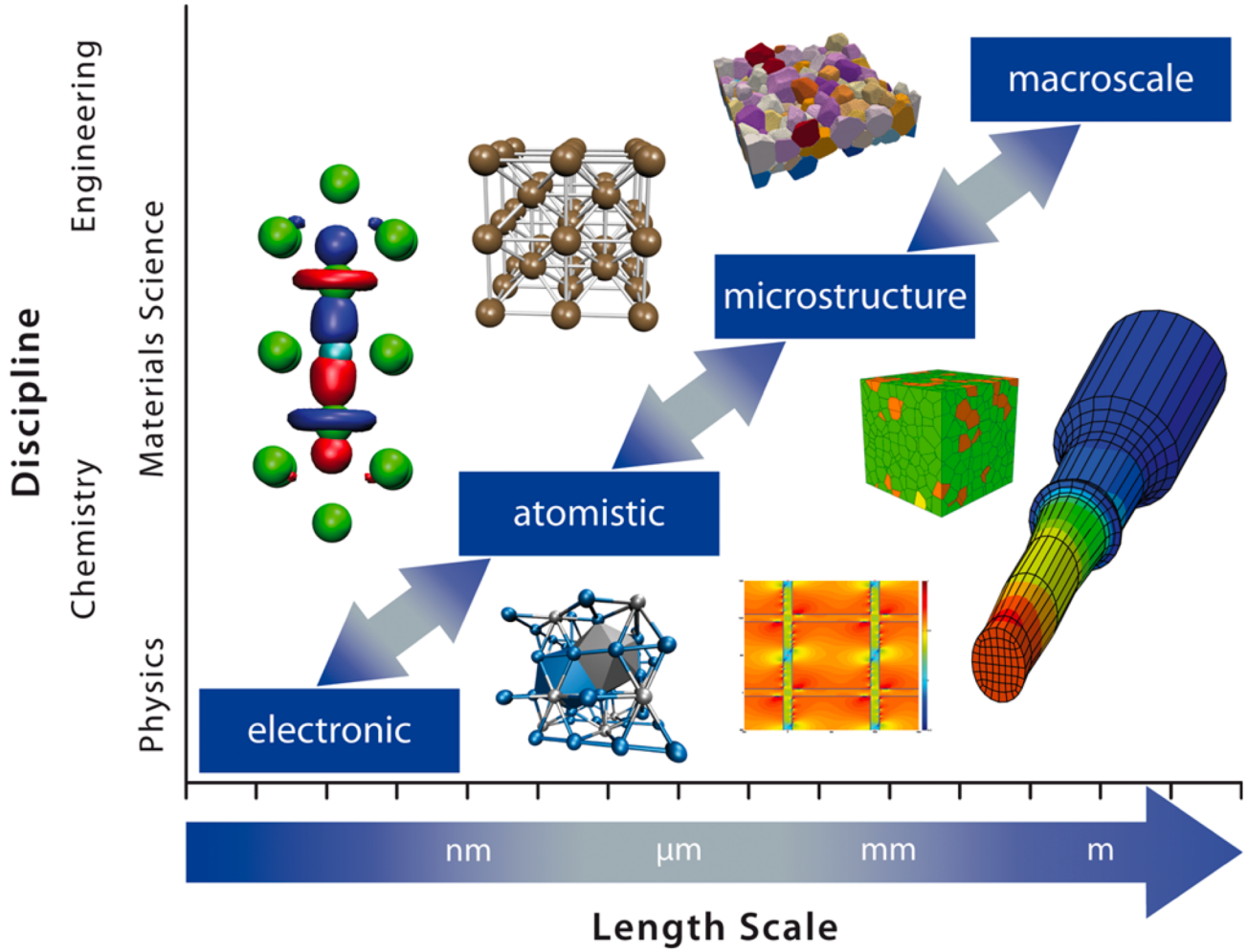
Brief Bio/Background

- Computational Nuclear Materials Scientist
- Expertise in advanced nuclear fuels
- Ph.D. in Nuclear Engineering from Georgia Tech
- Previously a staff scientist at Idaho National Laboratory in Fuel Modeling and Simulation Group
- Atomistic simulations: density functional theory and molecular dynamics



My viewpoint/approach

- Scientifically informed engineering is a multiscale problem
- Critical phenomena need to be identified from the macroscale, and informed from the lower length scales
- Perform good science, sometimes for science's sake, but often to address a key engineering problem or need



Syllabus

Course Overview

In this course we will study the basic role of fuel in reactor operation and understand how the fuel impacts heat generation and transport to the coolant. The course will begin with an overview of different fuels and the fabrication processes required to construct nuclear fuel. We will also study various fuel types and geometries, with a focus on light water reactor fuel and cladding. We will then study changes in the fuel and cladding material that degrade the performance of the fuel. Finally, student will apply knowledge gained to conduct fuel performance simulations.

Learning Outcomes

By the end of this course, the student should be able to:

1. Understand the basics of fuel fabrication
2. Calculate the rate at which heat is transported to the coolant from the fuel
3. List the most important microstructural changes that take place in the fuel and cladding and how they impact fuel performance
4. Use an existing fuel performance code

Planned Topical Outline

- Introduction and Overview
- Fuel types
- Fuel fabrication
- Thermal transport
- Mechanical behavior
- Materials issues in the fuel
- Materials issues in the cladding
- Used fuel disposition
- Overview of fuel performance codes
- Utilization of fuel performance codes

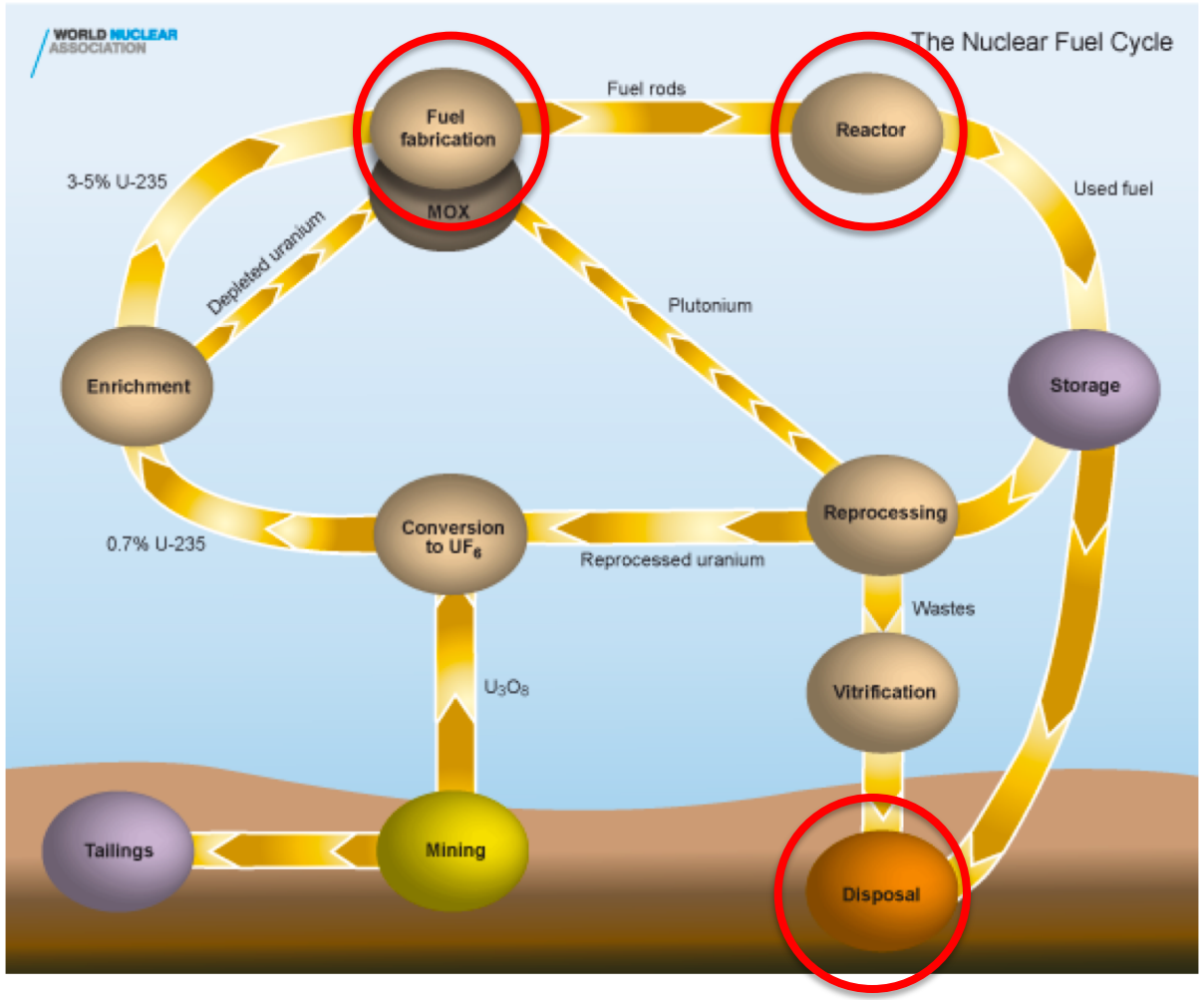
Graded Exercises

- Three exams
- One written project
- One final project
- Will see about homework…

Office Hours

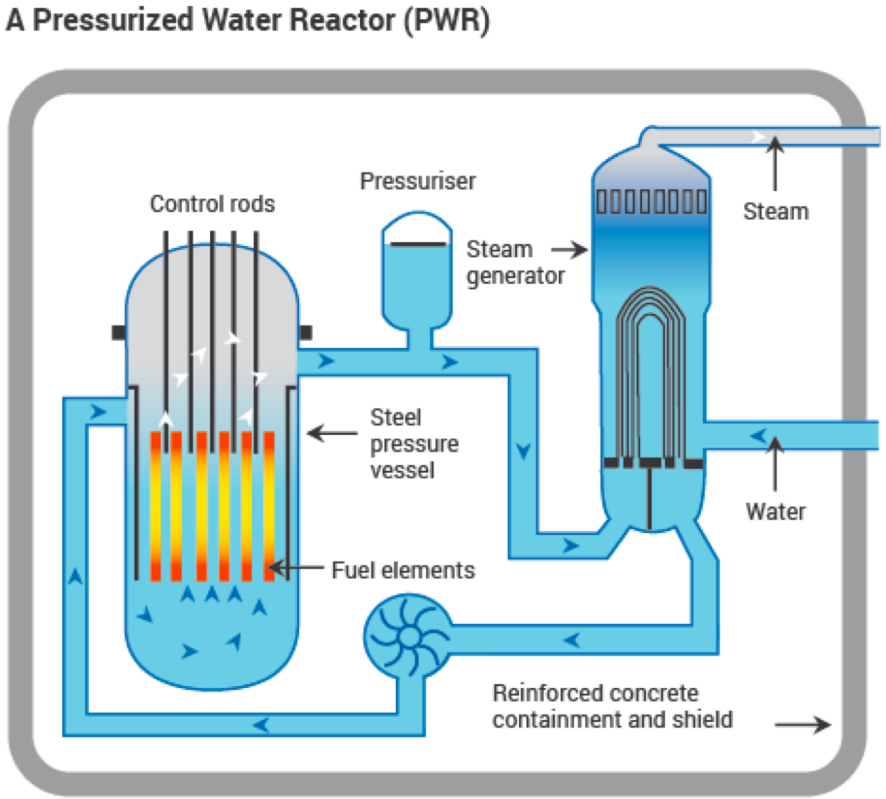
- Tentatively Wednesday's 10-11 am
- If this doesn't work, we can find some other time on Wednesday
- My office door may be closed, but I am still probably inside, so feel free to drop my if you have a pressing question

Complete nuclear fuel cycle



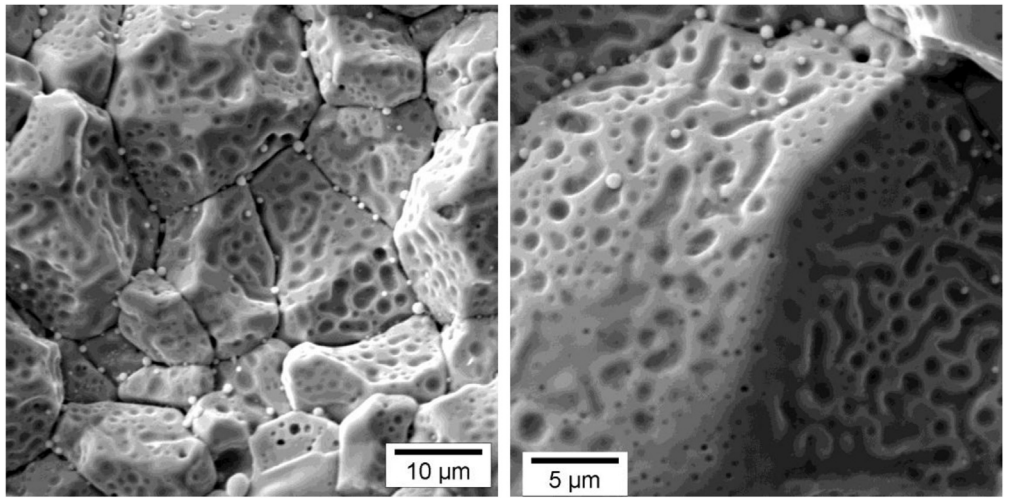
Emphasis on In-Reactor Behavior of Fuel

- The full reactor system is complex and substantial, and there are separate NE courses covering this area
- Although the fuel is a relatively small part of a reactor system, it determines thermal power, which drives electric power generation
- The performance of the fuel is measured by:
  - How much heat is delivered to the coolant
  - The length of time it operates without any problems
  - How well it performs during an accident



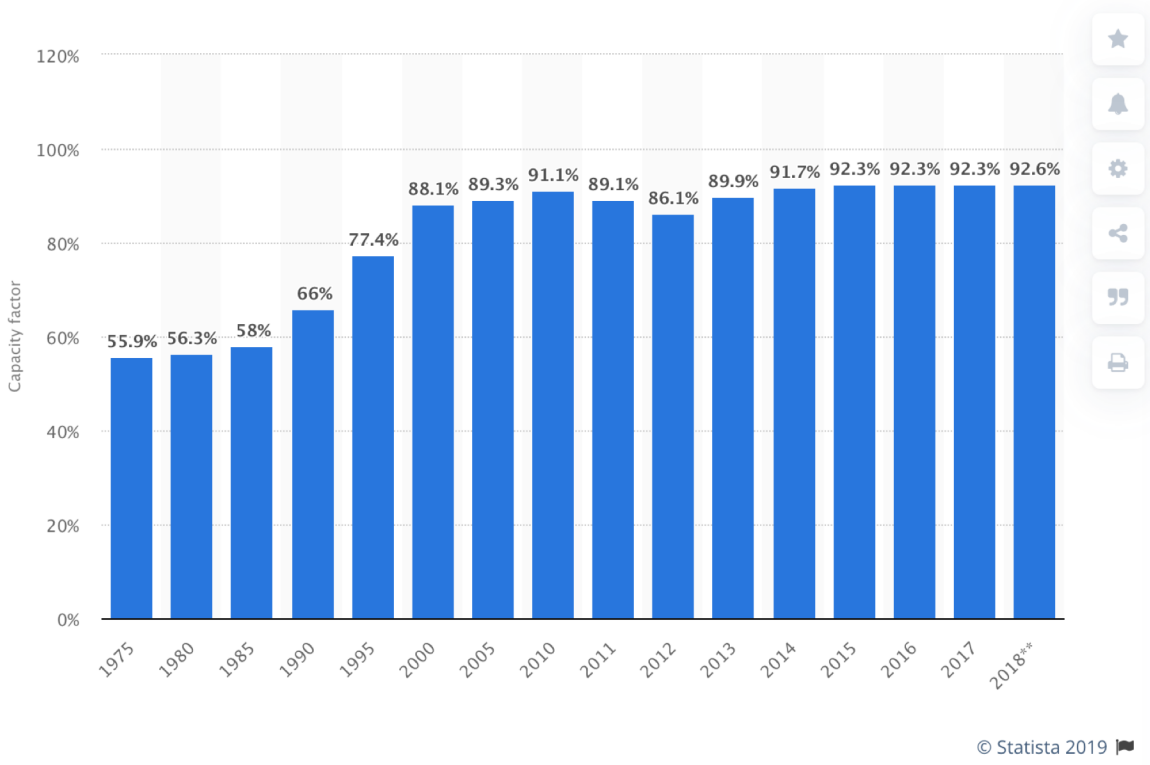
How much heat is delivered to the coolant?

- Heat transport is related to thermal conductivity
- In single crystal, pristine materials, thermal conductivity is reasonably straightforward
- In dynamic, radiation environments, thermal conductivity degrades, fission gas bubbles form, grain boundaries are generated and destroyed
- How does thermal conductivity vary?



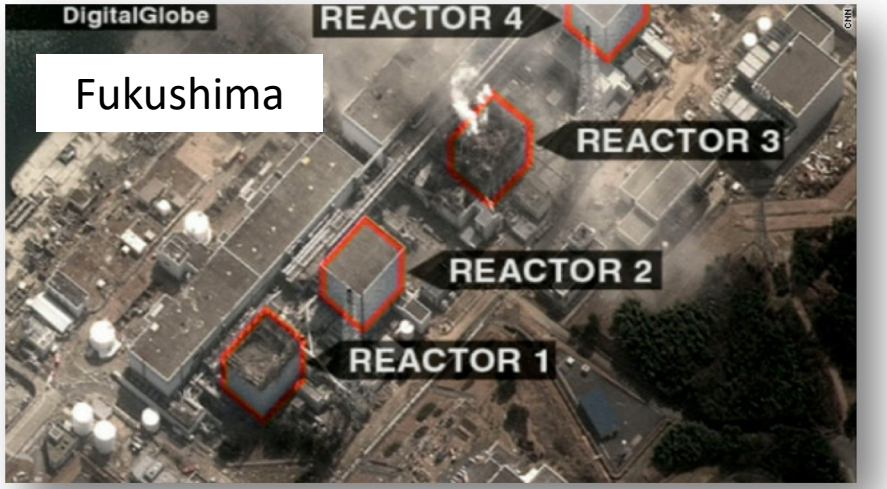
The length of time fuel operates without any problems

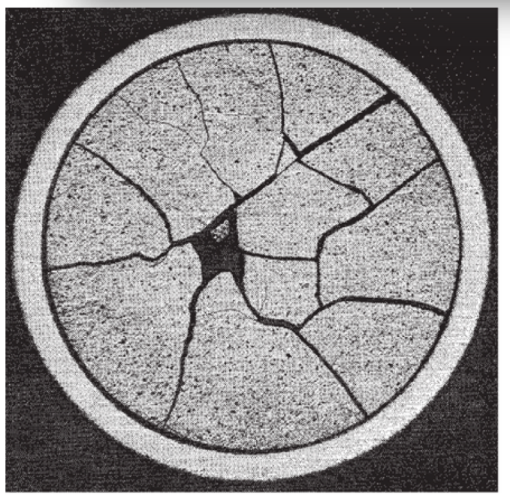
- There are 98 operating nuclear reactors in the US, producing 20% of the electricity
- The net capacity factor is the ratio of an actual electrical energy output to the maximum possible electrical energy output over a period of time
- Nuclear reactor capacity factor is ~92% over the past decade
- The ability to maintain high capacity factor, limit shutdown time, is key in making nuclear power economical
- Fuel is the primary component forcing reactor downtime



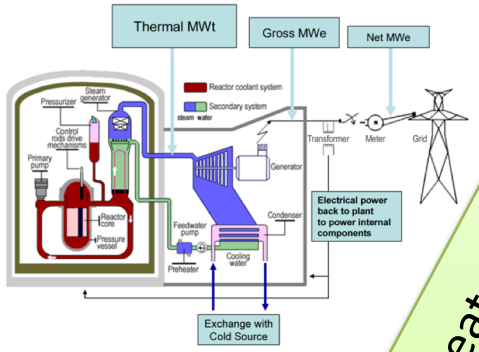
Fuel behavior during accidents

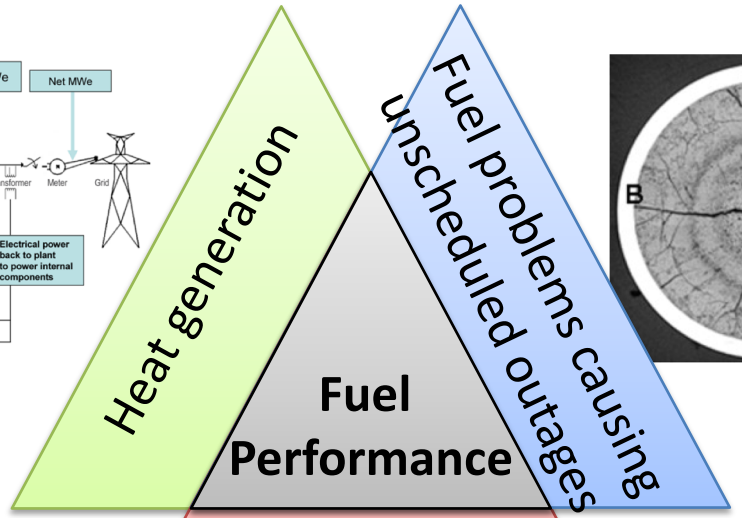
- In addition to normal operating conditions, the behavior of the fuel during accidents is of critical importance
- Predictable, and hopefully stable, behavior is desired during a variety of accident scenarios
- Even low impact accidents are detrimental to public opinion surrounding nuclear energy

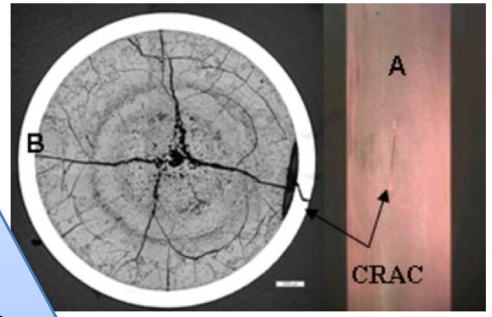


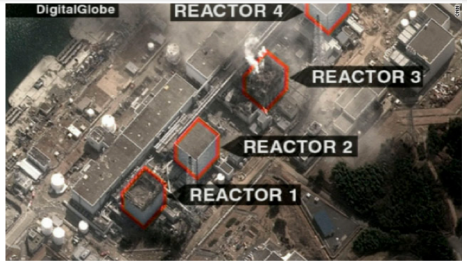


All of these factors together represent what we call “fuel performance”









Comments

THIS IS THE FIRST TIME THIS CLASS IS BEING TAUGHT AT NCSU

THIS IS THE FIRST CLASS I AM TEACHING

I wanted to make sure that this class is able to meet the needs of the students, provides relevant information, and is taught at a level commensurate with the abilities of the students.

I will need your feedback as we go along to make sure these goals are met.