DOCTORAL QUALIFYING EXAMINATION

The BME doctoral qualifying exam is an important evaluation of a student’s mastery of broad, coursework-based knowledge and their ability to analyze, synthesize, present, and discuss contemporary concepts in a specific area of research.

- These skills are fundamental for high-impact, creative doctoral research.
- The qualifier is an opportunity for students to demonstrate this capacity and for the faculty to identify any areas that need strengthening.
- The qualifier is distinct from coursework alone, in that appropriate sections focus on the use of fundamental concepts in research, as appropriate for an early graduate student. It is also distinct from the dissertation proposal and defense, as it does not require original research by the student.

The qualifier consists of two components: a written exam which tests core engineering topics and an oral examination that focuses on presentation and discussion, as discussed in the following sections. Please contact your advisor or the Graduate Committee (Prof. Hayden Huang or Prof. Andreas Hielscher in particular) with any questions.

I. Schedule

Jan. 21/22, 2010

Written Examination

Day 1: Jan. 21 1 pm -4 pm  Mathematics - select 4 of the 8 questions
Day 2: Jan. 22 9 am –12 noon  Physiology/biology - select 4 of 6 questions
Day 2: Jan. 22 1pm - 4 pm  Track-specific - select 4 of 18 questions (6 per track)

Feb. 1-12, 2010

Oral Examinations

The results from these sections will be reviewed by the DBME faculty in mid-February, with final decisions on the qualifier reported to the students shortly after that.

II. Eligibility

To be eligible for the Qualifying Examination:
- you must have been admitted to the doctoral (PhD or DES) or M.S. leading to doctoral (MS/PhD or MS/DES) degree program
- you must have completed 30 credits with a cumulative GPA of 3.2 or better.
- you may not delay the qualifying examination beyond the next examination given after you have accumulated 45 credits.
- you must receive permission from your advisor to take the qualifying exam.

III. Preparation

Please consult with your advisor on how to prepare for the written and oral exams, including a discussion on how much preparation time you need and how this review will be balanced against coursework and research. From past history, 2 months is a typical preparation time, but the time you should plan on will vary, depending on your background and how the review time will be conducted.

As part of preparing for this exam, review your previous graduate and late-undergraduate courses in mathematics, physiology, and biomedical engineering. Be comfortable with the main concepts of each course, which is often embodied in the mid-term
and final exams. Also, find links between coursework concepts and your potential area of research; parts of the written and oral exams test this integration, and this preparation is an opportunity to synthesize such knowledge. Additional routes of preparation and resources for the two exams are presented in the following sections. In addition, exams from past years are available to you to download and provide a sense of the format, scope, and breadth of the written exam. Go to the BME website under Resources, login as: bmegrad, pw: bmedqe1.

IV. The Written Examination
The written exam is closed-book, and tests the basic knowledge necessary to excel in research. There are three separate sessions – mathematics, physiology/biology, and track-specific knowledge. Example topics for each area are listed on the next page, and represent the knowledge gained through a strong, core engineering curriculum at the undergraduate and early graduate student levels.

While the questions of the track-specific section are organized into tracks (bioimaging, biomechanics, and cell/tissue), you are not limited to answering questions in one track, and will be given all of the questions. Your responses can address questions in any track, and can come from more than one track. The option to address questions outside your track reflects the increasingly interdisciplinary nature of the research and curriculum, but doesn’t mean that you now have to master all three tracks.

V. The Oral Examination
This exam focuses on your ability to critique contemporary literature and synthesize these multiple, discrete studies as parts of a single, cohesive concept.

• Your research advisor will assign 3-5 journal papers relevant to your anticipated area of thesis research when possible and appropriate.
• Work with your research advisor to form an examination committee of at least 3 BME faculty members. Faculty who do not have a formal appointment in BME should not be asked to serve on these committees.
• Schedule a 1.5-hr period for this exam, in consultation with your committee members. Coordinate with Jarmain on reserving a time and location for this exam. Oral exams will be given priority for scheduling in the BME conference rooms for the period of Feb. 1 – 12, 2010.
• Provide your committee members with the journal papers at least one week in advance of the exam.
• The exam will consist of a 40-minute talk by you on these papers and any additional material (such as background). The general content and organization of the presentation should be agreed upon with your research advisor in advance of the presentation. Committee members may ask questions at any time during your presentation.
• The exam will also include an interactive discussion after your presentation, which can focus on your understanding of the techniques used in the papers, critique of the authors’ conclusions, and presentation of these as different facets of a single research direction. The committee members may also ask questions that are broader-ranging.
• There is no requirement of a written report for the Oral Examination. However, you or your advisor may consider a written report useful for you to organize your presentation.
VI. Topics of Written Examination

**Physiology/Biology:**
- molecular-, cellular-, tissue- and system-level physiology
- mathematical models and quantitative analysis
- control mechanisms

**Mathematics:**
- vector algebra and calculus (vector and dot products; normal components; complex and real vector spaces; field theory; change of basis; line, surface, and volume integrals; directional derivatives/gradients)
- partial differential equations (chain rule; minima and maxima; Lagrange multipliers; geometric interpretation of partial derivatives; tangent planes)
- linear algebra (matrices; determinants; eigenvalue problems; orthogonal matrices and transforms; linear dependence; Cramer’s rule; numerical solutions by iterative methods; transformations in scale, rotation and position)
- Fourier series (orthogonal expansions; Legendre polynomials; convergence theorems)
- statistics (fundamental distributions, t-test, ANOVA and multiple comparisons, probability, descriptive statistics)

*Track-specific (you may answer any combination of 4 questions across all tracks)*

**Biomechanics Track:**
- solid mechanics (tensorial analysis of stress and strain; formulation of the problem of elastic equilibrium and balance laws; conservation of mass, momentum, energy, and entropy inequality)
- fluid mechanics (Eulerian and Lagrangian descriptions of motion; stress and strain rate tensors; vorticity; balance laws; potential flow, Navier-Stokes and inviscid flows)
- biomechanics (musculoskeletal biomechanics; cardiac mechanics)

**Biomedical Imaging Track:**
- digital signal and image processing (discrete representations; sampling theory; signal and image filtering; quantitative measures of image quality; image display)
- image formation and contrast mechanisms, including tomographic reconstruction in X-Ray CT, SPECT, and PET; magnetic resonance imaging and spectroscopy; radiography; ultrasound; optical tomographic imaging; optical microscopy and spectroscopy.
- image analysis, quantification and evaluation (transforms for analysis; Fourier and wavelet representations; segmentation algorithms; metrics & methods for the evaluation of human observer studies, classification methods and algorithms)

**Cellular and Tissue Engineering Track:**
- biomolecular processes (enzymatic reactions; molecular-, cell-, and organ-level transport; thermodynamics; electrochemistry; signal transduction)
- cell function (cell adhesion, migration, apoptosis, proliferation, and differentiation; cell-cell, cell-matrix, and cell-material interaction)
- molecular-, cellular-, and tissue-level design (biocompatibility; biomaterials; bioreactor design; assay design; scaffold design)