UNIVERSITY OF NEVADA, RENO – MECHANICAL ENGINEERING DEPARTMENT QUALIFYING EXAM (QE) POLICY AND PROCEDURES

Version Fall 2021

Abstract

Before a Ph.D. student becomes an official *candidate* for the PhD degree in Mechanical Engineering (ME), the Qualifying Exam (QE) and the Dissertation Proposal (formerly known as "Comprehensive Examination") must be passed.

The purpose of the QE is to improve the technical preparation of our graduate students. The mechanical engineering QE exists to provide assurance that all ME PhD candidates have sufficient knowledge of fundamental principles in selected areas of mechanical engineering and ability to apply such fundamental knowledge to the solution of new and/or unexpected problems. Accordingly, these procedures apply to all PhD students, including those who do not have Bachelor's or Master's degrees in Engineering. The student is expected to demonstrate a firm command of fundamental principles in Applied Mathematics and Mechanical Engineering. The area topics are approved by the ME faculty with recommendations by the Graduate committee.

General Requirements for Ph.D. Graduation

There are three requirements that every Ph.D. student must satisfy (besides required coursework/ dissertation credits) to be awarded the Ph.D. degree in Mechanical Engineering from the Mechanical Engineering Department at UNR: (1) the student must pass the **Qualifying Exam** (QE), which aims at assessing the student's sufficient knowledge of fundamental principles in selected areas of mechanical engineering and his/her ability to apply such fundamental knowledge to the solution of new and/or unexpected problems; (2) the **Proposal Defense** (formerly known as Comprehensive Exam), which typically incorporates a written report and an oral presentation, in front of the student Ph.D. Committee, of the completed and proposed research work towards graduation; and (3) the **Dissertation Defense**, which includes the preparation of the doctoral dissertation and its oral defense in front of the student Ph.D. Committee.

This document is concerned with the definition of the procedures and policies of point (1). The new guidelines on the QE were approved on March 12, 2021 and the new format of the QE is effective beginning Fall 2021 for all PhD students who have joined on or after Spring 2018.

1. Exam Format

1. To be permitted to take the Ph.D. Qualifying Exam, a student must be enrolled in the Ph.D. program in Mechanical Engineering at UNR.
2. The QE will consist of 2 parts: a written part and an oral part. The written part will include 2 exams that are mandatory for all students. The first exam covers topics in Applied Mathematics and the second exam covers topics in General Mechanical Engineering.
3. There is one single oral exam which may cover, in general, Applied Mathematics and General Mechanical Engineering topics from the student's research discipline.
4. The oral and written parts are focused on material from coursework and not from the student's academic research. In other words, the QE oral exam is not a Proposal Defense.

1.1 Written Exam

5. Each student, when applying for the written QE, will be tested in the Applied Math and General Mechanical Engineering areas.
6. The application must be approved by the student's advisor. If the student doesn't have an advisor, the QE committee will approve the application.
7. The QE application form will be made available to the students online.
8. At the discretion of the QE committee, the tests will include both advanced undergraduate and beginning graduate material. Each written exam will follow the format of "N questions choose x". That is, x questions of the exam must be solved in each designated exam.
9. Each exam will have a duration of 3 hours.
10. The General Mechanical Engineering exam is an all-encompassing topic exam that includes questions from the three broad disciplines of ME: Thermal/ Fluid Sciences, Systems/ Dynamics/ Controls, and Solids/ Materials/ Manufacturing. The format for the exams is: 3 questions will be given for each broad topic area, the student must answer 5 of the 9 questions. A passing score is greater than 60%.

1.2 Oral Exam

11. Once the student passes the written part of the QE, s/he will advance to the oral part of the QE that will be scheduled and administered by the QE committee in the same semester.
12. The oral part is typically focused on course work at the advanced undergraduate/ beginning graduate level, in the student's major field of study.

<u>2. Exam Results: Pass/ Fail</u>

13. For each individual exam in the written part, there will be numerical thresholds that define pass/ fail.
14. The oral part is graded on a pass/ fail basis, and the decision requires a majority approval from the QE committee.
15. If the student passes all written exams, the student will advance to the oral exam. If a student receives a "fail" in any exam, s/he will have to re-take that exam.
16. If a student fails any part of the QE, one re-take is allowed (for each written exam and for the oral part). A third re-take (in case of a second failure) may be granted, upon a special approval process involving written appeals from the student, advisor, and Department Chair that must be submitted to the graduate committee for review.
17. If a student fails the QE without possibility of further appeal, the student will be dismissed from the Ph.D. program in Mechanical Engineering at UNR.
18. When the student passes the oral part of the QE, s/he should form the PhD committee. Only after the QE is successfully completed, the student can proceed to the Proposal Defense.
19. The QE committee provides the problems for the written tests and administers the oral exams. The QE committee performs grading of the written part of the QE and recommends pass/ fail results for each individual topic exam in the written part. After the written part is completed, the QE committee communicates the results of the written part to the student and the advisor, and recommends admission of the student to the oral part of the QE. The QE committee decides pass/ fail results for the oral part and communicates the results in writing to the student, and to the Department Chair and to the advisor.
20. Under special circumstances, the QE committee may recommend a "remedial" activity to the student. This remedial activity may include: a project supervised by a specific faculty member, the completion of a specific course, etc. Criteria and timeline for the successful completion of the remedial activity will be defined ahead of time by the QE committee. Successful completion of the

remedial activity as assessed by the QE committee means that the student passes the exam for which the remedial activity has been recommended. If the student fails to successfully complete the remedial activity within the allotted time frame, the student fails the exam for which the remedial activity has been recommended.

3. Schedule and Required Students Actions

21. The QE is typically offered every semester, as long as students have applied.
22. A student must register for the QE within: 2 semesters (if the student has a MS already) or 3 semesters (if the student has only BS – direct PhD) of the admission to their degree program, for their first attempt to pass the QE. The student will then take the exam at the beginning of the semester following the registration.
23. In their first attempt, the student must take all exams in the written part of the exam. In their first attempt, the student must take the oral part if s/he passes the written part.
24. Taking classes in the Graduate Core Curriculum (GCC) is not a prerequisite to apply for the QE.

PhD QUALIFYING EXAMINATION TOPICS

1. Applied Mathematics

- Gradient, divergence, curl, and their properties; Vector line integral and path independence, potential, Jacobian, Green's theorem; Vector surface integral, Divergence theorem and its application: heat equation; Stokes' theorem, basic properties of harmonic function, Green's identity; Eigenvalue and Eigenvector, special real and complex matrices; Matrix diagonalisation, solve homogeneous linear system of ODEs; Solve non-homogeneous linear system of ODEs; Laplace transform and its properties, convolution; Solve non-homogeneous ODE by Laplace transform, solve PDE by Laplace transform; Fourier series, half-range expansion; Fourier integral, Fourier Sine and Cosine transform; Complex Fourier transform, Fast Fourier transform; Model and solve wave equation and D'Alembert's solution; Model and solve heat equation for bar with fixed ends, insulated ends, and for long bar; Laplace equation, Wave equation for rectangular membrane.
- Suggested textbooks:
  Kreyszig, "Advanced Engineering Mathematics"
  Boas, "Mathematical Methods in the Physical Sciences"
  Strang, "Introduction to Applied Mathematics"

2. Dynamics and Vibrations

- Vector Calculus; Kinematics; Mass Properties; Kinetics; Equations of Motion; Modeling: lumped elements; Harmonic motion; Harmonic analysis; Free, single-dof, undamped systems; Free, singledof, damped systems; Harmonic forced vibrations; Transfer function approach; General forcing conditions; Convolution; Response spectrum; Laplace/Fourier transform methods; 2-dof systems; Modal analysis; Vibration isolation and absorbers; Vibration measurements
- Suggested textbooks:
  Mitiguy, "Advanced Dynamics and Motion Simulation"
  Kane and Levinson, "Dynamics: Theory and Applications", McGraw-Hill
  Rao, "Mechanical Vibrations", Pearson/Prentice Hall
  Meirovitch, "Fundamentals of Vibrations", Waveland

3. Systems and Controls

- Laplace Transforms Methods; Transfer Functions; Mechanical Systems (Rotation, Translation, Spring-mass-damper); Electrical Systems; Coupled Systems; Energy Methods for obtaining E.O.M.; Time Response of 1st and 2nd order systems (Steady-state response, parameter estimation, impulse); Analog Computing; Frequency Response Methods (Bode Diagrams); Filters; Rotating Imbalance; Vibration Isolation; Nonlinear Systems; Electrical and Mechanical System Modeling and Transfer Functions; Linearization; State Space Representations; Block Diagrams, Signal Flow

Graphs, and Subsystem Reduction; Stability; Steady State Error; Root Locus; Root Locus Design; Frequency Response; Frequency Response Design

- Suggested textbooks:
  Palm, "System Dynamics", McGraw-Hill
  Nise, "Control Systems Engineering", Wiley
  Dorf and Bishop, "Modern Control Systems", Pearson Prentice Hall

4. Solid Mechanics

- Statics Review; Stress, Strain, and Hooke's Law; Properties of Stress-Strain Curves; Generalized Hooke's Law; Axial Deformations & Factor of Safety; Indeterminate Axial Systems; Gaps & Thermal Effects; Torsion; Indeterminate Torsional Systems; Internal Shear and Moment Functions; Shear & Bending Moment Diagrams; Bending Stress; Bending Stress & Combined Loading; Composite Beams/Eccentric Loads; Computing Shear Stress and Q; Built-Up Beams & Design for Shear; Plane Stress and Transformations; Mohr's Circle; Pressure Vessels; Beam Deflection & Superposition; Bending, singularity functions, and statically indeterminate problems; Buckling Theory and Applications; Unsymmetrical loading of beams; Transverse shear stresses, Shear Center; Composite Beams, Curved beams; Rotating disks, Torsion of thin-walled tubes; Energy methods; Strain energy and strain-energy theorem; Castigliano's Theorem and applications
- Suggested textbooks:
  Philpot, "Mechanics of Materials, an Integrated Learning System", Wiley
  Budynas, "Advanced Strength and Applied Stress Analysis", McGraw-Hill
  Boresi and Sidebottom, "Advanced Mechanics of Materials", Wiley
  Ugural and Fenster, "Advanced Strength and Applied Elasticity", Prentice Hall

5. Mechanical Design

- Safety factor, V-diagram and M-diagram; Principal stress, Mohr's circle; Beam bending & shear & torsion; Combined loads, Stress concentration; Curved beam, Pressure vessel; Buckling; Beam Direct integration, Singularity functions; Strain energy and Castigliano's theorem; Static failure; Rotating element; Fatigue; S-N curve; Endurance limit, Stress concentration; Fatigue failure criterion; Quality function deployment; Product design specification; Functional decomposition; Morphological chart, Decision matrix; Design philosophy; Friction and Wear; Geometric dimensioning & tolerance, fit system, limit system, deviations; Materials, properties and testing; Manufacturing processes; Simple stresses in machine part; thick shell; thin shell; Machine element: Leaf spring; V-belt drive; Shaft and shaft components; Threaded fasteners; Power screws; Flywheels; Helical Springs; Spur gears; Helical gears; Bevel gears; Worm gears; Shoe brakes; Disk brakes; Band brakes; Flat belt drives; Bearings; Sliding contact; Rolling contact; Levers; IC Engine parts; Pipes and pipe joints; Welded joints; Adhesive joints; Riveted joints; Screwed joints; Gaskets and Seals; Columns and struts; Couplings; Chain drives; Rope drives; Timing belt drives; Jigs and fixture; Linkages; Gear train
- Suggested textbooks:
  Budynas and Nisbett, "Shigley's Mechanical engineering design", McGraw-Hill

6. Manufacturing/Tribology

- Introduction to Manufacturing, Heat Treatment, Properties of Materials, Metrology, Fundamentals of Casting, Milling, Lathe, Fabrication of Plastics, Ceramics, and Composites; Cybersecurity in manufacturing; Fundamentals of metal machining, Fundamentals of metal forming, Sheet Metal Working, Bulk Metal Working; Tribology overview; Bio-Tribology; Surface nature: hydrophilic vs hydrophobic; Surface Layers, Surface Characterization; Surface Texturing, Roughness Parameters; Friction, Empirical Laws of Friction, Stick slip, Friction Mechanisms, Sliding and Rolling Friction, Factors Affecting Friction; Experimental Methods in Tribology, Friction of Metals, Polymers, and Ceramics; Contact Mechanics; Wear, Types of Wear; Role of Subsurface Zones, Deformation Modes; Factor Affecting Wear, Wear Debris, Wear of Metals, Polymers, Ceramics; Wear Regime Maps; Correlation between Friction and Wear, Tribology of Composites; Lubrication, Additives, Lubrication Regimes, Stribeck Curve, Film Thickness Calculations; Viscosity, Temperature Characteristics of Lubricants, Tribology of Solid Lubrication, Self-Lubrication; Computational Tribology and BioTribology
- Suggested textbooks:
  DeGarmo, Black, and Kohser, "Materials & Processes in Manufacturing"
  Kalpakjian, Schmid, and Kok, "Manufacturing Processes for Engineering Materials SI"
  Asthana, Kumar, Dahotre, "Materials Processing and Manufacturing Science"

Menezes et al, “Tribology for Scientists and Engineers”, Springer
Rabinowicz, “Friction and Wear of Materials”, Wiley
Bhushan, “Introduction to Tribology”, Wiley
Hutchings, “Tribology, Friction and Wear of Engineering Materials”, CRC Press
Halling, “Principles of Tribology”, Macmillan
Bhushan, “Principles and Applications of Tribology”, Wiley
Suh, “Tribophysics”, Prentice-Hall
Bowden and Tabor, “The Friction and Lubrication of Solids”, Clarendon Press
Stachowiak and Batchelor, “Engineering tribology”, Butterworth Heinemann

7. Thermodynamics

- Review of Units and Introduction; Energy and Energy Transfer; Properties of Pure Substances; Energy Analysis of Closed Systems; Mass and Energy Analysis of Open Systems; Second Law of Thermodynamics; Entropy; Exergy/Simple Cycles; Basic Considerations, Carnot Cycle, Air Standard Cycle, Otto Cycle, Diesel Cycle; Stirling, Ericsson, Brayton Cycles; Brayton Cycle with Regeneration, Intercooling, Reheating; Ideal Jet-Propulsion Cycles; Second Law Analysis; Carnot and Rankine Vapor Cycles; Parameters Affecting Efficiency, Reheat Cycle; Regenerative Rankine Cycle; Second Law Analysis of Vapor Power Cycles; Cogeneration; Combined Gas-Vapor Power Cycles; Refrigerators & Heat Pumps, Reversed Carnot Cycle, Ideal Refrigeration Cycle; Actual Vapor-Compression Refrigeration Cycle;
  Advanced Refrigeration Topics; The Maxwell Relations; The Clapeyron Equation; General Relations for du, dh, ds, Cv, and Cp; The Joule-Thomson Coefficient; Composition of Gas Mixtures, P-v-T Behavior of Gas Mixtures, Properties of gas mixtures, Properties of gas-vapor mixtures; Adiabatic Saturation and Wet-Bulb Temperatures; Psychrometric Chart, Air Cond. Processes; Fuels and Combustion; Theoretical and Actual Combustion Processes; Enthalpy of Formation and Enthalpy of Combustion; First Law Analysis of Reacting Systems; Adiabatic Flame Temperature; Entropy Change of Reacting Systems; Second-Law Analysis of Reacting Systems
- Suggested textbooks:
  Cengel and Boles, “Thermodynamics: An Engineering Approach”, McGraw-Hill

8. Heat Transfer

- Modes of Heat Transfer; Iterative Method for Solving Nonlinear Heat Transfer Equation;
  Derivation of the Heat Diffusion Equation; Application of the Heat Diffusion Equation in Cartesian Coordinate System; Application of the Heat Diffusion Equation in Cylindrical/Spherical Systems; Fin Heat Transfer Equations; Fin Heat Transfer Rate, Fin Performance; Introduction to Transient Heat Transfer; the Lumped-Capacitance Method; Transient Heat Transfer (General Case); Finite Difference Method (Derivations of Steady-state Equations); Derivation of Transient Finite Difference Equations; Programming for Finite Difference Solvers; Introduction to Heat Convection; Internal Flow; Derivation of Internal Flow Equations; Introduction to Thermal Radiation, View Factor; Radiation Exchange between Surfaces; Physics of Thermal Radiation; Kirchoff's Law
- Suggested textbooks:
  Bergman, Lavine, Incropera, and DeWitt, “Introduction to Heat Transfer”,
  Bergman, Lavine, Incropera, and DeWitt, “Fundamentals of Heat and Mass Transfer”,
  Wiley
  Lienhard and Lienhard, “A Heat Transfer Textbook”, web.mit.edu/lienhard/www/ahtt.html

9. Fluid Mechanics

- Review of fluid properties, vectorial notation, multivariable calculus; Kinematics; Conservation laws – Continuity (integral and differential forms); Conservation laws – Navier-Stokes (integral and differential forms); Euler's Equations and Bernoulli; Vorticity and Vortex Flows; Basic potential flow; Superposition of potential flows; Viscous flows: Couette and Poiseuille; Boundary Layers; Compressible flow; Shocks
- Suggested textbooks:
  Kundu and Cohen, “Fluid Mechanics”, Academic Press