Applied Science:

The Department assumes that students entering the program have had an undergraduate concentration in a physical science, mathematics, or engineering discipline. Information about the Department and applications for admission can be obtained from the Chair of Applied Science. It is required that each applicant submits the results of the general test and one subject test from the Graduate Record Examinations. Students from non-English speaking countries must submit TOEFL scores. Applications must be completed by 5:00 p.m. the first Friday of February for entrance into the Department Fall semester. Spring semester applications must be completed by 5:00 p.m. the second Friday in October.

Department Requirements for the Degrees of Master of Arts, Master of Science, and Doctor of Philosophy

The student and his or her advisory committee will plan a coherent degree program that best suits the student's educational goals. Students within the department will take a program of courses designed to meet their individual needs. For most students this will include the department's core sequence – APSC 603, 604, 607, 608, 621, and 622. Due to the different backgrounds, previous preparation, and career goals, not all Applied Science students will take the full core sequence. However, unless otherwise exempted by the department, students will be responsible for the material covered in the entire core. All students are required to take APSC 603 and APSC 604, the full sequence of *Introduction to Scientific Research.*

The Applied Science Faculty must approve thesis programs. A student in the Department must maintain a B average in order to remain in good standing.

MASTER OF ARTS AND MASTER OF SCIENCE

The student must successfully complete the program of courses approved by the Applied Science Faculty. The Master of Arts degree in Applied Science requires 24 semester hours of graduate credit, an examination covering the field of study of the student, and an original research thesis approved by the student's advisory committee and defended in an oral examination. The Master of Science degree in Applied Science differs from the Master of Arts degree in that the thesis requirement is replaced by the successful completion of eight additional hours of graduate coursework.

DOCTOR OF PHILOSOPHY

The candidate must successfully complete the program of courses approved by the Applied Science Faculty. He or she must pass a comprehensive qualifying examination designed to demonstrate competence in his or her field of study. The candidate must carry out a substantial original research project. The dissertation describing this research must be approved by the student's advisory committee and successfully defended in a public oral examination.

Qualifying Exams in the Department of Applied Science

Overall Philosophy

The Applied Science qualifying examination is designed to test three areas: 1) the student's background knowledge in their chosen area of study, 2) if the student has the intellectual capacity to be successful in a Ph.D. program and 3) the student's aptitude for research.

The Academic Progress Committee is responsible for the planning, administration, and grading of the exam. A panel of the full-time, tenure-track members of Applied Science Department (the Department) determines the final outcome. Exceptions from the procedure set forth here must be requested in writing from the Academic Progress Committee. Students are encouraged to discuss exceptions with their advisor and with the Chair of the Academic Progress committee before preparing a written request.

Scope

The overall scope of the exams includes material that is necessary for the student to be successful in their area of research at William and Mary; information that should be common knowledge to someone in the student's general field of study; and fundamental information necessary for a successful career in science in general. **Students are also expected to demonstrate an ability to function in areas not related to their primary interest. While the level of expectation of someone with a field of study well outside the area of examination is significantly reduced compared to students that are specializing in that area, students shall be passably conversant in the overall topics of the field.** A variety of methods can be used to meet this goal including testing of topics during the oral exam, grading questions on a scale appropriate to the student, and/or allowing students to choose questions from a list. The exact method is the sole discretion of the Academic Progress Committee.

Timing of the exam

Qualifying exams are given in August and January. Traditionally, the exams are usually given on consecutive Fridays immediately before the start of the fall and spring semesters. Students are expected to sit for the exams at the end of their fourth semester at W&M (for fall entries this would be the January after the first summer at the College). Exceptions are usually granted for unusual situations such as the need for more background course work and part-time status, although the Academic Progress Committee considers all situations on a case-by-case basis.

Signing up for the exam

Students who want to sit for the exam must submit to the Academic Progress Committee, in writing, a list of the areas they have chosen for the written portion of the exam. The sign-up sheet should also include current contact information (phone, email, address), the name of their advisor, and a list of graduate courses (with date of completion) that the student has taken both at William and Mary and other institutions (instructors should be listed for all William and Mary courses). The sheet should be signed by their advisor and submitted well in advance (at least six weeks) of the traditional exam dates (the first two Fridays before classes start).

Structure
The exam consists of five parts. The first four parts are two-hour written exams on various subjects, see below. Part five is a 20 – 30 minute oral presentation followed by questions from a panel of faculty members. It should be made clear that the content of the exam consists of information that should be known to someone in the field, or is necessary to someone performing research in the area. It is natural that the content of portions of the exam resembles content from courses offered at William and Mary. **There is, however, no explicit connection between the courses and the exams; information covered in the exams may not be covered in the classes and vice-versa.** All exams will be graded using the attached grading sheet. As indicated by the grading levels on the sheet, the exam is judged as an entire effort. Although different parts may be created and graded by different faculty members, the Department as a whole decides the final result based on the overall effort of the student.

- **Parts 1 – 4**

The student, in conjunction with their advisor and with the approval of the Academic Progress Committee, shall chose four of the following areas for the written portions of the exam.

Most Applied Science students are expected to choose Quantitative Applied Science and Materials Science as two of their four choices, unless there are specific reasons why other exams would be more appropriate. Other I and Other II are usually reserved for students with research areas outside the expertise of the core faculty of the Applied Science Department. Use of Other I and Other II by Applied Science students not in an outlying field of study is strongly discouraged and rarely approved by the Academic Progress Committee.

The information given below is illustrative and not all-inclusive. The topics and texts listed are meant to demonstrate the scope of the exam but are not a definitive list. As stated earlier, any information deemed relevant is an acceptable basis for questions.

Quantitative Applied Science
Section one covers general mathematical and computational methods. Here, computation implies both symbolic and numerical. Topics include (but are not limited to) linear algebra, analytic and numerical solutions to ordinary and partial differential equations, simulations, interpolation, special functions, and stability. The examination tests a student's proficiency at a level associated with texts such as:

"Mathematical Methods for Physicists" by Arfkin,
"Mathematics of Classical and Quantum Physics" by Byron and Fuller,
"Matrix Computations" by Golub and Van~Loan,
"Numerical Recipes" by Press Teukolsky, Vetterling, and Flannery
"Scientific Computing" by Heath,
"Introduction to Computer Simulation Methods" by Gould and Tobochnik
"Computer Simulation of Liquids" by Allen and Tildesley

Materials Science
Materials science addresses the relationship between properties and material composition and structure with an emphasis on how properties and processes arise from atomic-level interactions. Topics covered include atomic arrangement in solids, the principles of crystallography, electronic structure of atoms and solids, solid-state thermodynamics, and electrical, optical, mechanical and biological properties of materials. The "Introduction to Materials Science" texts by Askeland or Shackelford are good starting points, but are generally at too simple a level. Supplementary information should be sought from sources such as "Essentials of Crystallography" by McKie & McKie for crystallography, "Thermodynamics in Materials Science" by DeHoff for thermodynamics, and "Introduction to Solid State Physics" by Kittel or "Electrons in Solids" by Bube for electronic behavior of solids.

Polymers
This section covers all the major areas of polymer science including (but not limited to) the molecular-statistical nature of polymers, polymer synthesis, degradation, polymer characterization, polymer properties, molecular structure, dynamics and morphology as well as the interrelation of frequency, time, temperature and molecular weight. There are many reference texts at the proficiency level of the test including Flory's 1953 text, more recent general texts by Billmeyer, Sperling, Allcock-Lampe, Munk and specific topic texts by Ferry, McCrum-Read – Williams and others.

Surface Science/Thin Films
Topics covered include atomic arrangement, crystallography, electronic structure, solid-state thermodynamics, and electrical, optical, mechanical and biological properties of thin films, surfaces and interfaces. This exam also covers vacuum science and technology and surface, interface and microanalysis as well as thin-film and coating deposition methods. The material covered in "Thin Film Deposition" by Smith or :"The Materials Science of Thin Films" by Ohring is a good starting point but questions will usually be more complex than the coverage in these texts so supplemental reading is strongly encouraged. Recommendations on a reading list should be requested from the appropriate faculty member(s) well in advance of the exam.

Plasma Physics
Students interested in applied plasma processing will be expected to answer questions in kinetic theory and collisional dynamics, ionization and formation of plasmas, the interaction of plasma with material boundaries, sheath formation and dynamics, the effect of external fields. More advanced questions, typical of specialists in plasma tool production will demonstrate a deeper understanding of single-particle motions and guiding center formalisms, tensorial fluid formalisms for magnetized plasmas, wave propagation in magnetized plasmas, and advanced heating methods including resonant and non-resonant effects, stochastic heating, surf-riding, and intermediate and high-frequency phenomena. Advanced practitioners, such as those developing novel sources or diagnostics should be

quite familiar with advanced wave treatments and mode-conversion beyond the simple CMA picture, Boltzmann fluid formalisms, MHD instabilities, transport and confinement, collisional and collisionless damping, the BBGKY hierarchy, fast particle stream instabilitites, coupled and decoupled radiative trasnport, and high-pressure microwave conversion. Useful readings: it will be assumed that all students have mastered everything in "Intro.to Plasma Physics", by Frank Chen; more advanced students will master the material in "Principles of Plasma Discharges and Materials Processing", by M. Lieberman and A. Lichtenberg; the most advanced students will master material at the level of "Plasma confinement", by R. Hazeltine and J. Meiss, "Waves in Plasma", by T. Stix, and "Plasma Physics", by N. Krall and A. Trivelpiece.

Non-Destructive Evaluation
Topics covered include acoustic and elastic wave propagation in solids for ultrasonics (Schmerr), heat conduction in solids for thermography (Carslaw & Jaeger), electromagnetic NDE techniques (Blitz), acoustic microscopy (Briggs) and computed tomography (Kak & Slaney). In addition to mastery of the physics and mathematics necessary to model these phenomena, students will be expected to demonstrate the ability to describe appropriate measurement strategies when presented with realistic inspection scenarios.

Materials Characterization
Materials characterization covers the broad range of techniques that are used to characterize solid, liquid and gaseous samples. The fundamental science behind, practical use of, and strengths and weaknesses common characterization techniques may be probed. Emphasis may be placed on techniques that are common to or critical for the student's area of research. Texts such as "The Encyclopedia of Materials Characterization" edited by Brundle are a good introduction to many techniques although a more detailed grasp of the fundamentals of the techniques is expected, especially in the case of students who will rely heavily on a specific technique for their research.

Theoretical Modeling
The topics in this exam are similar to those in the Quantitative Applied Science exam. However, the level of knowledge tested by the exam is greater than that in the Quantitative Applied Science exam. The topics include (but are not limited to) those listed for the Quantitative Applied Science exam along with complex variables, optimization, perturbation theory, group theory, signal/image processing, and discrete systems. The examination tests a student's proficiency at a level associated with advanced methods in texts such as those listed for the Quantitative Applied Science exam.

Other I
The Academic Progress Committee will determine topics covered on a case-by-case basis.

Other II
The Academic Progress Committee will determine topics covered on a case-by-case basis.

- **Part 5 – Oral Presentation**

The last part will consist of a 20 –30 minute oral presentation by the student to a three-member faculty panel followed by up to 20 – 30 minutes of questions. The oral presentation will be given within the two weeks immediately after the conclusion of the written examination, at a time to be arranged between the members of the panel and the student. The panel will consist of three faculty members. At least two panelists must be core members of the Applied Science Department. Normally, the student's advisor will NOT be a member of this panel.

The subject of the presentation should be an outline of the type of research the student hopes to perform, and ideas for investigation. However, the purpose of the presentation is not to test the absolute amount of research done to this point in the student's career. A plan of action for the next year is a much more critical component than previous work. Thus, critical presentations of literature searches without any new results could be very acceptable. Questions from the panel may probe not only the nature and content of the presentation but also relevant general areas of science.