Rochester Institute of Technology
College of Science

Doctor of Philosophy in Color Science

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Color has been a topic of intense interest and inquiry for hundreds if not thousands of years. Philosophers (Aristotle), poets (Goethe), physicists (Newton), and mathematicians (Schrödinger) have all contributed to our understanding about color. As a generalization, color science can be defined as the quantification of our perception of color. Its mastery requires an interdisciplinary educational approach encompassing physics, chemistry, physiology, statistics, computer science and psychology. Color science is used in the design and control of most man-made colored materials including textiles, coatings, and polymers and to specify such diverse materials as soil and wine. It is used extensively in color reproduction including digital photography, desktop and projection display, and printing. As we begin the twenty first century, color science is ubiquitous.

Color science research at RIT encompasses such diverse fields as medical data visualization, computer graphics and animation, art conservation, spectral and spatial measurements of materials, color printing, digital photography, motion picture and television, and modeling of our perceptions for use in defining color quality. RIT has a long history of scholarship in this area through its M.S. degree in Color Science, begun in 1984, M.S. and Ph.D. degrees in Imaging Science, and M.S. degrees in Electrical Engineering, Quality and Applied Statistics, and Printing Management and Sciences.

The program is designed for students whose undergraduate majors are in physics, chemistry, mathematics, computer science, engineering, experimental psychology, imaging, or any applied discipline pertaining to the quantitative description of color, for example, textiles, graphic arts, animation, material science, and polymer science. All students must earn 99 credits as a graduate student. For full-time students, the program requires three or more years of study at the graduate level for students entering the program with a baccalaureate degree. The curriculum is a combination of

required courses in color science, elective courses appropriate for the candidate's background and interests, a three-quarter-research project during the second year of study, and a research dissertation. Students must pass a qualifying examination during their second year of study and a candidacy examination at least one year before completing their dissertation. Candidates who wish to enter the program but lack adequate preparation might have to take as many as 36 credits of undergraduate foundation courses in mathematics, statistics, computer science and general science before matriculating with graduate status.

ADMISSION REQUIREMENTS

The goal of the admissions process is to select students whose previous education, ability, and practical experience indicate a good chance of success. Scientific reasoning, technical writing, and oral communication skills are particularly important.

The specific requirements are as follows:

- Graduate application
- Earned baccalaureate degree
- Graduate record examination (GRE)
- Official undergraduate transcript
- Two professional recommendations
- An on-campus interview when possible
- GPA of 3.0 or higher
- Foundation course work of 3.0 or higher (if required)
- TOEFL score of at least 240 (computer-based) or 587 (paper-based) or 94 (new internet-based) (international students)

Students receiving fully funded assistantships tend to have undergraduate cumulative grade point averages of 3.5 and higher and exceptional GRE scores. Applicants whose native language is not English have TOEFL scores above 250 (computer based) or 600 (paper based) or 100 (new internet based).

Candidates without adequate undergraduate work in related sciences must take foundation courses prior to matriculation into the graduate program. Such students may be required to take as many as 36 credits in these subjects. A written agreement between the candidate and the program coordinator will identify the required foundation courses. Foundation courses must be completed with an overall B average before a student can matriculate into the graduate program. A maximum of nine graduate-level credit hours may be taken prior to matriculation into the graduate program.

The following lists the required undergraduate-level foundation courses.

One year of calculus
One year of college physics
One year of college physics laboratory

One course in computer programming
One course in matrix algebra
One course in statistics
One course in introductory psychology

CREDIT HOUR REQUIREMENT

The degree requires 99 credit hours of coursework and research. A minimum of 60 credit hours of coursework, including the core curriculum, is required. A minimum of 27 credit hours of research, including the second-year research project, is required. Three years of full-time study or their equivalent in part-time study are required.

CORE CURRICULUM

Core courses are completed during the first year of study.

Course #	*Course*	*Credits*
1051-720	Vision	4
1050-702	Applied Colorimetry	4
1050-703	Color Appearance	3
1050-721	Color Measurement Laboratory I	3
1050-722	Color Measurement Laboratory II	3
1050-801	Color Science Seminar	3
1050-813	Color Modeling	4
	Total	24

ELECTIVE COURSES

Elective courses are selected depending on the student's interests and background. All electives must be approved by the Color Science Graduate Coordinator or the student's dissertation research advisor.

Typically, 4 credit hours of electives are taken each quarter in years one through three until 36 quarter-credits hours have been accumulated. The following electives are typical examples:

Course #	*Department*	*Course*
0301-753	Electrical Engineering	Optimization Techniques
0307-834	Quality & Applied Statistics	Multivariate Statistics for Imaging Science
0307-851	Quality & Applied Statistics	Nonparametric Statistics
4005-757	Computer Science	Introduction to Computer Vision
4005-761	Computer Science	Computer Graphics I
4005-769	Computer Science	Topics in Computer Graphics
1008-711	Chemistry	Advanced Instrumental Analysis
1013-736	Chemistry	Spectrometric Identification of Organic Compounds
1051-728	Imaging Science	Design & Fabrication of Solid State Cameras
1051-782	Imaging Science	Introduction to Digital Imaging Processing
1051-784	Imaging Science	Spatial Pattern Recognition
1051-786	Imaging Science	Advanced Digital Image Processing
1051-790	Imaging Science	Image Rendering
1051-816	Imaging Science	Color Systems

SECOND YEAR RESEARCH PROJECT

During the second year, the student will engage in graduate-level research. The topic may or may not be the same as the dissertation topic. Nine credit hours are normally taken. One of the purposes of this research project is to evaluate the student's research capabilities and suitability for doctoral level research.

QUALIFYING EXAMINATION

All students must pass a qualifying examination. Its purpose is to determine whether the student has a sufficient depth of knowledge in color science and the ability to perform research at the doctoral level. The examination is administered by a committee that is appointed by the Color Science Graduate Coordinator.

One component of the examination is a written test (that in some cases could be given orally). The written test is given twice each year, during the first and sixth weeks of Spring Quarter and is ordinarily taken after completing the core curriculum and is based on the core curriculum in Color Science and any material deemed appropriate by the committee. Note that these courses' required readings include textbooks and current literature.

The second component of the examination is an evaluation of the second year research project. Criteria include depth of research, productivity, quality, analytical skills, and the ability to communicate results.

The student must successfully pass the qualifying examination to continue in the Ph.D. program.

Students that do not pass the qualifying examination may request in writing to the Color Science Graduate Coordinator to switch into the M.S. program. Requests must be received before the end of the quarter in which the second written test was taken. Students with permission to enter the M.S. program will use their second year research project as an M.S. research thesis topic. A written thesis is required. They can graduate with an M.S. in Color Science. Note that they will have completed the identical degree requirements as students matriculated into the M.S. program (except having taken additional elective courses).

DISSERTATION RESEARCH ADVISOR

After the student passes the qualifying examination, a dissertation research advisor will be selected based on the student's research interests, faculty research interests, and discussions with the Color Science Graduate Coordinator.

DISSERTATION COMMITTEE

After the student passes the qualifying examination, a Dissertation Committee of four members is appointed for the duration of the student's tenure in the program. The committee will include the dissertation research advisor, one member of the color-science faculty, and an external chair appointed by the Provost. The external chair

must be a member of the RIT faculty who is not a current member of the color- or imaging-science faculty, preferably with tenure. The fourth member may be an RIT faculty member, or affiliated with industry or another institution. The Color Science Graduate Coordinator must approve persons who are not members of the RIT faculty.

The duties of the Dissertation Committee include:

- Preparing and administering the examination for admission to candidacy,
- Assisting in planning and coordinating the research,
- Providing research advice,
- Supervising the writing of the dissertation, and
- Conducting the final examination of the dissertation.

STUDY PLAN

During the first quarter of study, the student and the Color Science Graduate Coordinator will develop a study plan. This plan may be revised as necessary, subject to approval by the Color Science Graduate Coordinator. For example, the dissertation research advisor or the Dissertation Committee may recommend a revised study plan to include specific graduate electives.

ADMISSION TO CANDIDACY

When the student thoroughly understands the dissertation research topic, the Dissertation Committee will administer an examination to determine if the student can be admitted to candidacy for the doctoral degree in Color Science. The purpose of the examination is to ensure the student has the necessary intellectual skills and background knowledge to carry out their specific doctoral-level research project. The dissertation research advisor will define the type of examination and any requirements prior to the examination. Requirements include a dissertation proposal and may additionally include a review of literature, preliminary experiments, and the preparation of an oral presentation. The examination must be administered no later than one year prior to defending the dissertation.

RESIDENCY

All students in the program must spend at least three consecutive quarters (summer quarter may be excluded) as resident full-time students to be eligible to receive the Ph.D. A full-time academic load is defined as a minimum of nine academic credits per quarter or an equivalent amount of research as certified by the Color Science Graduate Coordinator.

TIME LIMITATIONS

All candidates for the Ph.D. must maintain continuous enrollment during the research phase of the program. Such enrollment is not limited by the maximum number of research credits that apply to the degree. Normally, full-time students complete the course of study for the doctorate in approximately four to five years. Requirements for the degree must be completed within seven years of the date students pass the qualifying examination.

FINAL EXAMINATION OF THE DISSERTATION

Once the dissertation has been written, distributed to the Dissertation Committee, and the Committee agrees to administer the final examination, the doctoral candidate can schedule the final examination.

The final examination of the dissertation is open to the public and is primarily a defense of the dissertation research. The examination consists of an oral presentation by the student, followed by questions from the audience. The Dissertation Committee may also elect to privately question the candidate following the presentation. The Dissertation Committee will immediately notify the candidate and the Color Science Graduate Coordinator of the result of the examination.

TEACHING EXPERIENCE

All candidates for the Ph.D. must serve as a teaching assistant for a minimum of one course in color science to be eligible to receive the Ph.D. Candidates are encouraged to serve as a teaching assistant for two courses.

PUBLIC PRESENTATION EXPERIENCE

All candidates for the Ph.D. must present research in a public forum to be eligible to receive the Ph.D. The preferred public forum is a technical conference.

COLOR SCIENCE M.S. GRADUATES

Graduates from RIT's M.S. in Color Science are eligible to participate in the doctoral program in Color Science. It is suggested that graduates contact the Color Science Graduate Coordinator to discuss their suitability for doctoral level research. Before matriculating into the program, students must pass the qualifying examination. The written portion of the examination can be taken remotely using the same testing procedures as distance-learning students. Once the examination has been passed successfully, students can be admitted into the doctoral program. Up to 45 credits can be applied towards the degree including 24 credits of core courses, 12 credits of graduate elective courses, and 9 credits of M.S. level research. The doctoral degree can be completed on a full- or part-time basis as long as the residency requirements are met.

M.S. AND M.A. GRADUATES FROM RELATED DISCIPLINES

Because of the inter-disciplinary nature of color science, it is anticipated that students with M.S. and M.A. graduate degrees will apply to the Ph.D. degree. Graduate courses in related disciplines can be used as elective courses towards the degree. Furthermore, for degrees that required a research thesis, the second year research project may be waived. Thus, it may be possible for students with graduate degrees in a related discipline to take the qualifying examination during their first year of study at RIT. The total number of graduate credits that can be applied to the Ph.D. in Color Science cannot exceed 45 credit hours, limited to 36 credit hours of coursework and 9 credit hours of M.S. level research. The specific courses and credit hours that can be

applied towards the Ph.D. in Color Science are determined by the Color Science Graduate Coordinator.

PROGRAM SCHEDULING

YEAR ONE

FALL		WINTER		SPRING	
COURSE TITLE	**CREDITS**	**COURSE TITLE**	**CREDITS**	**COURSE TITLE**	**CREDITS**
Vision	4	Applied Colorimetry	4	Color Appearance	3
Color Measurement I Lab	3	Color Measurement Lab II	3	Color Modeling	4
Color Seminar	1	Color Seminar	1	Color Seminar	1
Graduate Elective	4	Graduate Elective	4	Graduate Elective	4
Course Credits	12	**Course Credits**	12 **(24)**	**Course Credits**	12 **(36)**
Research Credits	0	**Research Credits**	0	**Research Credits**	0
Total Credits	**12**	**Total Credits**	**24**	**Total Credits**	**36**

YEAR TWO

FALL		WINTER		SPRING	
COURSE TITLE	**CREDITS**	**COURSE TITLE**	**CREDITS**	**COURSE TITLE**	**CREDITS**
Research & Thesis	3	Research & Thesis	3	Research & Thesis	3
Graduate Elective	4	Graduate Elective	4	Graduate Elective	4
Course Credits	4 **(40)**	**Course Credits**	4 **(44)**	**Course Credits**	4 **(48)**
Research Credits	3	**Research Credits**	3 **(6)**	**Research Credits**	3 **(9)**
Total Credits	**43**	**Total Credits**	**50**	**Total Credits**	**57**

YEAR THREE

FALL		WINTER		SPRING	
COURSE TITLE	**CREDITS**	**COURSE TITLE**	**CREDITS**	**COURSE TITLE**	**CREDITS**
Research & Thesis	3	Research & Thesis	3	Research & Thesis	3
Graduate Elective	4	Graduate Elective	4	Graduate Elective	4
Course Credits	4 **(52)**	**Course Credits**	4 **(56)**	**Course Credits**	4 **(60)**
Research Credits	3 **(12)**	**Research Credits**	3 **(15)**	**Research Credits**	3 **(18)**
Total Credits	**64**	**Total Credits**	**71**	**Total Credits**	**78**

YEARS FOUR AND BEYOND

Student will follow their study plan that will consist of Research & Thesis credits and elective courses.