

**UNIVERSITY OF DELAWARE**

**MASTERS OF ENGINEERING IN  
PARTICLE TECHNOLOGY**

**ACADEMIC PROGRAM APPLICATION**

**SEPTEMBER 13, 2013**

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**PART I**

**UNIVERSITY FACULTY SENATE FORM**

# MASTERS OF ENGINEERING DEGREE IN PARTICLE TECHNOLOGY

## Academic Program Approval

This form is a routing document for the approval of new and revised academic programs. Proposing department should complete this form. For more information, call the Faculty Senate Office at 831-2921.

**Submitted by:** Eric M. Furst phone number 831-0102

**Department:** Chemical and Biomolecular Engineering .email address furst@udel.edu

**Action:** Request for new Masters of Engineering in Particle Technology (MEPT)

(Example: add major/minor/concentration, delete major/minor/concentration, revise major/minor/concentration, academic unit name change, request for permanent status, policy change, etc.)

**Effective term** 14F  
(use format 04F, 05W)

**Current degree** N/A  
(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

**Proposed change leads to the degree of:** MEng  
(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

**Proposed name:** Masters of Engineering in Particle Technology (MEPT)

Proposed new name for revised or new major / minor / concentration / academic unit  
(if applicable)

### Revising or Deleting:

**Undergraduate major / Concentration:** \_\_\_\_\_  
(Example: Applied Music – Instrumental degree BMAS)

**Undergraduate minor:** \_\_\_\_\_  
(Example: African Studies, Business Administration, English, Leadership, etc.)

**Graduate Program Policy statement change:** \_\_\_\_\_  
(Must attach your Graduate Program Policy Statement)

**Graduate Program of Study:** \_\_\_\_\_  
(Example: Animal Science: MS Animal Science: PHD Economics: MA Economics: PHD)

**Graduate minor / concentration:** \_\_\_\_\_

**Note: all graduate studies proposals must include an electronic copy of the Graduate Program Policy Document, highlighting the changes made to the original policy document.**

**List new courses required for the new or revised curriculum. How do they support the overall program objectives of the major/minor/concentrations)?**

(Be aware that approval of the curriculum is dependent upon these courses successfully passing through the Course Challenge list. If there are no new courses enter "None")

- CHEG670 – Rate Processes and Kinetics for Particle Systems
- CHEG671 – Particle Transport in Fluids and Powders
- CHEG672 – Mathematics for Particulate Systems
- CHEG673 – Particle Characterization and Measurement
- CHEG674 – Particle-Fluid and Particle-Particle Separation and Classification
- CHEG675 – Particle-Based Product Engineering & Economics

**Explain, when appropriate, how this new/revised curriculum supports the 10 goals of undergraduate education: <http://www.ugs.udel.edu/gened/>**

N/A

**Identify other units affected by the proposed changes:**

(Attach permission from the affected units. If no other unit is affected, enter "None")

None

**Describe the rationale for the proposed program change(s):**

(Explain your reasons for creating, revising, or deleting the curriculum or program.)

The Masters of Engineering program in Particle Technology will train talented science and engineering students in the principles of modern particle technology for careers in a broad range of industries, including chemicals, materials, nanotechnology and pharmaceuticals. Analysis of the employment market indicates a significant demand for training in particle technology, and the lack of competing programs suggests that this demand can be met by the unique opportunities afforded by the proposed UD program. The Masters of Engineering in Particle Technology provides Delaware with the important opportunity to define the core curriculum of particle technology and establish it as an academic discipline in the US, and realization of this opportunity will position UD as an international leader in particle technology. The breadth and rigor of the curriculum, together with the immersive industrial internship, will prepare the masters program graduates to pursue careers in industry, business, government agencies, and non-profit organizations.

**Program Requirements:**

(Show the new or revised curriculum as it should appear in the Course Catalog. If this is a revision, be sure to indicate the changes being made to the current curriculum and **include a side-by-side comparison** of the credit distribution before and after the proposed change.)

(see attached)

**ROUTING AND AUTHORIZATION**

(Please do not remove supporting documentation)

Department Chairperson \_\_\_\_\_

Date

9/23/13

Dean of College \_\_\_\_\_

Date

10/15/2013

Chairperson, College Curriculum Committee *Douglas J. Buttrey* Date 10/15/13

Chairperson, Senate Com. on UG or GR Studies \_\_\_\_\_ Date \_\_\_\_\_

Chairperson, Senate Coordinating Com. \_\_\_\_\_ Date \_\_\_\_\_

Secretary, Faculty Senate \_\_\_\_\_ Date \_\_\_\_\_

Date of Senate Resolution \_\_\_\_\_ Date to be Effective \_\_\_\_\_

Registrar \_\_\_\_\_ Program Code \_\_\_\_\_ Date \_\_\_\_\_

Vice Provost for Academic Affairs & International Programs \_\_\_\_\_ Date \_\_\_\_\_

Provost \_\_\_\_\_ Date \_\_\_\_\_

Board of Trustee Notification \_\_\_\_\_ Date \_\_\_\_\_

Revised 10/23/2007 /khs

# **GRADUATE CATALOG LISTING**

# MASTER'S OF ENGINEERING IN PARTICLE TECHNOLOGY

Telephone: (302) 831-0161

<http://www.che.udel.edu/mept>

Faculty Listing: <http://www.che.udel.edu/mept/faculty>

## A. PROGRAM OVERVIEW

Particle technology is the science and engineering of the production, handling, modification, and use of particulate materials. Particle systems include both wet systems (particles dispersed in a liquid phase, such as colloidal dispersions and slurries) or dry systems (i.e., granular solids and powders), involving particulates with sizes ranging from nanometers to centimeters. Particle technology spans a wide range of industries and disciplines that include chemical, petrochemical, agricultural, consumer products, food, pharmaceuticals, mineral processing, advanced materials, energy, and the environment.

The Master's of Engineering in Particle Technology program is administered through the Department of Chemical and Biomolecular Engineering.

The particle technology master's program prepares its students to work in particle technology product and process design through a comprehensive curriculum followed by a supervised internship in industry. This specialized training covers the analysis and design of particle products and particle technology processes.

## B. REQUIREMENTS FOR ADMISSION

The application deadline for the Master's of Engineering in Particle Technology is the spring semester prior to the semester of intended matriculation. Because students are expected to complete the program in one academic year, only admission to the Fall semester each year will be granted.

Admission to the graduate program is competitive. Those who meet stated requirements are not guaranteed admission, nor are those who fail to meet all of those requirements necessarily precluded from admission if they offer other appropriate strengths.

The following are the admission requirements to the Master's of Engineering in Particle Technology program:

- A bachelor's degree at an accredited four-year college or university with a minimum grade average of 3.0 on a 4.0 system;
- Applicants may have undergraduate degrees from chemical engineering, mechanical engineering, civil engineering, environmental engineering, chemistry, materials science, or physics disciplines.
- The Graduate Record Examination is required of all applicants. The following GRE scores are competitive: Quantitative: 154, Verbal + Quantitative: 310. No GRE subject test is required;
- International applicants must demonstrate a satisfactory level of proficiency in the English language if English is not the first language. The University requires an official TOEFL score of at least 550 on paper-based, 213 on computer-based, or 79 on Internet-based tests. TOEFL scores more than two years old cannot be considered official. Alternatively, IELTS can be accepted in place of the TOEFL. The minimum IELTS score is 6.5 overall with no individual sub-score below 6.0.
  - **Note:** Because excellent communication skills are necessary for success in the industry internship component of this degree, only students who have demonstrated fluency in English, both oral and written, will be considered. In addition to standard language proficiency assessments, such as TOEFL or IELTS, and the submission of a written statement of purpose, applicants may be invited to participate in a telephone interview.



- Three letters of recommendation are required. Letters can be from professors, employers or others who have had a supervisory relationship with the applicant and are able to assess the applicant’s potential for success in graduate studies; and
- Applications must also include a resume outlining work and academic experience, as well as an application statement of purpose consisting of the answers to the following questions:
  1. What educational background and scientific research or employment experience prepare you for this degree program?
  2. What are your long-term professional objectives?
  3. What specific attributes of the particle technology program make you feel that this degree is appropriate to help you achieve your professional objectives?

Upon admission to the program, students are advised by the Director of the Program.

## C. DEGREE REQUIREMENTS

The Master’s of Engineering in Particle Technology has the following curriculum requirements:

- Core particle technology courses (18 credits)
- Elective courses (6 credits)
- Internship (6 credits)

Six core courses (18 credits) are required to be taken as follows: four courses in the first semester and two courses in the second semester. Two elective courses (subject to program advisor approval) are required and typically taken during the second semester. Following the successful fulfillment of the coursework (24 credits), students will complete a design *practicum*, which will be a comprehensive, six-credit supervised project (internship) in industry to be completed on site with an industrial sponsor, typically over the summer. This internship (CHEG 684) is required for the degree and students will be matched with industrial sponsors in projects approved by the Program Director. The internship will be jointly supervised by a faculty advisor and a co-mentor at the host company. The internship will last 10 weeks (40 hr/week), and the evaluation will be based on a required final report and technical presentation.

### Credit Requirements

A. Particle technology core .....	18 credits
B. Electives .....	6 credits
C. Internship .....	6 credits
Total number of required credits: 30	

### Particle technology core

CHEG670 Rate Processes and Kinetics for Particle Systems .....	3
CHEG671 Particle Transport in Fluids and Powders .....	3
CHEG672 Mathematics for Particulate Systems .....	3
CHEG673 Rate Processes and Kinetics for Particle Systems .....	3
CHEG674 Particle-Fluid and Particle-Particle Separation and Classification .....	3
CHEG675 Particle-Based Product Engineering & Economics .....	3
CHEG684 Particle Technology Internship .....	6

### Electives

Elective courses will draw from relevant existing courses in engineering, science, or mathematics, and will be approved by the Program Director.

#### **D. PROGRESS TOWARD THE DEGREE**

Maintenance of steady, reasonable progress towards the degree is the responsibility of the student. A normal course load for a full-time student is 12 credits in the fall semester, 12 credits in the spring semester and 6 credits in the Summer. The expectation is that the student completes the degree in one academic year. A student may request an extension of this time limit by submitting a written request to the Director of the Program. In accordance with the Graduate Student Probation Policy, a cumulative GPA of 3.00 must be maintained in coursework for each semester.

#### **E. FINANCIAL AID**

Students enrolled in the Master's of Engineering in Particle Technology must be able to afford the tuition and living expenses of the program.

# **PROPOSAL**

## I. DESCRIPTION

Particle technology is the science and engineering of the production, handling, modification, and use of particulate materials. Particle systems include both wet systems (particles dispersed in a liquid phase, such as colloidal dispersions and slurries) or dry systems (i.e., granular solids and powders), involving particulates with sizes ranging from nanometers to centimeters. Particle technology spans a wide range of industries and disciplines that include chemical, petrochemical, agricultural, consumer products, food, pharmaceuticals, mineral processing, advanced materials, energy, and the environment.

The objective of the Master's of Engineering in Particle Technology is to train scientists and engineers in the analysis and design of particle products and particle technology processes. While particle technology draws from the curriculum common to the chemical, materials, and mechanical engineering disciplines, including topics such as fluid mechanics, heat and mass transfer, thermodynamics, and engineering mathematics, a significant number of topics are often not introduced at the bachelor's level or offered even in graduate courses. In industry, there is a strong demand for engineers and scientists with particle technology training. This need is not being met.

The particle technology master's program will prepare its students to work in particle technology product and process design through a comprehensive curriculum followed by a supervised, paid or unpaid internship in industry. The program is designed to be completed in 12 months and will consist of two semesters of coursework (12 credits per semester) followed by the internship in industry. The core course curriculum will include:

### Fall semester core

CHEG670 – Rate Processes and Kinetics for Particle Systems (3 credits)

CHEG671 – Particle Transport in Fluids and Powders (3 credits)

CHEG672 – Mathematics for Particulate Systems (3 credits)

CHEG673 – Particle Characterization and Measurement (3 credits)

### Spring semester core

CHEG674 – Particle-Fluid and Particle-Particle Separation and Classification (3 credits)

CHEG675 – Particle-Based Product Engineering & Economics (3 credits)

### Summer internship

CHEG684-060 – Particle Technology Internship (6 credits total)

Course descriptions for the core courses are provided in Appendix A. Two elective courses will be required during the second semester. The courses listed in Appendix B are suitable as electives, but the final selections will be made in consultation with a faculty advisor. Following successful completion of the coursework, students will complete a design *practicum* in the form of the industrial internship: a comprehensive, six-credit supervised project, typically to be completed over the summer terms, on site with an industrial sponsor.

The program will leverage the interactions with industry that Profs. Norman Wagner, Eric Furst, Abraham Lenhoff, and other faculty in the College of Engineering have in the particle technology community, including the International Fine Particles Research Institute. IFPRI is a unique global network of companies and academics with active research programs in particle science and technology. It is a non-profit organization. Its membership represents some of the world's largest

manufacturing industries, including bulk and specialty chemicals, pharmaceuticals, minerals, construction, coatings, detergents and foods. The industry members work alongside some of the finest academic researchers in the world in particle science and technology, and other allied areas. Prof. Furst hosted the IFPRI Annual General Meeting at Delaware in July 2013, which included the Robert Pfeffer Particle Technology Symposium. Two experienced particle technology engineers from industry, R. Bertrum Diemer (DuPont) and James N. Michaels (Merck), have been involved in the development of the proposed program structure and they or similarly qualified individuals will be hired as TNTT to help lead the particle technology master's program at Delaware. A number of experts from local industry are expected to contribute to the teaching mission of the program.

The Masters of Engineering in Particle Technology will provide a unique educational opportunity. Our analysis of existing programs, detailed in section II, shows that the demand for training in particle technology is not being met, and indeed, that there is a paucity of pedagogical materials such as textbooks to facilitate such training. By establishing this Master's of Engineering program, **Delaware has the distinctive opportunity to define what constitutes the core curriculum of particle technology and develop it into a coherent pedagogical subdiscipline of the larger engineering disciplines.**

## II. RATIONALE AND DEMAND

### A. DEMAND AND EMPLOYMENT FACTORS

Most of the materials industries, all of mining, and all of pharmaceuticals are primarily particle technology industries. Petrochemicals also have a significant need for particle technology when one considers catalytic processing. To hire someone with particle technology expertise, the current practice in industry is to hire either PhDs or individuals with previous industrial experience. This program will fill a void between undergraduates with no or little particle technology background (e.g. an elective course) and PhDs. There will be a strong demand locally, nationally, and internationally for students from this program. Our preliminary engagement with industry representatives, including those from **Merck, DuPont, Dow, AbbVie, Procter and Gamble, Abbott, Unilever, Lilly, GlaxoSmithKline, Particle Science, and DSM**, has been highly supportive about hiring from the program and participating in the internship program.

#### A.1. ENROLLMENT PROJECTIONS

We estimate that the program will start with a minimum of ten students in its first year and expand in the following two-to-three years to reach a steady state of between twenty and thirty full-time students. After the program has been established, we anticipate offering online courses and evening courses to enable currently employed students to begin the program part-time. Initially, students will be recruited through the master's program applicant pool in Chemical Engineering, as well as by direct marketing to graduating engineering students at UD and comparable programs across the US and abroad. As Chemical and Biomolecular Engineering typically accepts mainly students applying to the PhD degree program, the large number of master's applicants (typically ~80 applicants per year) constitute a pool of potential applicants for this program. This is a large, accomplished, and untapped applicant pool, especially for strong international students seeking advanced training in the US with access to industry positions. However, because of the distinctive nature of the program and the absence of similar programs at other institutions, we also anticipate significant demand from US students, including those already in the workforce.

## A.2. SURVEY OF EXISTING PROGRAMS

The particle technology master's program will provide students and professionals an in-depth training that includes coursework and a practicum (as an industrial internship) over a one-year period. **This program addresses important and currently unmet needs in engineering education.**

Despite the importance of particle processing and particle technology in industry, degree offerings in the field are limited, especially for post-baccalaureate students and practicing professionals. A number of research programs in particle technology can be found world-wide, but these lack the critical mass and supporting courses necessary to offer a degree program. Our research identified only one *bona fide* master's degree in particle technology, at the University of Western Ontario. Listed below are the current programs and offerings that we found:

- The University of Western Ontario Professional offers a master's degree in particle technology and fluidization ([http://www.eng.uwo.ca/chemical/files/meng\\_ptf.pdf](http://www.eng.uwo.ca/chemical/files/meng_ptf.pdf)). This appears to be focused on fluidized systems, especially reactors and therefore on a particular aspect of process engineering, as distinct from the broadly fundamental offering in process and product engineering that we propose.
- Five master's programs in *pharmaceutical engineering* are listed, at NJIT, Rutgers, Stevens Institute, Michigan and Purdue. These programs focus on training of engineers for the pharmaceutical industry. While particle technology is a major component of these programs, it is presented exclusively in a pharmaceutical processing perspective. These programs also include regulatory and biopharmaceutic topics as part of their core.
  - <http://pharmeng.rutgers.edu/acadMoe.html>
  - [http://chemicaleng.njit.edu/docs/Revised\\_Brochure8-PhEn\\_MS.pdf](http://chemicaleng.njit.edu/docs/Revised_Brochure8-PhEn_MS.pdf)
  - [http://www.purdue.edu/research/pharma/documents/pharm\\_ms\\_eng.pdf](http://www.purdue.edu/research/pharma/documents/pharm_ms_eng.pdf)
  - <http://www.stevens.edu/ses/me/pharmaceutical-manufacturing/masters-degree>
  - <http://isd.engin.umich.edu/degree-programs/pharmaceutical-engineering/biopharmaceutical-manufacturing-science.htm>
- The University of Florida does not offer a coherent particle technology curriculum despite the presence of the Particle Engineering Research Center (<http://perc.ufl.edu>). The University of Minnesota also has a particle technology laboratory in Mechanical Engineering, but no associated curriculum.
- The University of Washington offers a master's program in biopharmaceutical engineering. Similar to the programs above, particle technology is only a fraction of the degree curriculum.
  - <http://depts.washington.edu/bioe/education/prospective/pharbe-bioe-info.html>

There are a number of professional master's degrees in "conventional" engineering disciplines. These might touch particle technology, but they are generally much broader than that. Examples include Rice, Georgia Tech (their programs are on-line), Boston University, Penn, Johns Hopkins, Washington University, Purdue, University of Washington, Lehigh, and CCNY. These programs are designed primarily for people in industry looking to continue or expand their education. These

might touch on particle technology (e.g. as an elective), but none appear to focus on it (i.e., include it as part of their core).

We also assessed the state of particle technology offerings internationally. International schools that have strong particle technology research programs include TU Delft, University of Birmingham, University of Leeds, University of Queensland, U Pretoria and TU Braunschweig. While each of these schools has particle technology courses, none of them offers a coherent degree or concentration in particle technology and none has a particle technology curriculum.

## **B. INSTITUTIONAL FACTORS**

### **B.1. COMPATIBILITY WITH UNIVERSITY ACADEMIC PRIORITIES**

A strong educational program in Particle Technology will contribute to the scholarly and educational missions of the University—to *disseminate scientific, humanistic, and social knowledge for the benefit of the larger society* and to produce graduates who *are prepared to contribute to a global society, addressing the critical needs of the state, nation and global community*.

### **B.2. SIGNIFICANT IMPACT ON OTHER UNIVERSITY PROGRAMS**

The proposed Professional Master's in Particle Technology on University will not compete with any existing program at the University of Delaware but will complement several. We anticipate the following positive impacts:

- It will offer an **internationally visible** education in a discipline essential for modern industry;
- It will **strengthen interactions with local, national, and global industry**;
- It will create and offer new courses at UD that can be used as electives to enhance current graduate and undergraduate degree programs;
- The development of a new curriculum will likely spawn a series of new texts that cover and organize the subject;
- It will grow the number of highly qualified graduate students at UD who will take elective classes and participate in and potentially enhance graduate student life on campus.
- It represents a new source of income for the University.

### **B.3. UTILIZATION OF EXISTING RESOURCES**

With strong chemical, mechanical, and environmental engineering, materials science, and related science programs, and a central position in the heart of the east coast's chemical and manufacturing industries, the University of Delaware provides a rich educational environment and convenient location for this master's program. We anticipate that this will meet demand by students for this training, an alternative form of which has not been available elsewhere.

As the particle technology program matures, we anticipate offering particle technology training that is accessible globally through **online courses** and a complementary **certificate program**. Flexible online course offerings will also allow those who are currently employed in industry to acquire this unique training from the University of Delaware.

#### **B.4. SUPPORT OF THE COLLEGE OF ENGINEERING**

As described in the accompanying letter of support, the College of Engineering is committed to providing the resources for the successful start of this degree program. The College will provide initial support over three years to hire two temporary non-tenure track instructors who will oversee the program and provide its core instruction. The college will also support one-half of a staff position for administrative support, including admissions coordination, program publications, website support, course scheduling, and basic administrative tasks. The college support is subject to review of the educational and program goals for financial self-sufficiency.

#### **C. ACCESS TO GRADUATE AND PROFESSIONAL PROGRAMS**

Graduates of the professional master's in particle technology are expected to join or re-join industry in their discipline with the advanced training they receive. In cases when the program identifies students of exceptional talent, they may be encouraged to apply to the PhD program in Chemical Engineering or related disciplines at Delaware.

### **III. PROGRAM ADMINISTRATION**

#### **A. PROGRAM DIRECTION**

The Master's of Engineering in Particle Technology program will be administered by two TN\*TT faculty to be hired in the Department of Chemical and Biomolecular Engineering. While these faculty will be hired via a normal search process, we have targeted two experienced industrial engineers, Dr. R. Bertrum Diemer and Dr. James N. Michaels. Both Drs. Diemer and Michaels have an expertise of approximately 40 years in particle technology disciplines and strong teaching experience, and have expressed strong interest in helping to initiate and lead the program, including having been involved in developing the proposed structure. Brief biographies are provided below. Briefly, Dr. Diemer (PhD '99) is a graduate alumnus of the Department of Chemical and Biomolecular Engineering and currently serves as an off-campus faculty member with significant undergraduate and graduate teaching experience at UD, including currently serving as the lead instructor of the Chemical Engineering senior capstone design course. Dr. Michaels is a long-time research collaborator of Prof. Wagner and Furst at Merck, a former faculty member in Chemical Engineering at the University of California, Berkeley, and a member of the International Fine Particles Research Institute's governance board. They or similarly qualified candidates will be hired by the Department of Chemical and Biomolecular Engineering as temporary non-tenured track (TN\*TT) faculty upon approval of this program.

The responsibilities of the TN\*TT faculty will be to direct and administer the program under supervision of the Chairperson and other interested tenured faculty. This will include providing its core instruction, admissions (in coordination with the Department of Chemical and Biomolecular Engineering graduate admissions), student advisement, and administration of the internship program. Additional supporting instruction will be provided by instructors recruited from local industry, many of whom already teach or co-teach core and elective courses (e.g. James Tilton (DuPont), Arthur Etchells (DuPont, retired), Richard Grenville (Philadelphia Mixing Solutions)). Several faculty in Chemical and Biomolecular Engineering also offer elective courses of interest to



the students of this program. Administrative support for the program will be provided by the College of Engineering in conjunction with the Department of Chemical and Biomolecular Engineering.

## **B. DEGREE REQUIREMENTS**

The Master's of Engineering in Particle Technology has the following curriculum requirements:

### Fall semester core

CHEG670 – Rate Processes and Kinetics for Particle Systems (3 credits)

CHEG671 – Particle Transport in Fluids and Powders (3 credits)

CHEG672 – Mathematics for Particulate Systems (3 credits)

CHEG673 – Particle Characterization and Measurement (3 credits)

### Spring semester core

CHEG674 – Particle-Fluid and Particle-Particle Separation and Classification (3 credits)

CHEG675 – Particle-Based Product Engineering & Economics (3 credits)

### Summer internship

CHEG684-060 – Particle Technology Internship (6 credits total)

Two elective courses will be required during the second semester; the courses listed in Appendix B are suitable as electives with approval of the program director. Students will also be able to select other courses in consultation with the program director. Following the successful fulfillment of the coursework, students will complete a design *practicum*, which will be a comprehensive, six-credit supervised project in industry to be completed as an internship, typically over the summer terms, on site with an industrial sponsor. The internship will be completed at participating companies and be jointly supervised by the faculty advisor and a co-mentor in the hosting company, as described below.

## **C. INTERNSHIP SCOPE, EVALUATION AND ACCOUNTABILITY**

The internship is an important capstone element of the particle technology education, and serves as a design practicum. The purpose of the internship is to provide students with a real-world engineering or design experience in the application of particle technology principles.

The program director(s) will place students in paid or unpaid internship positions in coordination with a company co-mentor on a project tailored for the student's individualized professional goals and background. The intern will be expected to complete a project determined by the program director to be of sufficient technical scope and complexity to be suitable as a capstone for the degree. Examples of internship projects include the analysis of existing process equipment, the design of new processes, or the characterization of existing processes. The general scope and goals of the internship project and the mentor responsible for overseeing the project at the industry site will be established by the program director and industry representative prior to placement. Placement in the internship will require the student to have maintained a minimum 3.0 GPA in the master's program coursework. Students will work at least the equivalent of 40 hours per week for 10 weeks, typically during the summer term following successful completion of the core classes

(required). It is anticipated that some qualified students may begin the internship during the winter or spring semester concurrent with completing the core classes.

Over the course of the internship, students will be expected to make substantive technical contributions based on the skills developed in their coursework. The student's performance in the internship program will be evaluated by a written report submitted to the internship program director and an oral presentation to be given at the company or university. The audience of the report will generally consist of co-workers at the internship site, and will at minimum include the program director and industrial mentor. The report and oral technical presentation will be graded on a letter grade scale by the program director and the industrial mentor, with the result subject to final approval by the program director.

In addition to the final report, a minimum of two documented progress reports (requiring a personal meeting of the faculty and industrial mentors and the student, if need be by videoconferencing) is required for each student intern while located at the company to provide faculty **mentoring** and ongoing evaluation of the student's progress. The final grade will be based on the progress reports and the final report. Grades will be assigned based on the application of particle technology principles from the coursework and the standards of written and oral professional communication, as well as the technical merit of the finished project with respect to the initial project scope and goals.

Many of the companies we will partner with have established internship programs and often provide comprehensive resources that enable students to find summer housing and deal with other logistics. Because of the scale of these internship programs, there are often planned networking and professional development events accessible to the student that will enhance their professional and career development.

## **D. ADMISSIONS CRITERIA**

The application deadline for the Master's of Engineering in Particle Technology is the spring semester prior to the semester of intended matriculation. Because students are expected to complete the program in one academic year, only admission to the Fall semester each year will be granted.

Admission to the graduate program is competitive. Those who meet stated requirements are not guaranteed admission, nor are those who fail to meet all of those requirements necessarily precluded from admission if they offer other appropriate strengths.

The following are the admission requirements to the Master's of Engineering in Particle Technology program:

- A bachelor's degree at an accredited four-year college or university with a minimum grade average of 3.0 on a 4.0 system;
- Applicants may have undergraduate degrees from chemical engineering, mechanical engineering, civil engineering, environmental engineering, chemistry, materials science, or physics disciplines.
- The Graduate Record Examination is required of all applicants. The following GRE scores are competitive: Quantitative: 154, Verbal + Quantitative: 310. No GRE subject test is required;
- International applicants must demonstrate a satisfactory level of proficiency in the English language if English is not the first language. The University requires an official TOEFL score of at least 550 on paper-based, 213 on computer-based, or 79 on Internet-based tests. TOEFL scores more than two years old cannot be considered official. Alternatively, IELTS can be accepted in place of the TOEFL. The minimum IELTS score is 6.5 overall with no individual sub-score below 6.0.

- **Note:** Because excellent communication skills are necessary for success in the industry internship component of this degree, only students who have demonstrated fluency in English, both oral and written, will be considered. In addition to standard language proficiency assessments, such as TOEFL or IELTS, and the submission of a written statement of purpose, applicants may be invited to participate in a telephone interview.
- Three letters of recommendation are required. Letters can be from professors, employers or others who have had a supervisory relationship with the applicant and are able to assess the applicant's potential for success in graduate studies; and
- Applications must also include a resume outlining work and academic experience, as well as an application statement of purpose consisting of the answers to the following questions:
  4. What educational background and scientific research or employment experience prepare you for this degree program?
  5. What are your long-term professional objectives?
  6. What specific attributes of the particle technology program make you feel that this degree is appropriate to help you achieve your professional objectives?

Upon admission to the program, students are advised by the Director of the Program.

## **E. 4+1 MASTER'S PROGRAM**

The College of Engineering offers a 4+1 master's program that allows students to satisfy the degree requirements for both a Bachelor's degree and Master's of Engineering in Particle Technology degree. The approval of a 4+1 program requires a separate approval by the Undergraduate Senate Committee. After the establishment of the Master's of Engineering in Particle Technology program, we plan to formally establish a 4+1 program. Under this program, University of Delaware students will be able to enroll in up to six credits of approved courses during their first four years that satisfy both the Bachelor's degree and the Master's of Engineering in Particle Technology.

## APPENDIX A - COURSE DESCRIPTIONS

### **CHEG670 – Rate Processes and Kinetics for Particle Systems**

Analysis of physicochemical fundamentals and rate equations for key particle formation, growth and size reduction processes including: physical and chemical nucleation, accretional growth mechanisms, collisional growth, droplet and bubble coalescence, solid-state sintering, dissolution and comminution.

Prerequisites: CHEM444 or equivalent undergraduate level physical chemistry II

### **CHEG671 – Particle Transport in Fluids and Powders**

Analysis of the fundamentals of particle motion and their applications to transport processes involving particles, including granular and powder flows, dense and lean-phase pneumatic conveying, and slurry flows,

Prerequisites: CHEG 341 or equivalent undergraduate fluid mechanics

### **CHEG672 – Mathematics for Particulate Systems**

Analysis of population balance modeling in particulate systems with application to the design of particle-based unit operations. The course will draw on elements of linear analysis, ordinary differential equations and partial differential equations as needed to enable the solution of mathematical models of particulate systems based on the rate kernels presented in CHEG667-010 (Rate Processes and Kinetics for Particle Systems).

Prerequisites: Math305 or equivalent

### **CHEG673 – Particle Characterization and Measurement**

Analysis of particle properties, including single particle, aggregated particle, and particle population descriptors and the various techniques available for sampling, measurement and characterization particle systems. These include methods based on sedimentation, light scattering, particle charging, and microscopy.

Prerequisites: CHEM444 or equivalent undergraduate level physical chemistry II

### **CHEG674 – Particle-Fluid and Particle-Particle Separation and Classification**

Analysis of fundamental principles for separating particles from fluids as well as the various means of particle classification into fractions. Separators in wet systems include filters, centrifuges, hydroclones and particle scrubbers. Separators in dry systems include baghouses, cyclones and electrostatic precipitators. Classifiers include sieves and screens, settlers, and flotation columns.

Prerequisites: CHEG 341 or equivalent undergraduate fluid mechanics

### **CHEG675 – Particle-Based Product Engineering & Economics**

Capstone design course synthesizing the fundamentals of particle science and engineering into the design and production of particle-based products as well as the state-gate process for product engineering and development. This development process includes the phases of product conceptualization, feasibility testing, prototyping, assessment of manufacturing needs and costs, and development of a product introduction plan. The students will also develop a business plan for attracting capital necessary to startup a business based on their product concept.

Prerequisites: Particle Design and Technology Core Classes: CHEG 670, 671, 672, 673; Co-req: CHEG 674.

**CHEG684-010 – Particle Technology Internship**

Fieldwork designed to allow a student to apply acquired knowledge in an industrial setting. Requires a company sponsorship, a performance evaluation to be completed by that sponsor including an oral presentation, and a written paper to be submitted to the administrator of internships.

Prerequisites: Particle Design and Technology Core Classes: CHEG 670, 671, 672, 673, 674, 675.

## APPENDIX B – RELEVANT EXISTING COURSES

### **CHEG600 Introduction to Science and Engineering of Polymer Systems**

Academic year 2013 - 2014

3 credit hours

Provides an understanding of the science and engineering of macromolecules from a structure/property perspective. Topics include polymerization, chain structure and configuration, polymer size and shape, phase separation behavior, amorphous and crystalline state, glass-rubber transition, cross linking/rubber elasticity, viscoelasticity, rheology polymer processing and mechanical behavior.

**College:** Engineering ( EG )

**Department:** Chemical Engineering ( CHEG )

### **CHEG601 Structure and Properties of Polymer Materials**

Academic year 2013 - 2014

3 credit hours

Measurement and control of the microstructure and properties of solid polymers. Structure generation, structure-property models and effects of processing on properties.

**College:** Engineering ( EG )

**Department:** Materials Science & Engineer ( MSEG )

**Prerequisites:** MSEG302

### **CHEG615 Special Topics in Mixing**

Academic year 2013 - 2014

3 credit hours

Introduces basic principles of fluid dynamics, rheology and turbulence that dictate the mixing behavior required to implement a desired process result. Agitation in vessels and pipeline and viscous mixing discussed. Emphasis on recent research on the effects of mixing on chemical reactions.

**College:** Engineering ( EG )

**Department:** Chemical Engineering ( CHEG )

**Prerequisites:** CHEG341

### **CHEG616 Chemistry and Physics of Surfaces and Interfaces**

Academic year 2013 - 2014

3 credit hours

Fundamental and engineering aspects of metal, semiconductor, and oxide surfaces; their structure and defects, characterization, electronic properties, adsorption and reaction kinetics and thermodynamics. Applications to catalysis, microelectronics, and environment sensitive behavior.

**College:** Engineering ( EG )

**Department:** Chemical Engineering ( CHEG )

**Prerequisites:** CHEG332 and CHEM444

### **CHEG617 Colloid Science and Engineering**

Academic year 2013 - 2014

3 credit hours

Surface thermodynamics and intermolecular forces are related to the properties of colloidal dispersions and micellar and surfactant structures. Applications to biological systems, nanotechnology, powder dispersions and supramolecular structures.

**College:** Engineering ( EG )

**Department:** Chemical Engineering ( CHEG )

**Prerequisites:** CHEG325 and CHEM444

### Undergraduate and 500 level Classes

#### **CHEG404 Probability and Statistics for Engineer**

Academic year 2013 - 2014

3 credit hours

Fundamental approach to modeling, characterization and analysis of random phenomena with the objective of providing students with the basic principles, methods and tools for solving engineering problems involving randomly varying phenomena. Application areas explored include experimental design, manufacturing, system reliability, and cellular biology.

**College:** Engineering ( EG )

**Department:** Chemical Engineering ( CHEG )

**Prerequisites:** MATH302, MATH305, or equivalent with permission of instructor.

#### **CHEG595 Intellectual Property for Engineers and Scientists**

Academic year 2013 - 2014

3 credit hours

Methods of protecting intellectual property. Patents, trademarks, copyrights, trade secrets and unfair methods of competition, including analyses of significant court decisions in each area. Directed to innovators in all fields interested in legal protection of their ideas.

**College:** Engineering ( EG )

**Department:** Chemical Engineering ( CHEG )

### **CIVIL AND ENVIRONMENTAL ENGINEERING**

#### **CIEG670 Physics of Cohesive Sediment**

Academic year 2013 - 2014

3 credit hours

Mechanics of fine sediment transport processes in coastal environment; overview of sediment source to sink; bottom boundary layer; mechanics of transport; mixture theory; flocculation; settling and deposition, turbulence-sediment interactions; rheological effects; consolidation and bed erodibility; fluid mud; convective sedimentation; tidal flats.

**College:** Engineering ( EG )

**Department:** Civil & Environmental Engineer ( CIEG )

**Prerequisites:** CIEG 305 Fluid Mechanics; MATH 351 Engineering Math I (or equivalent).  
**COREQ:** CIEG 639 Ocean Fluid Dynamics (or equivalent).

#### **CIEG679 Sediment Transport Mechanics**

Academic year 2013 - 2014

3 credit hours

Mechanics and mathematical modeling of sediment transport in unidirectional and oscillatory flow; sediment properties, initiation of sediment movement, bedload and suspended load transport rates, formation of bed forms and flow resistance, erosion and deposition in the vicinity of structures, and practical applications.

**College:** Engineering ( EG )

**Department:** Civil & Environmental Engineer ( CIEG )

**Prerequisites:** CIEG305

## **MECHANICAL ENGINEERING**

### **MEEG613 Nanomaterials and Nanotechnology**

Academic year 2013 - 2014

3 credit hours

Advanced topics in nanoscience and nanotechnology including nanostructures, nanomaterial synthesis, properties, characterizations, and applications. The emphasis will be to introduce students to the science of the building blocks of nanostructured materials, material behavior when they are assembled, technology for building nanoscale structures and features, nanomaterials for energy conversion and storage, and the technological implications of these nanomaterials and nanotechnologies.

**College:** Engineering ( EG )

**Department:** Mechanical Engineering ( MEEG )

### **MEEG615 Mechanical Properties of Materials**

Academic year 2013 - 2014

3 credit hours

Stress, strain, tensor notation and elementary elasticity. Plasticity and ductility based upon continuum mechanics. Ideal strength of crystalline, polymer and amorphous materials. Real materials: amorphous, polymers, ceramics, metals and composites. Dislocations, strengthening of solids. Mechanisms of fracture, fracture mechanics, fatigue, creep and stress rupture.

**College:** Engineering ( EG )

**Department:** ( MASC )

**About this section:** Requires graduate status.

### **MEEG637 Multiphase Flow and Transport**

Academic year 2013 - 2014

3 credit hours

Principles of multiphase flows with particles, droplets, and bubbles. Local and averaging formulations of interfacial mass, momentum, energy transfers and related transport processes. Applications to industrial and environmental processes.

**College:** Engineering ( EG )

**Department:** Mechanical Engineering ( MEEG )

**Prerequisites:** MEEG630 or permission of instructor.

### **MEEG653 Manufacturing Processes and Systems**

Academic year 2013 - 2014

3 credit hours



Explains key concepts and elements of basic processes (metal cutting, forming, plastic molding), technologies (robotics, ergonomics, material handling, quality management, machine vision), industries/systems (pharmaceutical, automotive, packaging, food, and current advances (lean mfg., just-in-time).

**College:** Engineering ( EG )

**Department:** Mechanical Engineering ( MEEG )

**Prerequisites:** MEEG321 or graduate status.

### **MEEG837 Multiphase Flow and Transport**

Academic year 2013 - 2014

3 credit hours

Principles of multiphase flows with particles, droplets, and bubbles. Local and averaging formulations of interfacial mass, momentum, energy transfers and related transport processes. Applications to industrial and environmental processes.

**College:** Engineering ( EG )

**Department:** Mechanical Engineering ( MEEG )

**Prerequisites:** MEEG630 or permission of instructor.

## **CHEMISTRY**

### **CHEM685 Colloid Chemistry**

Academic year 2013 - 2014

3 credit hours

Introduction to the principles of colloid chemistry and discussion of applications, including surface and interfacial thermodynamics, surface and interfacial tension, capillarity, interfacial adsorption, adsorption isotherms, adhesion, contact angles, surface wetting and dewetting, emulsification, foaming and defoaming, interfacial thermodynamics and electrostatics.

**College:** Arts and Sciences ( AS )

**Department:** Chemistry & Biochemistry ( CHBC )

**Prerequisites:** MATH241. COREQ: MATH242.

### **CHEM810 Kinetics and Surface Chemistry of Soils**

Academic year 2013 - 2014

3 credit hours

Kinetics and mechanisms of soil chemical reactions, including application of chemical kinetics to natural systems, rates of sorption/desorption, redox, precipitation/dissolution, and ion exchange processes and application of surface spectroscopic and microscopic techniques to elucidate reactions at the soil mineral/water interface.

**College:** Agriculture & Nat Resources ( AG )

**Department:** Plant and Soil Sciences ( PLSC )

**Prerequisites:** PLSC608, and either CHEM418 or CHEM443.

## **PHYSICS**

### **PHYS624 Introduction to Condensed Matter Physics**

Academic year 2013 - 2014

3 credit hours

X-ray diffraction, structure and properties of metals, insulators and semiconductors, and band theory of solids; includes electrical, optical, magnetic and thermal properties.

**College:** Arts and Sciences ( AS )

**Department:** Physics and Astronomy ( PHYS )

**About this section:** Some knowledge of statistical physics and thermodynamics is recommended.

### **PHYS824 Introduction to Nanophysics**

Academic year 2013 - 2014

3 credit hours

Introduction to rapidly-evolving ideas in nanophysics. Covers principles involved in fabrication of nanosystems and in measurement of phenomena on the nanoscale. Concepts necessary to appreciate applications in such areas as nano-electronics, nano-magnetism, nano-mechanics and nano-optics, are discussed.

**College:** Arts and Sciences ( AS )

**Department:** Physics and Astronomy ( PHYS )

**APPENDIX C – LETTERS OF SUPPORT**



College of Engineering  
OFFICE OF THE DEAN

University of Delaware  
102 du Pont Hall  
Newark, DE 19716-3101  
Phone: 302-831-2401  
Fax: 302-831-8179

September 25, 2013

Dr. Bramie Lenhoff  
Allan P. Colburn Professor  
Chair, Department of Chemical & Biomolecular Engineering  
Colburn Lab

Dear Bramie,

I am pleased to write in strong support of your proposed new Master's of Engineering degree program in Particle Technology. This is the kind of innovative program that can provide visible leadership for the University and the College in a critical technical and educational field.

In the interests of launching the program and allowing a reasonable period to establish its viability, the College will provide salary and fringe benefit support for two temporary non-tenure track faculty positions and one soft-funded half-time staff position for an initial three-year period. This support will be continued beyond that point pending assessment of the program's performance in both educational accomplishments and recruiting and retention statistics.

I wish you the best of luck in this important initiative.

Sincerely,

A handwritten signature in cursive script that reads 'tunde ogunnaike'.

Babatunde A. Ogunnaike  
William L. Friend Chaired Professor  
and Dean

BAO/cm

cc: C. E. Cook  
S. Wilson



DEPARTMENT OF PHYSICS  
AND ASTRONOMY

University of Delaware  
Newark, Delaware 19716-2570  
Ph: 302/831-2661  
Fax: 302/831-1637

September 26, 2013

Re: Masters program in Particle Technology

Dear Dr. Lenhoff,

Thank you for sharing with me the proposal of a new Masters program in Particle Technology that is being developed by the Department of Chemical and Biomolecular Engineering. The program provides essential coursework in this area of study, including electives from physics, and affords more opportunities for graduate students to specialize in this high growth arena. I am pleased to declare my support of your department's plan for the Particle Technology Masters Program. If you require further information or would like to continue this discussion, please do not hesitate to contact me.

Cordially,

A handwritten signature in cursive script that reads "Edmund R. Nowak".

Dr. Edmund R. Nowak  
Professor and Chair  
Department of Physics and Astronomy



**Suresh G. Advani**  
George W. Laird Professor and Chair  
Of Mechanical Engineering  
Associate Director, Center For  
Composite Materials

University of Delaware  
Newark, Delaware 19716-3119  
Ph: 302/831-8975  
Fax: 302/831-3619

**TO: Abraham M Lenhoff, Chair and Allan P. Colburn Professor of Chemical Engineering**

**FROM: Suresh G. Advani, Chair and George W. Laird Professor of Mechanical Engineering**

**DATE: September 28, 2013**

**RE: Masters of Engineering in Particle Technology**

I enthusiastically support the Masters of Engineering in Particle Technology degree being offered after reviewing the academic program application and the list of course offerings

Sincerely,

A handwritten signature in black ink, appearing to read "S. Advani".

Suresh G. Advani

**Subject:** RE: Master's in Particle Technology  
**From:** "Shenton, Tripp" <shenton@UDel.Edu>  
**Date:** Mon, 30 Sep 2013 17:00:56 +0000  
**To:** "Lenhoff, Abraham M" <lenhoff@UDel.Edu>  
**CC:** "Shenton, Tripp" <shenton@UDel.Edu>

Bramie....

I have read through your proposal for the new Master's in Particle Technology and I have talked to the faculty who teach the CIEG classes you list in the proposal. The Department of Civil and Environmental Engineering is happy to support the proposal and approve of the listing of the two CIEG classes in the proposal as possible electives.

Regards

Tripp

Harry W. "Tripp" Shenton III, Ph.D.  
Professor and Chair  
Department of Civil and Env. Engineering  
301-B Dupont Hall  
University of Delaware  
Newark, Delaware 19716  
(302)831-2447  
(302)831-3640 Fax  
Email: [shenton@udel.edu](mailto:shenton@udel.edu)

-----Original Message-----

**From:** A. M. Lenhoff [<mailto:lenhoff@UDel.Edu>]  
**Sent:** Tuesday, September 24, 2013 4:56 PM  
**To:** Shenton, Tripp  
**Subject:** Master's in Particle Technology

Dear Tripp,

As was mentioned in the recent DCAC meeting, we are proposing a new master's program in particle technology; the proposal is attached herewith. We are planning to provide all the required offerings within CHEG, but have listed some relevant courses that students might consider taking as electives. These include some CIEG courses, but we do not expect the number of additional students in any particular class to be significant. Nevertheless, I am writing to ask if you would be willing to provide a letter that acknowledges this listing and that, I hope, could state your support for the program or at least no opposition. We hope that your students might also benefit from the appreciable new offerings that we are planning as part of the program.

Thanks for your consideration.

Best regards,  
Bramie



DEPARTMENT OF CHEMISTRY  
AND BIOCHEMISTRY  
OFFICE OF THE CHAIRMAN

102 Brown Laboratory  
University of Delaware  
Newark, Delaware 19716-2522  
Ph: 302/831-1247  
Fax: 302/831-6335

September 30, 2013

Professor Abraham Lenhoff  
Chair  
Chemical and Biomolecular Engineering

Dear Bramie,

I have reviewed the materials you sent me regarding the proposed Masters in Particle Technology program. I am writing to offer you my support for this program. It fills an important gap in the field and provides opportunities for our two departments to interact – both by students in the program taking courses in chemistry and biochemistry, and by students in our department taking courses that you propose. I wish you success.

Sincerely,

A handwritten signature in cursive script, reading "Murray V. Johnston".

Murray V. Johnston  
Professor and Chair  
Department of Chemistry and Biochemistry