TO: The Engineering Faculty

FROM: The Faculty of the School of Mechanical Engineering

RE: New Course – ME 53102, Particle, Powder, and Compact Characterization Laboratory

The Faculty of the School of Mechanical Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Course number and Title: ME 53102, Particle, Powder, and Compact Characterization Laboratory
Semester offered: Spring 2021 (offered every odd spring semesters)
Course credits: 1
Attributes: Upper division (senior level status and above)

Course Description: The goal of this laboratory course is to train students on state-of-the-art laboratory equipment used to measure the mechanical properties of particles, granules, powders, and compacts.

History: This course has previously been offered as an ME 597 course titled "Characterization of Particles, Powders, and Compacts" six times since 2010. The student enrollment in the course was as follows:

- Spring 2010: 9
- Fall 2011: 15
- Spring 2013: 12
- Spring 2015: 15
- Spring 2017: 9
- Spring 2019: 17

Details of this course are outlined in the appended material below.

Eckhard Groll, Head
William E. and Florence E. Perry Head of Mechanical Engineering,
and Reilly Professor of Mechanical Engineering

ME 53102
Particle, Powder, and Compact Characterization Laboratory

Course Outcomes [Related ME Program Outcomes in brackets]

1. Follow laboratory safety guidelines. [6]
2. Operate common laboratory equipment and follow standard operating procedures used to measure the mechanical properties of particles, granules, powders, and compacts. [6]
3. As part of a team, plan and perform measurements, analyze results, and summarize the results in a written report. [3,5,6]

Introduction and Fundamentals (0.5 weeks)

1. Material sampling

Particle characterization (1.5 weeks)

1. Particle size, size distribution, and shape
2. Particle density

Powder characterization (2 weeks)

1. Powder bulk density and compressibility
2. Surface area
3. Moisture sorption
4. Powder flow

Compact characterization (1 week)

1. Compact mechanical properties
2. Compact characterization using X-ray microtomography

COURSE NUMBER: Part Powd & Comp Char Lab/ME 53102	**COURSE TITLE:** Particle, Powder, and Compact Characterization Laboratory (1) **SHORT TITLE (max 30 char):** Part Powd & Comp Char Lab
REQUIRED COURSE OR ELECTIVE COURSE: Elective	**PROPOSED EFFECTIVE TERM:** Spring 2021 **TERMS OFFERED:** Spring semester (once in two years)
JUSTIFICATION FOR THE COURSE: Particulate materials are common in industrial practice. For example, approximately one-half of the products and at least three-quarters of the materials in the chemical industry are in granular form. Despite their ubiquity, a recent study found that 80% of solids processing facilities had solids handling difficulties. Furthermore, these facilities typically only reached between 40-50% of their design capacity. Unfortunately, most engineering students in the U.S. have no exposure to particulate materials. This course is the only one at Purdue to provide hands-on laboratory experiments for measuring the physical and mechanical characteristics of particulate materials. This course is foundational since other particle-related courses will build on this knowledge. This course is part of a goal to provide the knowledge, tools, and trained workforce needed to effectively design and manufacture particulate products.	**JUSTIFICATION OF THE NEED FOR THE COURSE:** Purdue, currently has more than 30 faculty with research interests involving particulate materials. The faculty research areas include pharmaceuticals, agricultural materials, energetic materials, chemicals, consumer products, food products, battery materials, and ceramics. This course teaches students how to make laboratory measurements of particle, powder, and compact properties in order to prepare them for careers in particle science and engineering. It is the only course at Purdue that focuses on this foundational topic. Enrollment over the last six offerings has consistently been on the order of 10 to 20 students, with students from a variety of engineering disciplines.
JUSTIFICATION THAT THE COURSE WILL BE TAUGHT AT GRADUATE LEVEL: This course is taught at the graduate level since students would benefit from prior exposure to courses on mechanics of materials and fluid mechanics, which are typically taught at the undergraduate level. The corresponding Particle, Powder, and Compact Characterization course, to be offered at the graduate level, should be taken as a co-requisite or pre-requisite to this laboratory course. In addition, this course will support student and faculty research activities in the field of particle science and engineering.	**JUSTIFICATION FOR ONLINE/DISTANCE DELIVERY:** N/A
TEXTBOOK/REQUIRED MATERIAL: None required	**PRE-REQUISITIES:** ME 53101 (or as co-requisite) **ATTRIBUTES**: Upper Division (senior status) **RESTRICTIONS:** **COURSE REPEATABLE?** Yes
COORDINATING FACULTY: Carl Wassgren, Kingsly Ambrose	
COURSE DESCRIPTION: The goal of this laboratory course is to train students on state-of-the-art laboratory equipment used to measure the mechanical properties of particles, granules, powders, and compacts.	**COURSE OUTCOMES** [Related ME Program Outcomes in brackets]: Students successfully completing the course will be able to: 1. Follow laboratory safety guidelines. [6]

ASSESSMENTS TOOLS:

1. Weekly lab reports
2. Quizzes

PROVIDE ADDT'L INFO ABOUT THE ASSESSMENT METHOD(s) THAT ADDRESS THE LEARNING OUTCOMES LISTED ABOVE (few sentences describing assignment, prj, etc and how they address learning objectives):

Students must pass safety quiz prior to entering the laboratory. The remainder of the course assessments will consist of laboratory reports that include the following sections: objectives, methods, results, discussion, and appendices.

2. Operate common laboratory equipment and follow standard operating procedures used to measure the mechanical properties of particles, granules, powders, and compacts. [6]
3. As part of a team, plan and perform measurements, analyze results, and summarize the results in a written report. [3,5,6]

NATURE OF DESIGN CONTENT: N/A

PROFESSIONAL COMPONENT:

Engineering Topics: Engineering Science – 100%
Engineering Design – 0%

COMPUTER USAGE: Word processing and spreadsheet software will be required to analyze data and prepare laboratory reports.

COURSE STRUCTURE/SCHEDULE:

Laboratory - 2 days per week at 75 minutes per lecture, 5 weeks

RELATED ME PROGRAM OUTCOMES:

1. Engineering fundamentals
2. Engineering design
3. Communication skills
4. Ethical/Prof. responsibilities
5. Teamwork skills
6. Experimental skills
7. Knowledge acquisition

GRADE MODE (Regular; Pass/No Pass; Audit; Satisfactory/Unsatisfactory: Regular, P/NP

FINAL GRADING CRITERIA (%):

Exams & Quizzes:

Papers & Projects:

Homework:

Laboratory Exercises and reports: 95%

Class Preparation:

Other: Safety quizzes: 5%

LIBRARY RESOURCES (describe any library resources that are currently available or the resources needed to support this proposed course. If none needed, explain how the students will complete their research for the course):

Allen, T., *Particle Size Measurement*, Vols. 1 and 2, 5th ed., Chapman and Hall.
Fayed, M.E. and Otten, L., eds., *Handbook of Powder Science and Technology*, Chapman and Hall. (ISBN 0-412-99621-9)
Ganderton, D., Jones, T., and McGinity, J., eds., *Advances in Pharmaceutical Sciences*, Vol. 7, Academic Press. (ISBN 0-12-032307-9)
Hiestand, E.N., *Mechanics and Physical Principles for Powders and compacts*, 2nd ed., SSCI Inc., West Lafayette, IN. (ISBN 978-0-96706-712-4)
Litster, J. and Ennis, B., *The Science and Engineering of Granulation Processes*, Kluwer. (ISBN 1-4020- 1877-0)
Masuda, H., Higashitani, K., and Yoshida, H., eds., *Powder Technology Handbook*, 3rd ed., Taylor and Francis. (ISBN 978-1-57444-782-8)
Rhodes, M., *Introduction to Particle Technology*, 2nd ed., Wiley. (ISBN 978-0-470-01428-8)
Rhodes, M.J., ed., *Principles of Powder Technology*, Wiley. (ISBN 0-471-92422-9)
Rumpf, H., *Particle Technology*, Chapman and Hall. (ISBN 0-412-35230-3)
Svarovsky, L., *Powder Testing Guide Methods of Measuring the Physical Properties of Bulk Powders*, Kluwer. (ISBN 1-85166-137-9)

ADDITIONAL FEES: No

EXPLANATION OF COURSE FEES (Coop, Lab, Rate Request): N/A

ADDITIONAL COURSE INFORMATION:

PREPARED BY: Carl Wassgren

REVISION DATE: 2020 Oct 08

PURDUE UNIVERSITY
ME 53102 (CRN XXXXX)/ABE 5XB (CRN XXXXX)
Laboratory on Characterization of Particles, Powders, and Compacts (1 credit)– Spring 2021

Course Syllabus

Class Meeting Time and Location

TuTh, 10.30 – 11:45 AM, FLEX 3001
Lectures start during week 11 of the semester. Refer to the schedule at the end of this document.

Course Instructor

Dr. Kingsly Ambrose
Office: FLEX 3021D (765-494-6599)
Email: rambrose@purdue.edu
Office hours by appointment

Dr. Carl Wassgren
Office: ME 3003J (765-494-5656)
Email: wassgren@purdue.edu
Office hours by appointment

Course Goals

The goal of this laboratory course is to train students on state-of-the-art laboratory equipment used to measure the mechanical properties of particles, granules, powders, and compacts.

Students successfully completing the course will be able to:
1. follow laboratory safety guidelines,
2. operate common laboratory equipment and follow standard operating procedures used to measure the mechanical properties of particles, granules, powders, and compacts,
3. as part of a team, plan and perform measurements, analyze results, and summarize the results in a written report.

Recommended References

The following books will be helpful for understanding the course material:

Allen, T., *Particle Size Measurement,* Vols. 1 and 2, 5th ed., Chapman and Hall.

Fayed, M.E. and Otten, L., eds., *Handbook of Powder Science and Technology*, Chapman and Hall. (ISBN 0-412-99621-9)

Ganderton, D., Jones, T., and McGinity, J., eds., *Advances in Pharmaceutical Sciences*, Vol. 7, Academic Press. (ISBN 0-12-032307-9)

Hiestand, E.N., *Mechanics and Physical Principles for Powders and compacts*, 2nd ed., SSCI Inc., West Lafayette, IN. (ISBN 978-0-96706-712-4)

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A number of supplemental references such as ASTM, ISO standards, standard operating procedure (SOP) of equipment will be presented to students throughout the course.

Prerequisite

ME 5XA/ABE 5XA (Characterization of Particles, Powders and Compacts).

Computer Usage

The use of spreadsheet and word processing software is required for most assignments.

PURDUE UNIVERSITY
ME 53102 (CRN XXXXX)/ABE 5XB (CRN XXXXX)
Laboratory on Characterization of Particles, Powders, and Compacts (1 credit)– Spring 2021

Course Syllabus

Attendance and Honesty Policies

Students are responsible for all material covered during class, including assignments and quizzes. If the instructor is late, students should wait 15 minutes before leaving. In the event of a major campus emergency, course requirements, deadlines, and grading schemes are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Refer to the *Emergency Preparedness Document* for more information at: https://www.purdue.edu/ehps/emergency_preparedness/. Students can also sign up for emergency text messages at: http://www.purdue.edu/securepurdue/.

Students are encouraged to avoid coming to class if they are ill so that they can recover more quickly and avoid infecting their colleagues. The instructor will work with the student to determine the best approach for getting the student caught up on the course material upon their return. Students must pre-arrange absences for graded assignments and exams, or submit a documented excuse, e.g., a signed note from a doctor indicating that an assignment could not be completed due to illness, if such arrangements cannot be made.

Grading Policy

Final grades will be determined using the following algorithm.

1. All final scores will be adjusted by adding a constant equal to or larger than (at the instructors' discretion) the difference between 100 and the highest score in the class. For example, if the highest score in the class is a 95, then all final scores will be increased by a value greater than or equal to 100 – 95 = 5 such that the new highest score in the class will now be ≥ 100. Continuing this example, if a different student has a score of 80, then that student's new final score will be ≥ 85.
2. The final grades will be determined using the following table, based on the adjusted final score.

$97 \leq$ score $\Rightarrow$ A+	$93 \leq$ score $< 97 \Rightarrow$ A	$90 \leq$ score $< 93 \Rightarrow$ A-
$87 \leq$ score $< 90 \Rightarrow$ B+	$83 \leq$ score $< 87 \Rightarrow$ B	$80 \leq$ score $< 83 \Rightarrow$ B-
$77 \leq$ score $< 80 \Rightarrow$ C+	$73 \leq$ score $< 77 \Rightarrow$ C	$70 \leq$ score $< 73 \Rightarrow$ C-
$67 \leq$ score $< 70 \Rightarrow$ D+	$63 \leq$ score $< 67 \Rightarrow$ D	$60 \leq$ score $< 63 \Rightarrow$ D-
score $< 60 \Rightarrow$ F		

Final scores will be determined as follows:

100% Reports: Five written reports will be collected during the semester; each report is worth 20%. Each special meeting in the laboratory will have a safety and operational quiz before the class and will be worth 10% of each report.

No final exam

1. Information concerning the written reports will be provided in a separate *Written Reports Policies and Procedures* document.
2. All re-grade requests must be submitted within one week of the date the graded document has been made available for return. Re-grades submitted after this deadline will not be considered. Requests must include a written statement detailing the justification for the re-grade. Note that documents are re-graded from scratch and may result in a score lower than the original score.
3. All assignments submitted for grading must be presented in a straightforward and neat manner. An appropriate number of significant digits is required. Answers should be clearly indicated. Your name must be written on each page of the assignment. Multiple page assignments must be stapled together. Points may be deducted for convoluted or sloppy work.

Course Syllabus

Tentative Course Schedule

LEC	Date			Topic
1	Tu	Mar	30	Sampling
2	Th	Apr	01	Particle size, size distribution, and shape
3	Tu		06	Particle size, size distribution, and shape
4	Th		08	Particle density
5	Tu		13	Powder bulk density and compressibility
6	Th		15	Powder surface area using BET; Moisture sorption
7	Tu		20	Powder flow
8	Th		22	Powder flow
9	Tu		27	Compact mechanical properties
10	Th		29	XRCT demonstration