TO: The Engineering Faculty

FROM: The Faculty of the School of Mechanical Engineering

RE: New Course – ME 53101, Particle, Powder, and Compact Characterization

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.

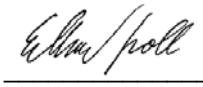
Course number and Title: ME 53101, Particle, Powder, and Compact Characterization
Semester offered: Spring 2021 (offered every odd spring semester)
Course credits: 2
Attributes: Upper division (senior level status and above)

Course Description: The goal of this course is to familiarize students with the properties and methods used to characterize the physical and mechanical behavior of particles, granules, and compacts with the intention of using these properties for process and performance design.

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 53101
Particle, Powder, and Compact Characterization

Course Outcomes [Related ME Program Outcomes in brackets]

1. Define and describe the significant properties of particles, granules, powders, and compacts. [1]
2. Explain how these properties are measured. [1]
3. Illustrate how these properties influence the performance of particle-based products and manufacturing processes. [1]
4. Create a computational or a web-based tool that demonstrates or implements concepts from the course. [1,2,3,5]

Introduction and Fundamentals
(1 week)

1. Importance of characterization
2. Material sampling

Particle characterization
(4 weeks)

1. Particle size characterization
2. Particle size distributions
3. Particle and granule shape, texture, surface area, porosity, and density
4. Particle adhesion

Powder characterization
(2.5 weeks)

1. Powder bulk density and compressibility
2. Powder flow
3. Constitutive laws

Compact characterization (2.5 weeks)

1. Mechanical properties
2. Friction and coefficient of restitution

COURSE NUMBER: Part Powd Comp Charact/ME 53101	**COURSE TITLE: Particle, Powder, and Compact Characterization** (2) **SHORT TITLE (max 30 char):** Part Powd Comp Charact
REQUIRED COURSE OR ELECTIVE COURSE: Elective	**PROPOSED EFFECTIVE TERM:** Spring 2021 **TERMS OFFERED:** Spring semester (once every 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 describe the physical and mechanical characteristics of particulate materials and the methods used to measure these properties. 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 the fundamentals of particle, powder, and compact characterization to students who work in these research areas and other allied subjects and 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. In addition, this course will support student and faculty research activities in the field of particle science and engineering.	**JUSTIFICATION FOR ONLINE/DISTANCE DELIVERY:** We intend to offer the course via online/distance delivery in order to reach students from other universities and employees from industry and national laboratories. This course is unique in the U.S. and has significant industrial importance in the chemical, pharmaceutical, food, agrochemical, and consumer product industries. Thus, we expect significant interest in the course from outside Purdue. In addition, this course is one of the courses in the current CHE Professional MS in Pharmaceutical Engineering and will be included in a Pharmaceutical Engineering online MS program that is currently being developed. Thus, it is important we offer the course via online/distance for the convenience of students in those programs. Expected online offering will be for SP'23, not Sp'21.
TEXTBOOK/REQUIRED MATERIAL: None	**PRE-REQUISITIES:** **ATTRIBUTES**: Upper Division (senior status and above) **RESTRICTIONS:** **COURSE REPEATABLE?** Yes
COORDINATING FACULTY: Carl Wassgren, Kingsly Ambrose	

COURSE DESCRIPTION: The goal of this course is to familiarize students with the properties and methods used to characterize the physical and mechanical behavior of particles, granules, and compacts with the intention of using these properties for process and performance design.

ASSESSMENTS TOOLS:

1. Weekly in-class quizzes
2. Project report
3. Project presentation

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):

Weekly in-class quizzes will be used to assess student performance on objectives 1, 2, and 3 (define, describe, explain, and illustrate properties, measurement techniques, and impact on product and manufacturing performance). The project report and presentation will satisfy learning objective 4, which focuses on applying the course knowledge to develop a characterization tool.

NATURE OF DESIGN CONTENT: The course project involves designing and creating a computational tool used for material characterization. Examples include a tool that converts between particle size distributions, reporting statistics from distributions, and the bulk solid fraction of particle mixtures.

PROFESSIONAL COMPONENT:

Engineering Topics: Engineering Science – 80%
Engineering Design – 20%

COMPUTER USAGE: Word processing, spreadsheet, and some programming will be required for the course project.

COURSE STRUCTURE/SCHEDULE:

Lecture - 2 days per week at 75 minutes per lecture, 10 weeks

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

COURSE OUTCOMES [Related ME Program Outcomes in brackets]:

1. Define and describe the significant properties of particles, granules, powders, and compacts. [1]
2. Explain how these properties are measured. [1]
3. Illustrate how these properties influence the performance of particle-based products and manufacturing processes. [1]
4. Create a computational or a web-based tool that demonstrates or implements concepts from the course. [1,2,3,5]

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

FINAL GRADING CRITERIA (%):

Exams & Quizzes: 80%

Papers & Projects: 20%

Homework:

	Laboratory Exercises: **Class Preparation:** **Other:**
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):**
ADDITIONAL COURSE INFORMATION:	
PREPARED BY: Carl Wassgren	**REVISION DATE: 2020 Oct 08**

PURDUE UNIVERSITY
ME 53101 (CRN XXXXX)/ABE 5XA (CRN XXXXX) –
Characterization of Particles, Powders, and Compacts (2 credits)– Spring 2021

Course Syllabus

Class Meeting Time and Location

TuTh, 10.30 – 11:45 A.M., ME 1051
Meetings during the first 10 weeks of the semester. Refer to the schedule at the end of this document.

Course Instructors

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 course is to familiarize students with the properties and methods used to characterize the physical and mechanical behavior of particles, granules, and compacts with the intention of using these properties for process and performance design.

Students successfully completing the course will be able to:

1. define and describe the significant properties of particles, granules, powders, and compacts,
2. explain how these properties are measured,
3. illustrate how these properties influence the performance of particle-based products and manufacturing processes,
4. create a computational or a web-based tool that demonstrates or implements concepts from the course.

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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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)

A number of supplemental references will be presented to students throughout the course.

Prerequisites

The following courses or equivalents will be helpful, but not necessary, for this course: ME32300 (Mechanics of Materials) and MSE23000 (Structure and Properties of Materials).

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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:

80% Quizzes:	10 short, in-class quizzes covering prior lecture topics; each quiz is worth 8%
20% Team Project:	3-4 course participants will work on a team project from a list of possible projects provided by the instructor OR the team can propose and develop a project with approval from the instructor.
No final exam	

Assignment 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. Re-grade requests must include a statement detailing the justification for the re-grade. Note that the item to be re-graded is re-graded from scratch and may result in a score lower than the original score.

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Notes:

1. The Purdue University Code of Honor is in effect for all students: http://www.purdue.edu/studentregulations/student_conduct/codeofhonor.html
   All academic dishonesty incidents will be reported to the Office of the Dean of Students.
2. Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 and http://www.purdue.edu/caps (during and after hours, on weekends and holidays), or through counselors located in PUSH (business hours).
2. Non-discrimination: Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue's non-discrimination policy can be found at http://www.purdue.edu/purdue/ea_eou_statement.html

Tentative Course Schedule

LEC	Date			Topic
01	Tu	Jan	12	Introduction
02	Th		14	Sampling
03	Tu		19	Particle size
04	Th		21	Particle size
05	Tu		26	Particle size distributions
06	Th		28	Particle size distributions
07	Tu	Feb	02	Particle and granule shape and texture
08	Th		04	Particle and granule surface area and porosity
09	Tu		09	Particle and granule density
10	Th		11	Particle adhesion
11	Tu	Feb	16	Powder bulk density and compressibility
12	Th		18	Powder flow
13	Tu		23	Powder flow
14	Th		25	Powder flow
15	Tu	Mar	02	Compact mechanical properties
16	Th		04	Compact mechanical properties
17	Tu		09	Friction, Coefficient of restitution
18	Th		11	Powder constitutive laws
			16	Holiday (No classes)
			18	Holiday (No classes)
19	Tu		23	Powder constitutive laws
20	Th		25	Team project presentations

Example Team Projects

1. Develop a tool to convert between different particle size distributions.
2. Develop a tool for calculating a flowability index (Carr's index).
3. Develop a tool to calculating a hopper half-angle to ensure mass flow.
4. Develop a tool to calculate Mohr's circle parameters from normal and shear stress values.
5. Develop a tool to calculate particle size, shape, volume, and surface area from 3D CAD files.
6. Develop a tool for calculating different statistical measures from a distribution.
7. Develop a tool for predicting solid fraction or void fraction for multi-component mixtures using literature data.
8. Develop a tool to calculate the mass fraction of fines that would give a certain coating coverage on coarse particles.
9. Develop a tool to calculate the size of a conical pile given the angle of repose and mass data.
10. Develop a tool to calculate the mass flow rate from a bin or hopper using different models.