TO: The Faculty of the College of Engineering

FROM: The School of Aeronautics and Astronautics

RE: New Graduate Course AAE 56100 Introduction to Convex Optimization

The faculty of the School of Aeronautics and Astronautics have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Course No: **AAE 56100 Introduction to Convex Optimization**
Sem. 1, Cr 3; Lecture 3
Graduate standing or permission of instructor
.

Description: Introduction to convex analysis, convex optimization problems, algorithms of convex optimization and measures of their complexity, and application of convex optimization in aerospace engineering. Recognition of convex optimization problems that arise in scientific and engineering applications. Introduction to software tools to solve convex optimization problems.

Reason: Convex optimization is a subset of optimization that studies problems involving convex sets and convex functions. It has a wide range of applications in many disciplines, such as control systems, optimal design, data analysis and modeling. The property of convexity can make the optimization more tractable than general optimization problems. This course reflects the advantages, new developments, and major challenges in convex optimization. The application examples used in this course are focused on aerospace engineering but the tools and techniques presented are applicable to other engineering fields. This course has been offered four times under the temporary number AAE59000 in Fall 2011, Spring 2013, Spring 2014, and Fall 2015, with enrollment accounts of 32, 17, 13, and 24, respectively. Less than 10% of the enrollment are undergraduate students in Aeronautics and Astronautics, while the majority are graduate students in Aeronautics and Astronautics, Electrical and Computer Engineering, Industrial Engineering, Civil and Environmental Engineering, Mechanical Engineering, Computer Science, Statistics, and Krannert School of Management.

Tom I-P. Shih, Professor and Head
School of Aeronautics and Astronautics

Approved for the faculty of the Schools of Engineering by the Engineering Curriculum Committee

ECC Minutes #5 Date 11-1-16
Chairman ECC [signature]

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE (50000-60000 LEVEL)

PRINT

DEPARTMENT: School of Aeronautics and Astronautics
EFFECTIVE SESSION: Fall 2017

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [x] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
- [ ] 3. Expiration of a course
- [ ] 4. Change in course number
- [ ] 5. Change in course title
- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

PROPOSED:
Subject Abbreviation: AAE
Course Number: 56100
Long Title: Introduction to Convex Optimization
Short Title: Intro. Convex Opt.
Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

EXISTING:
Subject Abbreviation: AAE
Course Number: 59000

TERMS OFFERED
Check All That Apply:
- [x] Fall
- [ ] Spring
- [ ] Summer

CAMPUS(ES) INVOLVED
- [ ] Calumet
- [ ] Cont Ed
- [ ] Ft. Wayne
- [ ] Indianapolis
- [ ] N. Central
- [ ] Tech Statewide
- [x] W. Lafayette

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range:
   Minimum Cr. Hrs
   (Check One) To [ ] Or [ ]
   Maximum Cr. Hrs
3. Equivalent Credit: Yes [ ] No [x]
4. Thesis Credit: Yes [ ] No [x]

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ]
   Maximum Repeatable Credit: [ ]
4. Credit by Examination [ ]
5. Fees [ ] Coop [ ] Lab [ ] Rate Request [ ]
   Include comment to explain fee
6. Registration Approval Type
   Department [ ] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	150	2	15	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

See attached course description

*COURSE LEARNING OUTCOMES:

On completing this course, the student shall be able to: 1) Understand basics of convex analysis and convex optimization problems. 2) Understand and develop basic algorithms of convex optimization and their complexities. 3) Apply convex optimization to solve engineering problems.

Calumet Department Head — Date	Calumet School Dean — Date	Calumet Director of Graduate Studies — Date
Fort Wayne Department Head — Date	Fort Wayne School Dean — Date	Fort Wayne Director of Graduate Studies — Date
Indianapolis Department Head — Date	Indianapolis School Dean — Date	IUPUI Associate Dean for Graduate Education — Date
North Central Department Head — Date	North Central School Dean — Date	North Central Director of Graduate Studies — Date
[signature] West Lafayette Department Head — Date	[signature] 3/9/16 West Lafayette College/School Dean — Date	Date Approved by Graduate Council — Date
Graduate Area Committee Convener — Date	Graduate Dean — Date	Graduate Council Secretary — Date
		West Lafayette Registrar — Date

OFFICE OF THE REGISTRAR
(Grad Form 40G [Excel format] - Does not include the Graduate Council's required supporting document. See pdf version of Form 40G)

Course Description:

Introduction to convex analysis, convex optimization problems, algorithms of convex optimization and measures of their complexity, and application of convex optimization in aerospace engineering. Recognition of convex optimization problems that arise in scientific and engineering applications. Introduction to software tools to solve convex optimization problems.

IE 330: Probability and Statistics in Engineering II

Course notes to accompany:

Montgomery and Runger's Applied Statistics and Probability for Engineers, 6^{th} edition

Roshi Nateghi, Ph.D.
Assitant Professor
Purdue Univerity
Office: GRIS 264
E-mail:rnateghi@purdue.edu

Fall 2016

- Please save your conversations for outside of class. This is a large class; even if you whisper, it is disruptive to me and distracting to other students.
- Turn off phones (and anything else that makes noise) before coming into class.
- You should have received an invitation from Piazza. Please post all your questions and comments there instead of emailing me or the TAs. We will respond through Piazza so everyone can see the questions/answers.
- Please read the syllabus very carefully; I will answer any questions you may have about it on Piazza.
- This class is important, there is a lot of work, and it can be difficult. DO NOT FALL BEHIND.
- The course grading is 100% objective and NOT scaled. Carefully read and understand the grading structure, including how to challenge a grade.
- I do not take attendance, but there is something due almost every period, so plan on being here. There are free drops for everything; this is in place of makeups. There are no makeups for anything except for the final. There are also opportunities to ear extra credits
- I have no tolerance for cheating. Cheat and you will be reported to the Dean of Students and fail the course.
- I encourage you to work with others on your homework/lecture assignments, but each person must submit their own work. Simply copying another person's homework or lecture assignment is not allowed, and will be considered cheating. Similarly, cutting and pasting solutions from the book or websites will also not be accepted.
- Copying, looking around during a test/quiz, plagiarizing, using cellphones or calculators are among the things considered unethical and will result in you receiving an F for ethics and being reported to the Dean of Students. Do not do it.
- If you do very well, you will be able to skip the final.

0.1.2 Accommodations

All students seeking accommodations should coordinate their accommodations in this class through the DRC. Any students requiring accommodations should notify me as soon as possible. Two weeks advance notice is required for accommodations on tests/exams so that I have time to make appropriate arrangements.

0.1.3 Emergency Preparedness

Please visit the emergency preparedness website:
`http://www.purdue.edu/ehps/emergencypreparedness/`
Also, please see the additional information on emergency preparedness posted on Black Board.

0.1.4 Tentative Course Calender

The course calender on Blackboard contains all the details for this course. Please refer to the calender to find out about homework due dates, dates of tests, lab sessions etc.
Class: MWF, 1:30-2:20 in Hampton Hall 1144

0.2 SYLLABUS

This course covers chapters 8 through 15 of Montgomery & Runger, 6^{th} Edition.

0.2.1 Basic Course Information

Instructor:

Prof. Roshi Nateghi
rnateghi@purdue.edu

Instructor Office Hours: Wednesday 7:10-8:10 PM in BRWN 1154 except for 09/07 and 12/07 where the office hours will be in ME 1061.
There will be no office hours on Aug 24th (first week), Oct 5th (test week) and Nov 30th (test week).

Teaching Assistants:

Name: Esmaeil Bahalkeh
Email: ebahalke@purdue.edu

TA Office Hours:
Monday 9:00-10:29 AM in GRIS 157D
Wednesday 9:00-10:29 AM in GRIS 157E

Name: Bikram Kishore Mahajan
Email: bmahaja@purdue.edu

TA Office Hours:
Monday 12:15-1:00 PM in GRIS 157E
Friday 9:00-9.45 AM 157C

0.2.2 Learning Outcomes

Upon the completion of this course students should be able to

1. Use statistical software packages (e.g. R or Minitab) to perform statistical tests;
2. Compute and interpret statistical confidence, tolerance, and prediction intervals given engineering and scientific data;
3. Conduct and interpret parametric statistical tests (e.g. t-test, ANOVA) on engineering and scientific data;
4. Conduct and interpret non-parametric statistical tests on engineering and scientific data;
5. Conduct and interpret regression analysis on engineering and scientific data;
6. Determine the appropriate statistical test or procedure to use on engineering and scientific data;
7. Design basic factorial experiments; and conduct basic statistical process control analysis.

0.2.3 Assignments

- There will be nine homework, eight quizzes, and many lecture assignments and in-class exercises during the semester. Homework is usually due by 6 pm on Saturdays with the exception of one (Homework 8). The lecture assignments (LA) will typically be assigned the night before the lab sessions and will be due in class. Lecture assignments should be submitted at the beginning of the class (late submissions won't be accepted). Lecture assignments and in-class exercises will count towards your class participation.
- There will be three 50-minute in-class tests, and a two-hour final. Make sure you always have your full name (that matches with your name on Blackboard). We have a no name; no grade policy.
- Tests are always <u>closed book</u>, <u>closed notes</u>, and <u>NO calculators</u>.

0.2.4 Grading

- 25% graded homework problems (9 sets of homework problems, the lowest dropped)
- 10% quizzes (1 per chapter, the lowest dropped)
- 5% class participation (in-class exercises, can miss 20% of them)
- 15% test 1 (Oct 5^{th}, in class, 50 minutes)
- 15% test 2 (Oct 31^{th}, in class, 50 minutes)
- 15% test 3 (Nov 30^{th}, in class, 50 minutes)
- 15% test 4 (TBA, 1 hour, *NOT* optional)
- 15% makeup/cumulative (final, 1 hour, optional), replaces lowest of test 1,2 of 3
- There are no makeup tests. When computing your final grade, I will drop the lowest of the following four tests: the three in-class tests and the cumulative part of the final. (The first part of the final cannot be dropped.)
- **There is also a grade for ethics. This is Pass-Fail. Not cheating and not being involved in any other unethical behavior according to the student honor code will be considered Pass. (Otherwise, it is a failure). Failing ethics will result in you getting an F for the course.**
- If you need less than a 75 on the final to get an A, without dropping your lowest test score, then you will be excused from (both parts of) the final and will get an A+ for the course.
- The following procedure will be used at the end of the semester for grading:
  I will start by setting thresholds (e.g., ≥ 90 is an A, ≥ 80.0 is a B, etc.), and assign a non-modified A, B, C, D, or F to each person.
  If you are within one point of getting an A, etc. (e.g., high B+), and you have not missed more than one homework and one quiz, you will be bumped to the next highest grade with a minus modifier (e.g., an A-). So the only way to get an A-, for example, is to get bumped up to it from below the threshold for an A, but only if you meet all the conditions indicated above.

- End of semester "negotiations":
  You can only question your grade regarding accuracy. Accuracy problems include such things as missing grades and incorrect grades, but not: "but I really tried hard and turned everything in." I will not give you extra work, I will not bump you up if you are 0.1 below a threshold, and I will not change the threshold. If you donť want to "just miss" an A, donť be close to the threshold. The time to worry about your grade is during the semester, not at the end of it.

- Homework should be uploaded on Blackboard on the date noted; do not wait until the last minute to do or turn in the homework. NO questions about the homework will be answered on the day it is due. The lowest homework will be dropped.

- Homework turned in by noon the next day is late and will have 15 points deducted. No homework will be accepted later than noon of the day after the homework is due.

- If you feel a mistake was made in grading your assignment:

  Within 1 week of its return, email a written explanation of what you think was wrong and why.

  No in-person discussions about grading are permitted.
  The TAs (or I) will re-grade the entire assignment, so your grade could go up or down. Change requests are submitted to the TAs that graded the work, unless I graded the assignment (tests). If you donť like the TAs´ answer, come to me.

Supporting Document to the Form 40G
for a New Graduate Course

To: Purdue University Graduate Council

From: Faculty Member: Dengfeng Sun

Department: School of Aeronautics and Astronautics

Campus: West Lafayette

Date: March 08, 2016

Subject: Proposal for New Graduate Course

Contact for information if questions arise:

Name: Dengfeng Sun
Phone: (510) 409-7869
Email: dsun@purdue.edu
Address: 701 W. Stadium Ave., West Lafayette, IN

Course Subject Abbreviation and Number: AAE56100

Course Title: Introduction to Convex Optimization

Course Description:

Introduction to convex analysis, convex optimization problems, algorithms of convex optimization and measures of their complexity, and application of convex optimization in aerospace engineering. Recognition of convex optimization problems that arise in scientific and engineering applications. Introduction to software tools to solve convex optimization problems.

Semesters Offered:

Every Fall semester.

A. Justification for the Course:

Convex optimization is a subset of optimization that studies problems involving convex sets and convex functions. It has a wide range of applications in many disciplines, such as control systems, optimal design, data analysis and modeling. The property of convexity can make the optimization more tractable than general optimization problems. This course reflects the advantages, new developments, and major challenges in convex optimization. The application examples used in this course are focused on aerospace engineering but the tools and techniques presented are applicable to other engineering fields. This course has been offered four times under the temporary number AAE59000 in Fall 2011, Spring 2013, Spring 2014, and Fall 2015, with enrollment accounts of 32, 17, 13, and 24, respectively. Less than 10% of the enrollment are undergraduate students in Aeronautics and Astronautics, while the majority are graduate students in Aeronautics and Astronautics, Electrical and Computer Engineering, Industrial Engineering, Civil and Environmental Engineering, Mechanical Engineering, Computer Science, Statistics, and Krannert School of Management.

- Anticipated enrollment
  - Undergraduate 2
  - Graduate 18

B. Learning Outcomes and Method of Evaluation or Assessment:

Course Objectives: On completing this course, the student shall be able to: 1) understand the basics of convex analysis and convex optimization problems, 2) understand and develop algorithms for convex optimization and measures of their complexity, 3) apply convex optimization to solve engineering problems.

Student Learning Outcomes:

Student learning outcomes (knowledge, skills, communication, critical thinking, and ethical research) that address the three (3) objectives above, are listed in the following table:

- Objective 1: Understand the basics of convex analysis and convex optimization problems.
  - **Knowledge:** Fundamental knowledge in properties of convex sets, convex functions, and convex optimization problems.
  - **Skills:** Convexity analysis of sets and functions. Recognize and formulate convex optimization problems.

- Objective 2: Understand and develop algorithms for convex optimization and measures of their complexity.
  - **Knowledge:** Basic algorithms (first order, second order methods) of convex optimization. Fundamental knowledge on measures of the complexity of algorithms.
  - **Skills:** Derive and implement first and second order algorithms and perform complexity analysis.

- **Critical thinking:** Identify the assumptions (such as continuity) made in mathematical models and understand the possible limitations in applying numerical algorithms for convex problems.

- Objective 3: Apply convex optimization to solve engineering problems.
  - **Knowledge:** Mathematical modeling of engineering problems using convex optimization, and solution methods using convex optimization algorithms.
  - **Skills:** Implement convex optimization models and algorithms using software tools.
  - **Communication:** Write a technical report in the style, format and standard of a peer-reviewed journal article.
  - **Critical thinking:** Evaluate published results. Comparison of results from different mathematical models and algorithms.
  - **Ethical research:** Properly cite references in technical reports.

- Grading Criteria

Grading Criteria (replace with check for all that apply)	**Weight Toward Final Grade**
Papers and Projects	40%
Homework	60%

- Methods of Instruction

Hours per Week	**Method of Instruction** (replace with check for all that apply)	**Contribution to Outcomes**
3	Lecture	Lectures will be used to contribute to all the outcomes.

C. Prerequisite(s):

Graduate standing or permission of instructor.

D. Course Instructor(s):

Name	Rank	Dept.	Graduate Faculty or expected date
Dengfeng Sun	Associate Professor	AAE	Yes

E. Course Outline:

1) General optimization (2 weeks)
2) Convex sets and convex functions (2 weeks)
3) Smooth convex optimization (3 weeks)
4) Nonsmooth convex optimization (2 weeks)
5) Convex optimization examples (2 weeks)
6) Self-concordant functions and self-concordant barriers (2 weeks)
7) Application of convex optimization (2 weeks)

F. Reading List (including course text):

Convex Optimization, by Stephen Boyd and LievenVandenberghe, Cambridge University Press, 2004.

G. Library Resources

Not necessary.

H. Course Syllabus

AAE 59000: Introduction to Convex Optimization
Fall 2015

1. Instructor Information
   - Dr. Dengfeng Sun, Associate Professor of AAE
   - Office: ARMS 3217
   - Phone: x4-5718
   - Email: dsun@purdue.edu
   - Office hours: Wednesday 2:30-3:30PM in ARMS 3217

2. Course Information
   - Description
     This course aims to introduce students basics of convex analysis and convex optimization problems, basic algorithms of convex optimization and their complexities, and applications of convex optimization in aerospace engineering. This course also trains students to recognize convex optimization problems that arise in scientific and engineering applications, and introduces software tools to solve convex optimization problems.
   - Prerequisites
     Graduate standing or permission of the instructor.

- Textbook
  Convex Optimization, by Stephen Boyd and LievenVandenberghe, Cambridge University Press, free downloadable from Prof. Stephen Boyd's webpage at Stanford University.

3. Course Objectives
   On completing this course, the student shall be able to: 1) Understand basics of convex analysis and convex optimization problems. 2) Understand and develop basic algorithms of convex optimization and their complexities. 3) Apply convex optimization to solve engineering problems.

4. Course Policies
   - Attendance
     The instructor will not take attendance, however, you are highly encouraged to attend every class. Projects and homeworks may require knowledge of ANY material presented in class. If you must miss a class, you are responsible for all covered lecture material, assignments and announcements made.
   - Grading criteria: Homework 60%, course project 40%.

5. Class Schedule
   1) General optimization (2 weeks)
   2) Convex sets and convex functions (2 weeks)
   3) Smooth convex optimization (3 weeks)
   4) Nonsmooth convex optimization (2 weeks)
   5) Convex optimization examples (2 weeks)
   6) Self-concordant functions and self-concordant barriers (2 weeks)
   7) Application of convex optimization (2 weeks)

6. Other Information
   - If you have a disability which requires some special accommodation, please let me know within the first two weeks of the semester to discuss the appropriateness of the instructor's methods in this class or any other accommodation you may need.
   - In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. If such unusual circumstances arise, we will notify you via email. A special note about highly-contagious disease – We do not want ill students in class spreading the virus. If you are diagnosed with any highly contagious disease, contact Professor Sun via email (dsun@purdue.edu) to make arrangements.