Math 5490 Network Flows Syllabus

University of Colorado Denver

Spring 2010

General Course Information

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Alexander Engau</th>
<th>Class Times</th>
<th>TR 4:00-5:15 p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>UCD Building 622</td>
<td>Class Meetings</td>
<td>UCD Building 626</td>
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<tr>
<td>Office Hours</td>
<td>TR 5:15-6:30 p.m.</td>
<td>Course Website</td>
<td>will be made available through</td>
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<tr>
<td></td>
<td>and by appointment</td>
<td>and Materials</td>
<td><a href="http://blackboard.cuonline.edu">http://blackboard.cuonline.edu</a></td>
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<tr>
<td>Phone</td>
<td>303.556.6121</td>
<td>Email</td>
<td><a href="mailto:alexander.engau@ucdenver.edu">alexander.engau@ucdenver.edu</a></td>
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</tbody>
</table>

Prerequisites: Graduate standing in math/computer science, or permission of instructor.


- **Auraria Library Call Number and Location:** T57.85.A37 (1993) on second floor.
- **Chinese Edition:** Some of my own class mates have (successfully) used the Pearson education Asia limited edition, China Machine Press, 2005. If you are lucky enough to find one cheap and can read Chinese (this will not be covered in this class), you may give it a try! **Disclaimer:** I have no idea as to how complete this “limited” edition is.
- **Online Errata and Solutions Manual:** (with answers to odd numbered exercises) [http://jorlin.scripts.mit.edu/Network_Flows:_Theory,_Algorithms,_and_Applications.html](http://jorlin.scripts.mit.edu/Network_Flows:_Theory,_Algorithms,_and_Applications.html)

Mathematical Sciences Course Catalog Description: Infrequent. Begins with the classical min-cost flow problem, defined on an ordinary network. Other problems, such as shortest path, are also shown in this class. Both theory and algorithms are presented. Extensions include generalized networks, nonlinear costs, fixed charges, multi-commodity flows, and additional applications, such as in communications networks. (3 credit hours)

Instructor Description: Over the last sixty years, the study of network flows has led to some of the most appealing and useful results in optimization and applied mathematics, in general. Initially motivated by problems from industrial operations research and developed in close relationship to linear programming, for which network structures can often be exploited very efficiently yielding solution algorithms with significantly reduced computational complexity, network flows have since then become a fascinating topic by themselves that attracts researchers and involves concepts from a wide variety of different areas including but not limited to operations research and graph theory, combinatorics and optimization, mathematical programming and computer science, and many other sciences and engineering disciplines. The lasting impact and truly interdisciplinary nature of this field is also reflected in its many successful applications by both researchers and practitioners to some of today’s most challenging problems ranging from water distribution and transportation over telecommunication and integrated circuits to bioinformatics and cancer radiation therapy.
In this introductory graduate course, we will explore the foundations, models, and methods of network flows with a strong emphasis on the stimulating interplay between theory and practice as well as inherently hard combinatorial and computational optimization problems and the efficient design and implementation of algorithms. Keeping the course prerequisites at a minimum level, however, students are expected to show a great deal of flexibility and willingness to read and learn supporting concepts quickly and independently if necessary, including \LaTeX, basic data structures, and programming competence in a compiled or interpreted object-oriented programming language (recommended and supported by the instructor are C, C++, Fortran, Java, or Python). [From the textbook’s preface: “Although students require some mathematical maturity - for example, a basic understanding of proof techniques - and some familiarity with computer programming, they need not be specialists in mathematics, computer science, or optimization.”] In addition to these new or refreshed computer skills, the successful student’s rewards will include a solid understanding of how to find shorter paths to greater flows at smaller costs, combined with practical knowledge of some fundamental network modeling techniques and culminating in the opportunity to extend her or his networking, communication, and writing skills in a final team project.

### Tentative Course Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Topics</th>
<th>Readings</th>
<th>Notes</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Part 1. Introduction</strong></td>
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<tr>
<td>1</td>
<td>1/19-21</td>
<td>Introduction</td>
<td>Chapter 1</td>
<td>HW 1 due 2/4</td>
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<tr>
<td>2</td>
<td>1/26</td>
<td>Paths, Trees, and Cycles</td>
<td>Chapter 2</td>
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<tr>
<td></td>
<td>1/28</td>
<td>Algorithm Design and Analysis</td>
<td>Chapter 3</td>
<td>Appendices A,B</td>
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<td></td>
<td></td>
<td><strong>Part 2. Shortest Paths</strong></td>
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<tr>
<td>3</td>
<td>2/2-4</td>
<td>Label-Setting Algorithms</td>
<td>Chapter 4</td>
<td>HW 2 due 2/18</td>
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<tr>
<td>4</td>
<td>2/9-11</td>
<td>Label-Correcting Algorithms</td>
<td>Chapter 5</td>
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<td></td>
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<td><strong>Part 3. Maximum Flows</strong></td>
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<tr>
<td>5</td>
<td>2/16-18</td>
<td>Basic Ideas</td>
<td>Chapter 6</td>
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<tr>
<td>6</td>
<td>2/23</td>
<td>Polynomial Algorithms</td>
<td>Chapter 7</td>
<td>HW 3 due 3/4</td>
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<td></td>
<td>2/25</td>
<td>Additional Topics</td>
<td>Chapter 8</td>
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<td><strong>Part 4. Minimum Cost Flows</strong></td>
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<tr>
<td>7</td>
<td>3/2-4</td>
<td>Basic Algorithms</td>
<td>Chapter 9</td>
<td></td>
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<tr>
<td>8</td>
<td>3/9</td>
<td>Polynomial Algorithms</td>
<td>Chapter 10</td>
<td>HW 4 due 3/18</td>
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<tr>
<td></td>
<td>3/11</td>
<td>Network Simplex Algorithms</td>
<td>Chapter 11</td>
<td>Appendix C</td>
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<tr>
<td>9</td>
<td>3/16</td>
<td>Midterm Exam</td>
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<td><strong>Part 5. Extensions</strong></td>
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<tr>
<td>10</td>
<td>3/18</td>
<td>Assignments and Matchings</td>
<td>Chapter 12</td>
<td>Proposal due 4/1</td>
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<tr>
<td></td>
<td>3/22-26</td>
<td>Spring Break</td>
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<tr>
<td>11</td>
<td>3/30-4/1</td>
<td>Minimum Spanning Trees</td>
<td>Chapter 13</td>
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<td>12</td>
<td>4/6</td>
<td>Convex Cost Flows</td>
<td>Chapter 14</td>
<td>HW 5 due 4/15</td>
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<td></td>
<td>4/8</td>
<td>Generalized Flows</td>
<td>Chapter 15</td>
<td></td>
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<tr>
<td>14</td>
<td>4/20-22</td>
<td>Multicommodity Flows</td>
<td>Chapter 17</td>
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<td>15</td>
<td>4/27-29</td>
<td>Computational Testing of Algorithms</td>
<td>Chapter 18</td>
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<td>16</td>
<td>5/4-6</td>
<td>Additional Applications</td>
<td>Chapter 19</td>
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<td>17</td>
<td>5/10-15</td>
<td>Finals Week</td>
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Course Policies and Grades

Homework and Reading Assignments  Students will receive bi-weekly homework and weekly reading assignments as indicated on the tentative course schedule. Please read the following instructions carefully to avoid any unpleasant surprises or zero homework scores.

- Homework assignments will be posted on Blackboard by Monday before completion of each major course unit, and at least 10 days before its indicated due date. Solutions are to be typed using LaTeX and turned in by 4:00 pm or immediately before class on that Thursday that the assignment is due (please also submit your original tex-source with any supplemental files and the compiled pdf in one rar/tar/zip-archive using the Digital Drop Box on Blackboard, or you will be given a zero score for that homework). Any attempt will be made to return marked assignments the following Tuesday and make detailed solutions available on Blackboard. Late submissions are not accepted, so please plan ahead: If you are not able to complete a given assignment on time and like to discuss a possible extension, contact me at least two days before the original due date, or right after class on the preceding Tuesday the latest. An example: HW 2 (due 2/18) will be posted before completion of “Part 2. Shortest Paths” by Monday, February 8 and is due - neatly typed - before class on Thursday, February 18, giving you 10 days to complete your work. Your last chance to discuss an extension will be right after class on Tuesday, February 16. I will return your marked assignment before class on Tuesday, February 23, or bring cookies and juice. Each assignment will consist of four problems worth five points each, assigned according to the following scheme.

<table>
<thead>
<tr>
<th>Points</th>
<th>Meaning</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>perfect solution and write-up that shows full understanding of the relevant course materials and matches or extends the solution key</td>
</tr>
<tr>
<td>4</td>
<td>correct solution and reasonable write-up that suggests your full understanding but lacks detail or contains some small mistake</td>
</tr>
<tr>
<td>3</td>
<td>reasonable solution and write-up that shows good understanding and is based on a correct idea but contains some major mistake</td>
</tr>
<tr>
<td>2</td>
<td>incomplete solution with sufficient explanations to show a basic understanding and a reasonable (although possibly wrong) idea</td>
</tr>
<tr>
<td>1</td>
<td>wrong solution with explanation that shows some understanding</td>
</tr>
<tr>
<td>0</td>
<td>none of the above</td>
</tr>
</tbody>
</table>

In addition, points may be marked off for bad writing such as incomplete sentences, repeated typographical mistakes, or abuse of mathematical notation. When turning in your assignments, please also pre-mark each problem yourself in consideration and honest assessment of your current understanding of the relevant course materials and confidence in your presented solution (unmarked problems will be assigned a zero score). If your personally assigned score and your actual score deviate by more than 5 points, or if either score is below 10 points, I encourage you to see me during my office hours or selected Fridays at Old Chicago to discuss this discrepancy and possible strategies to improve your performance in the course. Finally, I strongly encourage you to discuss homework or any other problems with your classmates, but you must type your own solution using your own words or give credit for any help that you received.
• Extensive reading assignments are given to help students prepare relevant class materials already before seeing them in the classroom. Although their detailed study is not necessary before class, it is always nice (and helpful!) to recall where we are coming from and be aware of where we are heading. Careful readings also lead to active participation and critical questions which are of true delight to any course instructor!

Class Participation, Note-Taking, and Quizzes Although class participation will have no direct influence on student evaluation, experience has shown that students that do actively participate typically achieve a better understanding of the course materials, perform better on homework assignments and exams and, thus, indirectly receive a better final course grade. Since preparation, attention, and review respectively before, during, and after class are key, the following two means will be used to help students achieve and enjoy the above benefits.

• Every student will serve as note-taker during selected classes and as such be responsible for producing a corresponding set of lecture notes, including a detailed list of topics discussed that day with references to the respective sections in the text book, together with any specific questions addressed or left open (if applicable). These notes should be typed using \LaTeX and sent to the instructor by email within three days after the respective class. During the first class of each week, the lecture notes of the previous week will be distributed to the students and be made available on Blackboard, thus allowing to reduce personal note-taking to a minimum and rather actively listen and engage in classroom activities and discussion.

• Together with the lecture notes, students may receive one or two short quiz questions on topics covered during the previous week, or any other earlier discussed material. Quiz scores are determined analogous to homework scores, and each quiz question can be used to substitute one homework problem (of equal or lesser value).

Midterm and Final Exams Students will be tested on two written in-class exams that together determine one third (33%) of the overall course grade.

• One midterm exam worth 40 points will be given that is in-class, closed-notes and closed-book, and cover all materials discussed until Thursday, March 11 inclusive. Unless specified otherwise later in the term, this exam is scheduled for Tuesday, March 16, and no make-up exam will be offered. If circumstances arise that prevent you from attending class that day, please contact me as soon as possible to discuss if there are any alternative options. Unexcused absences, unless supported by hard evidence such as death certificates or hospital paperwork, will result in a zero score on the exam.

• A comprehensive final exam worth 60 points will be given that is in-class and open-everything (date and time TBA later in the term). If circumstances arise that will prevent you from writing the exam that day, the same policies as above will apply.

Team Project, Proposal, and Final Report In addition to the individual homework assignments and exams, students will form teams of two to write a brief report highlighting a real-life network flow application of their own interest, including model formulation, programming, and some computational experimentation (a plethora of suggestions can be found in the text book). A brief project proposal (one page maximum) worth 10 points should be
submitted before class on April 1, consisting of a description of the problem with already identified data sources and related articles, the underlying network flow model and algorithm to be used (if known yet), and the programming effort anticipated. The final reports worth 90 points are due the last day of class and must not be longer than 10 pages maximum, including an annotated bibliography of related publications in the literature. Both proposal and report are to be typed using \LaTeX, and the original tex-sources with any supplemental files including the full program code and a compiled pdf-file are to be submitted in a single rar/tar/zip-archive using the Digital Drop Box on Blackboard by 4:00 pm on May 6.

<table>
<thead>
<tr>
<th>Homework (5 × 20 pts) / Quizzes</th>
<th>100 pts (33%)</th>
<th>Midterm Exam</th>
<th>40 pts (13%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal (10 pts) / Report (90 pts)</td>
<td>100 pts (33%)</td>
<td>Final Exam</td>
<td>60 pts (20%)</td>
</tr>
</tbody>
</table>

Communication and Policy Changes  The major means of communication outside of class and office hours will be emails to your UC Denver account and course announcements on Blackboard, so please make sure to check these two frequently. Should it become necessary to update or rectify this syllabus, you will be informed promptly of any changes both in class and by email, and the new syllabus will be posted on Blackboard.

University/College Policies and Dates

Academic Honesty: Plagiarism is the use of another person’s words or ideas without crediting that person. Plagiarism and cheating will not be tolerated and may lead to failure on an assignment, in the class, and/or dismissal from the University. You are responsible for being attentive to or observant of campus policies about academic honesty as stated in the University’s Student Conduct Code: [http://thunder1.cudenver.edu/studentlife/studentlife/discipline.html](http://thunder1.cudenver.edu/studentlife/studentlife/discipline.html)

Drops and Incompletes: Students have until April 2 to drop the course with only the instructor’s (but not a Dean’s) signature. After this date, the incomplete policy of the department and college is strictly enforced. Incomplete grades (IW or IF) are not granted for low academic performance. To be eligible for an incomplete grade, students must 1) successfully complete a minimum of 75% of the course; 2) have special circumstances beyond their control that preclude them from attending class and completing graded assignments; and 3) make arrangements to complete missing assignments with the original instructor. A CLAS Course Completion agreement is required.

H1N1 Flu: To minimize transmission of the virus, students who become sick with the flu are encouraged to inform their instructor and stay away from campus until they are symptom-free. Standard flu symptoms include fever (100 degrees or higher), cough, sore throat, body aches, headache, chills and fatigue. In addition, diarrhea and vomiting have been associated with H1N1 flu. When you return, your instructor will meet with you to discuss a reasonable time line to make up any missed assignments.
Spring 2010 CLAS Academic Policies

The following policies pertain to all students and are strictly adhered to by the
College of Liberal Arts and Sciences (CLAS).

• Every student MUST check and verify their schedule prior to the published
drop/add deadlines. Failure to verify a schedule is not sufficient reason to
justify a late add or drop later in the semester. It is the student’s
responsibility to make sure that their schedule is correct prior to the
appropriate deadlines.

• CLAS students must use their email.ucdenver.edu email address. Email is the
official method of communication for all University of Colorado Denver
business. All email correspondence will take place using your UCDHSC email
address. Go to http://www.ucdenver.edu/student-services/resources/registrar/
students/policies/Pages/EmailPolicy.aspx to activate your email address.

• Students are NOT automatically added to a course off a wait list after wait
lists are dropped. If a student is told by a faculty member that they will
be added off the wait list, it is the responsibility of the student to
complete the proper paperwork to add a course.

• Students are not automatically notified if they are added to a class from a
wait-list. Again, it is the responsibility of the student to verify their
schedule prior to any official dates to drop or add courses.

• Students must complete and submit a drop/add form to make any schedule
changes. Students are not automatically dropped from a class if they never
attended, stopped attending or do not make tuition payments.

• Late adds will be approved only when circumstances surrounding the late add
are beyond the student’s control and can be documented independently. This
will require a petition and documentation from the student. Please note that
the signature of a faculty member on an add form does not guarantee that a
late add petition will be approved. Petitions are available in NC 4011.

• Late drops will be approved only when circumstances surrounding the late
drop have arisen after the published drop deadlines, are beyond the
student’s control, and can be documented independently. This will require a
petition and documentation from the student. Pre-existing circumstances
(circumstances that existed prior to the published drop deadlines) regarding
illness, work, family, or other confounding issues will not be considered
adequate reason to drop or withdraw from courses after the published
University and/or College drop deadlines. Please note that the signature of
a faculty member does not guarantee that a late drop petition will be
approved. Petitions are available in NC 4011.

• Undergraduate students wishing to graduate in spring of 2010 must meet with
their academic advisor by census date to obtain a graduation application.
This application must be completed and submitted by 5 PM on February 3,
2010. You can obtain an application ONLY after meeting with your academic
advisor. There are no exceptions to this policy or date.

• Graduate students wishing to graduate in spring semester 2010 must complete
their Intent to Graduate form and have a Request for Admissions to Candidacy
on file with the CLAS Dean’s office no later than 5 PM, February 3, 2010.

• Students are responsible for completing financial arrangements with
financial aid, family, scholarships, etc. to pay their tuition. Students
will be responsible for all tuition and fees for courses they do not
officially drop using proper drop/add procedures and forms.

Students who drop after the published drop/add period will not be eligible for
a refund of the COF hours or tuition.
**Spring 2010 CLAS Important Dates**

- **January 19, 2010**: First day of Class
- **January 24, 2010**: Last day to add a class or be added to a wait list for a class using the SMART system.
- **January 25, 2010**: LAST DAY TO DROP WITHOUT DROP CHARGE – THIS INCLUDES SECTION CHANGES.
- **January 25, 2010**: Wait Lists are dropped. Any student who was not added to a course automatically from the wait list by this date and time MUST complete a schedule adjustment form to be added to the class. Students are NOT automatically added to the class from the wait list after this date and time. If your name is not on the official student roster, you are not registered for the course.
- **January 26-February 3, 2010**: Students are responsible for verifying an accurate spring 2010 course schedule via the SMART registration system. Students are NOT notified of their wait-list status by the university. All students must check their scheduled prior to February 3, 2010 for accuracy.
- **January 26, 2010**: First day instructor may approve request to add a student to a full course with a Schedule Adjustment Form.
- **February 3, 2010**: Census date.
- **February 3, 2010 at 5 PM**: Last day to add structured courses without a written petition for a late add. *This is an absolute deadline and is treated as such.* This deadline does not apply to independent study, internships, project hours, thesis hours, dissertation hours, and late-starting modular courses.
- **February 3, 2010 at 5 PM**: Last day to drop a spring 2010 course or completely withdraw from all spring 2010 courses *using a schedule adjustment form* with a tuition adjustment minus the drop charge and no transcript notation – this includes section changes. Drops after this date will appear on your transcript. *This is an absolute deadline and is treated as such.*
- **February 3, 2010 at 5 PM**: Last day to request pass/fail or no credit option for a course.
- **February 3, 2010 at 5 PM**: Last day to for a graduate student to register for a Candidate for Degree.
- **February 3, 2010 at 5 PM**: Last day for a Ph.D. student to petition for a reduction in hours.
- **February 3, 2010 at 5 PM**: Last day to apply for spring 2010 graduation. You must make an appointment and see your academic advisor before this date to apply for graduation if you are an undergraduate; you must complete the intent to graduate and candidate for degree form if you are a graduate student.
- **February 15-24, 2010**: Faculty can use the early alert system.
- **March 22-28, 2010**: Spring break (no classes/campus open)
- **April 2, 2010 at 5 PM**: Last day for non CLAS students to drop or withdraw from all classes without a petition and special approval from the student’s academic Dean. *After this date, a dean’s signature is needed.*
- **April 16, 2010 at 5 PM**: Last day for CLAS students to drop or withdraw from all classes with signatures from the faculty and Dean without a petition. *This is treated as an absolute deadline.*
- **After April 16, 2010** all schedule changes require a full petition. Petitions are available in NC 4011.
- **May 10-15, 2010**: Finals Week

*No schedule changes will be granted once finals week has started. There are NO exceptions to this policy.*
Additional University Resources

**Academic Advising Center**  This office serves as the first point of contact for students who are pre-business, pre-engineering, or who have not declared a major in CLAS or CAM. In addition, the center provides general information and resource referral to all students. *North Classroom Building (NC) Room 1, Phone 303-352-3520.*

**Program Access for Persons with Disabilities:**  UCD is committed to providing reasonable accommodation and access to programs and services to persons with disabilities. Students with disabilities requiring accommodations, please contact the Office of Disability Resources & Services located in NC 2514, phone 303.556.3450, TTY 303.556.4766. The staff will assist you in both determining reasonable accommodations as well as their coordination.

**The Center for Learning Assistance**  The Center for Learning Assistance is where students go to get help or insight with class assignments, course-loads, and study skills. The Center also helps with arranging tutoring sessions, which take place in the days or evenings. *NC Bldg. Room 2006, (303) 556-2802, Monday - Thursday 8am-7pm, Friday 8am-5pm.*

**Experiential Learning Center**  The ELC serves students, faculty, employers, and community partners as a resource for experiential learning opportunities, including a variety of activities with one common goal to immerse you in hands-on learning outside the classroom where your experience is at the heart of the learning process. The Center offers information, resources and support in the development and coordination of academic internships and co-ops, service-learning courses, volunteer opportunities, and undergraduate research experiences. *Tivoli Student Union, Suite 260, Phone: 303-556-6656, Hours: M-F 8:00-5:00.*

**Career Center**  The Career Center offers a full array of services that prepare students for career success, such as resume help, internship and career counseling and they have a large career library. *Tivoli Student Union Room 260.*

**Writing Center**  The Writing Center offers free one-on-one and small-group writing consultations in areas such as generating, organizing and developing ideas, analysis, synthesis and argument, and information literacy and research strategies. Consultants are available to work with writers on any type of written work, including scholarship applications, personal statements, resumes, article reviews, theses, statements of purpose, dissertations, and graduate school applications. *North Classroom Building, Room 4014, Phone: 303.556.4845, Fax: 303.352.3651, Email: writing.center@ucdenver.edu.*

**Counseling Center**  The UC Denver Student and Community Counseling Center provides mental health counseling services to the UC Denver student body as well as the Denver Metro community. If you are interested in counseling services, call 303-556-4372 or drop in at the North Classroom Building, Room 4036 to schedule an intake appointment.