Course: CS515

Title: Algorithm Design

**Term:** Fall 2023

**Credit hours:** 3

**Meeting days/time:** Tu, Th / 3:30 pm - 4:45 pm

**Location:** Mine and Minerals Research Bldg, Rm # 112

# Instructor Information

**Name:** Muhammad **Abu** Bakar Siddique

**Email:** [siddique@cs.uky.edu](mailto:siddique@cs.uky.edu)

**Office building and room number:** Davis Marksbury Building, Room # 321

**Office hours:** M, W, F / 12:00 pm - 1:00 pm

**Office Phone Number:** 8592573892

***Teaching Assistant***

Name: Halima Abukadah

Email: [Halima.Abukadah@uky.edu](mailto:Halima.Abukadah@uky.edu)

Office hours: Tu, Th / 11:00 am -12:00 pm

# Course Description

The design and analysis of efficient algorithms and data structures for problems in sorting, searching, graph theory, combinatorial optimization, computational geometry, and algebraic computation. Algorithm design techniques: divide-and-conquer, dynamic programming, greedy method, and randomization, approximation algorithms.

# Course Prerequisites

CS 315 Algorithm Design/analysis or instructor’s consent.

***Required course:*** elective for CS.

# Required Materials

Readings will primarily be drawn from:

* *Algorithms*by S. Dasgupta, C. Papadimitriou, and U. Vazirani (**DPV**)

The following textbooks are not required, but they may be useful references:

* [suggested] Introduction to the Theory of Computation, M. Sipser (3rd Edition).
* [suggested] Introduction to Algorithms, 3rd Edition (The MIT Press) by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein.
* [optional] Foundations of Data Science, A. Blum, J. Hopcroft and R. Kannan.

# Associated Expenses

Nothing anticipated.

# Activities Outside of Regular Class Meetings

Nothing anticipated.

# Skill and Technology Requirements

Programing skills in python (or any other programing language) are strongly required.

*For technical assistance, contact ITS Customer Services 24/7 at 859-218-HELP (4357) for urgent needs. For non-urgent matters, choose the option that works best for you at* [*https://techhelpcenter.uky.edu/gethelp*](https://uky.service-now.com/techhelp?id=kb_article&sysparm_article=KB0011425)

# Student Learning Outcomes

On completion of the course, students will demonstrate:

* Ability to prove algorithms are correct.
* Ability to analyze the complexity of algorithms.
* Ability to design new algorithms.
* Ability to use existing algorithms to build computational solutions for complex problems.
* Understanding of the relevance of algorithm design and analysis in CS.
* Ability to analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions. (SO1)
* Ability to design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline. (SO2)

## Teacher Course Evaluation (TCE) supplemental questions

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| --- |
| 1. I can prove algorithms are correct. 2. I can analyze the complexity of algorithms. 3. I can design new algorithms. 4. I can use existing algorithms to build computational solutions for complex problems. 5. I understand the relevance of algorithm design and analysis in CS. 6. I have the ability to analyze a problem, and identify and define the computing requirements appropriate to its solution. |

# Course Details

## Tentative Course Schedule

* **Dynamic Programing**: Fibonacci numbers, Longest Increasing Subsequence (LIS), and Longest Common Subsequence (LCS); Knapsack, and Chain Matrix Multiplication; Dynamic programming algorithms for solving various shortest path problems on graphs.
* **Divide and Conquer Algorithms**: Faster Divide-and-Conquer Algorithm for Multiplying Large Integers; Linear-time Divide-and-Conquer Algorithm for Finding the Median from an unsorted list; Recurrences; High-level approach for polynomial multiplication and FFT (Fast Fourier Transform); Complex numbers, including complex roots of unity; FFT and polynomial multiplication algorithms, and inverse FFT.
* **Graph Algorithms**: Connectivity: Connected components of undirected graphs, Topological sorting of a DAG, and strongly connected components of general directed graphs; Polynomial-time algorithm for 2-SAT, using the SCC algorithm; Minimum Spanning Tree (MST): Cut Property for MST's, and Kruskal's MST algorithm; Introduction to Markov Chains, and an exposition of the PageRank algorithm.
* **Max-Flow Algorithms**: Max-flow: Problem statement, residual network, and Ford-Fulkerson algorithm; Max-Flow Min-Cut Theorem: Statement and Proof, and proof of correctness of Ford-Fulkerson and Edmonds-Karp augmenting path algorithms; Application to Image Segmentation problem; Edmonds-Karp augmenting path algorithm; Generalization allowing demand constraints.
* **Randomized Algorithms**: Modular Arithmetic: Fast Modular Exponentiation and Multiplicative Inverses; RSA Cryptosystem: Fermat's Little Theorem, RSA Protocol, and Primality Testing.; Hashing: Toy problem of Balls into Bins, Traditional Chain Hashing, and Bloom Filters.
* **Linear Programing**: Linear Programming: Basics, Standard Form, and Simplex Algorithm Overview; Geometry of Linear Programs: Feasible Region, Infeasible LP's, and Unbounded LP's; Dual of a Linear Program, Converting an LP problem to its Dual, Weak and Strong Duality; Maximum Satisfiability Problem, Approximate Solutions, Integer Programming, Calculus.
* **NP-Completeness**: Definition of a Search Problem and Computational Complexity Classes P and NP, proving a Problem is in NP, Reductions, and the notion of NP-Completeness; 3-SAT Problem is NP-Complete; NP-Completeness of Graph Problems: Independent Sets, Clique, and Vertex Cover; Knapsack and Subset Sum Problems are NP-Complete; Halting Problem.

## Course Activities and Exams

* **6 (+ 1 optional) assignments (30%):** Students will design algorithms; usually code those algorithms in a well-known programing language. Best 6 will count towards the grade.
  + **Tentative Submission dates:**
    - Assignment # 1: 09/01/23
    - Assignment # 2: 09/15/23
    - Assignment # 3: 09/29/23
    - Assignment # 4: 10/16/23
    - Assignment # 5: 10/30/23
    - Assignment # 6: 11/10/23
    - Assignment # 7: 11/20/23
* **6 (+1 optional) quizzes (30%):** In class. Best 6 will count towards the grade. Quizzes will, mainly, be drawn from the topics covered in the class.
  + **Tentative dates:**
    - Quiz # 1: 09/05/23
    - Quiz # 2: 09/19/23
    - Quiz # 3: 10/03/23
    - Quiz # 4: 10/19/23
    - Quiz # 5: 11/02/23
    - Quiz # 6: 11/14/23
    - Quiz # 7: 11/21/23
* **Two exams (40%):** In class. Students will show their understanding of the theory and practice of algorithms by answering technical and conceptual questions. The percentage toward grade and tentative dates are as follows:
  + **Exam one (20%):** 10/10/23
  + **Exam two (20%):** 11/30/23

**Engagement Verification:** In order to meet federal regulations, the instructor will monitor student participation in this class through class participations. Students whose attendance or participation cannot be determined one time during the first three weeks of the semester may be dropped from the course. If you will be missing a class period or will not be submitting some assignment during that period, it is your responsibility to notify the instructor, even if the absence or missed assignment is not excused under university rules.

## Grading Scale

*Sample grading scale for undergraduate students:*

*90 – 100% = A*

*80 – 89% = B*

*70 – 79% = C*

*60 – 69% = D*

*Below 60% = E*

*Sample grading scale for graduate students:*

*90 – 100% = A*

*80 – 89% = B*

*70 – 79% = C*

*Below 70% = E*

## Midterm Grades

For undergraduates, midterm grades will be posted in myUK by the deadline established by the University Senate and published in the Academic Calendar. (http://www.uky.edu/registrar/content/‌academic-calendar)

## Attendance Policy/Acceptable Documentation

Your active participation is essential for your own success as well as for the success of this class. If you are absent you are personally responsible for learning about any missed material from the syllabus, from classmates. Students need to notify the professor of absences prior to class when possible. *Senate Rules 5.2.5.2* defines the following as acceptable reasons for excused absences: (a) serious illness, (b) death of family member, (c) University-related trips, (d) major religious holidays, (e) Interviews for full-time job opportunities, and (f) other circumstances found to fit “reasonable cause for nonattendance” by the professor.

Students anticipating an absence for a major religious holiday are responsible for notifying the instructor in writing of anticipated absences due to their observance of such holidays no later than the last day in the semester to add a class. Two weeks prior to the absence is reasonable but should not be given any later. Information regarding major religious holidays may be obtained through the Ombud (859-257-3737, <https://www.uky.edu/ombud/absences-excused>.

**Note on Covid-19-related absences:** If you are feeling sick, get tested. Do not attend class if you

aren’t feeling well. Quarantine/isolation for Covid-19 or for Covid-19 contact qualifies as an

excused absence. Documentation from UK HealthCorps is required. \*\* Unless we discover that UK

HealthCorps is no longer providing documentation.

# Assignment Policies

## Assignment Submissions

Assignments will be submitted via Canvas. Detailed expectations will be provided with each assignment. Any assignment you turn in may be submitted to an electronic database to check for plagiarism.

## Returning Assignments to Students

Grades will be posted on Canvas for each submitted assignment.

## Late Assignments

I deduct 10% for each late day, up to a maximum of two days per assignment. After one week you will receive zero credit.

* Each late day corresponds to 24 hours or part thereof.
* I round up to the nearest day, so ten minutes late is equivalent to 23 hours late.
* This policy does **not** apply to presentations and class participations. No late presentations or missed class participations.
* Late assignments will be accepted with appropriate documentation of illness or emergency; we will establish an alternative deadline that you’re expected to meet. If you exceed this deadline or do not have a verifiable excused absence, late work will be graded according to above policy. Assignments not submitted within one week of the due date will automatically get zero credit.

Please, also refer to the [University Senate Rules](https://www.uky.edu/universitysenate/rules-regulations) at the following URL: <https://www.uky.edu/universitysenate/rules-regulations>.

## Assignments Due during Prep Week

The course does not have a final exam. No course activity is anticipated during prep week.

# Academic Policy Statements

Please find Senate’s [Academic Policy Statements](https://www.uky.edu/universitysenate/acadpolicy) on this URL: <https://www.uky.edu/universitysenate/acadpolicy>.

# Academic Offenses (Cheating, Plagiarism, and Falsification or Misuse of Academic Records)

Per University policy, students shall not plagiarize, cheat, or falsify or misuse academic records. The minimum penalty for a first offense is a zero on the assignment on which the offense occurred. If the offense is considered severe or the student has other academic offenses on their record, more serious penalties, up to suspension from the University may be imposed. A plea of ignorance is not acceptable as a defense against the charge of academic dishonesty.

Plagiarism and cheating are serious breaches of academic conduct. Each student is advised to become familiar with the various forms of academic dishonesty as explained in the Code of Student Rights and Responsibilities. Complete information can be found at the following website: <http://www.uky.edu/Ombud>. It is important that you review this information as all ideas borrowed from others need to be properly credited.

*Senate Rules 6.3.1* (see <http://www.uky.edu/Faculty/Senate/> for the current set of *Senate Rules*) states that all academic work, written or otherwise, submitted by students to their instructors or other academic supervisors, is expected to be the result of their own thought, research, or self-expression. In cases where students feel unsure about a question of plagiarism involving their work, they are obliged to consult their instructors on the matter before submission.

When students submit work purporting to be their own, but which in any way borrows ideas, organization, wording, or content from another source without appropriate acknowledgment of the fact, the students are guilty of plagiarism.

Plagiarism includes reproducing someone else's work (including, but not limited to a published article, a book, a website, computer code, or a paper from a friend) without clear attribution. Plagiarism also includes the practice of employing or allowing another person to alter or revise the work, which a student submits as his/her own, whoever that other person may be. Students may discuss assignments among themselves or with an instructor or tutor, but when the actual work is done, it must be done by the student, and the student alone.

When a student's assignment involves research in outside sources or information, the student must carefully acknowledge exactly what, where and how he/she has employed them. If the words of someone else are used, the student must put quotation marks around the passage in question and add an appropriate indication of its origin. Making simple changes while leaving the organization, content, and phraseology intact is plagiaristic. However, nothing in these Rules shall apply to those ideas, which are so generally and freely circulated as to be a part of the public domain.

Moreover, please refer to the [Rules Regarding Academic Offenses](https://www.uky.edu/universitysenate/ao) at the following URL: (<https://www.uky.edu/universitysenate/ao>.

# On Usage of Generative Models (e.g., ChatGPT, Bard)

Any Policy from the University of Kentucky, College of Engineering, or the department of Computer Science will supersede (even after the course has started) what I am describing in the following.

I recognize the potential of generative models, such as ChatGPT, to enhance the learning and collaborative experience for my students. These models can serve as valuable tools for brainstorming, problem-solving, and exploring creative ideas. However, it is essential to approach their usage with mindfulness and responsibility. Therefore, I have established the following guidelines for utilizing generative models in the course:

**Learning and Collaboration:** Feel free to employ generative models like ChatGPT to facilitate learning and collaboration. These models can act as (virtual) teaching assistants, offering insights and guidance on various topics.Use generative models to generate sample responses, brainstorm ideas, and simulate discussions to enhance your understanding of the course material.

**Fact-Checking and Verification:** While generative models provide valuable information, it is crucial to remember that their responses might not always be accurate or up to date. Before incorporating information from these models into your work, verify the accuracy of the provided information.Relying solely on generative model outputs without learning the concepts kills the spirit of learning.

**Attribution and Usage Disclosure:** When using content generated by generative models in your assignments or projects, clearly indicate the source of the information and specify that it was produced with the assistance of a generative model along with the “exact prompt”.If you utilize full or partial answers from generative models, be transparent about their usage by acknowledging the prompts you provided to the model and clearly distinguishing between your original content and the generated output.

**Paid Plugins and Resources:** While I do not encourage the use of paid plugins or resources in conjunction with generative models, I acknowledge that students may choose to do so.If you decide to use any paid plugins or resources in combination with generative models, please disclose this information in your work to maintain transparency.

By adhering to these guidelines, the idea is to foster a productive and responsible usage of generative models within the context of this course. These models can be valuable tools for expanding your knowledge and collaborating with peers, but they should always be used in conjunction with critical thinking and independent research. Remember that your growth and understanding are the primary goals of this course, and the use of generative models should contribute positively to that objective.

# Resources

**Accommodations due to disability:** If you have a documented disability that requires academic accommodations, please see me as soon as possible during scheduled office hours. In order to receive accommodations in this course, you must provide me with a Letter of Accommodation from the Disability Resource Center (DRC). The DRC coordinates campus disability services available to students with disabilities. It is located on the corner of Rose Street and Huguelet Drive in the Multidisciplinary Science Building, Suite 407. You can reach them via phone at (859) 257-2754 and via email at [drc@uky.edu](mailto:drc@uky.edu). Their web address is <http://www.uky.edu/DisabilityResourceCenter>.

**Mental Health and Wellness:** University life can be a demanding and stressful experience. Please know there are numerous resources offered by the counseling center to support student growth and assist students with mental health, academic and/ or other personal concerns that might interfere with academic performance or a sense of personal well-being while at UK.

The University of Kentucky Counseling Center provides same day walk-in crisis appointments (24-hour Crisis Consultation: 859-257-8701) for all students Monday thru Friday between 8 am to 4:30 pm. The Counseling Center (<http://www.uky.edu/counselingcenter/>) is in Frazee Hall (Room 106).

Moreover, please have a look at the following resources that might be useful:

UK’s [Distance Learning Library Services](https://libraries.uky.edu/page.php?lweb_id=1020), [Tutoring and Coaching Resources](https://www.uky.edu/studentacademicsupport/free-tutoring-and-coaching-resources), proctoring information, etc. (<https://libraries.uky.edu/‌page.php?lweb_id=1020>, <https://www.uky.edu/studentacademicsupport/free-tutoring-and-coaching-resources>)]

# Diversity, Equity, and Inclusion

[Syllabus Statement on Diversity, Equity, and Inclusion (DEI)](https://www.uky.edu/universitysenate/syllabus-dei) can be found at this URL: <https://www.uky.‌edu/universitysenate/syllabus-dei>.

# Student Resources

Please Visit the University Senate’s[*Resources Available to Students*](https://www.uky.edu/universitysenate/student-resources) *to access that list* [*https://www.uky.edu/universitysenate/student-resources*](https://www.uky.edu/universitysenate/student-resources)*.*

# Classroom Behavior Policies

No cellphones, no laptops, and be respectful during dialogue or discussion.

**Face Covering Policy:**

Per current UK Covid-19 Guidance, masks are optional but encouraged: “While masks are optional, we strongly encourage members of our community who want to do so to wear them as an added layer of protection”. As outlined in the Discrimination and Harassment Policy in the Student Code of Conduct, UK-approved face coverings are free from discriminatory or harassing language and symbols.

**Classroom Professionalism:**

Good classroom citizenship requires a few basic considerations beyond preparing for and actively

participating in classroom activities. I expect you to be on time for class; repeated tardies or early

departures will be counted as absences. You will need to bring all necessary materials to class, including

reading materials, paper and a pen for taking notes, etc. Everyone should turn off their cell phones and

put them away promptly when class begins. I expect that you will pay attention and avoid distracting

others by talking, using your computer for reasons unrelated to class, etc. Your class participation grade

will suffer for violation of these policies and I will ask you to leave for repeated or excessive disruptions.

In short, please be courteous to your fellow students and to me while you’re in class.

# Course Recordings [if recorded]

The University of Kentucky [Code of Student Conduct](https://www.uky.edu/studentconduct/code-student-conduct) defines Invasion of Privacy as using electronic or other devices to make a photographic, audio, or video record of any person without their prior knowledge or consent when such a recording is likely to cause injury or distress.

Meetings of this course may be recorded. All video and audio recordings of lecturers and class meetings, provided by the instructors, are for educational use by students in this class only. They are available only through the Canvas shell for this course and are not to be copied, shared, or redistributed.

As addressed in the Code of Student Conduct, students are expected to follow appropriate university policies and maintain the security of the LinkBlue accounts used to access recorded class materials. Recordings may not be reproduced, shared with those not enrolled in the class, or uploaded to other online environments.

If the instructor or a University of Kentucky office plans any other uses for the recordings, beyond this class, students identifiable in the recordings will be notified to request consent prior to such use. In anticipation of such cases, students may be asked to complete an “authorization of use” form by a faculty member.

Video and audio recordings by students are not permitted during the class unless the student has received prior permission from the instructor. Any sharing, distribution, and or uploading of these recordings outside of the parameters of the class is prohibited. Students with specific recording accommodations approved by the Disability Resource Center should present their official documentation to the instructor.

# Course Copyright

All original instructor-provided content for this course, which may include handouts, assignments, and lectures, is the intellectual property of the instructor(s). Students enrolled in the course this academic term may use the original instructor-provided content for their learning and completion of course requirements this term, but such content must not be reproduced or sold. Students enrolled in the course this academic term are hereby granted permission to use original instructor-provided content for reasonable educational and professional purposes extending beyond this course and term, such as studying for a comprehensive or qualifying examination in a degree program, preparing for a professional or certification examination, or to assist in fulfilling responsibilities at a job or internship; other uses of original instructor-provided content require written permission from the instructor(s) in advance.