Syllabus for CECS 528, Advanced Algorithms

Instructor: Dr. Todd Ebert

Spring 2026, Last Updated: January 20th, 2026

General Course Information

Academic Unit Department of Computer Engineering and Computer Science, California State University, Long Beach

Prerequisite Open to Computer Science MS, Computer Engineering MS, or Engineering MS students only, or consent of instructor. Students are strongly encouraged to have completed an undergraduate course in data structures and algorithms similar to that of CECS 328.

Catalog Description Theoretical analysis of algorithms. Divide and conquer, dynamic programming and greedy algorithms; basic search and traversal techniques including search trees; sorting; matrix manipulations; NP-completeness.

Section Call Numbers 8210 (Section 1), 10686 (Section 2)

Instructor Dr. Todd Ebert (Todd.Ebert at csulb.edu)

Instructor Office Hours TuWTh 9:30 am - 10:30 am, ECS 548

Course Meeting Times Section 1: MW 8:00-9:15 am in ECS 412, Section 2: F 8:00-10:45 am in ECS 412

Textbook S. Dasgupta, C. Papadimitriou, U. Vazirani, **Algorithms**, McGraw-Hill Education, 1st edition, 2006

Course Topics

- Review of Big-O notation
- Analysis Tools for Divide-and-Conquer Algorithms: Recurrences, Master Theorem, Substitution Method
- Divide-and-Conquer Algorithms: Mergesort, Quicksort, Finding Array Statistics, Finding the Median of an Array, Karatsuba's Integer Multiplication Algorithm, Strassen't Matrix Multiplication Algorithm, Maximum Subsequence Sum, Minimum Positive Subsequence Sum, Fast Fourier Transform
- Data Structures for Greedy Algorithms: Binary Heaps, Disjoint Set Data Structure
- Greedy Algorithms: Dijkstra's, Prim, and Kruskal's algorithms, Unit Task Scheduling, Task Selection, Fractional Knapsack, Fuel Reloading
- Replacement Method for proving correctness of greedy algorithms
- Dynamic Programming Algorithms: 0-1 Knapsack, Edit Distance, Optimal Binary Search Tree, Longest Common Subsequence, Minimum and Maximum Single Source Distances in DAGs, Floyd Warshall Algorithm, Runaway Traveling Salesperson.
- Turing Reducibility with Applications: 2SAT, Max Flow/Min Cut, polynomial-time Turing reducibility
- Mapping Reducibility: Even to Odd (and vice versa), Independent Set to Clique (and vice versa), Embeddings, Set Partition to Subset Sum, Hamilton Path to LPath, Contractions, Subset Sum to Set Partition, Vertex Cover to Half Cover, Clique to Half Clique, Max Matching to Max Flow
- Introduction to Computational Complexity Theory: complexity classes `P`, `NP`, and `co-NP`, `NP`-complete problems, Cook's Theorem, mapping reductions that establish NP-completeness, SAT to 3SAT, 3SAT to Clique, 3SAT to Subset Sum, 3SAT to Directed Hamilton Path (DHP), Independent Set to Vertex Cover, DHP to Hamilton Path, Hamilton Path to Hamilton Cycle, Hamilton Cycle to Traveling Salesperson
- Approximation algorithms: Vertex Cover, Traveling Salesperson, Data Clustering, Load Balancing, Max Cut
- Review of Probability Theory: random variables and events, expectation and variance of a random variable, linearity of expectation, Independence of random variables and events, Bernoulli, Geometric, and Binomial random variables, conditional probability, conditional expectation, conditional-expectation random variables, chain rule (including generalized version).
- Randomized algorithms: Min Cut, 3SAT, Randomized Quicksort, Randomized Finding Array Statistics, Max Cut, Hashing, Set Balancing

Learning Outcomes

This course has eleven **core learning outcomes (LO's)** that will be assessed on each exam, as well as on five quizzes. For each outcome, your understanding is assessed via a problem that is provided on the quiz or exam. In addition to earning points (on exams only) for solving these problems, you will also receive either a Pass (P) or No Pass (NP) grade. Receiving a pass grade means that you have successfully demonstrated competency with respect to that LO.

The following are some guidelines for success towards passing each of the learning outcomes.

1. When preparing for the learning-outcome problem, carefully read its official description in the syllabus so that you know what is expected for a passing mark.

2. Each LO has a set of core exercises (with solutions) to help you prepare. These exercises are located at the end of the lecture that introduces the LO.

3. During exams and quizzes you are allowed to bring pens/pencils, eraser, and a non-programmable scientfic calculator **All other computing devices (cell phones, laptops, smart watches, etc.), notes, and books must be put away before starting. Failure to abide by these rules is grounds for receiving a final course grade of F without the possibility of having the grade forgiven**.

4. To help prevent cheating during in-class assessments, when possible, please select a seat that leaves one or more empty seats between you and your nearest neighbor. **When there is sufficient evidence of exam or quiz plagiarism, all involved students are subject to receiving a final course grade of F without the possibility of having the grade forgiven**.

5. Carefullly read the directions for each problem and include all the pertinent steps of your solution.

6. Solve each LO assessment problem on a **SINGLE and SEPARATE** sheet of paper that includes your first name and surname (the one that determines your alphabetical order).

7. During exams and quizzes, both a five and two-minute warning will be announced before solutions are to be turned in. Please have the courtesy to turn in your work before the final call. A student who is still working after the final call will receive a warning and any subsequent infractions will result in the student's work not being graded.

8. At the end of the semester each student will receive grade points in accordance with the following table and based on the number of different LO's passed.

Number Passed	Grade Points
1-3	0
4	0.5
5	1.0
6	1.25
7	1.5
8	2.0
9	3.0
10	3.5
11	4.0

The following are the LO's for which competency must be demonstrated.

LO1. The ability to use the Master Theorem to determine the growth of a function that satisfies a uniform divide-and-conquer recurrence, and the ability to use the Substitution Method to provide either a big-O upper bound or big-Omega lower bound for the growth of some function that satisfies a some divide-and-conquer recurrence.

LO2. An understanding of the concepts that establish the correctness or running time of a divide-and-conquer algorithm, and the ability to demonstrate the steps of the algorithm. The list of algorithms are Mergesort, Quicksort, Find-Statistic, Strassen's algorithm, Karatsuba's Integer Multiplication algorithm, Maximum Subsequence Sum, and Minimum Positive Subsequence Sum.

LO3. An understanding of the fundamental properties of complex numbers from which the FFT algorithm arises, and an understanding of how both the FFT and IFFT algorithms are used to efficiently compute the product of two polynomials. Finally, the ability to demonstrate both the FFT and IFFT algorithms.

LO4. The ability to demonstrate the steps of a greedy algorithm (see list in Course Topics section), and an understanding of how the binary heap and disjoint-set data structures are used for the sake of improving the running time of some greedy algorithms. The ability to demonstrate the use of one of these data structures within the context of Kruskal's, Prim's, Dijkstra's, and the `Unit Task Scheduling` algorithm.

LO5. The ability to provide a dynamic-programming recurrence and demonstrate the corresponding dynamic-programming algorithm for some problem studied either in lecture, or in the lecture exercises, including 0-1 Knapsack, Edit Distance, Longest Common Subsequence, Optimal Binary Search Tree, Matrix-Chain Multiplication, Shortest and Longest Paths in an Acyclic Graph, Runaway Traveling Salesperson, and the Floyd-Warshall algorithm.

LO6. The ability to understand the concept of Turing reducbility as a general algorithm strategy and how it is specifically used for solving the `2SAT` decision problem or the `Max Flow` problem. For the `2SAT`: Part 1: the ability to demonstrate the steps of the Improved `2SAT` Algorithm. Part 2: the ability to answer a question that arises from using the original `2SAT` algorithm that makes use of `Reachability`-oracle queries. For the `Max Flow`: Part 1: Given a network G and a flow f over that network, the ability to provide the residual network G_f and use it to either determine that f is a maximum flow for G, or to compute a larger flow via an augmenting path.

LO7. The ability to provide the definition of what it means to be a mapping reduction f from some problem A to another problem B, and demonstrate one of the following reductions, and verify that the solution to $x \in A$ the same as the solution to $f(x) \in B$.

(a) `Even` $\leq_m$ `Odd` See Exercise 1 of the Mapping Reducibility lecture for the kind of problem to expect.

(b) `Max Independent Set` $\leq_m$ `Max Clique` and vice versa

(c) `Set Partition` $\leq_m^p$ `Subset Sum`

(d) `Hamilton Path` $\leq_m^p$ `LPath`

(e) `Subset Sum` $\leq_m^p$ `Set Partition`

(f) `Vertex Cover` $\leq_m^p$ `Half Vertex Cover`

(g) `Clique` $\leq_m^p$ `Half Clique`

(h) `Max Bipartite Matching` $\leq_m^p$ `Max Flow`

LO8. An understanding of the complexity classes `P`, `NP`, and `co-NP` and the kinds of problems that belong in each class. Also, the ability to identify an appropriate certificate for an instance of some NP problem, the ability to provide pseudocode for a verifier of some NP problem, and to prove that the verifier requires a polynomial number of steps.

LO9. The ability to demonstrate and/or answer questions about one of the following polynomial-time mapping reductions that establishes the NP-completeness of some decision problem: 3SAT to Clique, 3SAT to Subset Sum, SAT to 3SAT, 3SAT to DHP, DHP to UHP, and Hamilton Cycle to Traveling Salesperson.

LO10. The ability to demonstrate the steps of an approximation algorithm on some problem instance and understand why a certain approximation algorithm achieves a certain approximation ratio. Algorithms include those for Min Vertex Cover, Clustering, Load Balancing, and Traveling Salesperson.

LO11. An understanding of the basic definitions, formulas, and techniques of probability theory and how they may be applied to the creation of novel and efficient algorithms for sorting, finding statistics, Matrix Multiplication Verification, finding minimum cuts in a graph, and solving `3SAT`.

Reading Assignments

A reading assignment will be provided on most weeks of the semester. Reading the textbook will offer a somewhat alternative and more comprehensive viewpoint of the subject matter. Please check the "Reading Assignments" link at the course website for the current and past assignments. The reading assignment topics pertain to those topics that will be covered in the class meetings for the following week.

Class Meetings

Our class meetings will be devoted to working through the course lecture notes. These notes have several examples. Some have provided solutions while the solutions to others will be demonstrated in class. The notes also contain all the needed definitions, formulas, theorems, exercises, and exercise solutions. Here is what to expect for each of the class meetings.

First Week traditional lecture

Quiz and Exam Weeks no lecture on exam days, shortened lecture on quiz days, traditional lecture given on the meeting following an exam or quiz (MW Section only).

Non-Assessment Weeks flipped meeting, meaning that lecture recordings will be made available in advance, and the class meetings will be used to i) review the lecture recording and address student issues and questions, and ii) have students work in groups of three to complete an in-class assignment.

Weekly Exercises

Associated with each learning outcome presented in lecture will be a set of assigned practice exercises, as well as some additional exercises that pertain to a related peripheral learning outcome or represents a more advanced LO exercise. Additional problems often serve as inspiration for exam problems.

In Class Assignments and Homework

In addition to the group assignments that are to be turned in during class, students will also be assigned a homework problem that will be turned in within three days after the day it is assigned.

The following are some rules and guidelines for solving the HW problems and submitting their solutions.

1. Solutions should be submitted by uploading a single PDF file to the appropriate Canvas drop box.
2. Please make sure to write your full name at the top of each page.
3. Solutions should be presented in the same order that they appear on the problem sheet.

4. **All solutions should be handwritten (including the use of an electronic writing tablet) Typed solutions will not be graded** unless the assignment directions provide an exception.

5. Homework plagiarism shall not be tolerated. When plagiarism is first detected, the students involved will receive a warning. Detecting plagiarism a second time will result in a final homework grade of F. It is OK for students to collaborate on homework, but it's not OK for students to copy one another or copy from a source on the web. Each student has the responsibility to present each solution in a unique way that is consistent with writing style and degree of understanding.

Quizzes

There will be five quizzes given during the semester. The purpose of each quiz is to provide students with the opportunity to demonstrate competency in one or more of the core learning outcomes. Therefore, each quiz problem is graded as pass/no pass. Quizzes will officially begin at 8:00 am and last for 40 minutes, but I hope to arrive early so that students can have more time if needed.

Featured Problems. Headlining each quiz (except for Quiz 5) are two **featured problems**, each pertaining to one of the course LO's. Although students are expected to solve these problems, there is no penalty for not doing so.

Makeup Problems. In addition to the two featured problems, there will also be LO make up problems. Each student may solve one of these problems (or one half of each of two different problems). When making up two halves of different LO problems, please include both on the same solution sheet.

Extra Credit. When a learning outcome is being assessed for the first time, and the assessment occurs on a quiz, then a student who *completely* passes the assessment shall be awarded extra credit in the form of 0.1 grade points (per passed LO) that are added to the student's end-of-semester final course GPA. For example, LO1 will be assessed for the first time on Quiz 1. Any student who completely passes this assessment will receive 0.1 extra credit. The same is true for LO's 2, 5, 6, 9, and 10 for a total of up to 0.6 in GPA boosting.

MW Quiz Dates and Featured LO's

Quiz 1 LO's 1 and 2, February 2nd

Quiz 2 LO's 5 and 6, March 9th

Quiz 3 LO's 7 and 8, April 6th

Quiz 4 LO's 9 and 10, April 20th

Quiz 5 LO's 1-10 (Choose three to solve or choose two plus two halves), May 4th

Friday Quiz Dates and Featured LO's

Quiz 1 LO's 1 and 2, February 6th

Quiz 2 LO's 5 and 6, March 13th

Quiz 3 LO's 7 and 8, April 10th

Quiz 4 LO's 9 and 10, April 24th

Quiz 5 LO's 1-10 (Choose three to solve or choose two plus two halves), May 8th

Exams

There will be two midterm exams and a final exam. Each exam will have six equally-weighted problems: four core learning-outcome assessment problems, and two additional problems. The additional problems are drawn from one of the following. Each exam is weighted as 20% of a student's final grade.

1. definitions, concepts, and resullts that support one of the core learning outcomes
2. a problem similar to one of the additional problems appearing at the end of one of the lectures
3. a problem similar to a learning outcome assessment problem but more advanced

Each exam is weighted as 20% of a student's final grade.

WARNING: passing a learning outcome on a previous quiz does **NOT** mean automatic awarded points for that LO on the exam. Students should solve **ALL** problems in order to earn a high grade on the exam. The benefits of having already passed a learning outcome that appears for points on an exam may include i) increased confidence and better preparation for solving the problem, and ii) less stress because, no matter what the outcome, at least the LO is passed (once an LO is passed, it stays passed).

MW Exam Dates

Exam 1 February 16th

Exam 2 March 23rd

Final Exam Monday, May 11th, 8:00-10:00 am

Friday Exam Dates

Exam 1 February 20th

Exam 2 March 27th

Final Exam Friday, May 15th, 10:15-12:15 pm

Exam and Quiz Makeups

Exam and Quiz Makeups will only be permitted in case of a documented accident, emergency, or illness. Acceptable documentation includes a note or letter from a medical establishment, a police report, and insurance documentation. Documentation must be provided before approving a makeup assessment.

Final Grade Determination

At the end of the semester, grades will be assigned based on the six categories shown in the table below.

Categories	Percentage Weight
Learning Outcomes	30%
Midterm 1	20%
Midterm 2	20%
Final	20%
In-Class/Homework	10%

The grade points earned for each category are weighted according to the percentage weight to obtain the final course grade point average

$$\text{GPA} = 0.3 \times \text{LO} + 0.2 \times M_1 + 0.2 \times M_2 + 0.2 \times F + 0.1 \times \text{HW} + \text{ Extra Credit}$$

which is rounded to the nearest tenth. The grade point average is then converted to a letter grade: A (3.5 and above), B (2.5 to 3.4), C (1.75 to 2.4), D (0.5 to 1.74), and F (0-0.5).

Registration Deadlines

February 2nd Last day to add or drop classes without approval

February 9th Deadline to add a course

April 17th Withdrawal deadline