Course code	Course Name	L-T-P Credits	Year of Introduction
CS469	**COMPUTATIONAL COMPLEXITY**	**3-0-0-3**	**2016**

Course Objectives:

- To introduce the fundamentals of computational complexity theory.
- To discuss basic concepts such as computational models, computational complexity measures (e.g., time and space complexity measures), complexity classes, reducibility and completeness notions.
- To familiarize the concepts of randomized and approximation algorithms and discuss the related complexity classes.

Syllabus:

Turing machines, decision problems, time and space complexity, polynomial time algorithms, NP and NP-completeness, standard time and space complexity classes, optimization problems and approximation algorithms, randomized algorithms and complexity classes based on randomized machine models, interactive proofs and their relation to approximation.

Expected Outcome

The Students will be able to :

i. determine whether a problem is computable, and prove that some problems are not computable
ii. categorize problems into appropriate complexity classes
iii. classify problems based on their computational complexity using reductions
iv. analyse optimization problems using the concept of interactive proofs
v. classify optimization problems into appropriate approximation complexity classes

Text Books:

1. Michael Sipser, Introduction to the Theory of Computation, (First edition - PWS Publishing Company, January 1997, or second edition - Thomson Course Technology, 2005).
2. Sanjeev Arora and Boaz Barak, Computational Complexity: A Modern Approach, Cambridge University Press,2009

References:

1. Christos H Papadimitriou, Computational Complexity, Addison-Wesley, 1994.
2. M R Garey and D S Johnson, Computers and Intractability: A Guide to the Theory of NP-Completeness, Freeman, 1979.
3. Oded Goldreich, Computational Complexity, Cambridge University press, 2008.
4. Vijay Vazirani, Approximation Algorithms, Springer--Verlag, 2001

Course Plan

Module	Contents	Hours	End Sem. Exam Marks %
I	**Introduction:** Easy and hard problems. Algorithms and complexity. **Turing machines:** Models of computation. Multi-tape deterministic and non-deterministic Turing machines. Decision problems	**5**	**15%**

II	**The Halting Problem and Undecidable Languages:** Counting and diagonalization. Tape reduction. Universal Turing machine. Undecidability of halting. Reductions. Rice's theorem. **Deterministic Complexity Classes:** DTIME[t]. Linear Speed-up Theorem. P Time. Polynomial reducibility. Polytime algorithms: 2-satisfiability, 2-colourability.	**8**	**15%**
	FIRST INTERNAL EXAM		
III	**NP and NP-completeness:** Non-deterministic Turing machines. NTIME[t]. NP. Polynomial time verification. NP-completeness. Cook-Levin Theorem. Polynomial transformations: 3-satisfiability, clique, colourability, Hamilton cycle, partition problems. Pseudo-polynomial time. Strong NP-completeness. Knapsack. NP-hardness.	**8**	**15%**
IV	**Space complexity and hierarchy theorems:** DSPACE[s]. Linear Space Compression Theorem. PSPACE, NPSPACE. PSPACE = NPSPACE. PSPACE-completeness. Quantified Boolean Formula problem is PSPACE-complete. L, NL and NL-completeness. NL=coNL. Hierarchy theorems.	**8**	**15%**
	SECOND INTERNAL EXAM		
V	**Randomized Complexity:** The classes BPP, RP, ZPP. Interactive proof systems: IP = PSPACE.	**6**	**20%**
VI	**Optimization and approximation:** Combinatorial optimization problems. Relative error. Bin-packing problem. Polynomial and fully polynomial approximation schemes. Vertex cover, traveling salesman problem, minimum partition.	**7**	**20%**
	END SEMESTER EXAM		

Question Paper Pattern (End semester exam)

1. There will be ***FOUR*** parts in the question paper – **A, B, C, D**
2. **Part A**
   a. **Total marks : 40**
   b. ***TEN*** questions, each have **4 marks**, covering **all the SIX modules** (***THREE*** questions from **modules I & II**; ***THREE*** questions from **modules III & IV**; ***FOUR*** questions from **modules V & VI**).
   All the TEN questions have to be answered.
3. **Part B**
   a. **Total marks : 18**
   b. ***THREE*** questions, each having **9 marks**. One question is from **module I**; one question is from **module II**; one question ***uniformly*** covers **modules I & II**.
   c. ***Any TWO*** questions have to be answered.
   d. Each question can have ***maximum THREE*** subparts.
4. **Part C**
   a. **Total marks : 18**

   b. ***THREE*** questions, each having **9 marks**. One question is from **module III**; one question is from **module IV**; one question ***uniformly*** covers **modules III & IV**.
   c. ***Any TWO*** questions have to be answered.
   d. Each question can have ***maximum THREE*** subparts.
5. **Part D**
   a. **Total marks : 24**
   b. ***THREE*** questions, each having **12 marks**. One question is from **module V**; one question is from **module VI**; one question ***uniformly*** covers **modules V & VI**.
   c. ***Any TWO*** questions have to be answered.
   d. Each question can have ***maximum THREE*** subparts.
6. There will be ***AT LEAST* 60%** analytical/numerical questions in all possible combinations of question choices.