Curriculum of

Artificial Intelligence
Data Science and
Cyber Security

BS Programs

March, 2020

National Computing Education Accreditation Council

Islamabad

NCEAC SECRETARIAT

Dr Mohammad Ayub Alvi	Chairman, NCEAC
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LIST OF PROGRAMS

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PREFACE

Curriculum, with varying definitions, is a plan of the teaching-learning process, that students of an academic program are required to undergo to achieve specific objectives. It includes a scheme of studies, objectives & learning outcomes, course contents, teaching methodologies and assessment/ evaluation. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

NCEAC undertook the development and revision of curricula through its NCEAC Curriculum Revision Committee (NCEAC-CRC) which consisted of eminent professors and researchers of relevant fields from public and private sector universities and professionals from the industry.

In order to impart quality education, meet local needs and international standards, NCEAC-CRC has developed unified framework/templates as guidelines for the development and revision of curricula in the Computing discipline. It includes both existing domains and the emerging domains.

In 2017, the HEC-NCRC prepared curriculum for following computing degree programs.

1. BS (Computer Science)
2. BS (Software Engineering)
3. BS (Information Technology)

In view of the changing world of computing, in 2020 NCEAC-CRC developed curriculum for following additional programs.

1. BS (Artificial Intelligence)
2. BS (Data Science)
3. BS (Cyber Security)

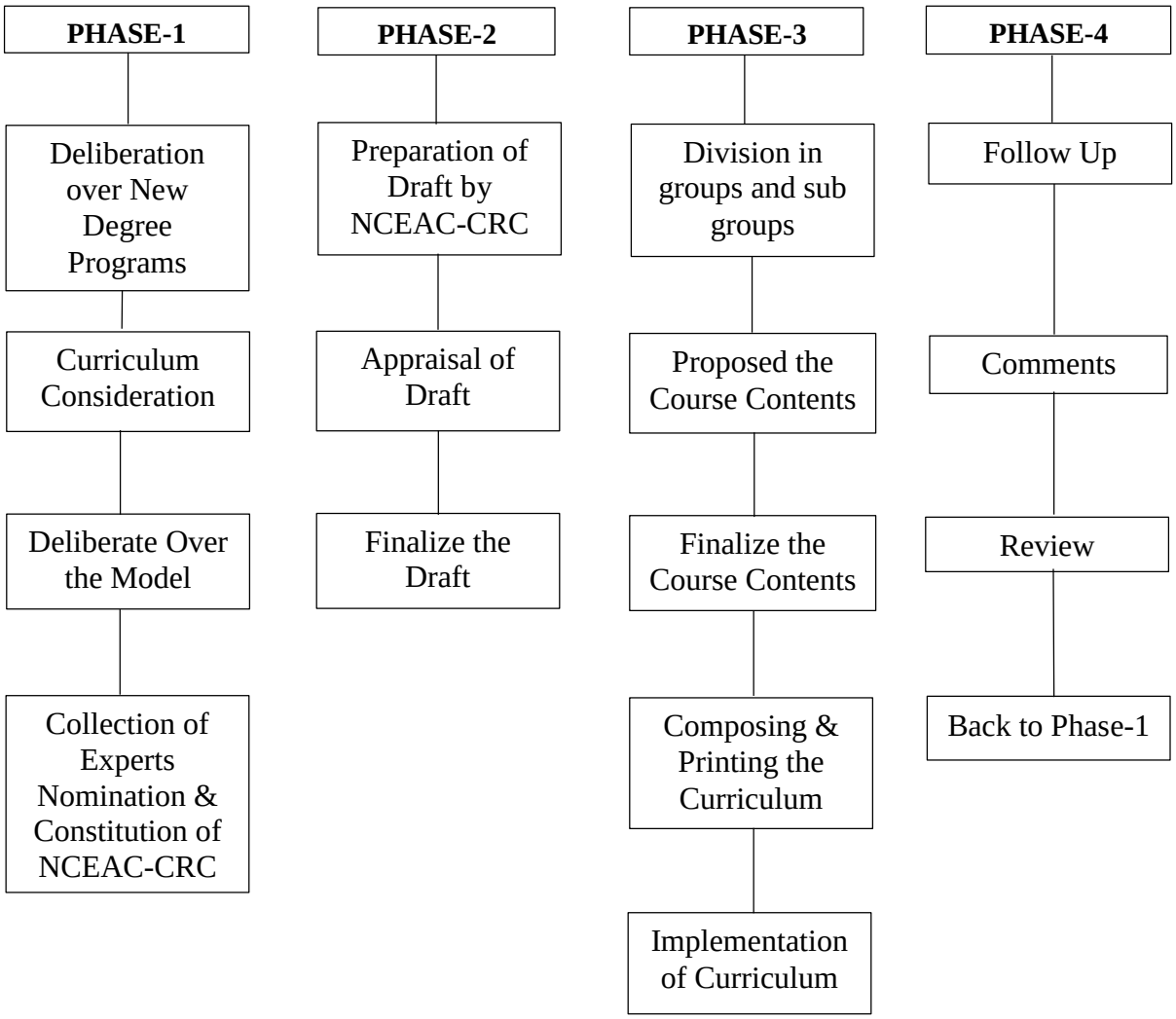
The universities may like to offer these as separate degree programs, or as specialization/major under a generic BS (Computer Science) program.

It is hoped that this curriculum document, prepared by NCEAC-CRC, would serve the purpose of meeting our national, social and economic needs, and it would also make it compatible with international educational standards. The curriculum is also placed on the NCEAC website. https://nceac.org.pk/curriculum

Dr Mohammad Ayub Alvi
Chairman, NCEAC

March, 2020

CURRICULUM DEVELOPMENT PROCESS



Minutes of Final Meeting

The sixth and final meeting of the NCEAC - Curriculum Revision Committee for computing programs was held on February 21, 2020 at 10:00 AM in LI Hall, HEC, H-8/1, Islamabad. Aims and objectives of this meeting were to discuss and finalize the draft of bachelor degree curriculum in Artificial Intelligence, Data Science & Cyber Security. Also, to make the curriculum compatible with international standards, satisfying indigenous demands as well as ensuring uniformity of academic standards within the country.

Following honorable members took part in development of the curricula of Computing Programs.

Chairman, NCEAC

Dr Mohammad Ayub Alvi
Chairman, National Computing Education Accreditation Council (NCEAC),
Rector, NUCES-FAST

Convener, NCEAC-CRC

Dr Muhammad Jamil Sawar
Director, BIIT, PAMS Arid Agriculture University, Rawalpindi

Vice Chairman, NCEAC

Dr Shoab Ahmad Khan
HoD (C&SE), EME, NUST, Rawalpindi

Academia Members (in alphabetical order)

1. Dr Ali Hassan, NUST, Islamabad
2. Dr Hammad Naveed, NUCES-FAST, Islamabad
3. Dr Jamil Ahmed, Vice Chancellor KUST, Kohat
4. Dr Kashif Kifayat, Air University, Islamabad
5. Dr Kifayat, NUCES-FAST, Islamabad
6. Dr Manzoor Ilahi Tamimy, COMSATS, Islamabad
7. Dr Mumraiz Kasi, BUITMS, Quetta
8. Dr Mirza Omer Beg, NUCES-FAST, Islamabad
9. Dr Muhammad Asim, NUCES-FAST, Islamabad
10. Mr Muhmmad Babar, KPK IT Board
11. Dr Muhammad Shahbaz, UET, Lahore
12. Dr Onaiza Maqbool, Quaid-e-Azam University, Islamabad
13. Dr Rafi-ud-din, KPK IT Board
14. Dr Raja Hashim Ali, GIKI, Swabi
15. Dr Sajid Anwar, GIKI, Swabi
16. Dr Sajjad Haider, IBA, Karachi
17. Dr Sohail Asghar, COMSATS, Islamabad
18. Dr Umer Farooq, NUST, Islamabad
19. Dr Zahid Halim, GIKI, Swabi

Industry Members (in alphabetical order)

20. Dr Affan Syed, Senior Constultant Emumba
21. Mr Barkan Saeed, Founder & CEO, Vizteck Solutions
22. Mr Mahir Mohsin Sheikh, Trilluim Information Security System
23. Mr Tayyab Tariq, Red Buffer
24. Mr Wahid Khan, President, Zigron Pakistan Pvt. Ltd.

Members of the NCEAC-CRC unanimously agreed to continue the meeting with Dr Mohammad Ayub Alvi, Dr Muhammad Jamil Sawar and Dr Shoab Ahmad Khan, as Chairman NCEAC, Convener NCEAC-CRC and Vice Chairman NCEAC, respectively.

During the Preliminary meeting on October 18, 2019 at 10:00 AM in LI Hall, HEC, H-8/1 Islamabad, the house was divided in two groups for recommending BS (AI), BS (DS) and BS (CySec) curriculum. The two groups were further subdivided into sub-groups for developing course descriptions, CLOs, objectives, pre-requisite etc. of their respective domains. The groups and sub-groups, led by a Group Convener and Associates/Members are mentioned below:

Groups:

A. BS (Artificial Intelligence) & BS (Data Science) Group

Group Convener: Dr Muhammad Jamil Sawar (BIIT, Rawalpindi)
Associates: Dr Shoab A Khan (Vice Chairman, NCEAC)
Dr Sajjad Haider (IBA, Karachi)
Dr Muhammad Shahbaz (UET, Lahore)
Dr Manzoor Ilahi Tamimy (COMSATS, Islamabad)
Dr Sohail Asghar (COMSATS, Islamabad)
Dr Onaiza Maqbool (Quaid e Azam University, Islamabad
Dr Affan Syed (Software Industry)
Mr Tayyab Tariq (Software Industry)

B. BS (Cyber Security) Group

Group Convener: Dr Shoab A Khan (Vice Chairman, NCEAC)
Associates: Dr Muhammad Jamil Sawar (Director MTBC, Rawalpindi)
Mr Barkan Saeed (Software Industry)
Dr Kashif Kifayat (Air University, Islamabad)
Dr Rafi-ud-din (KPK IT Board)

Sub Groups:

BS (Artificial Intelligence)

a. Artificial Intelligence

i. **Dr Jamil Sawar (BIIT)**
ii. Dr Shahbaz (UET)
iii. Dr Sajid (GIKI)

b. Machine Learning

i. **Dr Sohail (COMSATS**)
ii. Dr Onaiza (QAU)
iii. Dr Ali Hasan (CEME)
iv. Dr Manzoor (COMSATS)

c. **Knowledge Representation**
    i. **Dr Sajjid (IBA)**
    ii. Dr Jamil Sawar (BIIT)
    iii. Dr Hashim (GIKI)
d. **Artificial Neural Networks**
    i. **Mr Tayyab (Industry)**
    ii. Dr Onaiza (QAU)
    iii. Dr Sajid (GIKI)
    iv. Dr Shahbaz (UET)
    v. Dr Ali Hasan (CEME)
e. **Natural Language Programming**
    i. **Dr Hammad (FAST)**
    ii. Dr Sajjid (IBA)
    iii. Mr Tayyab (Software Industry)
f. **Computer Vision**
    i. **Dr Ali Hasan (CEME)**
    ii. Mr Tayyab (Industry)
    iii. Dr Hammad (FAST)
g. **Programming for AI**
    i. **Dr Hashim (GIKI)**
    ii. Dr Jamil Sawar (BIIT)
    iii. Dr Affan (Software Industry)
    iv. Mr Barkan (Software Industry)

BS (Data Science)

a. **Introduction to Data Science**
    i. **Dr Sohail (COMSATS)**
    ii. Dr Manzoor (COMSATS)
    iii. Dr Hammad (FAST)
b. **Data Warehouse & Big Data Analytics**
    i. **Dr Affan (Software Industry)**
    ii. Dr Onaiza (QAU)
    iii. Dr Manzoor (COMSATS)
c. **Business Process Analysis**
    i. **Dr Shoab (CEME)**
    ii. Mr Tayyab (Software Industry)
    iii. Mr Barkan Khan (Software Industry)
    iv. Dr Affan (Software Industry)
d. **Data Mining**
    i. **Dr Shahbaz (UET)**
    ii. Dr Sohail (COMSATS)
    iii. Dr Manzoor (COMSATS)
    iv. Dr Sajjid (IBA)
e. **Distributed Computing**
    i. **Dr Affan (Software Industry)**
    ii. Dr Hashim (GIK**)**
    iii. Dr Sajid (GIK)

f. Advance Database Systems

i. **Mr Barkan Khan (Software Industry)**
ii. Dr Affan (Software Industry)
iii. Dr Jamil (BIIT)

BS (Cyber Security)

i. **Dr Shoab A Khan**
ii. Dr Kashif Kifayat
iii. Dr Asim

The Committee during its meetings, considered inputs given by its members, and incorporated their suggestions in the curriculum document as deemed necessary. After thorough deliberations, the committee achieved the following objectives:-

a. Finalized the revision process of the draft curriculum in the discipline of Artificial Intelligence, Cyber Security and Data Science in order to bring it at par with international standards.
b. Developed objectives / learning outcomes, list of contents and pre-requisites to align with undergraduate programs.
c. Made recommendations for promotion/development of the discipline, keeping in view the futuristic needs of the society.

The Chairman, Convener and Vice Chairman thanked the NCEAC-CRC members (Academia and Software Industry) for their inputs in finalizing the draft curriculum of BS in Artificial Intelligence, Data Science and Cyber Security by keeping in view the requirements of the country and to make it more practical, competitive and effective.

The committee highly appreciated the hospitality shown by officials of NCEAC Secretariat and HEC Islamabad for making proper arrangements and facilitation. Committee members appreciated the kind patronage of Dr Mohammad Ayub Alvi, **Chairman NCEAC**, Dr Muhammad Jamil Sawar, **Convener NCEAC-CRC** and Dr Shoab Ahmad Khan, **Vice Chairman NCEAC** during the proceedings of the NCEAC-CRC meeting.

Curricula Consideration

Association of Computing Machinery (ACM), USA is the largest body in the world for computer scientists. Its membership is spread over the entire globe. It has a pool of highly reputed professionals which meet after a few years to assess the directions taken by the computing discipline. In view of its assessment, it identifies knowledge areas and also their relative importance in the years to come. Thus, ACM shows the path to the computing academia and professionals all over the world.

The committee kept the latest approved ACM recommendations in view, which are for Computer Science (2013) and Cyber Security (2017). Another consideration was to aim for a curriculum, which meets the current market requirements. The committee also agreed on common eligibility criteria for admission for all Bachelor degree programs in Computing.

Bachelor Degrees in Computing Programs

Curriculum for Bachelor Degrees in Computing

Introduction

The objective of the bachelor degrees in computing program is to produce well-rounded graduates, having a strong foundation in theoretical concepts and skills to design and implement complex software using multiple programming technologies under different operating systems and backend technologies. Also, strong academic preparation to pursue careers in local and international IT industry where they can communicate effectively and to continue seeking education through formal or informal methods.

Bachelor Degree Programs in Computing

Bachelor of Science in Artificial Intelligence	BS (AI)
Bachelor of Science in Data Science	BS (DS)
Bachelor of Science in Cyber Security	BS (CySec)

Eligibility Criteria

The minimum requirements for admission in a bachelor degree program in any computing program is any of following:

a) **At least 50% marks in Intermediate (HSSC) examination with Mathematics or equivalent qualification with Mathematics, certified by IBCC.**

OR

b) **At least 50% marks in Intermediate (HSSC) examination with Pre-Medical or equivalent qualification, certified by IBCC.**
Deficiency:
"Students with pre-medical, must have to pass deficiency courses of Mathematics of 6 credit hours in first two semesters."

Duration

The **minimum duration** for completion of BS degree is four years. The HEC allows a **maximum period of seven years** to complete BS degree requirements.

Degree Completion Requirements

To become eligible for award of BS degree, a student must satisfy the following requirements:

a) Must have studied and passed the **prescribed courses, totaling at least 130 credit hours**.
b) Must have earned **CGPA** (Cumulative Grade Point Average) **of at least 2.0 on a scale of 4.0**.

Program Learning Outcome (PLOs)

Computing programs prepare students to attain educational objectives by ensuring that students demonstrate achievement of the following outcomes (derived from Graduate Attributes define by Seoul Accord www.seoulaccord.org).

Program Learning Outcomes (PLOs)	Computing Professional Graduate Outcomes
1. Academic Education	To prepare graduates as computing professionals
2. Knowledge for Solving Computing Problems	Apply knowledge of computing fundamentals, knowledge of a computing specialization, and mathematics, science, and domain knowledge appropriate for the computing specialization to the 16 abstraction and conceptualization of computing models from defined problems and requirements
3. Problem Analysis	Identify, formulate, research literature, and solve complex computing problems reaching substantiated conclusions using fundamental principles of mathematics, computing sciences, and relevant domain disciplines
4. Design/ Development of Solutions	Design and evaluate solutions for complex computing problems, and design and evaluate systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations
5. Modern Tool Usage	Create, select, adapt and apply appropriate techniques, resources, and modern computing tools to complex computing activities, with an understanding of the limitations
6. Individual and Team Work	Function effectively as an individual and as a member or leader in diverse teams and in multi-disciplinary settings
7. Communication	Communicate effectively with the computing community and with society at large about complex computing activities by being able to comprehend and write effective reports, design documentation, make effective presentations, and give and understand clear instructions
8. Computing Professionalism and Society	Understand and assess societal, health, safety, legal, and cultural issues within local and global contexts, and the consequential responsibilities relevant to professional computing practice
9. Ethics	Understand and commit to professional ethics, responsibilities, and norms of professional computing practice
10. Life-long Learning	Recognize the need, and have the ability, to engage in independent learning for continual development as a computing professional

BS Curriculum Design

The combined structure of BS Programs in Computing is proposed to meet the needs of students through theory and practical computing experience. The students are expected to learn theoretical and practical understanding of the respective field of Computing.

The proposed structure is dynamic and provides basis for various options including Breadth-Based, Depth-Based, and Integrated Breadth & Depth Based specializations. Student may choose a particular option, which is most appropriate to their planned future career. The following are some relevant details:

- Minimum credit hours shall be 130 for BS (AI/DS/CySec) programs.
- Each program comprises eight semesters spread over four years.
- The following table gives the distribution of credit hours in different domains of knowledge.

Areas Covered in BS Programs

Common Courses for AI/ DS/ CySec

Course Group	Credit Hours	Number of Courses
General Education	19	7
University Electives	12	4
Mathematics & Science Foundation	12	4
Computing Core	39	11
Computer Science Core	18	5
Common Courses	**100**	**31**

Domain Courses for AI/ DS /CySec

Course Group	Credit Hours	Number of Courses
Domain Core (AI/DS/CySec)	18	6
Domain Electives (AI/DS/CySec)	12	4
Domain Courses	**30**	**10**
TOTAL	**130**	**41**

General Education Courses

Course Title	Credit Hours	Contact Hours
Introduction to Info. & Comm. Technologies	3 (2-1)	2-3
English Composition & Comprehension	3 (3-0)	3-0
Communication & Presentation Skills	3 (3-0)	3-0
Technical & Business Writing	3 (3-0)	3-0
Islamic Studies/ Ethics	2 (2-0)	2-0
Pakistan Studies	2 (2-0)	2-0
Professional Practices	3 (3-0)	3-0
TOTAL	**19 (18-1)**	**18-3**

University Elective Courses

(Not limited to the areas listed below, Institutions may add/replace courses)

Course Title	Credit Hours	Contact Hours
Foreign Language	2 (2-0)	2-0
Social Service	1 (1-0)	1-0
Management Related	3 (3-0)	3-0
Social Science Related	3 (3-0)	3-0
Economy Related	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Mathematics and Science Foundation Courses

Course Title	Credit Hours	Contact Hours
Calculus & Analytical Geometry	3 (3-0)	3-0
Linear Algebra	3 (3-0)	3-0
Probability & Statistics	3 (3-0)	3-0
Differential Equations	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Computing Core Courses

Course Title	Credit Hours	Contact Hours
Programming Fundamentals	4 (3-1)	3-3
Discrete Structures	3 (3-0)	3-0
Object Oriented Programming	4 (3-1)	3-3
Database Systems	4 (3-1)	3-3
Data Structures & Algorithms	4 (3-1)	3-3
Information Security	3 (3-0)	3-0
Computer Networks	4 (3-1)	3-3
Operating System	4 (3-1)	3-3
Software Engineering	3 (3-0)	3-0
Final Year Project - I	2 (0-2)	0-6
Final Year Project - II	4 (0-4)	0-12
TOTAL	**39 (27-12)**	**27-36**

Computer Science Core Courses

Course Title	Credit Hours	Contact Hours
Artificial Intelligence	4 (3-1)	3-3
Digital Logic Design	4 (3-1)	3-3
Analysis of Algorithms	3 (3-0)	3-0
Computer Organization & Assembly Language	4 (3-1)	3-3
Parallel & Distributed Computing	3 (2-1)	2-3
TOTAL	**18 (14-4)**	**14- 12**

BS (Artificial Intelligence)

BS (Artificial Intelligence)

Program Structure

The BS (AI) program gives the students an in-depth knowledge they need to transform large and complex scenarios into actionable decisions. The program and its curriculum focuses on how complex inputs — such as knowledge, vision, language and huge databases — can be used to make decisions to enhance human capabilities. The curriculum of the BS (AI) program includes coursework in computing, mathematics, automated reasoning, statistics, computational modeling, introduction to classical artificial intelligence languages and case studies, knowledge representation and reasoning, artificial neural networks, machine learning, natural language processing, vision and symbolic computation. The program also encourages students to take courses in ethics and social responsibility, with the opportunity to participate in long term projects in which artificial intelligence can be applied to solve problems that can change the world for the better — in areas like agriculture, defense, healthcare, governance, transportation, e-commerce, finance and education.

Proposed Curriculum for BS (AI)

Following are the proposed areas which are required to be covered to complete the degree. Covered areas consist of core courses (compulsory), foundation courses, general courses and electives.

Areas Covered in BS (AI)

Course Group	Credit Hour	Min No of Courses
General Education	19	7
University Electives	12	4
Mathematics & Science Foundation	12	4
Computing Core	39	11
Computer Science Core	18	5
AI Core (Domain Core)	18	6
AI Electives (Domain Electives)	12	4
TOTAL	**130**	**41**

General Education Courses

Course Title	Credit Hours	Contact Hours
Introduction to Info. & Comm. Technologies	3 (2-1)	2-3
English Composition & Comprehension	3 (3-0)	3-0
Communication & Presentation Skills	3 (3-0)	3-0
Technical & Business Writing	3 (3-0)	3-0
Islamic Studies/ Ethics	2 (2-0)	2-0
Pakistan Studies	2 (2-0)	2-0
Professional Practices	3 (3-0)	3-0
TOTAL	**19 (18-1)**	**18-3**

University Elective Courses

(Not limited to the areas listed below, Institutions may add/replace courses)

Course Title	Credit Hours	Contact Hours
Foreign Language	2 (2-0)	2-0
Social Service	1 (1-0)	1-0
Management Related	3 (3-0)	3-0
Social Science Related	3 (3-0)	3-0
Economy Related	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Mathematics and Science Foundation Courses

Course Title	Credit Hours	Contact Hours
Calculus & Analytic Geometry	3 (3-0)	3-0
Linear Algebra	3 (3-0)	3-0
Probability & Statistics	3 (3-0)	3-0
Differential Equations	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Computing Core Courses

Course Title	Credit Hours	Contact Hours
Programming Fundamentals	4 (3-1)	3-3
Discrete Structures	3 (3-0)	3-0
Object Oriented Programming	4 (3-1)	3-3
Database Systems	4 (3-1)	3-3
Data Structures & Algorithms	4 (3-1)	3-3
Information Security	3 (3-0)	3-0
Computer Networks	4 (3-1)	3-3
Operating System	4 (3-1)	3-3
Software Engineering	3 (3-0)	3-0
Final Year Project - I	2 (0-2)	0-6
Final Year Project - II	4 (0-4)	0-12
TOTAL	**39 (27-12)**	**27-36**

Computer Science Core Courses

Course Title	Credit Hours	Contact Hours
Artificial Intelligence	4 (3-1)	3-3
Digital Logic Design	4 (3-1)	3-3
Analysis of Algorithms	3 (3-0)	3-0
Computer Organization & Assembly Language	4 (3-1)	3-3
Parallel & Distributed Computing	3 (2-1)	2-3
TOTAL	**18 (14-4)**	**14- 12**

Artificial Intelligence Core Courses

Course Title	Credit Hours	Contact Hours
Programming for Artificial Intelligence	3 (2-1)	2-3
Machine Learning	3 (2-1)	2-3
Artificial Neural Networks	3 (2-1)	2-3
Knowledge Representation & Reasoning	3 (3-0)	3-0
Computing Vision	3 (2-1)	2-3
Natural Language Processing	3 (3-0)	3-0
TOTAL	**18 (14-4)**	**14-12**

Artificial Intelligence Elective Courses

(Must be any four courses or 12 credit hours, universities may add lab hours to elective courses, where labs are not mentioned)

Course Title	Credit Hours	Contact Hours
Advance Statistics	3 (3-0)	3-0
Theory of Automata & Formal Languages	3 (3-0)	3-0
Data Mining	3 (2-1)	2-3
Deep Learning	3 (3-0)	3-0
Speech Processing	3 (3-0)	3-0
Reinforcements Learning	3 (3-0)	3-0
Fuzzy Systems	3 (3-0)	3-0
Evolutionary Computing	3 (3-0)	3-0
Swarm Intelligence	3 (3-0)	3-0
Agent Based Modeling	3 (3-0)	3-0
Knowledge Based Systems	3 (3-0)	3-0
TOTAL (Any four courses or 12 credit hours)	**12 (11-1)**	**11-3**

Proposed Study Plan BS (Artificial Intelligence)

4-Year Program (8 Regular Semester of 18 weeks each) (130 Credit Hours)

Semester - I

Course Title	Cr hr	Cont hr	Pre-requisite
Introduction to ICT	3 (2-1)	2-3	
Programming Fundamentals	4 (3-1)	3-3	
Discrete Structures	3 (3-0)	3-0	
Calculus & Analytic Geometry	3 (3-0)	3-0	
English Composition & Comprehension	3 (3-0)	3-0	
Total	**16 (14-2)**	**14-6**	

Semester - II

Course Title	Cr hr	Cont hr	Pre-requisite
Object Oriented Programming	4 (3-1)	3-3	Prog Fundamentals
Database Systems	4 (3-1)	3-3	
Linear Algebra	3 (3-0)	3-0	Cal. & Anal. Geometry
Probability & Statistics	3 (3-0)	3-0	
Communication & Presentation Skills	3 (3-0)	3-0	Eng Comp & Compre
Total	**17 (15-2)**	**15-6**	

Semester - III

Course Title	Cr hr	Cont hr	Pre-requisite
Data Structures & Algorithms	4 (3-1)	3-3	Prog. Fundamentals
Information Security	3 (3-0)	3-0	
Artificial Intelligence	4 (3-1)	3-3	Object Oriented Prog
Digital Logic Design	4 (3-1)	3-3	
Differential Equations	3 (3-0)	3-0	Cal. & Anal. Geometry
Total	**18 (15-3)**	**15-9**	

Semester - IV

Course Title	Cr hr	Cont hr	Pre-requisite
Computer Networks	4 (3-1)	3-3	
Computer Org. & Assembly Language	4 (3-1)	3-3	Digital Logic Design
Analysis of Algorithms	3 (3-0)	3-0	Data Structures & Algo
Programming for Artificial Intelligence	3 (2-1)	2-3	Artificial Intelligence
AI Elective-1	3 (3-0)	3-0	
Total	**17 (14-3)**	**14-9**	

Semester - V

Course Title	Cr hr	Cont hr	Pre-requisite
Operating System	4 (3-1)	3-3	Data Structures & Algo
Artificial Neural Networks	3 (2-1)	2-3	Programming for AI
Machine Learning	3 (2-1)	2-3	Programming for AI
Knowledge Representation & Reasoning	3 (3-0)	3-0	Programming for AI
AI Elective-2	3 (3-0)	3-0	
University Elective-1	3 (3-0)	3-0	
Total	**19 (16-3)**	**16-9**	

Semester - VI

Course Title	Cr hr	Cont hr	Pre-requisite
Parallel & Distributed Computing	3 (2-1)	2-3	OOP, Operating Sys
Computing Vision	3 (2-1)	2-3	Artificial Neural Net
Natural Language Processing	3 (3-0)	3-0	Artificial Neural Net
AI Elective-3	3 (2-1)	2-3	
AI Elective-4	3 (3-0)	3-0	
University Elective-2	3 (3-0)	3-0	
Total	**18 (15-3)**	**15-9**	

Semester - VII

Course Title	Cr hr	Cont hr	Pre-requisite
Final Year Project - I	2 (0-2)	0-6	
Software Engineering	3 (3-0)	3-0	
University Elective-3	3 (3-0)	3-0	
Technical & Business Writing	3 (3-0)	3-0	Comm. & Present. Skills
Islamic Studies/ Ethics	2 (2-0)	2-0	
Total	**13 (11-2)**	**11-6**	

Semester - VIII

Course Title	Cr hr	Cont hr	Pre-requisite
Final Year Project - II	4 (0-4)	0-12	Final Year Project - I
University Elective-4	3 (3-0)	3-0	
Professional Practices	3 (3-0)	3-0	
Pakistan Studies	2 (2-0)	2-0	
Total	**12 (8-4)**	**8-12**	

BS (Data Science)

BS (Data Science)

Program Structure

BS (Data Science) has a dual emphasis on basic principles of statistics and computer science, with foundational training in statistical and mathematical aspects of data analysis. This program develops foundation on broad computer science principles, including algorithms, data structures, data management and machine learning. This program will prepare graduates for a career in data analysis, combining foundational statistical concepts with computational principles from computer science.

Proposed Curriculum for BS (Data Science)

Following are the proposed areas which are required to cover to complete the degree. Covered areas consist of core courses (compulsory), foundation courses, general courses and electives.

Areas Covered in BS (DS)

Course Group	Credit Hour	Min No of Courses
General Education	19	7
University Electives	12	4
Mathematics & Science Foundation	12	4
Computing Core	39	11
Computer Science Core	18	5
DS Core (Domain Core)	18	6
DS Electives (Domain Electives)	12	4
TOTAL	**130**	**41**

General Education Courses

Course Title	Credit Hours	Contact Hours
Introduction to Info. & Comm. Technologies	3 (2-1)	2-3
English Composition & Comprehension	3 (3-0)	3-0
Communication & Presentation Skills	3 (3-0)	3-0
Technical & Business Writing	3 (3-0)	3-0
Islamic Studies/ Ethics	2 (2-0)	2-0
Pakistan Studies	2 (2-0)	2-0
Professional Practices	3 (3-0)	3-0
TOTAL	**19 (18-1)**	**18-3**

University Elective Courses

(Not limited to the areas listed below, Institutions may add/replace courses)

Course Title	Credit Hours	Contact Hours
Foreign Language	2 (2-0)	2-0
Social Service	1 (1-0)	1-0
Management Related	3 (3-0)	3-0
Social Science Related	3 (3-0)	3-0
Economy Related	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Mathematics and Science Foundation Courses

Course Title	Credit Hours	Contact Hours
Calculus & Analytic Geometry	3 (3-0)	3-0
Linear Algebra	3 (3-0)	3-0
Probability & Statistics	3 (3-0)	3-0
Differential Equations	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Computing Core Courses

Course Title	Credit Hours	Contact Hours
Programming Fundamentals	4 (3-1)	3-3
Discrete Structures	3 (3-0)	3-0
Object Oriented Programming	4 (3-1)	3-3
Database Systems	4 (3-1)	3-3
Data Structures & Algorithms	4 (3-1)	3-3
Information Security	3 (3-0)	3-0
Computer Networks	4 (3-1)	3-3
Operating System	4 (3-1)	3-3
Software Engineering	3 (3-0)	3-0
Final Year Project - I	2 (0-2)	0-6
Final Year Project - II	4 (0-4)	0-12
TOTAL	**39 (27-12)**	**27-36**

Computer Science Core Courses

Course Title	Credit Hours	Contact Hours
Artificial Intelligence	4 (3-1)	3-3
Digital Logic Design	4 (3-1)	3-3
Analysis of Algorithms	3 (3-0)	3-0
Computer Organization & Assembly Language	4 (3-1)	3-3
Parallel & Distributed Computing	3 (2-1)	2-3
TOTAL	**18 (14-4)**	**14- 12**

Data Science Core Courses

Course Title	Credit Hours	Contact Hours
Advance Statistics	3 (3-0)	3-0
Introduction to Data Science	3 (2-1)	2-3
Data Mining	3 (2-1)	2-3
Data Visualization	3 (2-1)	2-3
Data Warehousing & Business Intelligence	3 (2-1)	2-3
Big Data Analytics	3 (2-1)	2-3
TOTAL	**18 (13-5)**	**13-15**

Data Science Elective Courses

(Must be any four courses or 12 credit hours, universities may add lab hours to elective courses, where labs are not mentioned)

Course Title	Credit Hours	Contact Hours
Advance Database Management Systems	3 (3-0)	3-0
Machine Learning	3 (2-1)	2-3
Deep Learning	3 (3-0)	3-0
Theory of Automata & Formal Languages	3 (3-0)	3-0
Artificial Neural Networks	3 (2-1)	2-3
Business Process Analysis	3 (3-0)	3-0
Platform & Architecture for Data Science	3 (3-0)	3-0
Privacy Preservation	3 (3-0)	3-0
Speech Processing	3 (3-0)	3-0
Cloud Computing	3 (3-0)	3-0
Agent Based Modeling	3 (3-0)	3-0
Text Mining	3 (3-0)	3-0
Topics in Data Science	3 (3-0)	3-0
TOTAL (Any four courses or 12 credit hours)	**12 (11-1)**	**11-3**

Proposed Study Plan BS (Data Science)

4-Year Program (8 Regular Semester of 18 weeks each) (130 Credit Hours)

Semester - I

Course Title	Cr hr	Cont hr	Pre-requisite
Introduction to ICT	3 (2-1)	2-3	
Programming Fundamentals	4 (3-1)	3-3	
Discrete Structures	3 (3-0)	3-0	
Calculus & Analytic Geometry	3 (3-0)	3-0	
English Composition & Comprehension	3 (3-0)	3-0	
Total	**16 (14-2)**	**14-6**	

Semester - II

Course Title	Cr hr	Cont hr	Pre-requisite
Object Oriented Programming	4 (3-1)	3-3	Prog Fundamentals
Database Systems	4 (3-1)	3-3	
Linear Algebra	3 (3-0)	3-0	Cal. & Anal. Geometry
Probability & Statistics	3 (3-0)	3-0	
Communication & Presentation Skills	3 (3-0)	3-0	Eng Comp & Compre
Total	**17 (15-2)**	**15-6**	

Semester - III

Course Title	Cr hr	Cont hr	Pre-requisite
Data Structures & Algorithms	4 (3-1)	3-3	Prog Fundamentals
Information Security	3 (3-0)	3-0	
Artificial Intelligence	4 (3-1)	3-3	Object Oriented Prog.
Digital Logic Design	4 (3-1)	3-3	
Differential Equations	3 (3-0)	3-0	Cal. & Anal. Geometry
Total	**18 (15-3)**	**15-9**	

Semester – IV

Course Title	Cr hr	Cont hr	Pre-requisite
Computer Networks	4 (3-1)	3-3	
Computer Org. & Assembly Language	4 (3-1)	3-3	Digital Logic Design
Analysis of Algorithms	3 (3-0)	3-0	Data Structures & Algo
Introduction to Data Science	3 (2-1)	2-3	Artificial Intelligence
Advance Statistics	3 (3-0)	3-0	Probability & Statistics
Total	**17 (14-3)**	**14-9**	

Semester - V

Course Title	Cr hr	Cont hr	Pre-requisite
Operating System	4 (3-1)	3-3	Data Structures & Algo
Data Mining	3 (2-1)	2-3	Adv Stat, Intro. to DS
Data Warehousing & Business Intel.	3 (2-1)	2-3	Intro. to Data Science
DS Electiv-1	3 (3-0)	3-0	
DS Elective-2	3 (2-1)	2-3	
University Elective-1	3 (3-0)	3-0	
Total	**19 (15-4)**	**15-12**	

Semester - VI

Course Title	Cr hr	Cont hr	Pre-requisite
Parallel & Distributed Computing	3 (2-1)	2-3	OOP, Operating Sys
Big Data Analytics	3 (2-1)	2-3	Intro. to Data Science
Data Visualization	3 (2-1)	2-3	Data Warehouse & BI
DS Elective-3	3 (3-0)	3-0	
DS Elective-4	3 (3-0)	3-0	
University Elective-2	3 (3-0)	3-0	
Total	**18 (15-3)**	**15-9**	

Semester - VII

Course Title	Cr hr	Cont hr	Pre-requisite
Final Year Project - I	2 (0-2)	0-6	
Software Engineering	3 (3-0)	3-0	
University Elective-3	3 (3-0)	3-0	
Technical & Business Writing	3 (3-0)	3-0	Comm. & Present Skills
Islamic Studies/ Ethics	2 (2-0)	2-0	
Total	**13 (11-2)**	**11-6**	

Semester - VIII

Course Title	Cr hr	Cont hr	Pre-requisite
Final Year Project - II	4 (0-4)	0-12	Final Year Project - I
University Elective-4	3 (3-0)	3-0	
Professional Practices	3 (3-0)	3-0	
Pakistan Studies	2 (2-0)	2-0	
Total	**12 (8-4)**	**8-12**	

BS (Cyber Security)

BS (Cyber Security)

Program Structure

The BS (CySec) program intended to produce skilled professionals to understand the processes that impact information security, safeguarding information assets, collection and preservation of digital evidences, analysis of data, and identification and fixing of security vulnerabilities. The program will equip students with the fundamental knowledge of computer science that forms the technical foundation of the field, with an essential focus on experiential learning through laboratory exercises in the security courses. This degree is a state-of-the-art course with a perfect blend of Cyber Security that is designed to set the graduates up for immediate industry success by combining and leveraging today's cutting-edge technology with real-world scenarios.

Proposed Curriculum for BS (Cyber Security)

Following are the proposed areas which are required to cover to complete the degree. Covered areas consist of core courses (compulsory), foundation courses, general courses and electives.

Areas Covered in BS (CySec)

Course Group	Credit Hour	Min No of Courses
General Education	19	7
University Electives	12	4
Mathematics & Science Foundation	12	4
Computing Core	39	11
Computer Science Core	18	5
CySec Core (Domain Core)	18	6
CySec Electives (Domain Electives)	12	4
TOTAL	**130**	**41**

General Education Courses

Course Title	Credit Hours	Contact Hours
Introduction to Info. & Comm. Technologies	3 (2-1)	2-3
English Composition & Comprehension	3 (3-0)	3-0
Communication & Presentation Skills	3 (3-0)	3-0
Technical & Business Writing	3 (3-0)	3-0
Islamic Studies/ Ethics	2 (2-0)	2-0
Pakistan Studies	2 (2-0)	2-0
Professional Practices	3 (3-0)	3-0
TOTAL	**19 (18-1)**	**18-3**

University Elective Courses

(Not limited to the areas listed below, Institutions may add/replace courses)

Course Title	Credit Hours	Contact Hours
Foreign Language	2 (2-0)	2-0
Social Service	1 (1-0)	1-0
Management Related	3 (3-0)	3-0
Social Science Related	3 (3-0)	3-0
Economy Related	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Mathematics and Science Foundation Courses

Course Title	Credit Hours	Contact Hours
Calculus & Analytic Geometry	3 (3-0)	3-0
Linear Algebra	3 (3-0)	3-0
Probability & Statistics	3 (3-0)	3-0
Differential Equations	3 (3-0)	3-0
TOTAL	**12 (12-0)**	**12-0**

Computing Core Courses

Course Title	Credit Hours	Contact Hours
Programming Fundamentals	4 (3-1)	3-3
Discrete Structures	3 (3-0)	3-0
Object Oriented Programming	4 (3-1)	3-3
Database Systems	4 (3-1)	3-3
Data Structures & Algorithms	4 (3-1)	3-3
Information Security	3 (3-0)	3-0
Computer Networks	4 (3-1)	3-3
Operating System	4 (3-1)	3-3
Software Engineering	3 (3-0)	3-0
Final Year Project - I	2 (0-2)	0-6
Final Year Project - II	4 (0-4)	0-12
TOTAL	**39 (27-12)**	**27-36**

Computer Science Core Courses

Course Title	Credit Hours	Contact Hours
Artificial Intelligence	4 (3-1)	3-3
Digital Logic Design	4 (3-1)	3-3
Analysis of Algorithms	3 (3-0)	3-0
Computer Organization & Assembly Language	4 (3-1)	3-3
Parallel & Distributed Computing	3 (2-1)	2-3
TOTAL	**18 (14-4)**	**14- 12**

Cyber Security Core Courses

Course Title	Credit Hours	Contact Hours
Introduction to Cyber Security	3 (3-0)	3-0
Digital Forensics	3 (2-1)	2-3
Information Assurance	3 (3-0)	3-0
Network Security	3 (2-1)	2-3
Secure Software Design and Development	3 (2-1)	2-3
Vulnerability Assessment & Reverse Engineering	3 (2-1)	2-3
TOTAL	**18(14-4)**	**(14-12)**

Cyber Security Elective Courses

(Must be any four courses or 12 credit hours, Universities may add lab hours to elective courses, where labs are not mentioned)

Course Title	Credit Hours	Contact Hours
Basic Electronics	3 (2-1)	2-3
Hardware Security	3 (3-0)	3-0
Malware Analysis	3 (3-0)	3-0
Wireless and Mobile Security	3 (3-0)	3-0
Penetration Testing	3 (2-1)	2-3
Computer Architecture	3 (3-0)	3-0
Advance Digital Logic Design	3 (3-0)	3-0
Cyber Law & Cyber Crime (Cyber Warfare)	3 (3-0)	3-0
Control System Security	3 (3-0)	3-0
Cryptanalysis	3 (3-0)	3-0
Embedded Systems	3 (2-1)	2-3
Embedded Systems Security	3 (2-1)	2-3
TOTAL (Any four courses or 12 credit hours)	**12 (11-1)**	**11-3**

Proposed Study Plan BS (Cyber Security)

4-Year Program (8 Regular Semester of 18 weeks each) (130 Credit Hours)

Semester - I

Course Title	Cr hr	Cont hr	Pre-requisite
Introduction to ICT	3 (2-1)	2-3	
Programming Fundamentals	4 (3-1)	3-3	
Discrete Structures	3 (3-0)	3-0	
Calculus & Analytic Geometry	3 (3-0)	3-0	
English Composition & Comprehension	3 (3-0)	3-0	
Total	**16 (14-2)**	**14-6**	

Semester - II

Course Title	Cr hr	Cont hr	Pre-requisite
Object Oriented Programming	4 (3-1)	3-3	Prog Fundamentals
Database Systems	4 (3-1)	3-3	
Linear Algebra	3 (3-0)	3-0	Cal. & Anal. Geometry
Probability & Statistics	3 (3-0)	3-0	
Communication & Presentation Skills	3 (3-0)	3-0	Eng Comp & Compre
Total	**17 (15-2)**	**15-6**	

Semester - III

Course Title	Cr hr	Cont hr	Pre-requisite
Data Structures & Algorithms	4 (3-1)	3-3	Prog Fundamentals
Information Security	3 (3-0)	3-0	
Artificial Intelligence	4 (3-1)	3-3	Object Oriented Prog.
Digital Logic Design	4 (3-1)	3-3	
Differential Equations	3 (3-0)	3-0	Eng Comp & Compre
Total	**18 (15-3)**	**15-9**	

Semester - IV

Course Title	Cr hr	Cont hr	Pre-requisite
Computer Networks	4 (3-1)	3-3	
Computer Org. & Assembly Language	4 (3-1)	3-3	Digital Logic Design
Analysis of Algorithms	3 (3-0)	3-0	Data Structures & Algo
Introduction to Cyber Security	3 (3-0)	3-0	Information Security
CySec Elective-1	3 (3-0)	3-0	
Total	**17 (14-3)**	**14-9**	

Semester - V

Course Title	Cr hr	Cont hr	Pre-requisite
Operating System	4 (3-1)	3-3	Data Structures & Algo
Digital Forensics	3 (2-1)	2-3	Intro. to Cyber Security
Information Assurance	3 (3-0)	3-0	
Network Security	3 (2-1)	2-3	Intro. to Cyber Security
CySec Elective-2	3 (3-0)	3-0	
University Elective-1	3 (3-0)	3-0	
Total	**19 (16-3)**	**16-9**	

Semester - VI

Course Title	Cr hr	Cont hr	Pre-requisite
Parallel & Distributed Computing	3 (2-1)	2-3	OOP, Operating Sys
Secure Software Design and Dev.	3 (2-1)	2-3	Intro. to Cyber Security
Vulnerability Assessment & Reverse Engg	3 (2-1)	2-3	Intro. to Cyber Security
CySec Elective-3	3 (3-0)	3-0	
CySec Elective-4	3 (3-0)	3-0	
University Elective-2	3 (3-0)	3-0	
Total	**18 (15-3)**	**15-9**	

Semester - VII

Course Title	Cr hr	Cont hr	Pre-requisite
Final Year Project - I	2 (0-2)	0-6	
Software Engineering	3 (3-0)	3-0	
University Elective-3	3 (3-0)	3-0	
Technical & Business Writing	3 (3-0)	3-0	Comm. & Present Skills
Islamic Studies/ Ethics	2 (2-0)	2-0	
Total	**13 (11-2)**	**11-6**	

Semester - VIII

Course Title	Cr hr	Cont hr	Pre-requisite
Final Year Project - II	4 (0-4)	0-12	Final Year Project - I
University Elective-4	3 (3-0)	3-0	
Professional Practices	3 (3-0)	3-0	
Pakistan Studies	2 (2-0)	2-0	
Total	**12 (8-4)**	**8-12**	

BS Courses Outline

BS Courses List

Courses Page

Data Science Core

Cyber Security Core

Artificial Intelligence Elective

Data Science Elective

BS Courses Contents

(Bloom's Taxonomy: C = Cognitive domain, P = Psychomotor domain, A = Affective domain)

General Education

Course Name: **Communication and Presentation Skills**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: English Composition & Comprehension

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Principles of writing good English, understanding the composition process: writing clearly; words, sentence and paragraphs; Comprehension and expression; Use of grammar and punctuation. Process of writing, observing, audience collecting, composing, drafting and revising, persuasive writing, reading skills, listening skills and comprehension, skills for taking notes in class, skills for exams; Business communications; planning messages, writing concise but with impact. Letter formats, mechanics of business, letter writing, letters, memo and applications, summaries, proposals, writing resumes, styles and formats, oral communications, verbal and non-verbal communication, conducting meetings, small group communication, taking minutes. Presentation skills; presentation strategies, defining the objective, scope and audience of the presentation, material gathering material organization strategies, time management, opening and concluding, use of audio-visual aids, delivery and presentation.

Reference Materials:

1. Practical Business English, Collen Vawdrey, 1993, ISBN = 0256192740
2. Effective Communication Skills: The Foundations for Change, John Nielsen, 2008, ISBN = 1453506748

Course Name: **English Composition & Comprehension**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Paragraph and Essay Writing, Descriptive Essays; Sentence Errors, Persuasive Writing; How to give presentations, Sentence Errors; Oral Presentations, Comparison and Contrast Essays, Dialogue Writing, Short Story Writing, Review Writing, Narrative Essays, Letter Writing

Reference Materials:

1. College Writing Skills with Readings, by John Langan, McGraw-Hill, 5th Edition.
2. A Textbook of English Prose and Structure by Arif Khattak, et al, GIKI Institute, 2000

Course Name:	**Introduction to Information and Communication Technologies**
Credit Hours:	2-1
Contact Hours:	2-3
Pre-requisites:	None

Course Introduction:

This is an introductory course in Computer Science designed for beginners. Apart from leading the participants through a whirlwind history of computing, the course also develops a feel for web programming through a series of lectures that help the students develop their own web page. Main objective of the course is to build an appreciation for the fundamental concepts in computing and to become familiar with popular PC productivity software.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand basics of computing technology	C1 (Knowledge)
CLO-2	Do number systems conversions and arithmetic	C2(Understand)
CLO-3	Have knowledge of types of software	C2(Understand)
CLO-4	Have knowledge of computing related technologies	C3 (Apply)

Course Outline:

Brief history of Computer, Four Stages of History, Computer Elements, Processor, Memory, Hardware, Software, Application Software its uses and Limitations, System Software its Importance and its Types, Types of Computer (Super, Mainframe, Mini and Micro Computer), Introduction to CBIS (Computer Based Information System), Methods of Input and Processing, Class2. Organizing Computer Facility, Centralized Computing Facility, Distributed Computing Facility, Decentralized Computing Facility, Input Devices. Keyboard and its Types, Terminal (Dump, Smart, Intelligent), Dedicated Data Entry, SDA (Source Data Automation), Pointing Devices, Voice Input, Output Devices. Soft- Hard Copies, Monitors and its Types, Printers and its Types, Plotters, Computer Virus and its Forms, Storage Units, Primary and Secondary Memories, RAM and its Types, Cache, Hard Disks, Working of Hard Disk, Diskettes, RAID, Optical Disk Storages (DVD, CD ROM), Magnetic Types, Backup System, Data Communications, Data Communication Model, Data Transmission, Digital and Analog Transmission, Modems, Asynchronous and Synchronous Transmission, Simplex. Half Duplex, Full Duplex Transmission, Communications, Medias (Cables, Wireless), Protocols, Network Topologies (Star, Bus, Ring), LAN, LAN, Internet, A Brief History, Birthplace of ARPA Net, Web Link, Browser, Internet Services provider and Online Services Providers, Function and Features of Browser, Search Engines, Some Common Services available on Internet.

Reference Materials:

1. Charles S. Parker, Understanding Computers: Today and Tomorrow, Course Technology, 25 Thomson Place, Boston, Massachusetts 02210, USA
2. Livesley, Robert Kenneth. An introduction to automatic digital computers. Cambridge University Press, 2017.
3. Zawacki-Richter, Olaf, and Colin Latchem. "Exploring four decades of research in Computers & Education." Computers & Education 122 (2018): 136-152.
4. Sinha, Pradeep K., and Priti Sinha. Computer fundamentals. BPB publications, 2010.
5. Goel, Anita. Computer fundamentals. Pearson Education India, 2010.

Course Name: **Islamic Studies**
Credit Hours: 2-0
Contact Hours: 2-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Basic Themes of Quran, Introduction to Sciences of Hadith, Introduction to Islamic Jurisprudence, Primary & Secondary Sources of Islamic Law, Makken & Madnian life of the Prophet, Islamic Economic System, Political theories, Social System of Islam

Reference Materials:

1. Introduction to Islam by Dr Hamidullah, Papular Library Publishers Lahore
2. Principles of Islamic Jurisprudence by Ahmad Hassan, Islamic Research Institute, IIUI
3. Muslim Jurisprudence and the Quranic Law of Crimes, By Mir Waliullah, Islamic Books Services

Course Name: **Pakistan Studies**
Credit Hours: 2-0
Contact Hours: 2-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Historical background of Pakistan: Muslim society in Indo-Pakistan, the movement led by the societies, the downfall of Islamic society, the establishment of British Raj- Causes and consequences. Political evolution of Muslims in the twentieth century: Sir Syed Ahmed Khan; Muslim League; Nehru; Allama Iqbal: Independence Movement; Lahore Resolution; Pakistan culture and society, Constitutional and Administrative issues, Pakistan and its geo-political dimension, Pakistan and International Affairs, Pakistan and the challenges ahead.

Reference Materials:

1. The Emergence of Pakistan, Chaudary M., 1967
2. The making of Pakistan, Aziz. 1976
3. A Short History of Pakistan, I. H. Qureshi, ed., Karachi, 1988

Course Name: **Professional Practices**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Computing Profession, Computing Ethics, Philosophy of Ethics. The Structure of Organizations, Finance and Accounting, Anatomy of a Software House, Computer Contracts, Intellectual Property Rights, The Framework of Employee Relations Law and Changing Management Practices, Human Resource Management and IT, Health and Safety at Work, Software Liability, Liability and Practice, Computer Misuse and the
Criminal Law, Regulation and Control of Personal Information. Overview of the British Computer Society Code of Conduct, IEEE Code of Ethics, ACM Code of Ethics and Professional Conduct, ACM/IEEE Software Engineering Code of Ethics and Professional Practice. Accountability and Auditing, Social Application of Ethics.

Reference Materials:

1. Professional Issues in Software Engineering by Frank Bott, Allison Coleman, Jack Eaton and Diane Rowland, CRC Press; 3rd Edition (2000). ISBN-10: 0748409513
2. Computer Ethics by Deborah G. Johnson, Pearson; 4th Edition (January 3, 2009). ISBN-10: 0131112414
3. A Gift of Fire: Social, Legal, and Ethical Issues for Computing and the Internet (3rd Edition) by Sara Baase, Prentice Hall; 3rd Edition (2008). ISBN-10: 0136008488
4. Applied Professional Ethics by Gregory R. Beabout, University Press of America (1993). ISBN-10: 0819193747.

Course Name: **Technical and Business Writing**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Communication and Presentation Skills

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Overview of technical reporting, use of library and information gathering, administering questionnaires, reviewing the gathered information; Technical exposition; topical arrangement, exemplification, definition, classification and division, casual analysis, effective exposition, technical narration, description and argumentation, persuasive strategy, Organizing information and generation solution: brainstorming, organizing material, construction of the formal outline, outlining conventions, electronic communication, generation solutions. Polishing style: paragraphs, listening sentence structure, clarity, length and order, pomposity, empty words, pompous vocabulary, document design: document structure, preamble, summaries, abstracts, table of contents, footnotes, glossaries, cross-referencing, plagiarism, citation and bibliography, glossaries, index, appendices, typesetting systems, creating the professional report; elements, mechanical elements and graphical elements. Reports: Proposals, progress reports, Leaflets, brochures, handbooks, magazines articles, research papers, feasibility reports, project reports, technical research reports, manuals and documentation, thesis. Electronic documents, Linear verses hierarchical structure documents.

Reference Materials:

1. Technical Report Writing, by Pauley and Riordan, Houghton Mifflin Company, 8th Edition.
2. Effective Technical Communication by Ashraf Rizvi, Tata McGraw-Hill.

Mathematics & Science Foundation

Course Name: **Calculus and Analytic Geometry**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Limits and Continuity; Introduction to functions, Introduction to limits, Techniques of funding limits, Indeterminate forms of limits, Continuous and discontinuous functions and their applications, Differential calculus; Concept and idea of differentiation, Geometrical and Physical meaning of derivatives, Rules of differentiation, Techniques of differentiation, Rates of change, Tangents and Normals lines, Chain rule, implicit differentiation, linear approximation, Applications of differentiation; Extreme value functions, Mean value theorems, Maxima and Minima of a function for single-variable, Concavity, Integral calculus; Concept and idea of Integration, Indefinite Integrals, Techniques of integration, Riemann sums and Definite Integrals, Applications of definite integrals, Improper integral, Applications of Integration; Area under the curve, Analytical Geometry; Straight lines in R3, Equations for planes.

Reference Materials:

1. Calculus and Analytic Geometry by Kenneth W. Thomas.
2. Calculus by Stewart, James.
3. Calculus by Earl William Swokowski; Michael Olinick; Dennis Pence; Jeffery A. Cole

Course Name: **Differential Equations**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Calculus and Analytical Geometry

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Identify, analyze and subsequently solve physical situations whose behavior can be described by ordinary differential equations	-
CLO-2	Determine solutions to first order separable differential equation	-
CLO-3	Determine solutions to first order linear differential equations	-
CLO-4	Determine solutions to first order exact differential equations	-
CLO-5	Determine solutions to second order linear homogeneous and non-homogeneous differential equations with constant coefficients.	-

Course Outline:

Ordinary Differential Equations of the First Order: Geometrical Considerations, Isoclines, Separable Equations, Equations Reducible to Separable Form, Exact Differential Equations, Integrating Factors, Linear First-Order Differential Equations, variation of Parameters. Ordinary Linear Differential Equations; Homogeneous Linear Equations of the Second Order, Homogeneous Second-Order Equations with Constant Coefficients, General Solution, Real Roots, Complex Roots, Double Root of the Characteristic Equation, Differential Operators, Cauchy Equation, Homogeneous Linear Equations of Arbitrary Order, Homogeneous Linear Equations of Arbitrary Order with Constant Coefficients, Non-homogeneous Linear Equations. Modelling of Electrical Circuits. Systems of Differential Equations. Series Solutions of Differential Equations. Partial Differential Equations: Method of Separation of variables, wave, Heat & Laplace equations and their solutions by Fourier series method.

Reference Materials:

1. Advanced Engineering Mathematics Michael, G.th edition, Erwin, K. 1993, John Wiley &1996, Prentice Hall Publishers. Sons
2. Advanced Engineering Mathematics, 7 Inc.
3. A First Course in Differential Equation Zill. Prindle. Weber. Schmidt.1996. Brooks/Cole Publishing.
4. Differential Equations with Boundary-Value Problems, Dennis. G. Zill, Michael, R. Cullen. 1996, Brooks/Cole Publishing
5. Elementary Differential Equations with Applications C. H. Edwards. David, E. 1993. Penney, Prentice Hall.

Course Name: **Linear Algebra**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Calculus and Analytical Geometry

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:
Algebra of linear transformations and matrices. determinants, rank, systems of equations, vector spaces, orthogonal transformations, linear dependence, linear Independence and bases, eigenvalues and eigenvectors ,characteristic equations, Inner product space and quadratic forms

Reference Materials:
1. Elementary Linear Algebra by Howard Anton
2. Linear Algebra and its Applications by Gibert Strang

Course Name: **Probability and Statistics**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
-	-	-

Course Outline:

Introduction to Statistics and Data Analysis, Statistical Inference, Samples, Populations, and the Role of Probability. Sampling Procedures. Discrete and Continuous Data. Statistical Modeling. Types of Statistical Studies. Probability: Sample Space, Events, Counting Sample Points, Probability of an Event, Additive Rules, Conditional Probability,

Independence, and the Product Rule, Bayes' Rule. Random Variables and Probability Distributions. Mathematical Expectation: Mean of a Random Variable, Variance and Covariance of Random Variables, Means and Variances of Linear Combinations of Random Variables, Chebyshev's Theorem. Discrete Probability Distributions. Continuous Probability Distributions. Fundamental Sampling Distributions and Data Descriptions: Random Sampling, Sampling Distributions, Sampling Distribution of Means and the Central Limit Theorem. Sampling Distribution of S2, t-Distribution, FQuantile and Probability Plots. Single Sample & One- and Two-Sample Estimation

Problems. Single Sample & One- and Two-Sample Tests of Hypotheses. The Use of PValues for Decision Making in Testing Hypotheses (Single Sample & One- and TwoSample Tests), Linear Regression and Correlation. Least Squares and the Fitted Model, Multiple Linear Regression and Certain, Nonlinear Regression Models, Linear Regression Model Using Matrices, Properties of the Least Squares Estimators.

Reference Materials:

1. Probability and Statistics for Engineers and Scientists by Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying E. Ye, Pearson; 9th Edition (January 6, 2011). ISBN-10: 0321629116
2. Probability and Statistics for Engineers and Scientists by Anthony J. Hayter, Duxbury Press; 3rd Edition (February 3, 2006), ISBN-10:0495107573
3. Schaum's Outline of Probability and Statistics, by John Schiller, R. Alu Srinivasan and Murray Spiegel, McGraw-Hill; 3rd Edition (2008). ISBN-10:0071544259

Computing Core

Course Name: **Computer Networks**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Describe the key terminologies and technologies of computer networks	C2 (Describe)
CLO-2	Explain the services and functions provided by each layer in the Internet protocol stack.	C2 (Explain)
CLO-3	Identify various internetworking devices and protocols and their functions in a networking	C4 (Identify)
CLO-4	Analyze working and performance of key technologies, algorithms and protocols	C4 (Analyze)
CLO-5	Build Computer Network on various Topologies	P3 (Build)

Course Outline:
Introduction and protocols architecture, basic concepts of networking, network topologies, layered architecture, physical layer functionality, data link layer functionality, multiple access techniques, circuit switching and packet switching, LAN technologies, wireless networks, MAC addressing, networking devices, network layer protocols, IPv4 and IPv6, IP addressing, sub netting, CIDR, routing protocols, transport layer protocols, ports and sockets, connection establishment, flow and congestion control, application layer protocols, latest trends in computer networks.

Reference Materials:
1. Computer Networking: A Top-Down Approach Featuring the Internet, 6th edition by James F. Kurose and Keith W. Ross
2. Computer Networks, 5th Edition by Andrew S. Tanenbaum
3. Data and Computer Communications, 10th Edition by William Stallings
4. Data Communication and Computer Networks, 5th Edition by Behrouz A. Forouzan

Course Name: **Database System**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Explain fundamental database concepts.	C2 (Explain)
CLO-2	Design conceptual, logical and physical database schemas using different data models.	C5 (Design)
CLO-3	Identify functional dependencies and resolve database anomalies by normalizing database tables.	C2 (Identify)
CLO-4	Use Structured Query Language (SQL) for database definition and manipulation in any DBMS	C4 (Use)

Course Outline:

Basic database concepts, Database approach vs. file based system, database architecture, three level schema architecture, data independence, relational data model, attributes, schemas, tuples, domains, relation instances, keys of relations, integrity constraints, relational algebra, selection, projection, Cartesian product, types of joins, normalization, functional dependencies, normal forms, entity relationship model, entity sets, attributes, relationship, entity-relationship diagrams, Structured Query Language (SQL), Joins and sub-queries in SQL, Grouping and aggregation in SQL, concurrency control, database backup and recovery, indexes, NoSQL systems.

Reference Materials:

1. Database Systems: A Practical Approach to Design, Implementation, and Management, 6th Edition by Thomas Connolly and Carolyn Begg
2. Database Systems: The Complete Book, 2nd Edition by Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom
3. Database System Concepts, 6th Edition by Avi Silberschatz, Henry F. Korth and S. Sudarshan.
4. Database Management Systems, 3rd Edition by Raghu Ramakrishnan, Johannes Gehrke

Course Name: **Data Structures and Algorithms**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: Programming Fundamentals

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Implement various data structures and their algorithms and apply them in implementing simple applications	C3 (Apply)
CLO-2	Analyze simple algorithms and determine their complexities.	C5 (Analyze)
CLO-3	Apply the knowledge of data structure to other application domains.	C3 (Apply)
CLO-4	Design new data structures and algorithms to solve problems.	C6 (Design)

Course Outline:
Abstract data types, complexity analysis, Big Oh notation, Stacks (linked lists and array implementations), Recursion and analyzing recursive algorithms, divide and conquer algorithms, Sorting algorithms (selection, insertion, merge, quick, bubble, heap, shell, radix, bucket), queue, dequeuer, priority queues (linked and array implementations of queues), linked list & its various types, sorted linked list, searching an unsorted array, binary search for sorted arrays, hashing and indexing, open addressing and chaining, trees and tree traversals, binary search trees, heaps, M-way tress, balanced trees, graphs, breadth-first and depth-first traversal, topological order, shortest path, adjacency matrix and adjacency list implementations, memory management and garbage collection.

Reference Materials:
1. Data Structures and Algorithms in C++ by Adam Drozdek
2. Data Structures and Algorithm Analysis in Java by Mark A. Weiss
3. Data Structures and Abstractions with Java by Frank M. Carrano & Timothy M. Henry
4. Data Structures and Algorithm Analysis in C++ by Mark Allen Weiss
   Java Software Structures: Designing and Using Data Structures by John Lewis and Joseph Chase

Course Name: **Discrete Structure**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand the key concepts of Discrete Structures such as Sets, Permutations, Relations, Graphs and Trees etc.	C2 (Understand)
CLO-2	Apply formal logic proofs and/or informal, but rigorous, logical reasoning to real problems, such as predicting the behavior of software or solving problems such as puzzles.	C3 (Apply)
CLO-3	Apply discrete structures into other computing problems such as formal specification, verification, databases, artificial intelligence, and cryptography.	C3 (Apply)
CLO-4	Differentiate various discrete structures and their relevance within the context of computer science, in the areas of data structures and algorithms, in particular	C4 (Differentiate)

Course Outline:

Mathematical reasoning, propositional and predicate logic, rules of inference, proof by induction, proof by contraposition, proof by contradiction, proof by implication, set theory, relations, equivalence relations and partitions, partial orderings, recurrence relations, functions, mappings, function composition, inverse functions, recursive functions, Number Theory, sequences, series, counting, inclusion and exclusion principle, pigeonhole principle, permutations and combinations. Algorithms, Searching and Sorting Algorithms, elements of graph theory, planar graphs, graph coloring, Graph Algorithms, euler graph, Hamiltonian path, rooted trees, traversals.

Reference Materials:

1. Discrete Mathematics and Its Applications, 7th edition by Kenneth H. Rosen
2. Discrete Mathematics with Applications, 4th Edition by Susanna S. Epp
3. Discrete Mathematics, 7th edition by Richard Johnson Baugh
4. Discrete Mathematical Structures, 4th edition by Kolman, Busby & Ross
5. Discrete and Combinatorial Mathematics: An Applied Introduction by Ralph P. Grimaldi
6. Logic and Discrete Mathematics: A Computer Science Perspective by Winifred Grassman

Course Name: **Information Security**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Explain key concepts of information security such as design principles, cryptography, risk management, and ethics	C2 (Explain)
CLO-2	Discuss legal, ethical, and professional issues in information security	A2 (Discuss)
CLO-3	Apply various security and risk management tools for achieving information security and privacy	C3 (Apply)
CLO-4	Identify appropriate techniques to tackle and solve problems in the discipline of information security	C4 (Identify)

Course Outline:

Information security foundations, security design principles; security mechanisms, symmetric and asymmetric cryptography, encryption, hash functions, digital signatures, key management, authentication and access control; software security, vulnerabilities and protections, malware, database security; network security, firewalls, intrusion detection; security policies, policy formation and enforcement, risk assessment, cybercrime, law and ethics in information security, privacy and anonymity of data.

Reference Materials:

1. Computer Security: Principles and Practice, 3rd edition by William Stallings
2. Principles of Information Security, 6th edition by M. Whitman and H. Mattord
3. Computer Security, 3rd edition by Dieter Gollmann
4. Computer Security Fundamentals, 3rd edition by William Easttom
5. Official (ISC)2 Guide to the CISSP CBK, 3rd edition

Course Name: **Object Oriented Programming**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: Programming Fundamentals

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand principles of object oriented paradigm.	C2 (Understand)
CLO-2	Identify the objects & their relationships to build object oriented solution	C3 (Identify)
CLO-3	Model a solution for a given problem using object oriented principles	C3 (Apply)
CLO-4	Examine an object oriented solution	C4 (Examine)

Course Outline:

Introduction to object oriented design, history and advantages of object oriented design, introduction to object oriented programming concepts, classes, objects, data encapsulation, constructors, destructors, access modifiers, const vs non-const functions, static data members & functions, function overloading, operator overloading, identification of classes and their relationships, composition, aggregation, inheritance, multiple inheritance, polymorphism, abstract classes and interfaces, generic programming concepts, function & class templates, standard template library, object streams, data and object serialization using object streams, exception handling.

Reference Materials:

1. Starting Out with C++ from Control Structures to Objects, 9th Edition, Tony Gaddis
2. C++ How to Program, 10th Edition, Deitel & Deitel.
3. Object Oriented Programming in C++, 3rd Edition by Robert Lafore
4. Java: How to Program, 9th Edition by Paul Deitel
5. Beginning Java 2, 7th Edition by Ivor Horton
6. An Introduction to Object Oriented Programming with Java, 5th Edition by C. Thomas Wu

Course Name: **Operating Systems**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: Data Structure and Algorithms

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand the characteristics of different structures of the Operating Systems and identify the core functions of the Operating Systems	C2 (Understand)
CLO-2	Analyze and evaluate the algorithms of the core functions of the Operating Systems and explain the major performance issues with regard to the core functions	C5 (Evaluate)
CLO-3	Demonstrate the knowledge in applying system software and tools available in modern operating systems.	C3 (Demonstrate)

Course Outline:

Operating systems basics, system calls, process concept and scheduling, inter-process communication, multithreaded programming, multithreading models, threading issues, process scheduling algorithms, thread scheduling, multiple-processor scheduling, synchronization, critical section, synchronization hardware, synchronization problems, deadlocks, detecting and recovering from deadlocks, memory management, swapping, contiguous memory allocation, segmentation & paging, virtual memory management, demand paging, thrashing, memory-mapped files, file systems, file concept, directory and disk structure, directory implementation, free space management, disk structure and scheduling, swap space management, system protection, virtual machines, operating system security

Reference Materials:

1.Operating Systems Concepts, 9th edition by Abraham Silberschatz
2.Modern Operating Systems, 4th edition by Andrew S. Tanenbaum
3.Operating Systems, Internals and Design Principles, 9th edition by William StallingsWu

Course Name: **Programming Fundamentals**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand basic problem solving steps and logic constructs	C2 (Understand)
CLO-2	Apply basic programing concepts	C3 (Apply)
CLO-3	Design and implement algorithms to solve real world problems	C3 (Solve)

Course Outline:

Introduction to problem solving, a brief review of Von-Neumann architecture, Introduction to programming, role of compiler and linker, introduction to algorithms, basic data types and variables, input/output constructs, arithmetic, comparison and logical operators, conditional statements and execution flow for conditional statements, repetitive statements and execution flow for repetitive statements, lists and their memory organization, multi-dimensional lists, introduction to modular programming, function definition and calling, stack rolling and unrolling, string and string operations, pointers/references, static and dynamic memory allocation, File I/O operations

Reference Materials:

1. Starting out with Python, 4th Edition, Tony Gaddis.
2. Starting out with Programming Logic & Degins, 4th Edition, Tony Gaddis,
3. The C Programming Language, 2nd Edition by Brian W. Kernighan, Dennis M. Ritchie
4. Object Oriented Programming in C++ by Robert Lafore
5. Introduction to Computation and Programming Using Python: With Application to Understanding Data, 2nd Edition by Guttag, John
6. Practice of Computing Using Python, 3rd Edition by William Punch & Richard Enbody
7. C How to Program, 7th Edition by Paul Deitel & Harvey Deitel
8. Problem Solving and Program Design in C++, 7th Edition by Jeri R. Hanly & Elliot B. Koffman

Course Name: **Software Engineering**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Describe various software engineering processes and activates	C1 (Describe)
CLO-2	Apply the system modeling techniques to model a medium size software systems	C3 (Apply)
CLO-3	Apply software quality assurance and testing principles to medium size software systems	C4 (Apply)
CLO-4	Discuss key principles and common methods for software project management such as scheduling, size estimation, cost estimation and risk analysis	C2 (Discuss)

Course Outline:

Nature of Software, Overview of Software Engineering, Professional software development, Software engineering practice, Software process structure, Software process models, Agile software Development, Agile process models, Agile development techniques, Requirements engineering process, Functional and non-functional requirements, Context models, Interaction models, Structural models, behavioral models, model driven engineering, Architectural design, Design and implementation, UML diagrams, Design patterns, Software testing and quality assurance, Software evolution, Project management and project planning, configuration management, Software Process improvement

Reference Materials:

1. Software Engineering, Sommerville I., 10th Edition, Pearson Inc., 2014
2. Software Engineering, A Practitioner's Approach, Pressman R. S.& Maxim B. R., 8th Edition, McGraw-Hill, 2015.

Computer Science Core

Course Name: **Analysis of Algorithms**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Data Structures & Algorithms

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Explain what is meant by "best", "expected", and "worst" case behavior of an algorithm	-
CLO-2	Identify the characteristics of data and/or other conditions or assumptions that lead to different behaviors.	-
CLO-3	Determine informally the time and space complexity of simple algorithms	-
CLO-4	List and contrast standard complexity classes	-
CLO-5	Use big O, Omega, Theta notation formally to give asymptotic upper bounds on time and space complexity of algorithms	-
CLO-6	Use of the strategies(brute-force, greedy, divide-and-conquer, and dynamic programming) to solve an appropriate problem	-
CLO-7	Solve problems using graph algorithms, including single-source and all-pairs shortest paths, and at least one minimum spanning tree algorithm	-
CLO-8	Trace and/or implement a string-matching algorithm	-

Course Outline:

Introduction; role of algorithms in computing, Analysis on nature of input and size of input Asymptotic notations; Big-O, Big Ω, Big Θ, little-o, little-ω, Sorting Algorithm analysis, loop invariants, Recursion and recurrence relations; Algorithm Design Techniques, Brute Force Approach, Divide-and-conquer approach; Merge, Quick Sort, Greedy approach; Dynamic programming; Elements of Dynamic Programming, Search trees; Heaps; Hashing; Graph algorithms, shortest paths, sparse graphs, String matching; Introduction to complexity classes.

Reference Materials:

1. Introduction to Algorithms (3rd edition) by Thomas H. Corman, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein
2. Algorithm Design, (1st edition, 2013/2014), Jon Kleinberg, Eva Tardos,
3. Algorithms, (4th edition, 2011), Robert Sedgewick, Kevin Wayne

Course Name: **Artificial Intelligence**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: Object Oriented Programming

Course Introduction:

Artificial Intelligence has emerged as one of the most significant and promising areas of computing. This course focuses on the foundations of AI and its basic techniques like Symbolic manipulations, Pattern Matching, Knowledge Representation, Decision Making and Appreciating the differences between Knowledge, Data and Code. AI programming language Lisp has been proposed for the practical work of this course.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand the fundamental constructs of Lisp programming language.	C2 (Understand)
CLO-2	Understand key concepts in the field of artificial intelligence	C2 (Understand)
CLO-3	Implement artificial intelligence techniques and case studies	C3 (Apply)

Course Outline:

An Introduction to Artificial Intelligence and its applications towards Knowledge Based Systems; Introduction to Reasoning and Knowledge Representation, Problem Solving by Searching (Informed searching, Uninformed searching, Heuristics, Local searching, Min-max algorithm, Alpha beta pruning, Game-playing); Case Studies: General Problem Solver, Eliza, Student, Macsyma; Learning from examples; Natural Language Processing; Recent trends in AI and applications of AI algorithms. Lisp & Prolog programming languages will be used to explore and illustrate various issues and techniques in Artificial Intelligence.

Reference Materials:

1. Russell, S. and Norvig, P. “Artificial Intelligence. A Modern Approach”, 3rd ed, Prentice Hall, Inc., 2015.
2. Norvig, P., “Paradigms of Artificial Intelligence Programming: Case studies in Common Lisp”, Morgan Kaufman Publishers, Inc., 1992.
3. Luger, G.F. and Stubblefield, W.A., “AI algorithms, data structures, and idioms in Prolog, Lisp, and Java”, Pearson Addison-Wesley. 2009.

Course Name: **Computer Organization and Assembly Language**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: Digital Logic Design

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Acquire the basic knowledge of computer organization computer architecture and assembly language	C2 (Understand)
CLO-2	Understand the concepts of basic computer organization, architecture, and assembly language techniques	C2 (Understand)
CLO-3	Solve the problems related to computer organization and assembly language	C3 (Apply)

Course Outline:

Introduction to computer systems: Information is bits + context, programs are translated by other programs into different forms, it pays to understand how compilation systems work, processors read and interpret instructions stored in memory, caches matter, storage devices form a hierarchy, the operating system manages the hardware, systems communicate with other systems using networks; Representing and manipulating information: information storage, integer representations, integer arithmetic, floating point; Machine-level representation of programs: a historical perspective, program encodings, data formats, accessing information, arithmetic and logical operations, control, procedures, array allocation and access, heterogeneous data structures, putting it together: understanding pointers, life in the real world: using the gdb debugger, out of-bounds memory references and buffer overflow, x86-64: extending ia32 to 64 bits, machine-level representations of floating-point programs; Processor architecture: the Y86 instruction set architecture, logic design and the Hardware Control Language (HCL), sequential Y86 implementations, general principles of pipelining, pipelined Y86 implementations

Reference Materials:

1. Computer Systems: A Programmer's Perspective, 3/E (CS:APP3e), Randal E. Bryant and David R.O' Hallaron, Carnegie Mellon University
2. Robert Britton, MIPS Assembly Language Programming, Latest Edition,
3. Computer System Architecture, M. Morris Mano, Latest Edition,
4. Assembly Language Programming for Intel- Computer, Latest Edition

Course Name: **Digital Logic Design**
Credit Hours: 3-1
Contact Hours: 3-3
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Acquire knowledge related to the concepts, tools and techniques for the design of digital electronic circuits	-
CLO-2	Demonstrate the skills to design and analyze both combinational and sequential circuits using a variety of techniques	-
CLO-3	Apply the acquired knowledge to simulate and implement small-scale digital circuits	-
CLO-4	Understand the relationship between abstract logic characterizations and practical electrical implementations.	-

Course Outline:

Number Systems, Logic Gates, Boolean Algebra, Combination logic circuits and designs, Simplification Methods (K-Map, Quinn Mc-Cluskey method), Flip Flops and Latches, Asynchronous and Synchronous circuits, Counters, Shift Registers, Counters, Triggered devices & its types. Binary Arithmetic and Arithmetic Circuits, Memory Elements, State Machines. Introduction Programmable Logic Devices (CPLD, FPGA) Lab Assignments using tools such as Verilog HDL/VHDL, MultiSim

Reference Materials:

1. Digital Fundamentals by Floyd, 11/e.
2. Fundamental of Digital Logic with Verilog Design, Stephen Brown, 2/e

Course Name: **Parallel and Distributed Computing**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Object Oriented Programming , Operating Systems

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Learn about parallel and distributed computers.	-
CLO-2	Write portable programs for parallel or distributed architectures using Message-Passing Interface (MPI) library	-
CLO-3	Analyze complex problems with shared memory programming with openMP.	-

Course Outline:

Asynchronous/synchronous computation/communication, concurrency control, fault tolerance, GPU architecture and programming, heterogeneity, interconnection topologies, load balancing, memory consistency model, memory hierarchies, Message passing interface (MPI), MIMD/SIMD, multithreaded programming, parallel algorithms & architectures, parallel I/O, performance analysis and tuning, power, programming models (data parallel, task parallel, process-centric, shared/distributed memory), scalability and performance studies, scheduling, storage systems, synchronization, and tools (Cuda, Swift, Globus, Condor, Amazon AWS, OpenStack, Cilk, gdb, threads, MPICH, OpenMP, Hadoop, FUSE).

Reference Materials:

1. Distributed Systems: Principles and Paradigms, A. S. Tanenbaum and M. V. Steen, Prentice Hall, 2nd Edition, 2007
2. Distributed and Cloud Computing: Clusters, Grids, Clouds, and the Future Internet, K Hwang, J Dongarra and GC. C. Fox, Elsevier, 1st Ed.

Artificial Intelligence Core

Course Name: **Artificial Neural Networks**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Programming for Artificial Intelligence

Course Introduction:
This course will introduce Artificial Neural Networks, their basic architecture and how they mimic the human brain using simple mathematical models. Many of the important concepts and techniques around brain computing and the major types of ANN will also be introduced. Emphasis is made on the mathematical models, understanding learning laws, selecting activation functions and how to train the networks to solve classification problems. Students would be able to understand and use different types of neural networks and would be able to use different activation functions and construct layered networks to solve classification problems.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand the fundamentals of neural networks in AI	C2 (Understand)
CLO-2	Explain how simple ANNs can be designed	C2 (Understand)
CLO-3	Apply ANN for classification Problems	C3 (Apply)
CLO-4	Differentiate between different Networks and their learning laws	C4 (Analyze)

Course Outline:
Introduction and history of neural networks, Basic architecture of neural networks, Perceptron and Adaline (Minimum Error Learning) for classification, Gradient descent (Delta) rule, Hebbian, Neo-Hebbian and Differential Hebbian Learning, Drive Reinforcement Theory, Kohonen Self Organizing Maps, Associative memory, Bi-directional associative memory (BAM), Energy surfaces, The Boltzmann machines, Backpropagation Networks, Feedforward Networks; Introduction to Deep learning and its architecture.

Reference Materials:

1. Neural Network Design, 2nd Edition, Martin T. Hagan, Howard, B. Demuth, Mark Hudson Beale and Orlando De Jesus, Publisher: Martin Hagan; 2 edition (September 1, 2014), ISBN-10: 0971732116
2. An Introduction to Neural Networks, James A Anderson, Publisher: A Bradford Book (March 16, 1995), ISBN-10: 0262011441
3. Fundamentals of Artificial Neural Networks, Mohammad Hassoun, Publisher: A Bradford Book (January 1, 2003), ISBN-10: 0262514672

Course Name: **Computer Vision**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Artificial Neural Networks

Course Introduction:

With a single glance a human interprets the entire scene. How many objects are present in the scene and where they are located. Which person is present in the scene. What will happen next. However, computers lack this capability. We have seen only face detectors so far working in our mobile phones? What is the challenge in understanding the 3D scene, i.e., the identity, the location and the size of the objects present in the scene. In this course we will introduce the basic concepts related to 3D scene modelling from single view and multiple views.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understanding the single view geometry concepts	C2 (Understand)
CLO-2	Understanding the multiple view geometry concepts	C2 (Understand)
CLO-3	Apply concepts of CV for solving real world problems	C3 (Apply)

Course Outline:
Introduction to Computer Vision (Problems faced, History and Modern Advancements). Image Processing, Image filtering, Image pyramids and Fourier transform, Hough transform. Camera models, Setting up a camera model from parameters, Camera looking at a plane, Relationship of plane and horizon line, Rotation about camera center. Concatenation, Decomposition and Estimation of transformation from point correspondences, Points and planes in 2D/3D, Transformations in 2D/3D, Rotations in 2D/3D. Edge detection, corner detection. Feature descriptors and matching (HoG features, SIFT, SURF). Applications of Computer Vision Traditional Methods: Image Stitching: Making a bigger picture from smaller picturesSingle View Geometry: Converting a single image into a 3D model. Applications of CV using Deep Learning: Image Detection (Localization, Historical Techniques, RCNN, FRCNN, YOLO, Retina), Image Segmentation (UNet, SegNet, MaskRCNN), Image Generation (GANN)

Reference Materials:

Text Book:

1. Computer Vision: Algorithms and Applications, by Richard Szeliski.

Reference Book:

2. Multiple View Geometry in Computer Vision, by Richard Hartley and Andrew Zisserman.
3. Computer Vision: A Modern Approach, by David Forsyth and Jean Ponce.
4. Digital Image Processing, by Rafael Gonzalez and Richard Woods.

Course Name: **Knowledge Representation and Reasoning**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Artificial Intelligence

Course Introduction:

Knowledge representation is one of the fundamental areas of Artificial Intelligence. It is the study of how knowledge about the world can be represented and manipulated in an automated way to enable agents to make intelligent decisions. This course will provide an overview of existing knowledge representation frameworks developed within AI including but not limited to propositional and first-order logic, ontologies, planning, reasoning and decision making under uncertainty. The assignments component of the course would provide hands-on experience of software like Prolog, Protégé, probabilistic reasoning APIs and tools to support complex decision making. It is expected that after completing this course, students will understand (a) the foundations of Knowledge Representation & Reasoning and (b) which tools and techniques are appropriate for which tasks.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand the fundamentals of knowledge representation and reasoning in deterministic situations	C2 (Understand)
CLO-2	Understand the challenges in representing knowledge and reasoning under uncertainty	C2 (Understand)
CLO-3	Analyze different situations and apply appropriate knowledge representation frameworks	C4 (Analyze)
CLO-4	Development of hybrid approaches by synergizing the existing framework to solve complex decision-making problems.	C4 (Analyze)

Course Outline:

Propositional Logic, First-order Logic, Horn Clauses, Description Logic, Reasoning using Description Logic, Forward and Backward Chaining in Inference Engines, Semantic Networks, Ontologies and Ontology Languages, Logical Agents, Planning, Rule-based Knowledge Representation, Reasoning Under Uncertainty, Bayesian Networks Representation, Inference in Bayesian Networks, Fuzzy Logic, Inferene using Fuzzy Rules, Markov Models, Commonsense Reasoning, Explainable AI.

Reference Materials:

1. Stuard Russell and Peter Norvig, Artificial Intelligence: A Modern Approach (3rd Ed.) (2015)
2. David Poole and Alan Mackworth, Artificial Intelligence: Foundations of Computational Agents, 2nd Ed, 2017
3. Ronald Brachman and Hector Levesque. Knowledge Representation and Reasoning, 2004

Course Name: **Machine Learning**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Programming for Artificial Intelligence

Course Introduction:

Machine learning is one of the fastest growing areas of computer science, with far-reaching applications. The aim of this course is to: a) Present the basic machine learning concepts; b) Present a range of machine learning algorithms along with their strengths and weaknesses; c) Apply machine learning algorithms to solve problems of moderate complexity.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Describe basic machine learning concepts, theories and applications.	C1 (Knowledge)
CLO-2	Apply supervised learning techniques to solve classification problems of moderate complexity.	C3 (Apply)
CLO-3	Apply unsupervised learning techniques to solve clustering problems of moderate complexity	C3 (Apply)
CLO-4	Apply reinforcement learning algorithms to environments with complex dynamics.	C3 (Apply)
CLO-5	Develop a reasonable size project using suitable machine learning technique	C6 (Create)

Course Outline:

Introduction to machine learning; concept learning: General-to-specific ordering of hypotheses, Version spaces Algorithm, Candidate elimination algorithm; Supervised Learning: decision trees, Naive Bayes, Artificial Neural Networks, Support Vector Machines, Overfitting, noisy data, and pruning, Measuring Classifier Accuracy; Linear and Logistic regression; Unsupervised Learning: Hierarchical Aglomerative Clustering. k-means partitional clustering; Self-Organizing Maps (SOM) k-Nearest-neighbor algorithm; Semi-supervised learning with EM using labeled and unlabled data; Reinforcement Learning: Hidden Markov models, Monte Carlo inference Exploration vs. Exploitation Trade-off, Markov Decision Processes; Ensemble Learning: Using committees of multiple hypotheses. Bagging, boosting.

Reference Materials:

1. Machine Learning, Tom, M., McGraw Hill, 1997.
2. Machine Learning: A Probabilistic Perspective, Kevin P. Murphy, MIT Press,2012

Course Name: **Natural Language Processing**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Artificial Neural Networks

Course Introduction:

Natural Language Processing (NLP) is the application of computational techniques to the analysis and synthesis of natural language and speech. This course is an introduction to NLP with prior programming experience in Python.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand techniques for information retrieval, language translation, and text classification.	C2 (Understand)
CLO-2	Understand the advantages of using standard corpora. Identify examples of current corpora for a variety of NLP tasks.	C2 (Understand)
CLO-3	Understand and contrast deterministic and stochastic grammars, providing examples to show the adequacy of each	C2 (Understand)
CLO-4	Solve classic and stochastic algorithms for parsing natural language.	C3 (Apply)

Course Outline:

Introduction & History of NLP, Parsing algorithms, Basic Text Processing, Minimum Edit Distance, Language Modeling, Spelling Correction, Text Classification, Deterministic and stochastic grammars, CFGs, Representing meaning /Semantics, Semantic roles, Semantics and Vector models, Sentiment Analysis, Temporal representations, Corpus-based methods, N-grams and HMMs, Smoothing and backoff, POS tagging and morphology, Information retrieval, Vector space model, Precision and recall, Information extraction, Relation Extraction (dependency, constituency grammar), Language translation, Text classification, categorization, Bag of words model, Question and Answering, Text Summarization

Reference Materials:

1. Daniel Jurafsky and James H. Martin. 2018. Speech and Language Processing: An Introduction to Natural Language Processing,. Third Edition. Prentice Hall
2. Foundations of Statistical Natural Language Processing, Manning and Schütze, MIT Press. Cambridge, MA: May 1999

Course Name: **Programming for Artificial Intelligence**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Artificial Intelligence

Course Introduction:

This course aims to introduce standard programming practices and to help develop programming skills necessary for designing and implementing Artificial Intelligence systems. The course introduces a modern state of the art programming language for Artificial Intelligence, and builds up the necessary programming background for the main courses like Knowledge Representation & Reasoning, Machine Learning, Artificial Neural Networks, and Natural Language Processing. This course will help the students of Artificial Intelligence develop the programming acumen and style. The ultimate aim of this course is to help students in using the programming language to solve problems of interest to them.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Comprehend the fundamental constructs of programming language for data analysis and representation.	C2 (Understand)
CLO-2	Understand and apply the Object-oriented concepts in the programming language	C2 (Understand)
CLO-3	Solve and analyze programming and data analysis problems using standard libraries and/or toolboxes of the programming language.	C4 (Analyze)

Course Outline:

Introduction to Programming language (Python): The first objective of the course is to introduce and then build the proficiency of students in the programming language. The basics include IDE for the language (e.g., Jupyter Notebook or IPython), variables, expressions, operands and operators, loops, control structures, debugging, error messages, functions, strings, lists, object-oriented constructs and basic graphics in the language. Special emphasis is given to writing production quality clean code in the programming language using version control (git and subversion).
Introducing libraries/toolboxes necessary for data analysis: The course should introduce some libraries necessary for interpreting, analyzing and plotting numerical data (e.g., NumPy, MatPlotLib, Anaconda and Pandas for Python) and give examples of each library using simple use cases and small case studies.

Reference Materials:

Text Book:

1. Severance, C.R., 2016. “Python for everybody: Exploring data using Python 3.” CreateSpace Independent Publ Platform.

2. Miller, B.N., Ranum, D.L. and Anderson, J., 2019. “Python programming in context.” Jones & Bartlett Pub.
3. McKinney, W., 2012. “Python for data analysis: Data wrangling with Pandas, NumPy, and IPython.” O'Reilly Media, Inc.

Reference Book:

1. Joshi, P., 2017. “Artificial intelligence with python.” Packt Publishing Ltd.
2. Janert, P.K., 2010. “Data analysis with open source tools: a hands-on guide for programmers and data scientists.” O'Reilly Media, Inc.

Data Science Core

Course Name: **Advance Statistics**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Probability and Statistics

Course Introduction:
Statistical methods are used for analysis of different datasets for forecasting the values, predicting the unknowns, relating the variables for getting deeper insights and relating data differences with real world complexities. Data Science extracts knowledge from data on the basis of hidden patterns which can be made explicit by incorporating the statistical algorithms in it. This course is designed to prepare students on statistical techniques with a purview of artificial intelligence and data science.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Describe what part of statistics is meant for data scientist and what the applications of statistics in data science are.	C1 (Knowledge)
CLO-2	Apply Statistical techniques in real life problems.	C3(Apply)
CLO-3	Analyze, Correlate, Forecast data by using different statistical techniques	C2 (Understand)
CLO-4	Apply basic data science statistical techniques by using SPSS on real world datasets.	C3 (Apply)

Course Outline:

Introduction to Statistics, Use of Statistics in Data Science, Experimental Design, Statistical Techniques for Forecasting, Interpolation/ Extrapolation, Introduction to Probability, Conditional Probability, Prior and Posterior Probability, Random number generation (RNG), Techniques for RNG, Correlation analysis, Chi Square Dependency tests, Diversity Index, Data Distributions Multivariate Distributions, Error estimation, Confidence Intervals, Linear transformations, Gradient Descent and Coordinate Descent, Likelihood inference, Revision of linear regression and likelihood inference, Fitting algorithms for nonlinear models and related diagnostics, Generalized linear model; exponential families; variance and link functions, Proportion and binary responses; logistic regression, Count data and Poisson responses; log-linear models, Overdispersion and quasi-likelihood; estimating functions, Mixed models, random effects, generalized additive models and penalized regression; Introduction to SPSS, Probability/ Correlation analysis/ Dependency tests/ Regression in SPSS.

Reference Materials:

1. Probability and Statistics for Computer Scientists, 2nd Edition, Michael Baron.
2. Probability for Computer Scientists, online Edition, David Forsyth
3. Discovering Statistics using SPSS for Windows, Andy Field

Course Name: **Big Data Analytics**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Introduction to Data Science

Course Introduction:

The course objective is to develop understanding about the core concept of Big Data, why Big Data requires a different programming paradigm and mindset, and what are the various programming approaches used, what type of data can be processed.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understand the fundamental concepts of Big Data and its programming paradigm.	C2 (Understand)
CLO-2	Hadoop/MapReduce Programming, Framework, and Ecosystem	C3 (Apply)
CLO-3	Apache Spark Programming	C3 (Apply)

Course Outline:

Introduction and Overview of Big Data Systems; Platforms for Big Data, Hadoop as a Platform, Hadoop Distributed File Systems (HDFS), MapReduce Framework, Resource Management in the cluster (YARN), Apache Scala Basic, Apache Scala Advances, Resilient Distributed Datasets (RDD), Apache Spark, Apache Spark SQL, Data analytics on Hadoop / Spark, Machine learning on Hadoop / Spark, Spark Streaming, Other Components of Hadoop Ecosystem

Reference Materials:

1. White, Tom. “Hadoop: The definitive guide." O'Reilly Media, Inc., 2012.
2. Karau, Holden, Andy Konwinski, Patrick Wendell, and Matei Zaharia. “Learning spark: lightning-fast big data analysis." O'Reilly Media, Inc., 2015.
3. Miner, Donald, and Adam Shook. “MapReduce design patterns: building effective algorithms and analytics for Hadoop and other systems." O'Reilly Media, Inc., 2012.

Course Name: **Data Mining**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Advance Statistics, Introduction to Data Science

Course Introduction:
Data Mining has emerged at the confluence of artificial intelligence, statistics, and databases as a technique for automatically discovering hidden patterns in large datasets. The main purpose of this course is the ability to analyze and construct knowledge from data.
The aims of this course are to:

- Expand on the student's understanding and awareness of the concepts of data mining basics, techniques, and application.
- Introduce the concepts of ***Data Pre-processing and Summary Statistics***.
- Introduce the concepts of ***Frequent Item Set Generation, Associations and Correlations measures***.
- Introduce the concepts of ***Classification, Prediction, and Clustering algorithms***.

Build on the programming and problem-solving skills developed in previous subjects studied by the student, to achieve an understanding of the development of Classification, Prediction, and Clustering applications.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Apply preprocessing techniques on any given raw data.	C3 (Apply)
CLO-2	Select and apply proper data mining algorithm to discover interesting patterns	C3 (Apply)
CLO-3	Analyze and extract patterns to solve problems and point out how to deploy solution	C4 (Analyze)
CLO-4	Evaluate systematically supervised, semi supervised and unsupervised models and algorithms with respect to their accuracy	C4 (Analyze)

Course Outline:
Introduction to data mining and basic concepts, Pre-Processing Techniques & Summary Statistics, Association Rule mining using Apriori Algorithm and Frequent Pattern Trees, Introduction to Classification Types, Supervised Classification (Decision trees, Naïve Bae Classification, K-Nearest Neighbors, Support Vector Machines etc.), Unsupervised Classification (K Means, K Median, Hieratical and Divisive Clustering, Kohonan Self Organizing maps), outlier & anomaly detection, Web and Social Network Mining, Data Mining Trends and Research Frontiers. Implementing concepts using Python

Reference Materials:

1. Jiawei Han & Micheline Kamber, Jian Pei (2011). Data Mining: Concepts and Techniques, 3rd Edition.
2. Pang-Ning Tan, Michael Steinbach, and Vipin Kumar (2005). Introduction to Data Mining.
3. Charu C. Aggarwal (2015). Data Mining: The Textbook
4. D. Hand, H. Mannila, P. Smyth (2001). Principles of Data Mining. MIT Press.

Course Name: **Data Visualization**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Data Warehousing & Business Intelligence

Course Introduction:

Data Visualization is a process of obtaining detailed insights hidden in the data. It is a necessary component in the pipeline of any data science project. This course teaches skills specifically in terms of how to effectively present the data and findings. Further, this course provides hands on skills using R for data exploration and visualization.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Provides knowledge about importance, necessity, and justification of performing exploratory data analysis and visualization	C2 (Understand)
CLO-2	Introduce various type of charts along with their alternatives solution to show same data from versatile aspects.	C2 (Understand)
CLO-3	Improving the competency of the students to analyze different problems and select the most appropriate solution.	C3 (Apply)
CLO-4	Use of R, various recent tools, and technologies to develop hands-on skills for exploratory data analysis and visualization.	C3 (Apply)

Course Outline:

Introduction of Exploratory Data Analysis and Visualization, Building Blocks and Basic Operations; Types of Exploratory Graphs, single and multi-dimensional summaries, five number summary, box plots, histogram, bar plot and others; Distributions, their representation using histograms, outliers, variance; Probability Mass Functions and their visualization; Cumulative distribution functions, percentile-based statistics, random numbers; Modelling distributions, exponential, normal, lognormal, pareto; Probability density functions, kernel density estimation; Relationship between variables, scatter plots, correlation, covariance; Estimation and Hypothesis Testing; Clustering using K-means and Hierarchical; Time series and survival analysis; Implementing concepts with R (or similar language)

Reference Materials:

1. “Exploratory Data Analysis with R” by Roger D. Peng

Course Name: **Data Warehousing and Business Intelligence**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Introduction to Data Science

Course Introduction:

Gives an overview about importance & significance of Data Warehousing (DWH) and Business Intelligence (BI). Discusses the main concepts and solutions for DWH and BI. The key concepts underpinning the logical design, physical design and implementation of data warehouses are appraised. Data collection, data extraction, cleansing, transformation and loading methods are considered along with query optimization techniques. Differentiation between OLAP & OLTP. Data Warehousing supports information processing by providing a solid platform of integrated, historical, and consistent data for performing enterprise- wide data analysis.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Demonstrate an appreciation of the role that Data Warehouses and Business Intelligence play in enhancing the decision-making process	C2 (Understand)
CLO-2	Demonstrate an understanding of the fundamental concepts of the Star and the Snowflake Schema; learn how to design the schema of a DW based on these two models.	C2 (Understand)
CLO-3	Understand the architecture of DW Systems and be able to specify the advantages and potential problem areas	C3 (Apply)
CLO-4	Use Analytic SQL to aggregate, analyze and report, and model data.	C3 (Apply)

Course Outline:

Introduction to Data Warehouse and Business Intelligence; Necessities and essentials of Business Intelligence; DW Life Cycle and Basic Architecture; DW Architecture in SQL Server; Logical Model; Indexes; Physical Model; Optimizations; OLAP Operations, Queries and Query Optimization; Building the DW; Data visualization and reporting based on Datawarehouse using SSAS and Tableau; Data visualization and reporting based on Cube; Reports and Dashboard management on PowerBI; Dashboard Enrichment; Business Intelligence Tools.

Reference Materials:

1. W. H. Inmon, “Building the Data Warehouse”, Wiley-India Edition.
2. Ralph Kimball, “The Data Warehouse Toolkit – Practical Techniques for Building Dimensional Data Warehouse,” John Wiley & Sons, Inc.
3. Matteo Golfarelli, Stefano Rizzi, “Data Warehouse Design - Modern Principles and Methodologies”, McGraw Hill Publisher

Course Name: **Introduction to Data Science**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Artificial Intelligence

Course Introduction:

Data Science is the study of the generalizable extraction of knowledge from data. Being a data scientist requires an integrated skill set spanning mathematics, statistics, machine learning, databases and other branches of computer science along with a good understanding of the craft of problem formulation to engineer effective solutions. The aim of this course is to: Introduce students to this rapidly growing field and equip them with some of its basic principles and tools as well as its general mindset. Explain the significance of exploratory data analysis in data science. Identify common approaches used for Feature Generation as well as Feature Selection, and finally discuss the Ethical and Privacy issues. Programming language Python has been proposed for the practical work of this course.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Describe what Data Science is and the skill sets needed to be a data scientist.	C2 (Understand)
CLO-2	Apply EDA and the Data Science process in a case study.	C3 (Apply)
CLO-3	Comprehend the fundamental constructs of Python programming language.	C2 (Understand)
CLO-4	Apply basic machine learning algorithms to solve real world problems of moderate complexity.	C3 (Apply)

Course Outline:

Introduction: What is Data Science? Big Data and Data Science hype, Datafication, Current landscape of perspectives, Skill sets needed; Statistical Inference: Populations and samples, Statistical modeling, probability distributions, fitting a model, Intro to Python; Exploratory Data Analysis and the Data Science Process; Basic Machine Learning Algorithms: Linear Regression, k-Nearest Neighbors (k-NN), k-means, Naive Bayes; Feature Generation and Feature Selection; Dimensionality Reduction: Singular Value Decomposition, Principal Component Analysis; Mining Social-Network Graphs: Social networks as graphs, Clustering of graphs, Direct discovery of communities in graphs, Partitioning of graphs, Neighborhood properties in graphs; Data Visualization: Basic principles, ideas and tools for data visualization; Data Science and Ethical Issues: Discussions on privacy, security, ethics, Next-generation data scientists.

Reference Materials:

1. Foundations of data science, Blum, A., Hopcroft, J., & Kannan, R., Vorabversion eines Lehrbuchs, 2016.
2. An Introduction to Data Science, Jeffrey S. Saltz, Jeffrey M. Stanton, SAGE Publications, 2017.
3. Python for everybody: Exploring data using Python 3, Severance, C.R., CreateSpace Independent Pub Platform. 2016.
4. Doing Data Science, Straight Talk from the Frontline, Cathy O'Neil and Rachel Schutt, O'Reilly. 2014.
5. Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data, EMC Education Services, John Wiley & Sons, 2015.

Cyber Security Core

Course Name: **Digital Forensics**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Introduction to Cyber Security

Course Introduction:

This course is an introduction to computer forensics and investigation. It provides an understanding of how to conduct investigations to correctly gather, analyze and present digital evidence to different audiences. It also outlines the tools to locate and analyze digital evidence on a variety of devices, how to keep up to date with changing technologies, and laws and regulations in digital forensics.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	To develop knowledge about forensic law, standards, regulations and ethical values	C2 (Understand)
CLO-2	To be able to conduct digital forensics for multiple platforms and applications by various tools	C3 (Apply)
CLO-3	To be able to generate reports based on digital forensic tools for security systems and platforms	C3 (Apply)

Course Outline:

An introduction to Digital Forensics; use of digital forensics; Key technical concepts; Challenges in Digital Forensics ; The Difference between Computer Experts and Digital Forensics Experts; Investigative Process Methodologies ; Education, Training, and Awareness; Laws, Standards, and Regulations; Ethics and Professional Conduct; Digital Evidence Management; Collecting evidence; Antiforensics; Network forensics; Mobile and Embedded Forensics; Cloud forensics; Internet Forensics; social media forensics; Investigation Methods for Collecting Digital Evidence; Digital Forensic Readiness; Digital forensics tools; Discovery of Computers and Storage Media; Discovery of Audio/ Video Evidence; Data Visualization; Data Sources; Graphing and Charting; Analyzing Data; Data Distributions; Analysis Scenarios; Data Visualization Tools.

Reference Materials:

1. The Basics of Digital Forensics: The Primer for Getting Started in Digital Forensics by John Sammons, 2nd Edition or latest
2. Digital Forensics and Incident Response : Incident Response Techniques and Procedures to Respond to Modern Cyber Threats, 2nd Edition
3. Guide to Digital Forensics : A Concise and Practical Introduction by Joakim Kävrestad (latest edition)

Course Name: **Information Assurance**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

To understand the role and interaction of policies, laws, procedures, management issues, and technical issues in protecting information resources.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Apply security governance principles; organizational processes; developing and implementing a documented security policy.	C3 (Apply)
CLO-2	Understand and apply risk management concepts	C2 (Understand)
CLO-3	To understand the business, legal, and technical knowledge needed to secure vital government and business assets.	C2 (Understand)

Course Outline:

Introduction to (IS) Information System (Concept, Design, Functions, Architecture, Components and applications of IS); Secure System Planning and Administration; Information Security Policies and Procedures; Asset Management; Organizational and Human Security; Cyber Security Management Concepts; NIST Cyber Security Framework; Enterprise Roles and Structures; Strategic Planning; Security Plans and Policies; Contingency Planning; Laws;

Laws and Regulatory Requirements; Security Standards and Controls, Risk Management Process, NIST Risk Management Framework, Security Metrics and Key Performance Indicators (KPIs); Physical Security and Environmental Events; Contingency Planning; Security Education, ISO 27001 Compliance, Training, and Awareness.

Reference Materials:

1. Principles of Information Security by Michael E. Whitman, 6th Edition, 2017
2. Reference Material: CISSP Study Guide, 7th Edition
3. Information Assurance: Managing Organizational IT Security Risks by Joseph Boyce and Daniel Jennings, 1 Edition or Latest
4. Information Assurance: Security in the Information Environment by Andrew Blyth and Gerald L. Kovacich, Springer, 2nd Edition or Latest

Course Name: **Introduction to Cyber Security**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Information Security

Course Introduction:

This course provides students an introduction to common cyber security threats, vulnerabilities, and risks related to web applications, networks, software and mobile applications. The course provides basic concepts and terminology used in the information and cyber security fields. Moreover, it will also enable students to differentiate between the various forms of malware and how they affect computers and networks.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	To be able to identify computer system threats	C2 (Understand)
CLO-2	To be able to identify Malware attacks, and understand the stages of attack and payloads.	C2 (Understand)
CLO-3	Implement various cryptographic techniques and simulate attack scenarios	C3 (Apply)

Course Outline:

Introduction to Cyber security; Networks and the Internet; cyber threat landscape; understanding security; information security Principles (Confidentiality, Integrity, Availability); Information Security Terminology; Who are the attackers; Advanced Persistent Threat (APT); Malware, types of malware; Attacks using malware; Malware Attack Lifecycle: Stages of Attack; Social engineering attacks; types of payload; Industrial Espionage in Cyberspace; Basic cryptography; Web application attacks; Database security; Cyber kill chain; Privacy and anonymity; Network security; Software security; Mobile device security; Mobile app security; Cyber Terrorism and Information Warfare; Introduction to Digital Forensics; Digital Forensics Categories.

Reference Materials:

1. Computer Security Fundamentals by Chuck Easttom, 4th edition or latest
2. Security+ Guide to Network Security Fundamentals, by Mark Ciampa, 5th Edition
3. Security in Computing by C.P. Pfleeger, Prentice-Hall, 4th Edition or Latest

Course Name: **Network Security**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Introduction to Cyber Security

Course Introduction:

The module aims to develop core competencies in the fields of Network security and offer the opportunity of learning the current network security landscape, understanding current threats and vulnerabilities and examining ways of developing effective countermeasures. It also provides a brief overview to network forensics for analyzing network traffic for the purposes of information gathering, legal evidence, or intrusion detection.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	To be able to understand network security threats and methods for security networks	C2 (Understand)
CLO-2	To be able to secure wired networks by deploying various methods	C3 (Apply)
CLO-3	To be able to secure wireless networks by deploying various methods	C3 (Apply)

Course Outline:

Introduction to network security, Networking Concepts and Protocols, Network Threats and Vulnerabilities, Network Security Planning and Policy, Access Control, Defense against Network Attacks, DOS and DDOS detection and prevention, Firewalls, Intrusion Detection and Prevention Systems, Antivirus Filtering, Naming and DNS Security, DNSSEC, IP security, Secure Sockets Layer, VPN, Packet Sniffing and spoofing, Honeypot, Ethernet Security, Wireless Security, Wireless Attacks, Wireless LAN Security with 802.11i, Wireless Security Protocols, Wireless Intrusion Detection, Physical access and Security, Tor Network, Network Forensics. Defense against Network Attacks.

Reference Materials:

1. Network Security Assessment: Know Your Network by Chris McNab, 3rd Edition or latest
2. Corporate Computer Security, by Randall J. Boyle, 3th Edition
3. Bulletproof Wireless Security by Praphul Chandra
4. Network Security Essentials: Applications and Standards by William Stallings, 3rd Edition or Latest
5. Cryptography and Network Security Principles and Practices by William Stallings, Latest Edition

Course Name: **Secure Software Design and Development**
Credit Hours: 2-1
Contact Hours: 2-3
Pre-requisites: Introduction to Cyber Security

Course Introduction:

The module aims to develop core competencies in the fields of Secure Software Concepts, Secure Software Requirements, Secure Software Design, Secure Software Implementation/Coding, and Secure Software Testing. The course details the software security activities that need to be incorporated throughout the software development lifecycle. It provides comprehensive coverage that includes the people, processes, and technology components of software, networks, and host defenses.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	A good comprehension of software security standards, models, processes and best practices that need to be incorporated throughout the software development lifecycle.	C2 (Understand)
CLO-2	Identify insecure programming patterns and the ability to replace them with secure alternatives.	C2 (Understand)
CLO-3	Know tools for software security analysis and testing, and the ability to use them in practice and understand their capabilities and limitations.	C3 (Apply)

Course Outline:
Secure software concepts; System issues; System properties; Software Project Time Management; Software Project Costing; Software Quality Assurance; Security Concepts in the SDLC; Risk management; Security standards (e.g., coding standards, NIST standards, Federal Information Processing Standards); Best practices (e.g., OWASP development guide, OWASP code review guide, OWASP testing guide); Security methodologies (e.g., Socratic Methodology, Operationally Critical Threat, Asset, and Vulnerability Evaluation, STRIDE and DREAD, Open Source Security Testing Methodology Manual); Security frameworks (e.g., Zachman Framework, Control Objectives for Information and Related Technology, Sherwood Applied Business Security Architecture (SABSA)); Regulations-Privacy and Compliance; Security Models (e.g., BLP Confidentiality Model, Clark and Wilson Model (Access Triple Model)); Trusted Computing; Secure Software Requirements (Sources for Security Requirements, Types of Security Requirements); Secure Software Design (Design consideration, Information Technology Security Principles and Secure Design, Designing Secure Design Principles); Design Processes; Secure Software Implementation/Coding; Software Development Methodologies; Common Software Vulnerabilities and Controls; Defensive Coding Practices—Concepts and Techniques; Code Vulnerabilities and Avoiding Polymorphic Malware Attacks: Buffer overflow, Format string

bug, Code vulnerabilities SQL Injection, Cross-site Scripting, Cross-site Request Forgery, Session management, Replication of vulnerabilities and exploitation; Secure Software Testing; Security Testing Methodologies; Software Security Testing; Software Acceptance; Legal Protection Mechanisms; Software Deployment- Operations- Maintenance and Disposal.

Reference Materials:

1. Official (ISC)2 Guide to the CSSLP (latest)
2. Software Security: Building Security In, 1st Edition by Gary McGraw

Course Name: **Vulnerability Assessment & Reverse Engineering**
Credit Hours: 2-1
Contact Hours: 2-3

Pre-requisites: Introduction to Cyber Security

Course Introduction:

The course aims to develop core competencies in the field of vulnerability assessment covering software, networks and Web applications. It also covers reverse engineering techniques to analyze software, exploit targets, and defend against security threats like malware and viruses.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Basic Understanding of Hacking and Ethical Hacking.	C2 (Understand)
CLO-2	Apply techniques for vulnerability assessment and penetration testing.	C3 (Apply)
CLO-3	Understand Software vulnerabilities, Network vulnerabilities, Types of Malware and its Analysis.	C2 (Understand)

Course Outline:

Understanding the need for security assessments; Classifying vulnerabilities; Software vulnerabilities; Network vulnerabilities; Vulnerability assessment versus penetration testing; Vulnerability Assessment Tools; Vulnerability management Regulatory compliance; Calculating ROIs; Application review process; Pre-assessment; Code navigation; Code-auditing tactics; Memory corruption; understanding issues in programming languages; Steps in Reverse engineering, Common tools used for Reverse engineering; Binary Obfuscation techniques; Understanding core assembly concepts to perform malicious code analysis, Identifying key assembly logic structures with a disassembler, Malware analysis Types of malware analysis; Malware Taxonomy; Static analysis; Dynamic analysis; Malware Inspection; Malware analysis tools; Sandboxing and virtualization;

Reference Materials:

1. Finding and Fixing Vulnerabilities in Information Systems: The Vulnerability Assessment and Mitigation Methodology by Philip S. Anton
2. The Art of Software Security Assessment: Identifying and Preventing Software Vulnerabilities by Mark Dowd
3. Reversing: Secrets of Reverse Engineering by Eldad Eilam (latest edition)
4. Practical Malware Analysis: The Hands-On Guide to Dissecting Malicious Software by Michael Sikorski (latest edition)

Artificial Intelligence Elective

Course Name: **Deep Learning**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Artificial Neural Networks

Course Introduction:

Deep neural networks have achieved state of the art performance on several compute vision and speech recognition benchmarks. Deep learning algorithms extract layered high and low-level features from raw data. With increasing non-line hidden layers, the discriminative power of the network improves. This course builds on the fundamentals of Neural networks and artificial intelligence and covers advanced topics in neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning. It also embeds applications of these algorithms to several real-world problem in computer vision, speech recognition, natural language processing, game theory, etc.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Apply deep learning algorithms to real-world problems	C3 (Apply)
CLO-2	Analyze results from deep learning to select appropriate solutions	C4 (Analyze)
CLO-3	Code the novel neural network architectures from scratch and evaluating the performance on application specific standard benchmarks	C3 (Apply)

Course Outline:

Basics of deep learning, learning networks, Shallow vs. Deep learning etc.; Machine learning theory – training and test sets, evaluation, etc. Theory of Generalization; Multi-layer perceptrons, error back-propagation; Deep convolutional networks, Computational complexity of feed forward and deep convolutional neural networks; Unsupervised deep learning including auto-encoders; Deep belief networks; Restricted Boltzman Machines; Deep Recurrent Neural Networks (BPTT, LSTM, etc.); GPU programming for deep learning CuDNN; Generative adversarial networks (GANs); Sparse coding and auto-encoders; Data augmentation, elastic distortions, data normalization; Mitigating overfitting with dropout, batch normalization, dropconnect; Novel architectures, ResNet, GoogleNet, etc

Reference Materials:

1. Deep Learning by Ian Goodfellow, Yoshua Bengio, Aaron Courville (http://www.deeplearningbook.org/)
2. Deep learning with python by Francoise Chollet, ISBN-10: 9781617294433, 2017

Course Name: **Theory of Automata & Formal Languages**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: None

Course Introduction:

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Explain and manipulate the different concepts in automata theory and formal languages such as formal proofs, automata, regular expressions, Turing machines etc.	C2 (Understand)
CLO-2	Prove properties of languages, grammars and automata with rigorously formal mathematical methods	C2 (Understand)
CLO-3	Design of automata, RE and CFG	C3 (Apply)
CLO-4	Transform between equivalent NFAs, DFAs and REs	C3 (Apply)
CLO-5	Define Turing machines performing simple tasks	C2 (Understand)
CLO-6	Differentiate and manipulate formal descriptions of languages, automata and grammars with focus on regular and context-free languages, finite automata and regular expressions.	C3 (Apply)

Course Outline:

Finite State Models: Language definitions preliminaries, Regular expressions/Regular languages, Finite automata (FAs), Transition graphs (TGs), NFAs, Kleene's theorem, Transducers (automata with output), Pumping lemma and non-regular language Grammars and PDA: CFGs, Derivations, derivation trees and ambiguity, Simplifying CFLs, Normal form grammars and parsing, Decidability, Context sensitive languages, grammars and linear bounded automata (LBA), Chomsky's hierarchy of grammars Turing Machines Theory: Turing machines, Post machine, Variations on TM, TM encoding, Universal Turing Machine, Defining Computers by TMs.

Reference Materials:

1. Introduction to computer theory, Daniel I. A. Cohen, 2nd Edition
2. Automata, Computability and Complexity: Theory and Applications, by Elaine Rich, 2011
3. An Introduction to Formal Languages and Automata, by Peter Linz, 4th edition, Jones & Bartlett Publishers, 2006
4. Theory of Automata, Formal Languages and Computation, by S. P. Eugene, Kavier, 2005, New Age Publishers

Data Science Elective

Course Name: **Advance Database Management Systems**
Credit Hours: 3-0
Contact Hours: 3-0
Pre-requisites: Database Systems

Course Introduction:

Advanced Database Management Systems is an extension to "Database Systems" course. The aim of the course is to enhance the previous knowledge of database systems by deepening the understanding of the theoretical and practical aspects of the database technologies, and showing the need for distributed database technology to tackle deficiencies of the centralized database systems. Moreover, it focuses to introduce the basic principles and implementation techniques of distributed database systems, and expose emerging research issues in database systems and application development.

CLO No.	Course Learning Outcomes	Bloom Taxonomy
CLO-1	Understanding advance data models, technologies and approaches for building distributed database systems.	C2 (Understand)
CLO-2	Applying the models and approaches in order to become enabled to select and apply appropriate methods for a particular case	C3 (Apply)
CLO-3	To develop a database solution for a given scenario/ challenging problem in the domain of distributed database systems.	C3 (Apply)

Course Outline:

Introduction to advance data models such as object relational, object oriented. File organizations concepts, Transactional processing and Concurrency control techniques, Recovery techniques, Query processing and optimization, Database Programming (PL/SQL, T-SQL or similar technology), Integrity and security, Database Administration (Role management, managing database access, views), Physical database design and tuning, Distributed database systems, Emerging research trends in database systems, MONGO DB, NO SQL (or similar technologies)

Reference Materials:

1. Database Systems: A Practical Approach to Design, Implementation, and Management, 6th Edition by Thomas Connolly and Carolyn Begg
2. Database Management Systems, 3rd Edition by Raghu Ramakrishnan, Johannes Gehrke
3. Database System Concepts, 6th Edition by Avi Silberschatz, Henry F. Korth and S. Sudarshan.
4. Database Systems: The Complete Book, 2nd Edition by Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom