Sana'a University
Faculty of Engineering
Electrical Engineering Department
Title of the Program: B.Sc. of Communication Engineering and Networks

Course Specification of Smart Antenna Systems

I. Course Identification and General Information:

1.	Course Title:	Smart Antenna Systems				
2.	Course Code &Number:	CNE334				
3.	Credit hours:	C.H				Credit Hours
		Th.	Tu.	Pr.	Tr.	
		2	2	-	-	3
4.	Study level/ semester at which this course is offered:	4^{th} Level/ 2^{nd} semester				
5.	Pre –requisite (if any):	None.				
6.	Co –requisite (if any):	Waves Propagation and Antennas (CNE322)				
7.	Program (s) in which the course is offered:	Communication Engineering and Networks				
8.	Language of teaching the course:	English+ Arabic				
9.	Location of teaching the course:	Faculty of Engineering, Sana'a University				
10.	Prepared By:	Tr. Abdulbaset Al-Bshah				
11.	Date of Approval:	2020				

II. Course Description:

This course aims to provide students with an understanding of the design, configuration and architecture of smart antennas systems, with the study of the Classical Beam former and adaptive algorithms for beamforming (LMS, RLS). It includes the approach and methods to estimate the Direction of Arrival (DOA). The course gives comprehensive study of Space–Time channel and signal models and Space–Time beamforming.

Prepared by	Head of Department	Quality Assurance Unit	Dean of the Faculty	Academic Development Center & Quality Assurance
Tr. Abdulbaset Al-Bshah	Asst. Prof. Dr. Adel Ahmed Al-Shakiri	Assoc. Prof. Dr. Mohammad Algorafi	Prof. Dr. Mohammed AL-Bukhaiti	Assoc. Prof. Dr. Huda Al-Emad

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III. Course Intended learning outcomes (CILOs) of the course		Referenced PILOs
a1	Illustrate key benefits and drawbacks for both the basic antennas and smart antenna technology.	A1
a2	Explain the principles of configuration and architecture differences between smart and basic antennas.	A2
b1	Identify the Approach and Methods to estimate the Direction of Arrival (DOA) and Maximum SNR/ SINR Beam former.	B1
b2	Analyze the Discrete Space–Time processing and adaptive algorithms for Beamforming (LMS, RLS).	B3
c1	Perform the requirements for the design and implementation of smart antenna systems.	C2
c2	Analyze of Multiple Input - Multiple Output (MIMO) Communications Systems (frequency selective scenarios, capacity and data Rates)	C3
d1	Perform specific tasks individually and present his tasks' ideas clearly.	D2
d2	Conduct scientific research and drafting reports for it.	D5

(A) Alignment Course Intended Learning Outcomes of Knowledge and Understanding to Teaching Strategies and Assessment Strategies:

Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
a1: Illustrate key benefits and drawbacks for both the basic antennas and smart antenna technology.	▪ Lectures. ▪ Dialogue and discussion. ▪ Brainstorming. ▪ Research assignments. ▪ Self-learning.	▪ Final & Midterm exams. ▪ Quizzes & Oral discussion. ▪ Assignments evaluation.

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a2:	Explain the design, Configuration and Architecture differences between smart and basic antennas.	▪ Lectures. ▪ Dialogue and discussion. ▪ Brainstorming. ▪ Research assignments.	▪ Final & Midterm exams. ▪ Quizzes & Oral discussion. ▪ Assignments evaluation.

(B) Alignment Course Intended Learning Outcomes of Intellectual Skills to Teaching Strategies and Assessment Strategies:

Course Intended Learning Outcomes		Teaching strategies	Assessment Strategies
b1:	Identify the Approach and Methods to estimate the Direction of Arrival (DOA) and Maximum SNR/ SINR Beam former.	▪ Lectures. ▪ Dialogue and discussion. ▪ Brainstorming. ▪ Research assignments. ▪ Self-learning.	▪ Final & Midterm exams. ▪ Quizzes & Oral discussion. ▪ Assignments evaluation.
b2:	Analyze the Discrete Space–Time processing and adaptive algorithms for Beamforming (LMS, RLS).	▪ Lectures. ▪ Dialogue and discussion. ▪ Brainstorming. ▪ Research assignments.	▪ Final & Midterm exams. ▪ Quizzes & Oral discussion. ▪ Assignments evaluation.

C Alignment Course Intended Learning Outcomes of Professional and Practical Skills to Teaching Strategies and Assessment Strategies:

Course Intended Learning Outcomes		Teaching strategies	Assessment Strategies
c1:	Perform the requirements for the design and implementation of smart antenna systems.	▪ Lectures. ▪ Dialogue and discussion. ▪ Brainstorming. ▪ Research assignments. ▪ Self-learning.	▪ Final & Midterm exams. ▪ Quizzes & Oral discussion. ▪ Assignments evaluation.

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c2:	Analyze of Multiple Input - Multiple Output (MIMO) Communications Systems (frequency selective scenarios, Capacity and Data Rates).	▪ Lectures. ▪ Dialogue and discussion. ▪ Brainstorming. ▪ Research assignments. ▪ Self-learning.	▪ Final & Midterm exams. ▪ Quizzes & Oral discussion. ▪ Assignments evaluation.

(D) Alignment Course Intended Learning Outcomes of Transferable Skills to Teaching Strategies and Assessment Strategies:

Course Intended Learning Outcomes		Teaching strategies	Assessment Strategies
d1:	Perform specific tasks individually and present his tasks' ideas clearly.	▪ Brainstorming ▪ Research assignments.	▪ Assignments evaluation.
d2:	Conduct scientific research and drafting reports for it.	▪ Dialogue and discussion ▪ Brainstorming ▪ Research assignments.	▪ Assignments evaluation.

IV. Course Content:

A – Theoretical Aspect:

Order	Units/Topics List	Learning Outcomes	Sub Topics List	Number of Weeks	Contact hours
1.	Antenna Arrays Overview	a1, a2,d1, d2	- Isotropic Radiators - Omnidirectional Antennas - Directional Antennas - Phased Array Antennas	2	4

			- Adaptive Arrays - Diversity Techniques		
2.	Smart Antennas for Wireless Communications	a1,a2,c1,c2,d1,d2	- Need for Smart Antennas. - Smart Antenna Configurations (Switched-Beam, Adaptive Antenna Approach). - Space Division Multiple Access (SDMA). - Architecture of a Smart Antenna System (Receiver, Transmitter). - Benefits and Drawbacks. - Basic Principles. - Mutual Coupling Effects. - Multiple Input - Multiple Output (MIMO) Communications Systems, MIMO for frequency selective scenarios.	3	6
3.	DOA Estimation Fundamentals	a1,a2,b1,c1,d2	- Array Response Vector. - Received Signal Model. - Subspace-Based Data Model. - Signal Autocovariance. - Conventional DOA Estimation Methods. - Subspace Approach to DOA Estimation (MUSIC	2	4

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			Algorithm, ESPRIT Algorithm). - Uniqueness of DOA Estimates.		
4.	Beam Forming Fundamentals	a1,a2,b1,b2,c1,d2	- Classical Beam former. - Statistically Optimum Beamforming weight vectors. - Maximum SNR Beam former. - Multiple Side-lobe Canceller and maximum SINR Beam former. - Minimum Mean Square Error (MMSE). - Direct Matrix Inversion (DMI). - Linearly Constrained Minimum Variance (LCMV). - Adaptive Algorithms for Beamforming (LMS, RLS)	4	8
5.	Space–Time Processing	a1,b2,c1,c2,d2	- Discrete Space–Time Channel and Signal Models. - Space–Time Beamforming. - Intersymbol and Co-Channel Suppression. - Space–Time Processing for DS-CDMA.	3	6

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			- Capacity and Data Rates in MIMO Systems.		
Number of Weeks /and Units Per Semester				**14**	**28**

B- Tutorials Aspect:

Order	Tutorial Skills List	Nº of Weeks	C.H.	CILOs
1.	Antenna Arrays Overview • Isotropic Radiators • Omnidirectional Antennas • Directional Antennas • Phased Array Antennas • Adaptive Arrays • Diversity Techniques	2	4	a1, a2, d1, d2
2.	Smart Antennas for Wireless Communications • Need for Smart Antennas. • Smart Antenna Configurations (Switched-Beam, Adaptive Antenna Approach) • Space Division Multiple Access (SDMA). • Architecture of a Smart Antenna System (Receiver, Transmitter.(• Benefits and Drawbacks . • Basic Principles. • Mutual Coupling Effects. • Multiple Input - Multiple Output (MIMO) Communications Systems, MIMO for frequency selective scenarios.	3	6	a1, a2, c1, c2, d1, d2

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3.	DOA Estimation Fundamentals • Array Response Vector. • Received Signal Model. • Subspace-Based Data Model. • Signal Autocovariance. • Conventional DOA Estimation Methods. • Subspace Approach to DOA Estimation (MUSIC Algorithm, ESPRIT Algorithm). • Uniqueness of DOA Estimates.	3	6	a1, a2, b1, c1, d2
4.	Beam Forming Fundamentals • Classical Beam former. • Statistically Optimum Beamforming weight vectors. • Maximum SNR Beam former. • Multiple Side-lobe Canceller and maximum SINR Beam former. • Minimum Mean Square Error (MMSE). • Direct Matrix Inversion (DMI) . • Linearly Constrained Minimum Variance (LCMV) • Adaptive Algorithms for Beamforming (LMS, RLS)	3	6	a1, a2, b1, b2,c1, d2
5.	Space–Time Processing • Discrete Space–Time Channel and Signal Models. • Space–Time Beamforming. • Intersymbol and Co-Channel Suppression. • Space–Time Processing for DS-CDMA. • Capacity and Data Rates in MIMO Systems.	3	6	a1, b2, c1, c2, d2
Number of Weeks /and Units Per Semester		**14**	**28**	

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V. Teaching strategies of the course:

- Lectures
- Assignments.
- Dialogue and discussion.
- Brainstorming.
- Self-learning.

VI. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1.	Phased array antennas, adaptive arrays and diversity techniques.	a1, a2, d1, d2	2nd	1.5
2.	Smart antenna configurations and architecture.	a1, a2, c1, c2, d1, d2	4th	2.25
3.	Multiple Input - Multiple Output (MIMO) Communications Systems for frequency selective scenarios	a1, a2, c1, c2, d1, d2	6th	3
4.	Approach and Methods to Estimate the Direction of Arrival (DOA).	a1, a2, b1, c1, d1, d2	9th	3
5.	Classical/ Space–Time Beam former methods and adaptive algorithms for beamforming (LMS, RLS).	a1, a2, b1, b2, c1, d2	11th	3
6.	Space–Time channel and signal models and Space–Time processing for DS-CDMA.	a2, b2, c1, c2, d2	13th	2.25
	Total			**15**

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VII. Schedule of Assessment Tasks for Students During the Semester:

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment	Aligned Course Learning Outcomes
1.	Assignments	2nd ,4th, 6th ,9th, 11th ,13th	15	10%	a1, a2, b1, b2, c1, c2. d1, d2
2.	Quiz 1&2	4th, 10th	7.5	5%	a1, a2, b1, b2
3.	Midterm Exam	8th	22.5	15%	a1, a2, b1, b2, c1, c2. d1, d2
4.	Final Exam	16th	105	70%	a1, a2, b1, b2, c1, c2. d1, d2
	Sum		**150**	**100%**	

VIII. Learning Resources:

1- Required Textbook(s) (maximum two).

1. Introduction to Smart Antennas, C.A.Balanis, Morgan and Claypool, 2007
2. Smart Antennas, L.C.Godra, CRC Press, 2004

2- Essential References.

1. Smart Antenna for Wireless Communication, T.S.Rappaport and J.C.Liberti, Prentice Hall, 1999
2. Adaptive Filter Theory, S. Haykin. Prentice Hall, 1985
3. Smart Antenna Engineering, Ahmed El Zooghby, Artech House, 2005.

3- Electronic Materials and Web Sites etc.

1. http://www.wiley.com/go/permissions.
2. http://www.cst.com
3. http://he-cda.wiley.com/wileycda/
4. www.mm-microwave.com

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IX.Course Policies:	
1.	**Class Attendance:** - The students should have more than 75% of attendance according to rules and regulations of the faculty.
2.	**Tardy:** - The students should respect the timing of attending the lectures. They should attend within 15 minutes from starting of the lecture.
3.	**Exam Attendance/Punctuality:** - The student should attend the exam on time. The punctuality should be implemented according to rules and regulations of the faculty for mid-term exam and final exam.
4.	**Assignments & Projects:** - The assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time.
5.	**Cheating:** - If any cheating occurred during the examination, the student is not allowed to continue and he has to face the examination committee for enquires.
6.	**Plagiarism:** - If one student attends the exam on another behalf; he will be dismissed from the faculty according to the policy, rules and regulations of the university.
7.	**Other policies:** - All the teaching materials should be kept out the examination hall and mobile phones are not allowed. - Mutual respect should be maintained between the student and his teacher and also among students. Failing in keeping this respect is subject to the policy, rules and regulations of the university.

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Sana'a University
Faculty of Engineering
Electrical Engineering Department
Title of the Program: B.Sc. of Communication Engineering and Networks

Reviewed By	**Vice Dean for Academic Affairs and Post Graduate Studies: Asst. Prof. Dr. Tarek A. Barakat** **President of Quality Assurance Unit: Assoc. Prof. Dr. Mohammed Algorafi** **Name of Reviewer from the Department: Asst. Prof. Dr. Mohammed Al-Suraby**
	Deputy Rector for Academic Affairs Asst. Prof. Dr. Ibrahim AlMutaa **Assoc. Prof. Dr. Ahmed Mujahed** **Asst. Prof. Dr. Munasar Alsubri**

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Template for Course Plan of Smart Antenna Systems

I. - Information about Faculty Member Responsible for the Course:							
Name of Faculty Member	Tr. Abdulbaset Al-Bshah	**Office Hours**					
Location &Telephone No.	Engineering Faculty	**SAT**	**SUN**	**MON**	**TUE**	**WED**	**THU**
E-mail	drmurad00@yahoo.com			8 - 12			

II. Course Identification and General Information:						
1.	Course Title:	Smart Antenna Systems				
2.	Course Number & Code:	CNE334				
3.	Credit hours:	C.H				Credit Hours
		Th.	Tu.	Pr.	Tr.	
		2	2	-	-	3
4.	Study level/year at which this course is offered:	4th Level/ 1st semester				
5.	Pre –requisite (if any):	Waves Propagation and Antennas (CNE322)				
6.	Co –requisite (if any):	None.				
7.	Program (s) in which the course is offered	Communication Engineering and Networks				
8.	Language of teaching the course:	English+ Arabic				
9.	System of Study:	Regular				
10.	Mode of delivery:	Lecture				
11.	Location of teaching the course:	Faculty of Engineering – Sana'a University				

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III. Course Description:

This course aims to provide students with an understanding of the design, configuration and architecture of smart antennas systems, with the study of the Classical Beam former and adaptive algorithms for beamforming (LMS, RLS). It includes the approach and methods to estimate the Direction of Arrival (DOA). The course gives comprehensive study of Space–Time channel and signal models and Space–Time beamforming.

IV. Intended learning outcomes (ILOs) of the course:

- Brief summary of the knowledge or skill the course is intended to develop:

1. Illustrate key benefits and drawbacks for both the basic antennas and smart antenna technology.
2. Explain the principles of configuration and architecture differences between smart and basic antennas.
3. Identify the Approach and Methods to estimate the Direction of Arrival (DOA) and Maximum SNR/ SINR Beam former.
4. Analyze the Discrete Space–Time processing and adaptive algorithms for Beamforming (LMS, RLS).
5. Perform the requirements for the design and implementation of smart antenna systems.
6. Analyze of Multiple Input - Multiple Output (MIMO) Communications Systems (frequency selective scenarios, capacity and data Rates)
7. Perform specific tasks individually and present his tasks' ideas clearly.
8. Conduct scientific research and drafting reports for it.

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V. Course Content:

A – Theoretical Aspect:

Order	Units/Topics List	Sub Topics List	Number of Weeks	Contact hours
1.	Antenna Arrays Overview	- Isotropic Radiators - Omnidirectional Antennas - Directional Antennas - Phased Array Antennas - Adaptive Arrays - Diversity Techniques	1st,2nd	4
2.	Smart Antennas for Wireless Communications	- Need for Smart Antennas. - Smart Antenna Configurations (Switched-Beam, Adaptive Antenna Approach). - Space Division Multiple Access (SDMA). - Architecture of a Smart Antenna System (Receiver, Transmitter). - Benefits and Drawbacks. - Basic Principles. - Mutual Coupling Effects. - Multiple Input - Multiple Output (MIMO) Communications Systems, MIMO for frequency selective scenarios.	3rd, 4th,5th	6
3.	DOA Estimation Fundamentals	- Array Response Vector. - Received Signal Model. - Subspace-Based Data Model. - Signal Autocovariance. - Conventional DOA Estimation Methods.	6th, 7th	4

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		- Subspace Approach to DOA Estimation (MUSIC Algorithm, ESPRIT Algorithm). - Uniqueness of DOA Estimates.		
4.	Midterm Exam	All previous topics	8th	2
5.	Beam Forming Fundamentals	- Classical Beam former. - Statistically Optimum Beamforming weight vectors. - Maximum SNR Beam former. - Multiple Side-lobe Canceller and maximum SINR Beam former. - Minimum Mean Square Error (MMSE). - Direct Matrix Inversion (DMI). - Linearly Constrained Minimum Variance (LCMV). - Adaptive Algorithms for Beamforming (LMS, RLS)	9th, 10th,11th,12th	8
6.	Space–Time Processing	- Discrete Space–Time Channel and Signal Models. - Space–Time Beamforming. - Intersymbol and Co-Channel Suppression. - Space–Time Processing for DS-CDMA. - Capacity and Data Rates in MIMO Systems.	13th,14th, 15th	6
7.	Final Exam	All topics	16th	2
Number of Weeks /and Units Per Semester			**16**	**32**

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B. Tutorials Aspect:

Order	Tutorial Skills List	Nº of Weeks	C.H.
6.	Antenna Arrays Overview • Isotropic Radiators • Omnidirectional Antennas • Directional Antennas • Phased Array Antennas • Adaptive Arrays • Diversity Techniques	1st ,2nd	4
7.	Smart Antennas for Wireless Communications • Need for Smart Antennas. • Smart Antenna Configurations (Switched-Beam, Adaptive Antenna Approach) • Space Division Multiple Access (SDMA). • Architecture of a Smart Antenna System (Receiver, Transmitter.(• Benefits and Drawbacks . • Basic Principles. • Mutual Coupling Effects. • Multiple Input - Multiple Output (MIMO) Communications Systems, MIMO for frequency selective scenarios.	3rd, 4th,5th	6
8.	DOA Estimation Fundamentals • Array Response Vector. • Received Signal Model. • Subspace-Based Data Model. • Signal Autocovariance. • Conventional DOA Estimation Methods. • Subspace Approach to DOA Estimation (MUSIC Algorithm, ESPRIT Algorithm).	6th .7th,8th	6

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	• Uniqueness of DOA Estimates.		
9.	Beam Forming Fundamentals • Classical Beam former. • Statistically Optimum Beamforming weight vectors. • Maximum SNR Beam former. • Multiple Side-lobe Canceller and maximum SINR Beam former. • Minimum Mean Square Error (MMSE). • Direct Matrix Inversion (DMI) . • Linearly Constrained Minimum Variance (LCMV) • Adaptive Algorithms for Beamforming (LMS, RLS)	9^{th} ,10^{th} ,11^{th}	6
10.	Space–Time Processing • Discrete Space–Time Channel and Signal Models. • Space–Time Beamforming. • Intersymbol and Co-Channel Suppression. • Space–Time Processing for DS-CDMA. • Capacity and Data Rates in MIMO Systems.	12^{th} ,$13^{th.}$,14^{th}	6
Number of Weeks /and Units Per Semester		**14**	**28**

VI. Teaching strategies of the course:

- Lectures
- Assignments.
- Dialogue and discussion.
- Brainstorming.
- Self-learning.

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VII. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1.	Phased array antennas, adaptive arrays and diversity techniques.	a1, a2, d1, d2	2nd	1.5
2.	Smart antenna configurations and architecture.	a1, a2, c1, c2, d1, d2	4th	2.25
3.	Multiple Input - Multiple Output (MIMO) Communications Systems for frequency selective scenarios	a1, a2, c1, c2, d1, d2	6th	3
4.	Approach and Methods to Estimate the Direction of Arrival (DOA).	a1, a2, b1, c1, d1, d2	9th	3
5.	Classical/ Space–Time Beam former methods and adaptive algorithms for beamforming (LMS, RLS).	a1, a2, b1, b2, c1, d2	11th	3
6.	Space–Time channel and signal models and Space–Time processing for DS-CDMA.	a2, b2, c1, c2, d2	13th	2.25
	Total			**15**

VIII.Schedule of Assessment Tasks for Students During the Semester:

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment
1.	Assignments	2nd ,4th, 6th ,9th, 11th ,13th	15	10%
2.	Quiz 1&2	4th, 10th	7.5	5%
3.	Midterm Exam	8th	22.5	15%
4.	Final Exam	16th	105	70%
	Sum		**150**	**100%**

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IX. Learning Resources:

1- Required Textbook(s) (maximum two).

1. Introduction to Smart Antennas, C.A.Balanis, Morgan and Claypool, 2007
2. Smart Antennas, L.C.Godra, CRC Press, 2004

2- Essential References.

1. Smart Antenna for Wireless Communication, T.S.Rappaport and J.C.Liberti, Prentice Hall, 1999
2. Adaptive Filter Theory, S. Haykin. Prentice Hall, 1985
3. Smart Antenna Engineering, Ahmed El Zooghby, Artech House, 2005.

3- Electronic Materials and Web Sites etc.

1. http://www.wiley.com/go/permissions.
2. http://www.cst.com
3. http://he-cda.wiley.com/wileycda/
4. www.mm-microwave.com

X. Course Policies:

1.	**Class Attendance:** - The students should have more than 75% of attendance according to rules and regulations of the faculty.
2.	**Tardy:** - The students should respect the timing of attending the lectures. They should attend within 15 minutes from starting of the lecture.
3.	**Exam Attendance/Punctuality:** - The student should attend the exam on time. The punctuality should be implemented according to rules and regulations of the faculty for mid-term exam and final exam.
4.	**Assignments & Projects:** - The assignment is given to the students after each chapter; the student has to submit all the assignments for checking on time.

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Rector of Sana'a University
Prof. Dr. Al-Qassim Mohammed Abbas

5.	**Cheating:** - If any cheating occurred during the examination, the student is not allowed to continue and he has to face the examination committee for enquires.
6.	**Plagiarism:** - If one student attends the exam on another behalf; he will be dismissed from the faculty according to the policy, rules and regulations of the university.
7.	**Other policies:** - All the teaching materials should be kept out the examination hall and mobile phones are not allowed. - Mutual respect should be maintained between the student and his teacher and also among students. Failing in keeping this respect is subject to the policy, rules and regulations of the university.

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