Sana'a University
Faculty of Engineering
Mechatronics Engineering Department
Mechatronics Engineering Program

Elective Course (2)
Course Specification of Refrigeration and Air Conditioning

I. Course Identification and General Information:

1.	Course Title:	Refrigeration and Air Conditioning.				
2.	Course Code & Number:	MT404.				
3.	Credit hours:	C.H				TOTAL CR. HRS
		Th.	Seminar	Pr.	Tu.	
		2	-	-	2	3
4.	Study level/ semester at which this course is offered:	Fifth Year- First Semester.				
5.	Pre –requisite (if any):	Thermodynamics and Heat Transfer.				
6.	Co –requisite (if any):	Nil.				
7.	Program (s) in which the course is offered:	Mechatronics Engineering Program.				
8.	Language of teaching the course:	English Language.				
9.	Location of teaching the course:	Mechatronics Engineering Department.				
10.	Prepared By:	Dr. Eng. Hamoud A. Al-Nehari.				
11.	Date of Approval:					

II. Course Description:

The course is designed to give fundamental knowledge of types of refrigeration, refrigeration cycles, refrigerants and behavior under various conditions, different air conditioning terms and load calculation, designing of components of air distribution system.

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Dr. Hamoud Al-Nehari	Ass. Prof. Dr. Abdul-Malik Momin	Ass. Prof. Dr. Mohammad Algorafi	Prof. Dr. Mohammed AL-Bukhaiti	Ass. Prof. Dr. Huda Al-Emad

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III. Course Intended learning outcomes (CILOs) of the course		**Referenced PILOs**
a.1	Characterize fundamental principles of refrigeration and air conditioning systems.	A2
a.2	Define various refrigeration cycles.	
b.1	Design air conditioning system using cooling load calculations.	B1
b.2	Analyze problems, conclude software solutions associated with refrigeration and air conditioning.	
c.1	Apply calculations of psychometric properties, processes, heating and cooling load requirements.	C1
c.2	Choose various important components of the refrigeration and air conditioning systems.	
d.1	Cooperate in work successfully as a part of a team through training on simulation software and presentations.	D1
d.2	Examine results and defend ideas.	D6

(A) Alignment Course Intended Learning Outcomes of Knowledge and Understanding to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
a.1 Characterize fundamental principles of refrigeration and air conditioning systems.	• Lectures. • Tutorials. • Interactive class discussion.	• Written tests and quizzes. • Homework and assignments.
a.2 Define various refrigeration cycles.		

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(B) Alignment Course Intended Learning Outcomes of Intellectual Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
b.1 Design air conditioning system using cooling load calculations.	• Lectures. • Tutorials. • Interactive class discussion.	• Written tests and quizzes. • Homework and assignments.
b.2 Analyze problems, conclude software solutions associated with refrigeration and air conditioning.		

© Alignment Course Intended Learning Outcomes of Professional and Practical Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
c.1 Make calculations of psychometric properties, processes, heating and cooling load requirements.	• Lectures. • Tutorials. • Simulations using computer software	• Written tests and quizzes. • Homework and assignments.
c.2 Choose various important components of the refrigeration and air conditioning systems.		

(D) Alignment Course Intended Learning Outcomes of Transferable Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
d.1 Cooperate in work successfully as a part of a team through training on simulation software and presentations.	• Lectures. • Tutorials. • Simulations using computer software • Group learning.	• Written tests and quizzes. • Homework and assignments. • Project reports.
d.2 Examine results and defend ideas.		

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IV. Course Content:

A – Theoretical Aspect: Lectures and Exercises

Order	Units/Topics List	Learning Outcomes	Sub Topics List	Number of Weeks	Contact hours
1.	Introduction.	a1, a2, b1, b2	Brief history, need of refrigeration and air conditioning, methods of producing cooling, ton of refrigeration, coefficient of performance, types and application of refrigeration and air condensing systems.	1	1
2.	Refrigerants and their Characteristics.	a1, a2, b1, b2	Classification, nomenclature, desirable properties, secondary refrigerants, future industrial refrigerants		1
3.	Air Refrigeration.	a1, a2, b1, b2, c1, c2, d1, d2	Reversed Carnot cycle and its limitation, Bell-Coleman cycle, aircraft refrigeration, working and analysis of Simple; Bootstrap; Reduced ambient and Regenerative air refrigeration systems	1	2
4.	Vapor Compression System.	a1, a2, b1, b2, c1, c2, d1, d2	Simple system on P-h and T-s diagrams, analysis of the simple cycle, factors affecting the performance of the cycle, actual cycle	1	2
5.	Compound Compression System.	a1, a2, b1, b2, c1, c2, d1, d2	Compound compression with intercooler, flash gas removal and flash intercooler, multiple evaporators with back pressure	2	4

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			valves and with multiple expansion valves without flash inter cooling, analysis of two evaporators with flash intercooler and individual expansion valve and multiple expansion valve, cascade refrigeration system		
6.	Absorption Refrigeration System.	a1, a2, b1, b2, c1, c2, d1, d2	Desirable **c**haracteristics of refrigerant, selection of pair, practical H2O -NH3 cycle, LiBr – H2O system and its working, h-x diagram and simple calculation of various process like adiabatic mixing and mixing with heat transfer, throttling, Electrolux refrigeration system.	1	2
7.	Refrigeration System Components.	a1, a2, b1, b2, c1, c2, d1, d2	Types; construction; working; comparison and selection of compressors; condensers; expansion devices; and evaporators, refrigeration piping accessories, evacuation and charging of refrigerant, properties and classification of thermal insulation.	1	2
8.	Mid-Term Exam	a1, a2, b1, b2, c1, c2	The first 7 chapters.	1	2
9.	Psychrometry	a1, a2, b1, b2, c1, c2, d1, d2	Dalton's law of partial pressure, Properties of moist air, temperature and humidity	1	2

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			measuring instruments, psychometric chart, psychometric processes.		
10.	Human Comfort.	a1, a2, b1, b2, c1, c2, d1, d2	Selection of inside design conditions, thermal comfort, heat balance equation for a human being, factors affecting thermal comfort, Effective temperature, comfort chart and factors governing effective temperature, selection of outside design conditions		2
11.	Load Analysis.	a1, a2, b1, b2, c1, c2, d1, d2	Site survey, outdoor and indoor design conditions, classification of loads, flywheel effect of building material and its use in design, effect of wall construction on cooling load, instantaneous heat gain (IHG) and instantaneous cooling load (ICL) heat transmission through sunlit and shaded glass using tables, method of reduction of solar heat gain through glass, calculations of cooling load TETD due to sunlit and shaded roof and walls using tables, ventilation and air infiltration, load due to outside air, heat gain from occupants; electric lights; product; electric motor and appliances, load calculations for automobiles,	2	2

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			use of load estimation sheet, introduction of CLTD method		
12.	Duct Design and Air Distribution.	a1, a2, b1, b2, c1, c2, d1, d2	Function; classification and economic factors influencing duct layout, equal friction method of duct design, use of friction chart, dynamic losses and its determination, Requirements of air distribution system, air distribution, grills, outlets, application, location	1	2
13.	Air-Conditioning Systems.	a1, a2, b1, b2, c1, c2, d1, d2	Classification, system components, all air; all water; and air-water systems, room air conditioners, packaged air conditioning plant, central air conditioning systems, split air conditioning systems	1	2
14.	Controls and Applications.	a1, a2, b1, b2, c1, c2, d1, d2	Controls – LP/HP cutoff, Thermostats, Humidistats, Interlocking control, Electronic Controllers Applications Refrigeration & A/C Ice plant – food storage plants – diary and food processing plants, Food preservation, Freeze Drying, A/c in textile, printing pharmaceutical industry and Hospitals, Liquefaction of LNG, Liquefaction of gases (cryogenics), Deep sea water air-conditioning	2	4

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15.	Final Exam.	a1, a2, b1, b2, c1, c2	All the chapters.	1	2
Number of Weeks /and Units Per Semester				**16**	**32**

B – Tutorial Aspect:

Order	Tasks/ Experiments	Number of Weeks	Contact hours	Learning Outcomes
1.	Introduction.	1	2	a1, a2, b1, b2
2.	Refrigerants and their Characteristics.			a1, a2, b1, b2
3.	Air Refrigeration.	1	2	a1, a2, b1, b2, c1, c2, d1, d2
4.	Vapor Compression System.	1	2	a1, a2, b1, b2, c1, c2, d1, d2
5.	Compound Compression System.	2	4	a1, a2, b1, b2, c1, c2, d1, d2
6.	Absorption Refrigeration System.	1	2	a1, a2, b1, b2, c1, c2, d1, d2
7.	Refrigeration System Components.	1	2	a1, a2, b1, b2, c1, c2, d1, d2
8.	Psychrometry	1	2	a1, a2, b1, b2, c1, c2, d1, d2
9.	Human Comfort.	2	4	a1, a2, b1, b2, c1, c2, d1, d2
10.	Load Analysis.			a1, a2, b1, b2, c1, c2, d1, d2
11.	Duct Design and Air Distribution.	1	2	a1, a2, b1, b2, c1, c2, d1, d2
12.	Air-Conditioning Systems.	1	2	a1, a2, b1, b2, c1, c2, d1, d2
13.	Controls and Applications.	2	4	a1, a2, b1, b2, c1, c2, d1, d2
Number of Weeks /and Units Per Semester		**14**	**28**	

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V. Teaching strategies of the course:

1. Lectures.
2. Tutorials.
3. Simulations using Computer Software.
4. Interactive Class Discussion.

VI. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1.	Exercises & Home works (all the chapters)	a1, a2, b1, b2, c1, c2, d1, d2	Weekly	5 for all
2.	Project (single\group)	a1, a2, b1, b2, c1, c2, d1, d2	13	5
Total				**10**

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 (all the chapters).	Weekly	5	3.33 %	a1, a2, b1, b2, c1, c2,d1, d2
2.	Project (single\group).	13	5	3.33 %	a1, a2, b1, b2, c1, c2,d1, d2
3.	Quizzes.	7,12	15	10%	a1, a2, b1, b2, c1, c2,d1, d2
4.	Mid-Term Exam.	8	20	13.33 %	a1, a2, b1, b2, c1, c2,d1, d2
5.	Final Exam.	16	105	70 %	a1, a2, b1, b2, c1, c2,d1, d2
Total			**150**	**100%**	

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VIII. Learning Resources:

- Written in the following order: (Author - Year of publication – Title – Edition – Place of publication – Publisher).

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

1. W.F. Stoecker and J. W. Jones, 1982 Refrigeration and Air Conditioning, McGraw-Hill.
2. C P Arora, 2015, Refrigeration and Air Conditioning, McGraw-Hill.

2- Essential References.

1- Refrigeration and Air-conditioning by Ramesh Arora.
2- ASHRAE Refrigeration Handbook.

3- Electronic Materials and Web Sites *etc*.

http://www.springer.com/engineering/mechanical+engineering/journal/231

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.

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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.

Reviewed By	Vice Dean for Academic Affairs and Post Graduate Studies: Dr. Tarek A. Barakat President of Quality Assurance Unit: Ass. Prof. Dr. Mohammed Algorafi Head of Mechatronics Engineering Department: Ass. Prof. Dr. Abdul-Malik Momin
	Deputy Rector for Academic Affairs Dr. Ibrahim AlMutaa Ass. Prof. Dr. Ahmed Mujahed Dr. Munaser Alsubri

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Elective Course (2)
Template for Course Plan of Refrigeration and Air Conditioning

I. - Information about Faculty Member Responsible for the Course:							
Name of Faculty Member	Dr. Eng. Hamoud A. Al-Nehari	**Office Hours**					
Location& Telephone No.		**SAT**	**SUN**	**MON**	**TUE**	**WED**	**THU**
E-mail	h_nahary@hotmail.com	8-10					

II. Course Identification and General Information:						
1-	Course Title:	Refrigeration and Air Conditioning.				
2-	Course Number & Code:	MT404.				
3-	Credit hours:	C.H				Total Cr. Hrs
		Th.	Seminar	Pr.	Tu.	
		2	-	-	2	3
4-	Study level/year at which this course is offered:	Fifth Year- First Semester.				
5-	Pre –requisite (if any):	Thermodynamics and Heat Transfer.				
6-	Co –requisite (if any):	Nil.				
7-	Program (s) in which the course is offered	Mechatronics Engineering Program.				
8-	Language of teaching the course:	English Language.				
9-	System of Study:	Semesters.				
10-	Mode of delivery:	Lectures and Tutorials.				
11-	Location of teaching the course:	Mechatronics Engineering Department.				

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III. Course Description:

The course is designed to give fundamental knowledge of types of refrigeration, refrigeration cycles, refrigerants and behavior under various conditions, different air conditioning terms and load calculation, designing of components of air distribution system.

IV. Course Intended learning outcomes (CILOs) of the course		Referenced PILOs
a.1	Characterize fundamental principles of refrigeration and air conditioning systems.	A2
a.2	Define various refrigeration cycles.	
b.1	Design air conditioning system using cooling load calculations.	B1
b.2	Analyze problems, conclude software solutions associated with refrigeration and air conditioning.	
c.1	Apply calculations of psychometric properties, processes, heating and cooling load requirements.	C1
c.2	Choose various important components of the refrigeration and air conditioning systems.	
d.1	Cooperate in work successfully as a part of a team through training on simulation software and presentations.	D1
d.2	Examine results and defend ideas.	D6

V. Course Content:

A – Theoretical Aspect: Lectures and Exercises

Order	Units/Topics List	Sub Topics List	Number of Weeks	Contact hours
1.	Introduction.	Brief history, need of refrigeration and air conditioning, methods of producing cooling, ton of refrigeration, coefficient of	1	1

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		performance, types and application of refrigeration and air condensing systems.		
2.	Refrigerants and their Characteristics.	Classification, nomenclature, desirable properties, secondary refrigerants, future industrial refrigerants		1
3.	Air Refrigeration.	Reversed Carnot cycle and its limitation, Bell-Coleman cycle, aircraft refrigeration, working and analysis of Simple; Bootstrap; Reduced ambient and Regenerative air refrigeration systems	2	2
4.	Vapor Compression System.	Simple system on P-h and T-s diagrams, analysis of the simple cycle, factors affecting the performance of the cycle, actual cycle	3	2
5.	Compound Compression System.	Compound compression with intercooler, flash gas removal and flash intercooler, multiple evaporators with back pressure valves and with multiple expansion valves without flash inter cooling, analysis of two evaporators with flash intercooler and individual expansion valve and multiple expansion valve, cascade refrigeration system	4,5	4
6.	Absorption refrigeration System.	Desirable **c**haracteristics of refrigerant, selection of pair, practical H2O -NH3 cycle, LiBr – H2O system and its working, h-x diagram and simple calculation of various process like adiabatic mixing and mixing with heat transfer, throttling, Electrolux refrigeration system.	6	2
7.	Refrigeration System Components.	Types; construction; working; comparison and selection of compressors; condensers; expansion devices; and evaporators, refrigeration piping accessories, evacuation	7	2

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		and charging of refrigerant, properties and classification of thermal insulation.		
8	Mid-Term Exam.	The first 7 chapters.	8	2
9.	Psychrometry	Dalton's law of partial pressure, Properties of moist air, temperature and humidity measuring instruments, psychometric chart, psychometric processes.	9	2
10.	Human Comfort.	Selection of inside design conditions, thermal comfort, heat balance equation for a human being, factors affecting thermal comfort, Effective temperature, comfort chart and factors governing effective temperature, selection of outside design conditions	10,11	2
11.	Load Analysis.	Site survey, outdoor and indoor design conditions, classification of loads, flywheel effect of building material and its use in design, effect of wall construction on cooling load, instantaneous heat gain (IHG) and instantaneous cooling load (ICL) heat transmission through sunlit and shaded glass using tables, method of reduction of solar heat gain through glass, calculations of cooling load TETD due to sunlit and shaded roof and walls using tables, ventilation and air infiltration, load due to outside air, heat gain from occupants; electric lights; product; electric motor and appliances, load calculations for automobiles, use of load estimation sheet, introduction of CLTD method		2
12.	Duct Design and Air Distribution.	Function; classification and economic factors influencing duct layout, equal friction method of duct design, use of friction chart, dynamic	12	2

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		losses and its determination, Requirements of air distribution system, air distribution, grills, outlets, application, location		
13.	Air-Conditioning systems.	Classification, system components, all air; all water; and air-water systems, room air conditioners, packaged air conditioning plant, central air conditioning systems, split air conditioning systems	13	2
14.	Controls and Applications.	Controls – LP/HP cutoff, Thermostats, Humidistats, Interlocking control, Electronic Controllers Applications Refrigeration & A/C Ice plant – food storage plants – diary and food processing plants, Food preservation, Freeze Drying, A/c in textile, printing pharmaceutical industry and Hospitals, Liquefaction of LNG, Liquefaction of gases (cryogenics), Deep sea water air-conditioning	14,15	4
15.	Final Exam.	All the chapters.	16	2
Number of Weeks /and Units Per Semester			**16**	**32**

B – Tutorial Aspect:

Order	Tasks/ Experiments	Number of Weeks	Contact hours	Learning Outcomes
1.	Introduction.	1	2	a1, a2, b1, b2
2.	Refrigerants and their Characteristics.			a1, a2, b1, b2
3.	Air Refrigeration.	2	2	a1, a2, b1, b2, c1, c2, d1, d2
4.	Vapor Compression System.	3	2	a1, a2, b1, b2, c1, c2, d1, d2
5.	Compound Compression System.	4,5	4	a1, a2, b1, b2, c1, c2, d1, d2

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6.	Absorption Refrigeration System.	6	2	a1, a2, b1, b2, c1, c2, d1, d2
7.	Refrigeration System Components.	7	2	a1, a2, b1, b2, c1, c2, d1, d2
8.	Psychrometry	8	2	a1, a2, b1, b2, c1, c2, d1, d2
9.	Human Comfort.	9,10	4	a1, a2, b1, b2, c1, c2, d1, d2
10.	Load Analysis.			a1, a2, b1, b2, c1, c2, d1, d2
11.	Duct Design and Air Distribution.	11	2	a1, a2, b1, b2, c1, c2, d1, d2
12.	Air-Conditioning Systems.	12	2	a1, a2, b1, b2, c1, c2, d1, d2
13.	Controls and Applications.	13,14	4	a1, a2, b1, b2, c1, c2, d1, d2
Number of Weeks /and Units Per Semester		**14**	**28**	

VI. Teaching strategies of the course:

1. Lectures.
2. Tutorials.
3. Simulations using Computer software.
4. Interactive Class Discussion.

VII. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1.	Exercises & Home works (all the chapters)	a1, a2, b1, b2, c1, c2, d1, d2	Weekly	5 for all
2.	Project (single\group)	a1, a2, b1, b2, c1, c2, d1, d2	13	5
Total				**10**

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VIII. 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 (all the chapters).	Weekly	5	3.33 %	a1, a2, b1, b2, c1, c2,d1, d2
2.	Project (single\group).	13	5	3.33 %	a1, a2, b1, b2, c1, c2,d1, d2
3.	Quizzes.	7,12	15	10%	a1, a2, b1, b2, c1, c2,d1, d2
4.	Mid-Term Exam.	8	20	13.33 %	a1, a2, b1, b2, c1, c2,d1, d2
5.	Final Exam.	16	105	70 %	a1, a2, b1, b2, c1, c2,d1, d2
Total			**150**	**100%**	

IX. Learning Resources:

- Written in the following order: (Author - Year of publication – Title – Edition – Place of publication – Publisher).

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

3. W.F. Stoecker and J. W. Jones, 1982 Refrigeration and Air Conditioning, McGraw-Hill.
4. C P Arora, 2015, Refrigeration and Air Conditioning, McGraw-Hill.

2- Essential References.

1- Refrigeration and Air-conditioning by Ramesh Arora.
2- ASHRAE Refrigeration Handbook.

3- Electronic Materials and Web Sites *etc*.

http://www.springer.com/engineering/mechanical+engineering/journal/231

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Dr. Hamoud Al-Nehari	Ass. Prof. Dr. Abdul-Malik Momin	Ass. Prof. Dr. Mohammad Algorafi	Prof. Dr. Mohammed AL-Bukhaiti	Ass. Prof. Dr. Huda Al-Emad

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

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.
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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