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

47. Course Specification of Thermal / Fluid Lab.

I. Course Identification and General Information:						
1.	Course Title:	Thermal / Fluid Lab.				
2.	Course Code & Number:	ME354.				
3.	Credit Hours:	C.H				TOTAL CR. HRS
		Th.	Seminar/Tu.	Pr	Tr.	
		-	-	2	-	1
4.	Study level/ semester at which this course is offered:	Fourth Year - First Semester				
5.	Pre –requisite (if any):	ME241 (Fluid Mechanics-I), ME251 (Thermodynamics –I), ME242 (Fluid Mechanics –II) and ME252 (Thermodynamics-II).				
6.	Co –requisite (if any):	ME354 (Heat and Mass Transfer).				
7.	Program (s) in which the course is offered:	Mechanical Engineering Program.				
8.	Language of teaching the course:	English Language.				
9.	Location of teaching the course:	Mechanical Engineering Department.				
10.	Prepared By:	Asst. Prof. Dr. Eng. Hamoud A. Al-Nahari				
11.	Date of Approval:					

II. Course Description:

This lab course will deal with emphasis on thermal fluid sciences. All experiments are conducted in this lab combined elements of theory and practice. Many of the concepts and basic theories, which the student learns in the lectures of thermodynamics, fluid mechanics and heat transfer are demonstrated and confirmed in the lab through different experiments.

III. Alignments of the Course Intended learning outcomes (CILOs)		Referenced PILOs)
a1	Classify the principles of thermal fluid sciences.	A1
a2	Describe experimental techniques in the thermal fluid sciences.	A3
b1	Explore principles of thermodynamics, fluid dynamics, and heat transfer.	B1

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b2	Investigate the experiments professionally in the lab taking into account the best techniques.	
c1	Choose a variety of thermal fluid measuring devices and instruments and be able to interpret their accuracy.	C1, C2
c2	Apply computer software for analysis and design of thermal fluid systems or components.	
d1	Assess a professional lab. report.	D4
d2	Review experimental results.	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- Classify the principles of thermal fluid sciences. **a2-** Describe experimental techniques in the thermal fluid sciences.	• Theory of Experiments. • Laboratory. • Seminars. • Interactive Discussion.	• Individual Lab. Report. • Group Lab Report. • Exams. • Quizzes.

(B) Alignment Course Intended Learning Outcomes of Intellectual Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
b1- Explore principles of thermodynamics, fluid dynamics, and heat transfer. **b2-** Investigate the experiments professionally in the lab taking into account the best techniques.	• Theory of Experiments. • Laboratory. • Seminars. • Interactive Discussion	• Individual Lab. Report. • Group Lab Report. • Exams. • Quizzes.

© 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- Choose a variety of thermal fluid measuring devices and instruments and be able to interpret their accuracy. **c2-** Apply computer software for analysis and design of thermal fluid systems or components.	• Theory of Experiments. • Laboratory. • Seminars. • Interactive Discussion. • Simulation Tools.	• Individual Lab. Report. • Group Lab. Report. • Exams. • Quizzes.

(D) Alignment Course Intended Learning Outcomes of Transferable Skills to Teaching Strategies and Assessment Strategies:		
Course Intended Learning Outcomes	Teaching strategies	Assessment Strategies
d1- Assess a professional lab report. **d2-** Review experimental results.	• Theory of experiments. Laboratory. • Seminars. • Interactive Discussion.	• Individual Lab. Report. • Group Lab. Report. • Exams. • Quizzes.

IV. Course Content:

A. Practical Aspect:

Order	Tasks/ Experiments	Number of Weeks	Contact Hours	Learning Outcomes
1.	Basic Experimental Procedures and Principles of Measurement in Mechanical Engineering.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
2.	Data Presentation and Report Writing.		1	
3.	Proximate Analysis and Calorimetry.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
4.	Analysis of a simple Thermodynamic Cycle.		1	
5.	Calibration of a Pressure Gauge.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
6.	Pressure Measurement.		1	
7.	Study of the Relationship between Pressure and Temperature of Steam.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
8.	Effect of Initial Composition on Boiling Temperature and Vapor Phase Composition.		1	
9.	Determination of Minimum Boiling Point of Binary Mixture.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
10.	Flow through Orifices and Nozzles.		1	
11.	Flow through a Venturi Meter.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
12.	Velocity, Flow and Pressure Drop Measurement.		1	
13.	Impact of a Jet.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
14.	Determination of Force on Objects in Internal and External Flow.		1	
15.	Mid-Term Exam.	1	2	a1,a2, b1, b2, c1,c2
16.	Temperature Measurement.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
17.	Linear and Radial Heat Conduction.		1	

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18.	Conduction along a Composite Bar.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
19.	Thermal Conductivity of Various Solid Materials.		1	
20.	Effect of Cross-Sectional Area on Heat Conduction.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
21.	Effect of Insulation on Heat Conduction.		1	
22.	Free Convection Heat Transfer from a Horizontal Flat Surface.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
23.	Free and Forced Convection from: Vertical Flat Surface, Extended Surface of Constant and Varying Cross Section.		1	
24.	Relationship Between Air velocity and Surface Temperature.	1	1	a1,a2, b1, b2, c1,c2, d1,d2
25.	Combined Convection/Radiation Heat Transfer under Natural Convection.		1	
26.	Checking of the Course File.	2	4	a1,a2, b1, b2, c1,c2, d1,d2
27.	Final Exam.	1	2	a1,a2, b1, b2, c1,c2,
Number of Weeks /and Units Per Semester		**16**	**32**	

V. Teaching strategies of the course:

Theory of Experiments.
Laboratory.
Seminars.
Interactive Discussion.
Simulation Tools.

VI. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark

1.	Lab Report on: Analysis of a simple Thermodynamic Cycle.	a1,a2, b1, b2, c1.c2, d1,d2	2nd	1.5
2.	Lab Report on: Calibration of a Pressure Gauge.	a1,a2, b1, b2, c1.c2, d1,d2	3rd	1.5
3.	Lab Report on: Pressure Measurement.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
4.	Lab Report on: Study of the Relationship between Pressure and Temperature of Steam.	a1,a2, b1, b2, c1.c2, d1,d2	4th	1.5
5.	Lab Report on: Effect of Initial Composition on Boiling Temperature and Vapor Phase Composition.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
6.	Lab Report on: Determination of Minimum Boiling Point of Binary Mixture.	a1,a2, b1, b2, c1.c2, d1,d2	5th	1.5
7.	Lab Report on: Flow through Orifices and Nozzles.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
8.	Lab Report on: Flow through a Venturi Meter.	a1,a2, b1, b2, c1.c2, d1,d2	6th	1.5
9.	Lab Report on: Velocity, Flow and Pressure Drop Measurement.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
10.	Lab Report on: Impact of a Jet.	a1,a2, b1, b2, c1.c2, d1,d2	7th	1.5
11.	Lab Report on: Determination of Force on Objects in Internal and External Flow.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
12.	Lab Report on: Temperature Measurement.	a1,a2, b1, b2, c1.c2, d1,d2	9th	1.5
13.	Lab Report on: Linear and Radial Heat Conduction.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
14.	Lab Report on: Conduction along a Composite Bar.	a1,a2, b1, b2, c1.c2, d1,d2	10th	1.5
15.	Lab Report on: Thermal Conductivity of Various Solid Materials.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
16.	Lab Report on: Effect of Cross-Sectional Area on Heat Conduction.	a1,a2, b1, b2, c1.c2, d1,d2	11th	1.5
17.	Lab Report on: Effect of Insulation on Heat Conduction.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
18.	Lab Report on: Free Convection Heat Transfer from a Horizontal Flat Surface.	a1,a2, b1, b2, c1.c2, d1,d2	12th	1.5

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19.	Lab Report on: Free and Forced Convection from: Vertical Flat Surface, Extended Surface of Constant and Varying Cross Section.	a1,a2, b1, b2, c1.c2, d1,d2		1
20.	Lab Report on: Relationship Between Air velocity and Surface Temperature.	a1,a2, b1, b2, c1.c2, d1,d2	13th	1
21.	Lab Report on: Combined Convection/Radiation Heat Transfer under Natural Convection.	a1,a2, b1, b2, c1.c2, d1,d2	14th	1
Total				**30**

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.	Lab report (Group & Individual) with Present of Results and Discussion.	2 nd-12th	30	30%	a1,a2, b1, b2, c1,c2, d1,d2
2.	Quizzes (Lab. & Theory).	5th and 11th	20	20 %	a1,a2, b1, b2, c1,c2, d1,d2
3.	Mid-Term Exam.	8th	10	10 %	a1,a2, b1, b2, c1,c2
4.	Final Exam.	16th	40	40 %	a1,a2, b1, b2, c1,c2, d1,d2
Total			**100**	**100%**	

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. Lab. Book consisting of Instructions and all Experiment Information.
2. Wheeler, A.J., and A.R. Ganji., 2004, "Introduction to Engineering Experimentation", Prentice Hall.

2- Essential References.

1. Laboratory Notes/Manuals.
2. Various Textbooks related to the Respective taught Courses.
3. Text Books from the Prerequisite Courses are also required.
4. J. P. Holman, "Experimental Methods for Engineers", McGraw-Hill.

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	5. Essick, "Hands-on Introduction to Lab.VIEW", Oxford University Press.
3- Electronic Materials and Web Sites *etc*.	
	http://www.eng.fsu.edu/~alvi/eml4304/webpage/

I. Course Policies:

1	**Class Attendance:** - The student should be attending not less than 75% of total contact hours of the subject, otherwise he will not able to take exam and be considerd as an exam failure. If the student is absent due to illness, he/she should bring an approved statement from university Clinic.
2	**Tardy:** - For lateness in attending the class, the student will be initially notified. If he repeates late in attending class he will be considered absent.
3	**Exam Attendance/Punctuality:** - The student should attend the exam on time. He is permitted to attend the exam half one hour from exam beginning, after that he/she will not be permitted to take exam and he/she is considered absent in the exam.
4	**Assignments & Projects:** - In general one assignment is given after each chapter of a course. The student should submit the assignment on time, mostly one week after giving the assignment
5	**Cheating**: - For cheating in exam, the student is considered as failure. In case the cheating is repeated three times during study the student will be disengaged from the Faculty
6	**Plagiarism**: Plagiarism is the attending of the student the exam of a course instead of other student. If the examination committee proved a plagiarism of a student, he will be disengaged from the Faculty. The final disengagement of the student from the Faculty should be confirmed from the Student Affair Council of the university.
7	**Other policies:** - The mobile phone is not allowable to be used during class lecture. It must be switched off, otherwise the student will be ordered to leave the lecture room. - The mobile phone is not allowed to be taken during the examination time. - Lecture notes and assignments may be given directly to students using soft or hard copy.

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: Assoc. Prof. Dr. Abdul-Malik Momin**
	Deputy Rector for Academic Affairs Asst. Prof. Dr. Ibrahim AlMutaa **Assoc. Prof. Dr. Ahmed Mujahed** **Asst. Prof. Dr. Munasar Alsubri**

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47. Template for Course Plan of Thermal / Fluid Lab.

I. Information about Faculty Member Responsible for the Course:

Name of Faculty Member	Asst. Prof. Dr. Eng. Hamoud A. Al-Nahari	**Office Hours**					
Location& Telephone No.		**SAT**	**SUN**	**MON**	**TUE**	**WED**	**THU**
E-mail	h_nahary@hotmail.com						

II. Course Identification and General Information:

1.	Course Title:	Thermal / Fluid Lab.				
2.	Course Number & Code:	ME354.				
3.	Credit hours:	C.H				Total Cr. Hrs
		Th.	Seminar/Tu.	Pr	Tr.	
		-	-	2	-	1
4.	Study level/year at which this course is offered:	Fourth Year - First Semester.				
5.	Pre –requisite (if any):	ME241 (Fluid Mechanics-I), ME251 (Thermodynamics –I), ME242 (Fluid Mechanics –II) and ME252 (Thermodynamics-II).				
6.	Co –requisite (if any):	ME354 (Heat and Mass Transfer).				
7.	Program (s) in which the course is offered	Mechanical Engineering Program.				
8.	Language of teaching the course:	English Language.				
9.	System of Study:	Semesters.				
10.	Mode of delivery:	Lab. Work.				
11.	Location of teaching the course:	Mechanical Engineering Department.				

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III. Course Description:

This lab course will deal with emphasis on thermal fluid sciences. All experiments are conducted in this lab combined elements of theory and practice. Many of the concepts and basic theories, which the student learns in the lectures of thermodynamics, fluid mechanics and heat transfer are demonstrated and confirmed in the lab through different experiments.

IV. Course Intended learning outcomes (CILOs) of the course

1.	Classify the principles of thermal fluid sciences.
2.	Describe experimental techniques in the thermal fluid sciences.
3.	Explore principles of thermodynamics, fluid dynamics, and heat transfer.
4.	Investigate the experiments professionally in the lab taking into account the best techniques.
5.	Choose a variety of thermal fluid measuring devices and instruments and be able to interpret their accuracy.
6.	Apply computer software for analysis and design of thermal fluid systems or components.
7.	Assess a professional lab. report.
8.	Review experimental results.

V. Course Content:

A. Practical Aspect:

Order	Tasks/ Experiments	Week Due	Contact Hours	Learning Outcomes
1.	Basic Experimental Procedures and Principles of Measurement in Mechanical Engineering.	1st	1	a1, a2, b1, b2, c1.c2, d1,d2
2.	Data Presentation and Report Writing.		1	
3.	Proximate Analysis and Calorimetry.	2 nd	1	a1, a2, b1, b2, c1.c2, d1,d2
4.	Analysis of a simple Thermodynamic Cycle.		1	

5.	Calibration of a Pressure Gauge.	3 rd	1	a1, a2, b1, b2, c1.c2, d1,d2
6.	Pressure Measurement.		1	
7.	Study of the Relationship between Pressure and Temperature of Steam.	4 th	1	a1, a2, b1, b2, c1.c2, d1,d2
8.	Effect of Initial Composition on Boiling Temperature and Vapor Phase Composition.		1	
9.	Determination of Minimum Boiling Point of Binary Mixture.	5 th	1	a1, a2, b1, b2, c1.c2, d1,d2
10.	Flow through Orifices and Nozzles.		1	
11.	Flow through a Venturi Meter.	6 th	1	a1, a2, b1, b2, c1.c2, d1,d2
12.	Velocity, Flow and Pressure Drop Measurement.		1	
13.	Impact of a Jet.	7 th	1	a1, a2, b1, b2, c1.c2, d1,d2
14.	Determination of Force on Objects in Internal and External Flow.		1	
15.	Mid-Term Exam.	8 th	2	a1, a2, b1, b2, c1.c2
16.	Temperature Measurement.	9 th	1	a1, a2, b1, b2, c1.c2, d1,d2
17.	Linear and Radial Heat Conduction.		1	
18.	Conduction along a Composite Bar.	10 th	1	a1, a2, b1, b2, c1.c2, d1,d2
19.	Thermal Conductivity of Various Solid Materials.		1	
20.	Effect of Cross-Sectional Area on Heat Conduction.	11 th	1	a1, a2, b1, b2, c1.c2, d1,d2
21.	Effect of Insulation on Heat Conduction.		1	
22.	Free Convection Heat Transfer from a Horizontal Flat Surface.	12 th	1	a1, a2, b1, b2, c1.c2, d1,d2
23.	Free and Forced Convection from: Vertical Flat Surface, Extended Surface of Constant and Varying Cross Section.		1	

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24.	Relationship Between Air velocity and Surface Temperature.	13 th	1	a1, a2, b1, b2, c1.c2, d1,d2
25.	Combined Convection/Radiation Heat Transfer under Natural Convection.		1	
26.	Checking of the Course File.	14 th and 15 th	4	a1, a2, b1, b2, c1.c2, d1,d2
27.	Final Exam.	16 th	2	a1, a2, b1, b2, c1.c2,
Number of Weeks /and Units Per Semester		**16**	**32**	

VI. Teaching strategies of the course:

- Theory of Experiments.
- Laboratory.
- Seminars.
- Interactive Discussion.
- Simulation Tools.

VII. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1.	Lab Report on: Analysis of a simple Thermodynamic Cycle.	a1,a2, b1, b2, c1.c2, d1,d2	2nd	1.5
2.	Lab Report on: Calibration of a Pressure Gauge.	a1,a2, b1, b2, c1.c2, d1,d2	3rd	1.5
3.	Lab Report on: Pressure Measurement.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
4.	Lab Report on: Study of the Relationship between Pressure and Temperature of Steam.	a1,a2, b1, b2, c1.c2, d1,d2	4th	1.5
5.	Lab Report on: Effect of Initial Composition on Boiling Temperature and Vapor Phase Composition.	a1,a2, b1, b2, c1.c2, d1,d2		1.5

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6.	Lab Report on: Determination of Minimum Boiling Point of Binary Mixture.	a1,a2, b1, b2, c1.c2, d1,d2	5th	1.5
7.	Lab Report on: Flow through Orifices and Nozzles.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
8.	Lab Report on: Flow through a Venturi Meter.	a1,a2, b1, b2, c1.c2, d1,d2	6th	1.5
9.	Lab Report on: Velocity, Flow and Pressure Drop Measurement.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
10.	Lab Report on: Impact of a Jet.	a1,a2, b1, b2, c1.c2, d1,d2	7th	1.5
11.	Lab Report on: Determination of Force on Objects in Internal and External Flow.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
12.	Lab Report on: Temperature Measurement.	a1,a2, b1, b2, c1.c2, d1,d2	9th	1.5
13.	Lab Report on: Linear and Radial Heat Conduction.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
14.	Lab Report on: Conduction along a Composite Bar.	a1,a2, b1, b2, c1.c2, d1,d2	10th	1.5
15.	Lab Report on: Thermal Conductivity of Various Solid Materials.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
16.	Lab Report on: Effect of Cross-Sectional Area on Heat Conduction.	a1,a2, b1, b2, c1.c2, d1,d2	11th	1.5
17.	Lab Report on: Effect of Insulation on Heat Conduction.	a1,a2, b1, b2, c1.c2, d1,d2		1.5
18.	Lab Report on: Free Convection Heat Transfer from a Horizontal Flat Surface.	a1,a2, b1, b2, c1.c2, d1,d2	12th	1.5
19.	Lab Report on: Free and Forced Convection from: Vertical Flat Surface, Extended Surface of Constant and Varying Cross Section.	a1,a2, b1, b2, c1.c2, d1,d2		1
20.	Lab Report on: Relationship Between Air velocity and Surface Temperature.	a1,a2, b1, b2, c1.c2, d1,d2	13th	1

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21.	Lab Report on: Combined Convection/Radiation Heat Transfer under Natural Convection.	a1,a2, b1, b2, c1.c2, d1,d2	14th	1
Total				**30**

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.	Lab report (Group & Individual) with Present of Results and Discussion.	2 nd- 12th	30	30%	a1,a2, b1, b2, c1.c2, d1,d2
2.	Quizzes (Lab. & Theory).	5th and 11th	20	20 %	a1,a2, b1, b2, c1.c2, d1,d2
3.	Mid-Term Exam.	8th	10	10 %	a1,a2, b1, b2, c1.c2
4.	Final Exam.	16th	40	40 %	a1,a2, b1, b2, c1.c2, d1,d2
Total			**100**	**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).

1. Lab. Book consisting of Instructions and all Experiment Information.
2. Wheeler, A.J., and A.R. Ganji., 2004, "Introduction to Engineering Experimentation", Prentice Hall.

2- Essential References.

1. Laboratory Notes/Manuals.
2. Various Textbooks related to the Respective taught Courses.
3. Text Books from the Prerequisite Courses are also required.
4. J. P. Holman, "Experimental Methods for Engineers", McGraw-Hill.
5. Essick, "Hands-on Introduction to Lab.VIEW", Oxford University Press.

3- Electronic Materials and Web Sites *etc*.

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Asst. Prof. Dr. Adel Ahmed Al-Shakiri	Assoc. Prof. Dr. Mohammad Algorafi	Prof. Dr. Mohammed AL-Bukhaiti	Assoc. Prof. Dr. Huda Al-Emad	Prof. Dr. Al-Qassim Mohammed Abbas

	http://www.eng.fsu.edu/~alvi/eml4304/webpage/

II. Course Policies:

1	**Class Attendance:** - The student should be attending not less than 75% of total contact hours of the subject, otherwise he will not able to take exam and be considerd as an exam failure. If the student is absent due to illness, he/she should bring an approved statement from university Clinic.
2	**Tardy:** - For lateness in attending the class, the student will be initially notified. If he repeates late in attending class he will be considered absent.
3	**Exam Attendance/Punctuality:** - The student should attend the exam on time. He is permitted to attend the exam half one hour from exam beginning, after that he/she will not be permitted to take exam and he/she is considered absent in the exam.
4	**Assignments & Projects:** - In general one assignment is given after each chapter of a course. The student should submit the assignment on time, mostly one week after giving the assignment
5	**Cheating**: - For cheating in exam, the student is considered as failure. In case the cheating is repeated three times during study the student will be disengaged from the Faculty
6	**Plagiarism**: Plagiarism is the attending of the student the exam of a course instead of other student. If the examination committee proved a plagiarism of a student, he will be disengaged from the Faculty. The final disengagement of the student from the Faculty should be confirmed from the Student Affair Council of the university.
7	**Other policies:** - The mobile phone is not allowable to be used during class lecture. It must be switched off, otherwise the student will be ordered to leave the lecture room. - The mobile phone is not allowed to be taken during the examination time. - Lecture notes and assignments may be given directly to students using soft or hard copy.