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

43. Course Specification of Theory of Metal Forming

I. Course Identification and General information:

1.	Course Title:	Theory of Metal Forming.				
2.	Course Code & Number:	ME314.				
3.	Credit Hours:	C.H				TOTAL Cr. Hrs.
		Th.	Seminar/Tu	Pr	Tr.	
		2	2	-	-	3
4.	Study level/ semester at which this course is offered:	Fourth Year - First Semester.				
5.	Pre –requisite (if any):	Manufacturing Processes-II (ME113) and Mechanics of Materials - II (ME234).				
6.	Co –requisite (if any):	None.				
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. Abdullah Dhaiban.				
11.	Date of Approval					

II. Course Description:

This course deals with the techniques used in the design of metal forming processes. It includes the principles of mathematical analysis and finite element application for determination the load and power during metal forming process. The effect of various metallurgical and geometrical parameters on the workability of materials is discussed in context of metal forming operations, such as forging, rolling, extrusion, wire and bar drawing, and Sheet Metal forming. Also, the techniques of analysis: slab method, upper bound method, slip-line fields, application to indentation problem will be discussed.

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III. Alignment course intended learning outcomes (CILOs)		Referenced PILOs
a1	Describe the basic principles of metal forming theory, technology, and the effected parameters.	**A1.** Demonstrate knowledge & understanding of Mathematics, Science, and Engineering relevant to Mechanical Engineering.
a2	Recognize the various analysis methods of metal forming processes.	**A2.** Clarify general principles of design, design techniques, and characteristics of engineering materials and components.
b1	Analyse the metal forming process and select the process parameters based on engineering plasticity concepts.	**B1.** Apply the principles of engineering, basic science and mathematics to model, analyze, design, and realize physical systems, components or processes in innovative ways.
b2	Justify the appropriate material and forming method based on the features and application of the component.	**B2.** Design the Mechanical systems or processes within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
c1	Use the techniques of analysis (slab method, …etc.) and computer software to solve problems in the field of theory of metal forming.	**C1.** Use the various techniques, skills, equipment and modern engineering tools and methods necessary for Mechanical Engineering practice.
c2	Solve the metal forming problems analytically and using Finite element method.	**C2.** Conduct experiments; analyze data and present results for various mechanical systems.
d1	Examine the different ideas, views, and knowledge from a range of sources in topics related to metal forming including manufacturing, development and selection.	**D3.** Recognize the needs for, and engage in life-long learning.
d2	Communicate concepts and experimental/ modeling results in clear and logical fashion, both verbally and in writing	**D5.** Communicate effectively both orally and in writing technical reports.

(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- Describe the basic principles of metal forming theory, technology, and the effected parameters.	Lectures, Tutorials	Examinations, Homework Presentations
a2- Recognize the various analysis methods of metal forming processes.	Lectures, Tutorials, Seminars	Examinations, Homework Presentations

(B) Alignment Course intended Learning Outcomes of intellectual Skills to Teaching Strategies and assessment Strategies:		
Course intended Learning Outcomes	Teaching strategies	Assessment Strategies
b1- Analyse the metal forming process and select the process parameters based on engineering plasticity concepts.	Lectures, Tutorials, Seminars, Projects	Examinations, Homework Presentations, Individual and Group Project Reports
b2- Justify the appropriate material and forming method based on the features and application of the component.	Lectures, Tutorials, Seminars, Projects	Examinations, Homework Presentations, Individual and Group Project Reports

(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- Use the techniques of analysis (slab method, …etc.) and computer software to solve problems in the field of theory of metal forming.	Lectures, Seminars, Projects	Examinations, Homework Presentations, Individual and Group Project Reports
c2- Solve the metal forming problems analytically and using Finite element method.	Lectures, Computer Based Session(ANSYS), Seminars, Projects	Examinations, Homework Presentations, Individual and Group Project Reports

(D) Alignment Course intended Learning Outcomes of Transferable Skills to Teaching Strategies and assessment Strategies:		
Course intended Learning Outcomes	Teaching strategies	Assessment Strategies
d1- Examine the different ideas, views, and knowledge from a range of sources in topics related to metal forming including manufacturing, development and selection.	Seminars, Projects	Presentations, Reports
d2- Communicate concepts and experimental/ modeling results in clear and logical fashion, both verbally and in writing	Seminars, Projects	Presentations, Reports

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IV. Course Content:

A – Theoretical aspect:

Order	Units/Topics List	Learning Outcomes	Sub topics List	Number of Weeks	Contact hours
1.	Stress Tensor and Yield Criteria	a1, a2, b1	• Sate of Stress, • Representing Stress as Tensor, • Principal Stresses, • Stress Deviator. • Yield Criteria, • Octahedral Shear Stress and Shear Strain	1	2
2.	Fundamentals of Metal Forming	a1, a2, b1	• Classification of forming Processes. • Mechanics of Metal Working. • Flow Stress Determination. • Friction and Lubrication. • Deformation Zone Geometry. • Workability, Residual Stresses, Strain Rate Sensitivity.	2	4
3.	Working Load Determination	a1, a2, b1, b2, c1, c2, d1	• Slab Method • Upper and Lower Bound Analysis, • Slip Line Field Analysis, • Application of Slip Line Theory.	1	2
4.	Forging	a1, a2, b1, c1, c2, d1	• Forging • Classification of forging Processes. • Analysis of forging Process. • Forging Defects. • Residual Stresses in forging	2	4
5.	Modeling of Metal	a2, b1, c1, c2, d1	• Introduction to Finite Element Methods Software.	1	2

	forming Processes Using Finite Element Method		• ANSYS Workbench • General Steps of Modeling Metal forming Processes.		
6.	Mid – Term Exam1	a1, a2, b1, b2, c1, d1	The first seventh lectures.	1	2
7.	Rolling	a1, a2, b1, c1, c2, d1	• Rolling. • Classification of Rolling Processes. • Analysis of Rolling Process. • Rolling Defects	2	4
8.	Extrusion and Drawing	a1, a2, c1, c2, d1	• Direct and indirect Extrusion. • Analysis of Extrusion Process. • Wire and Bar Drawing. • Analysis of Drawing	2	4
9.	Sheet Metal Forming Processes	a1, a2, c1, c2, d1	• Shearing. • Blanking. • Bending, Stretch forming. • Deep Drawing. • Defects in formed Part. • Sheet Metal formability. • Formability Limit Diagram	3	6
10.	Final Exam	a1, a2, b1, b2, c1, d1	All the fifteen lectures.	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.	**Tutorial One:** • Principal Stresses. • Stress Deviator. • Yield Criteria, Comparison of Yield Criteria. • Octahedral Shear Stress and Shear Strain	1	2	a1, a2, b1
2.	**Tutorial Two:** • Flow Stress Determination. • Strain Rate. • Workability.	2	4	a1, a2, b1
3.	**Tutorial Three:** • Forging Process**.**	1	2	a1, a2, b1, c1, c2, d1,d2
4.	**ANSYS Workbench One:** • ANSYS Workbench • Static Structural. • Geometry Modeling, (Axisymmetry, 2d and 3d Model)	1	2	a1, a2, b1, c1, c2, d1,d2
5.	**Tutorial Four:** • Rolling Forces Torque and Power.	1	2	a1, a2, b1, c1, c2, d1
6.	**ANSYS Workbench Two:** • Materials Model (Metal). • Create Finite Element Model.	1	2	a1, a2, b1, c1, c2, d1,d2
7.	**Tutorial Five:** • Extrusion Load (Direct and Indirect).	1	2	a1, a2, c1, c2, d1
8.	**ANSYS Workbench Three;** • Apply Load and Boundary Conditions. • Get the Result.	1	2	a1, a2, c1, c2, d2
9.	**Tutorial Six:** • Bar/Wire Drawing Load	1	2	a1, a2, c1, c2, d1
10.	**ANSYS Workbench Four:** • Metal forming Process (Forging, Rolling, Extrusion, Wire and Bar Drawing**)**	1	2	a1, a2, c1, c2, d1, d2
11.	**Tutorial Seven:** • Sheet Metal Forming Process.	1	2	a1, a2, c1, c2, d1

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12.	**ANSYS Workbench Five:** • Sheet Metal forming Processes.	1	2	a1, a2, c1, c2, d1, d2
13.	**Discussion of the Project**	1	2	a1, a2, c1, c2, d1,d2
Number of Weeks /and Units Per Semester		**14**	**28**	

V. Teaching strategies of the course:

- Lectures
- Tutorials
- Computer Based Session (ANSYS)
- Seminars.
- Projects.

VI. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark out of 100
1	Project Report and Presentation.	a1, a2, b1, c1, c2, d1	15th week	15
2	Exercises and Homework	a1, a2, b1, b2, c1, c2	3th to 14th weeks	10
3	Class Attendance & Participation.	d1, d2	Weekly	5
	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	Assignments	Weekly	30	20%	a1, a2, b1, b2,c1, c2, d1,d2
2	Quizzes (3)	4th , 10th and 13th weeks	10	6. 7 %	a1, a2, b1, b2, c1, d1
3	Mid-Term Exam	8th week	20	13.3 %	a1, b2, c1, c2

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4	Final Exam	16th week	90	60 %	a1, b2, c1, c2
Total			**150**	**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- Dieter G.E., 2005, "Mechanical Metallurgy", McGraw-Hill.
2- Reddy, N.V. and Lal, G.K., 2009, "Theory of Plasticity", Narosa Publication, New

2- Essential References.

1- Hosford, W.F. Caddell, R.M., 2011, "Metal forming – Mechanics and Metallurgy", Cambridge University Press.
2- Juneja B.L., 2010, "Fundamentals of Metal Forming Processes", New Age Internat
3- Nagpal G.R, 2004. "Metal Forming Processes", Khanna Publishers, New Delhi,

3- Electronic Materials and Web Sites *etc*.

1. http://www.madehow.com/
2. https://slideplayer.com/search/?q=ME+612+metal+forming+and+theory+of+plas
3. https://www.machinemfg.com/

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**:

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	- 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. Khalil Al-Hatab**
	Deputy Rector for Academic Affairs Asst. Prof. Dr. Ibrahim AlMutaa **Assoc. Prof. Dr. Ahmed Mujahed** **Asst. Prof. Dr. Munasar Alsubri**

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43. Course Plan of Theory of Metal Forming

I. Information about Faculty Member Responsible for the Course:

Name of Faculty Member	Dr. Abdullah Dhaiban	**Office Hours**					
Location& Telephone No.		**SAT**	**SUN**	**MON**	**TUE**	**WED**	**THU**
E-mail							

II. Course Identification and General information:

1.	Course Title:	Theory of Metal Forming.				
2.	Course Number & Code:	ME314**.**				
3.	Credit hours:	C.H				TOTAL Cr. Hrs.
		Theory	Seminar	Pr	Tu.	
		2	2	-	-	3
4.	Study level/year at which this course is offered:	Fourth Year - First Semester				
5.	Pre –requisite (if any):	Manufacturing Processes-II (ME113) and Mechanics of Materials - II (ME234)				
6.	Co –requisite (if any):	None.				
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:	Lectures, Tutorials and Comp. Lab.				
11.	Location of teaching the course:	Mechanical Engineering Department.				

III. Course Description:

This course deals with the techniques used in the design of metal forming processes. It includes the principles of mathematical analysis and finite element application for determination the load and power during metal forming process. The effect of various metallurgical and geometrical parameters on the workability of materials is discussed in context of metal forming operations, such as forging, rolling, extrusion, wire and bar

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drawing, and Sheet Metal forming. Also, the techniques of analysis: slab method, upper bound method, slip-line fields, application to indentation problem will be discussed.

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

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

1. Describe the basic principles of metal forming theory, technology, and the effected parameters.
2. Recognize the various analysis methods of metal forming processes.
3. Analyse the metal forming process and select the process parameters based on engineering plasticity concepts.
4. Justify the appropriate material and forming method based on the features and application of the component.
5. Use the techniques of analysis (slab method, …etc.) and computer software to solve problems in the field of theory of metal forming.
6. Solve the metal forming problems analytically and using Finite element method.
7. Examine the different ideas, views, and knowledge from a range of sources in topics related to metal forming including manufacturing, development and selection.
8. Communicate concepts and experimental/ modeling results in clear and logical fashion, both verbally and in writing.

V. Course Content:

- Distribution **of** Semester Weekly Plan of Course topics/Items and Activities.

A – Theoretical aspect:

Order	Topics List	Sub topics List	Week Due	Contact Hours
1.	Stress Tensor and Yield Criteria	• Sate of Stress, • Representing Stress as Tensor, • Principal Stresses, • Stress Deviator.	1st week	2

		• Yield Criteria, • Octahedral Shear Stress and Shear Strain		
2.	Fundamentals of Metal Forming	• Classification of forming Processes. • Mechanics of Metal Working. • Flow Stress Determination. • Friction and Lubrication. • Deformation Zone Geometry. • Workability, Residual Stresses, Strain Rate Sensitivity.	2nd and 3rd weeks	4
3.	Working Load Determination	• Slab Method • Upper and Lower Bound Analysis, • Slip Line Field Analysis, • Application of Slip Line Theory.	4th week	2
4.	Forging	• Forging • Classification of forging Processes. • Analysis of forging Process. • Forging Defects. • Residual Stresses in forging	5th week	2
5.	Modeling of Metal forming Processes Using Finite Element Method	• Introduction to Finite Element Methods Software. • ANSYS Workbench • General Steps of Modeling Metal forming Processes.	6th and 7th weeks	4
6.	Mid – Term Exam	• The first seventh lectures.	8th week	2
7.	Rolling	• Rolling. • Classification of Rolling Processes. • Analysis of Rolling Process. • Rolling Defects	9th and 10th weeks	4
8.	Extrusion and Drawing	• Direct and indirect Extrusion. • Analysis of Extrusion Process. • Wire and Bar Drawing.	11th and 12th weeks	4

		• Analysis of Drawing		
9.	Sheet Metal Forming Processes	• Shearing. • Blanking. • Bending, Stretch forming. • Deep Drawing. • Defects in formed Part. • Sheet Metal formability. • Formability Limit Diagram	13th ,14th and 15th weeks	6
10.	Final Exam	All the fifteen lectures.	16th week	2
Number of Weeks /and Units Per Semester			**16**	**32**

B – Tutorial aspect:			
Order	**Topics List**	**Week Due**	**Contact Hours**
1.	**Tutorial One:** • Principal Stresses. • Stress Deviator. • Yield Criteria, Comparison of Yield Criteria. • Octahedral Shear Stress and Shear Strain	2nd week	2
2.	**Tutorial Two:** • Flow Stress Determination. • Strain Rate. • Workability.	3rd and 4th weeks	4
3.	**Tutorial Three:** • Forging Process**.**	5th week	2
4.	**ANSYS Workbench One:** • ANSYS Workbench • Static Structural. • Geometry Modeling, (Axisymmetry, 2d and 3d Model)	6th week	2
5.	**Tutorial Four:** • Rolling Forces Torque and Power.	7th week	2

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6.	**ANSYS Workbench Two:** • Materials Model (Metal). • Create Finite Element Model.	8th week	2
7.	**Tutorial Five:** • Extrusion Load (Direct and Indirect).	9th week	2
8.	**ANSYS Workbench Three;** • Apply Load and Boundary Conditions. • Get the Result.	10th week	2
9.	**Tutorial Six:** • Bar/Wire Drawing Load	11th week	2
10.	**ANSYS Workbench Four:** • Metal forming Process (Forging, Rolling, Extrusion, Wire and Bar Drawing**)**	12th week	2
11.	**Tutorial Seven:** • Sheet Metal Forming Process.	13th week	2
12.	**ANSYS Workbench Five:** • Sheet Metal forming Processes.	14th week	2
13.	**Discussion of the Project**	15th week	2
Number of Weeks /and Units Per Semester		**14**	**28**

VI. Teaching strategies of the course:

- Active Lectures
- Tutorials
- Computer Based Session (ANSYS)
- Seminars.
- Projects.

VII. Assignments:

No	Assignments	Aligned CILOs(symbols)	Week Due	Mark
1	Project Report and Presentation.	a1, a2, b1, c1, c2, d1	15th week	15

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2	Exercises and Homework	a1, a2, b1, b2, c1, c2	3th to 14th weeks	10
3	Class Attendance & Participation.	d1,d2	Weekly	5
	Total			**30**

I. Schedule of assessment Tasks for Students During the Semester:

Assessment	Type of assessment Tasks	Week Due	Mark	Proportion of Final assessment
1	Assignments	Weekly	30	20%
2	Quizzes (3)	4th , 10th and 13th weeks	10	6. 7 %
3	Mid-Term Exam	8th week	20	13.3 %
4	Final Exam	16th week	90	60 %
Total			**150**	**100 %**

II. Learning Resources:

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

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

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