6- Course Specification of: Advanced Robotics and Automation

Course Code: (MTE563)

• General Information About the Course:						
1.	**Course Title:**	**Advanced Robotics and Automation**				
2.	**Course Code and Number:**	**MTE563**				
3.	**Credit Hours:**	**Credit Hours**			**Total**	
		Lecture	Practical	Seminar/Tutorial		
		3	0	0	**3**	
4.	**Study Level and Semester:**	**Second Semester**				
5.	**Pre-requisites (if any):**	**Robotics**				
6.	**Co-requisites (if any):**	**None**				
7.	**Program (s) in which the course is offered:**	MSc. In Mechatronics Engineering Program				
8.	**Language of teaching the course:**	English				
9.	**Study System:**	Courses & Thesis				
10.	**Prepared By:**	Dr. Hatem Al-Dois				
11.	**Reviewed by:**	Dr. ……				
12.	**Date of Approval:**					

•Course Description:

This course will provide students the knowledge in the core areas of robotics: robot dynamics, control and motion planning and its related aspects to technology and automated systems. The following topics are covered: differential motions and velocities, dynamic analysis and forces, trajectory planning, linear, nonlinear and force control of robotic manipulators. Students will also learn about robotics industrial applications such as fabrication, processing, casting, molding, forging, spot and arc welding, material handling, loading and unloading applications, in addition to the use of robots in automobile industry and aerospace manufacturing.

•Course Intended Learning Outcomes (CILOs):

Upon successful completion of Advanced Robotics and Automation Course, the graduates will be able to:

a1- Express in-depth knowledge of robot dynamics and control which is applicable to the design and control of robotic systems.

•Course Intended Learning Outcomes (CILOs):

a2- Explain differential motions and velocities of a robot and its hand frame.

a3- Describe appropriate trajectory-planning techniques for robotic manipulators taking into account ways to perform collision avoidance and speed up optimal path evaluation.

b1- Apply control design techniques for robotics applications based on open loop and closed loop characteristics.

b2- Integrate robots in a larger context (e.g. in a manufacturing enterprise) to meet desired needs within realistic constraints.

b3- Design and implement linear and non-linear robot controllers systems.

c1- Solve complex technical problems in the field of robotics and automation by applying the dynamics and control principles.

c2- Derive Newton-Euler and Lagrange-Euler formulations of manipulator dynamics.

d1- Research current worldwide initiatives for the future development of digital manufacturing, and exploration of how proposals for future development given would affect the current processes.

d2- Develop personal and professional strategies and plans to adapt to change, maintain currency and foster interprofessionalism.

•Alignment of Course Intended Learning Outcomes (CILOs) to Program Intended Learning Outcomes (PILOs)

CILOs		PILOs
q.	**Knowledge and Understanding:** Upon successful completion of **the Advanced Robotics and Automation Course**, the graduates will be able to:	**Q. Knowledge and Understanding:** Upon successful completion of the **MSc. In Mechatronics Engineering Program**, the graduates will be able to:
a1.	Express in-depth knowledge of robot dynamics and control which is applicable to the design and control of robotic systems.	**A1.** Demonstrate in-depth understanding of applied mathematics in Mechatronics engineering, control system, computer engineering and science, and electronics to design more functional, adaptable and cost-effective products.
a2.	Explain differential motions and velocities of a robot and its hand frame.	**A2.** Recognize and explain the contemporary engineering technologies and issues in the field of Mechatronics engineering.
a3.	Describe appropriate trajectory-planning techniques for robotic manipulators taking into account ways	**A3.** Explain in-depth the principles of sustainable design and development of

	to perform collision avoidance and speed up optimal path evaluation.	Mechatronics engineering.
r.	**Cognitive/ Intellectual Skills:** Upon successful completion of the **Advanced Robotics and Automation Course,** the graduates will be able to:	**R. Cognitive/ Intellectual Skills:** Upon successful completion of the **MSc. In Mechatronics Engineering Program,** the graduates will be able to:
b1.	Apply control design techniques for robotics applications based on open loop and closed loop characteristics.	**B1.** Apply appropriate principles, methodologies, techniques, tools and packages in the analysis, development and evaluation of mechatronics engineering systems.
b2.	Integrate robots in a larger context (e.g. in a manufacturing enterprise) to meet desired needs within realistic constraints.	**B2.** Identify, formulate and analyze research and solve complex Mechatronics engineering problems.
b3.	Design and implement linear and non-linear robot controllers systems.	**B3.** Design Mechatronics system, component, or process to meet desired needs within realistic constraints.
s.	**Professional and Practical Skills:** Upon successful completion of the **Advanced Robotics and Automation Course,** the graduates will be able to:	**S. Professional and Practical Skills:** Upon successful completion of the **MSc. In Mechatronics Engineering Program,** the graduates will be able to:
c1.	Solve complex technical problems in the field of robotics and automation by applying the dynamics and control principles.	**C2.** Use advanced methodologies and skills to solve Mechatronics engineering problems.
c2.	Derive Newton-Euler and Lagrange-Euler formulations of manipulator dynamics.	**C3.** Apply acquired knowledge of analysis and design for mechatronics engineering systems and implementation process.
t.	**Transferable Skills:** Upon successful completion of the **Advanced Robotics and Automation Course,** the graduates will be able to:	**T. Transferable Skills:** Upon successful completion of the **MSc. In Mechatronics Engineering Program,** the graduates will be able to:
d1.	Research current worldwide initiatives for the future development of digital manufacturing, and exploration of how	**D3.** Conduct independently and communicate research that advances and extends knowledge and

	proposals for future development given would affect the current processes.	scholarship in related fields.
d2.	Develop personal and professional strategies and plans to adapt to change, maintain currency and foster interprofessionalism.	**D4.** Independent learning ability, self-direction and independence leading to the ability to continue to develop their knowledge understanding and skills through further professional development

•Alignment of CILOs to Teaching and Assessment Strategies

q. Alignment of Knowledge and Understanding CILOs:

Knowledge and Understanding CILOs		Teaching Strategies	Assessment Strategies
a1.	Express in-depth knowledge of robot dynamics and control which is applicable to the design and control of robotic systems.	▪ Lectures, ▪ Self-Learning Problems/Studies, ▪ Active learning.	▪ Written Exam, ▪ Assignments.
a2.	Explain differential motions and velocities of a robot and its hand frame.	▪ Lectures, ▪ Self-Learning Problems/Studies, ▪ Active learning.	▪ Written Exam, ▪ Reports, ▪ Assignments.
a3.	Describe appropriate trajectory-planning techniques for robotic manipulators taking into account ways to perform collision avoidance and speed up optimal path evaluation.	▪ Lectures, ▪ Self-Learning Problems/Studies, ▪ Case study.	▪ Written Exam, ▪ Reports, ▪ Assignments.

r. Alignment of Intellectual Skills CILOs:

Intellectual Skills CILOs		Teaching Strategies	Assessment Strategies
b1.	Apply control design techniques for robotics applications based on open loop and closed loop characteristics.	▪ Lectures, ▪ Case Study, ▪ Simulation Exercises, ▪ Independent Study, ▪ Analysis and Problem Solving.	▪ Written Exam, ▪ Assignments.
b2.	Integrate robots in a larger context (e.g. in a manufacturing enterprise) to meet desired needs	▪ Case Study, ▪ Simulation Exercises, ▪ Independent Study, ▪ Analysis and Problem	▪ Written Exam, ▪ Assignments Reports.

•Alignment of CILOs to Teaching and Assessment Strategies

	within realistic constraints.	Solving, ▪ Presentations.	
b3.	Design and implement linear and non-linear robot controllers systems.	▪ Lectures, ▪ Self-Learning, ▪ Case Study, ▪ Analysis and Problem Solving.	▪ Written Exam, ▪ Assignments, ▪ Reports.

s. Alignment of Professional and Practical Skills CILOs:

Professional and Practical Skills CILOs		Teaching Strategies	Assessment Strategies
c1.	Solve complex technical problems in the field of robotics and automation by applying the dynamics and control principles.	▪ Independent Study, ▪ Analysis and Problem Solving.	▪ Seminar Report, ▪ Written Research Proposal.
c2.	Derive Newton-Euler and Lagrange-Euler formulations of manipulator dynamics.	▪ Independent Study, ▪ Analysis and Problem Solving.	▪ Written Exam, ▪ Assignments.

t. Alignment of Transferable (General) Skills CILOs:

Transferable (General) Skills CILOs		Teaching Strategies	Assessment Strategies
d1.	Research current worldwide initiatives for the future development of digital manufacturing, and exploration of how proposals for future development given would affect the current processes.	▪ Independent Study, ▪ Presentation, ▪ Research Papers.	▪ Assignments, ▪ Survey, ▪ Presentation, ▪ Written Report.
d2.	Develop personal and professional strategies and plans to adapt to change, maintain currency and foster interprofessionalism.	▪ Independent Study, ▪ Presentation,	▪ Experimental and Field Work, ▪ Survey, ▪ Presentation.

•Course Content

13. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours	Course ILOs
1	**Introduction**	– Fundamental Concepts – Robot Components	1	3	a1, b2

•Course Content

13. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours	Course ILOs
		– Robot Coordinates – Programming Modes – Robot Characteristics – Robot Languages – Social Issues			
2	**Differential Motions and Velocities**	– Differential Relationships – Jacobian – Differential versus Large-Scale Motions – Differential Motions of a Frame versus a Robot – Differential Transformations of a Frame	1	3	a2
3	**Interpretation of the Differential Change**	– Differential Changes between Frames – Differential Motions of a Robot and its Hand Frame – Calculation of the Jacobian – Calculations of the Jacobian and the Differential Operator – Inverse Jacobian – Design Projects – The 3-DOF Robot – The 3-DOF Mobile Robot	1	3	a2
4	**Dynamic Analysis and Forces**	– Acceleration of a Rigid Body – Newton's Equation, Euler's Equation – Iterative Newton—Euler Dynamic Formulation – Iterative Vs. Closed Form – The Structure of A Manipulator's Dynamic Equations – Lagrangian Formulation of Manipulator Dynamics – Formulating Manipulator Dynamics	2	6	a1, c1, c2

•Course Content

13. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours	Course ILOs
		in Cartesian Space – Inclusion of Non rigid Body Effects – Dynamic Simulation – Computational Considerations			
5	**Trajectory Planning**	– Basics of Trajectory Planning – Path versus Trajectory – Joint-Space versus Cartesian-Space Descriptions – Joint-Space Trajectory Planning – Third-Order Polynomial Trajectory Planning – Fifth-Order Polynomial Trajectory Planning – Linear Segments with Parabolic Blends – Linear Segments with Parabolic Blends and Via Points – Higher-Order Trajectories – Other Trajectories – Cartesian-Space Trajectories – Continuous Trajectory Recording	2	6	a3
6	**Mid-Term Theoretical Exam**	– Previous Topics	1	3	a1, a2, a3, b2, c1, c2
7	**Linear Control of Robotic Manipulators**	– Feedback and Closed-Loop Control – Second-Order Linear Systems – Control of Second-Order Systems – Control-Law Partitioning – Trajectory-Following Control – Disturbance Rejection – Continuous Vs. Discrete Time Control – Modeling and Control of a Single	1	3	a1, b1, b3

•Course Content

13. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours	Course ILOs
		Joint – Architecture of an Industrial-Robot Controller			
8	**Non-Linear Control of Robotic Manipulators**	– Nonlinear And Time-Varying Systems – Multi-Input, Multi-Output Control Systems – The Control Problem For Manipulators – Practical Considerations – Current Industrial-Robot Control Systems – Lyapunov Stability Analysis – Cartesian-Based Control Systems – Adaptive Control	2	6	a1, b1, b3
9	**Force Control of Robotic Manipulators**	– Application of Industrial Robots to Assembly Tasks – A Framework for Control in Partially Constrained Tasks – The Hybrid Position/Force Control Problem – Force Control of a Mass—Spring System – The Hybrid Position/Force Control Scheme – Current Industrial-Robot Control Schemes	2	6	a1, b1, b3
10	**Robotics Industrial Applications**	– An Overview of Fabrication and Processing Applications – Robots in the Automobile Industry – Robot Applications in Aerospace Manufacturing – Robots in Casting, Moldi.ng, and Forging	1	3	b2, c1, d2

•Course Content

13. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours	Course ILOs
		– Robots in Foundries – Flexible Machining Cell with Robots – An Integrated Laser Processing Robotic Cell			
11	**Robotics Industrial Applications**	– Robots in the Woodworking Industry – Robots in Spot Welding – Robots in Arc Welding – The Operation of Robotic Welding – Robots in Material Handling – Workpiece Handling and Gripper Selection – Robotic Loading of Machine Tools – Machine Loading Application Cases	1	3	b2, c1, d2
12	**Final Theoretical Exam**	– All Topics	1	3	a1, a2, a3, b1, b2, b3, c1, c2
Number of Weeks /and Contact Hours Per Semester			**16**	**48**	

14. Practical Aspect

Order	Practical / Tutorials topics	Number of Weeks	Contact Hours	Course ILOs
1	None			
Number of Weeks /and Contact Hours Per Semester				

15. Tutorial Aspect:

No.	Tutorial	Number of Weeks	Contact Hours	Course ILOs
1	None			
Number of Weeks /and Units Per Semester				

•Teaching Strategies:

– Lectures,

•Teaching Strategies:

- Self-Learning Problems/Studies,
- Active learning,
- Case study,
- Simulation Exercises,
- Independent Study,
- Analysis and Problem Solving,
- Presentations,
- Research Papers.

•Assessment Methods of the Course:

- Written Exam,
- Reports,
- Assignments,
- Seminar Report,
- Written Research Proposal,
- Survey,
- Experimental and Field Work,
- Presentation,
- Written Report.

•Tasks and Assignments:

No.	Assignments/ Tasks	Individual/ Group	Mark	Week Due	CILOs (symbols)
1	**Literature Survey Paper** Students will pick a problem related to robotics and automation that interests them. The students will be asked to put themselves in the position of authors of a conference or a journal survey paper. They are supposed to search the literature for approaches to tackle this problem. Then they survey and discuss the relative strengths of each approach. The paper will be 4-6 pages. Student must comply strictly with the formatting instructions using the IEEE template,.	**Individual**	**5**	**7**	b2, d1, d2
2	**Paper Critics** The students must pick one of a highly cited paper related to robotics industrial or non-industrial applications (at least 100 citation as per Google	**Individual**	**5**	**12**	b2, d1, d2

•Tasks and Assignments:

No.	Assignments/ Tasks	Individual/ Group	Mark	Week Due	CILOs (symbols)
	Scholar). The students will be asked to put themselves in the position of a reviewer for a conference or journal. They should give constructive feedback to the authors. They will mention also the good and weak aspects of the paper. For every criticism, students will make a suggestion to improve the paper.				
3	**Mini-project** Projects can be done individually but preferably in group of 2 to 3 students. Students will be requested to select one of the following project types: ***Type A: System Design and Implementation*** - Students identify a problem in a pertinent area of robotics and automation, industrial or commercial importance for which there are no available system with reasonable cost and capabilities. This system must contain a combination of mechanical, electronic, computer and control components integrated together in order to solve the problem at hand. - Design and develop a new mechatronics system to solve this problem. - Analyze experimentally or analytically the performance of the developed system. ***Type B: Empirical Evaluation*** - In this type of projects, the student will pick a problem that interests him/her related to robotics and automation. Student is supposed to search the literature for approaches to tackle this problem, identifies strong and weak points of each approach and selects the most appropriate approach. - He/she must implement and experiment with the selected technique to quantitatively evaluate its performance in tackling the problem. ***Results Delivery:*** - The result of the course project will be a scientific paper (minimum 5 pages) along with part of the	**Group 2-3 students or Individual**	**10**	**15**	b1, b2, b3, c1, d1, d2

•Tasks and Assignments:

No.	Assignments/ Tasks	Individual/ Group	Mark	Week Due	CILOs (symbols)
	source code developed to solve a given problem (if any). - IEEE Manuscript Template must be used.				
Total Score			**20**		

•Learning Assessment:

No.	Assessment Tasks	Week due	Mark	Proportion of Final Assessment	CILOs
1	**Tasks and Assignments**	**6, 12, 15**	**20**	**20%**	b1, b2, b3, c1, d1, d2
2	**Midterm Exam (Theoretical)**	**8**	**20**	**20%**	a1, a2, a3, b2, c1, c2
3	**Final Exam (Theoretical)**	**16**	**60**	**60%**	a1, a2, a3, b1, b2, b3, c1, c2
Total			**100**	**100%**	

•Learning Resources :

12.Required Textbook(s) :

3- J. Craig, 2017, Introduction to Robotics: Mechanics and Control, 4th Edition, NJ-USA, Pearson Education.
4- James A. Rehg, 2002, Introduction to Robotics in CIM Systems, 5th Edition, NJ-USA, Prentice Hall.

13.Essential References:

•Learning Resources :

1- Saeed B. Niku, 2020, Introduction to Robotics: Analysis, Control, Applications, 3rd Edition, NY-USA, Wiley.
2- Shimon Y. Nof, 1999, Handbook of Industrial Robotics, 2nd Edition, NY-USA, Wiley.
3- Tsuneo Yoshikawa, 2003, Foundations of Robotics: Analysis and Control, 1st Edition, MA-USA, MT Press.
4- Robert J. Schilling, 2001, Fundamentals of Robotics: Analysis and Control, 1st Edition, New-Delhi, Prentice Hall of India.
5- Mikell P. Groover, 2018, Automation Production Systems and Computer-Integrated Manufacturing, 5th Edition, NJ-USA, Pearson Education.
6- B. Benhabib, 2003, Manufacturing: Design, Production, Automation and Integration, 1st Edition, FL-USA, CRC Press.
7- Mike Wilson, 2014, Implementation of Robot Systems: An Introduction to Robotics, Automation, and Successful Systems Integration in Manufacturing, 1st Edition, MA-USA, Butterworth-Heinemann.
8- Darrell M. West,2018, The Future of Work: Robots, AI, and Automation, 1st Edition, MA-USA, Brookings Institution Press.
9- Tom Taulli, 2020, The Robotic Process Automation Handbook: A Guide to Implementing RPA Systems, 1st Edition, NY-USA, APress Publishing.
10- Ben-Zion Sandler, 1999, Robotics, Designing the Mechanisms for Automated Machinery, 2nd Edition, MA-USA, Academic Press.
11- Craig A Kluever , 2015, Dynamic Systems: Modeling, Simulation, and Control, 1st Edition, NY-USA, Wiley.
12- B. Siciliano and O. Khatib, 2016, Springer Handbook of Robotics, Berlin Heidelberg, Springer.

14.Electronic Materials and Web Sites *etc.*

1- CMTC's Robotics and Automation Consulting Services for Small & Medium-Sized Manufacturers
https://www.cmtc.com/advanced-robotics
2- Industry Today, Advanced Robotics and Automation
https:// www.industrytoday.com/advanced-robotics-and-automation/
3- FIRST®: A Global Robotics Community Preparing Young People For The Future
https:// www.usfirst.org
4- MATE: Marine Advanced Technology Education
https:// www..marinetech.org
5- Journal of Advances in Robotics & Automation
https://www.hilarispublisher.com/advances-in-robotics-automation.html

• الضوابط والسياسات المتبعة في المقرر Course Policies

بعد الرجوع للوائح الجامعة يتم كتابة السياسة العامة للمقرر فيما يتعلق بالآتي:

1	سياسة حضور الفعاليات التعليمية Class Attendance: - يلتزم الطالب بحضور 75% من المحاضرات ويحرم في حال عدم الوفاء بذلك.

• الضوابط والسياسات المتبعة في المقرر Course Policies	
بعد الرجوع للوائح الجامعة يتم كتابة السياسة العامة للمقرر فيما يتعلق بالآتي:	
- يقدم أستاذ المقرر تقريرا بحضور وغياب الطلاب للقسم ويحرم الطالب من دخول الامتحان في حال تجاوز الغياب 25% ويتم اقرار الحرمان من مجلس القسم.	
الحضور المتأخر Tardy: - يسمح للطالب حضور المحاضرة إذا تأخر لمدة ربع ساعة لثلاث مرات في الفصل الدراسي، وإذا تأخر زيادة عن ثلاث مرات يحذر شفويا من أستاذ المقرر، وعند عدم الالتزام يمنع من دخول المحاضرة.	2
ضوابط الامتحان Exam Attendance/Punctuality: - لا يسمح للطالب دخول الامتحان النهائي إذا تأخر مقدار (20) دقيقة من بدء الامتحان - إذا تغيب الطالب عن الامتحان النهائي تطبق اللوائح الخاصة بنظام الامتحان في الكلية.	3
التعيينات والمشاريع Assignments & Projects: - يحدد أستاذ المقرر نوع التعيينات في بداية الفصل ويحدد مواعيد تسليمها وضوابط تنفيذ التكليفات وتسليمها. - إذا تأخر الطالب في تسليم التكليفات عن الموعد المحدد يحرم من درجة التكليف الذي تأخر في تسليمه.	4
الغش Cheating: - في حال ثبوت قيام الطالب بالغش في الامتحان النصفي أو النهائي تطبق عليه لائحة شؤون الطلاب. - في حال ثبوت قيام الطالب بالغش او النقل في التكليفات والمشاريع يحرم من الدرجة المخصصة للتكليف.	5
الانتحال Plagiarism: – في حالة وجود شخص ينتحل شخصية طالب لأداء الامتحان نيابة عنه تطبق اللائحة الخاصة بذلك	6
سياسات أخرى Other policies: - أي سياسات أخرى مثل استخدام الموبايل أو مواعيد تسليم التكليفات ..... الخ	7

Academic Year: 2021-2022

Course Plan (Syllabus): Advanced Robotics and Automation

• Information about Faculty Member Responsible for the Course:

Name	Dr. Hatem Al-Dois	Office Hours					
Location &Telephone No.	774677493	SAT	SUN	MON	TUE	WED	THU
E-mail	haldois@yah.com						

• General information about the course:

37.	Course Title	Advanced Robotics and Automation			
38.	Course Code and Number	MTE563			
39.	Credit Hours	Credit Hours			Total
		Lecture	Practical	Seminar/Tutorial	
		3	0	0	3
40.	Study Level and Semester	Second Semester			

41.	**Pre-requisites**	**Robotics**
42.	**Co –requisite**	**None**
43.	**Program (s) in which the course is offered**	MSc. In Mechatronics Engineering Program
44.	**Language of teaching the course**	English
45.	**Location of teaching the course**	**Faculty of Engineering, Sana'a University**

•Course Description:

This course will provide students the knowledge in the core areas of robotics: robot dynamics, control and motion planning and its related aspects to technology and automated systems. The following topics are covered: differential motions and velocities, dynamic analysis and forces, trajectory planning, linear, nonlinear and force control of robotic manipulators. Students will also learn about robotics industrial applications such as fabrication, processing, casting, molding, forging, spot and arc welding, material handling, loading and unloading applications, in addition to the use of robots in automobile industry and aerospace manufacturing.

•Course Intended Learning Outcomes (CILOs):

Upon successful completion of Advanced Robotics and Automation Course, the graduates will be able to:

a1- Express in-depth knowledge of robot dynamics and control which is applicable to the design and control of robotic systems.

a2- Explain differential motions and velocities of a robot and its hand frame.

a3- Describe appropriate trajectory-planning techniques for robotic manipulators taking into account ways to perform collision avoidance and speed up optimal path evaluation.

b1- Apply control design techniques for robotics applications based on open loop and closed loop characteristics.

b2- Integrate robots in a larger context (e.g. in a manufacturing enterprise) to meet desired needs within realistic constraints.

b3- Design and implement linear and non-linear robot controllers systems.

c1- Solve complex technical problems in the field of robotics and automation by applying the dynamics and control principles.

c2- Derive Newton-Euler and Lagrange-Euler formulations of manipulator dynamics.

d1- Research current worldwide initiatives for the future development of digital manufacturing, and exploration of how proposals for future development given would affect the current processes.

d2- Develop personal and professional strategies and plans to adapt to change, maintain currency and foster interprofessionalism.

•Course Content

1. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours
1	**Introduction**	– Fundamental Concepts – Robot Components – Robot Coordinates – Programming Modes – Robot Characteristics – Robot Languages – Social Issues	1	3
2	**Differential Motions and Velocities**	– Differential Relationships – Jacobian – Differential versus Large-Scale Motions – Differential Motions of a Frame versus a Robot – Differential Transformations of a Frame	1	3
3	**Interpretation of the Differential Change**	– Differential Changes between Frames – Differential Motions of a Robot and its Hand Frame – Calculation of the Jacobian – Calculations of the Jacobian and the Differential Operator – Inverse Jacobian – Design Projects – The 3-DOF Robot – The 3-DOF Mobile Robot	1	3
4	**Dynamic Analysis and Forces**	– Acceleration of a Rigid Body – Newton's Equation, Euler's Equation – Iterative Newton—Euler Dynamic Formulation – Iterative Vs. Closed Form – The Structure of A Manipulator's Dynamic Equations – Lagrangian Formulation of Manipulator Dynamics – Formulating Manipulator Dynamics in	2	6

•Course Content

1. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours
		Cartesian Space – Inclusion of Non rigid Body Effects – Dynamic Simulation – Computational Considerations		
5	**Trajectory Planning**	– Basics of Trajectory Planning – Path versus Trajectory – Joint-Space versus Cartesian-Space Descriptions – Joint-Space Trajectory Planning – Third-Order Polynomial Trajectory Planning – Fifth-Order Polynomial Trajectory Planning – Linear Segments with Parabolic Blends – Linear Segments with Parabolic Blends and Via Points – Higher-Order Trajectories – Other Trajectories – Cartesian-Space Trajectories – Continuous Trajectory Recording	2	6
6	**Mid-Term Theoretical Exam**	– Previous Topics	1	3
7	**Linear Control of Robotic Manipulators**	– Feedback and Closed-Loop Control – Second-Order Linear Systems – Control of Second-Order Systems – Control-Law Partitioning – Trajectory-Following Control – Disturbance Rejection – Continuous Vs. Discrete Time Control – Modeling and Control of a Single Joint – Architecture of an Industrial-Robot Controller	1	3
8	**Non-Linear Control of Robotic**	– Nonlinear And Time-Varying Systems – Multi-Input, Multi-Output Control Systems – The Control Problem For Manipulators	2	6

•Course Content

1. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours
	Manipulators	– Practical Considerations – Current Industrial-Robot Control Systems – Lyapunov Stability Analysis – Cartesian-Based Control Systems – Adaptive Control		
9	**Force Control of Robotic Manipulators**	– Application of Industrial Robots to Assembly Tasks – A Framework for Control in Partially Constrained Tasks – The Hybrid Position/Force Control Problem – Force Control of a Mass—Spring System – The Hybrid Position/Force Control Scheme – Current Industrial-Robot Control Schemes	2	6
10	**Robotics Industrial Applications**	– An Overview of Fabrication and Processing Applications – Robots in the Automobile Industry – Robot Applications in Aerospace Manufacturing – Robots in Casting, Moldi.ng, and Forging – Robots in Foundries – Flexible Machining Cell with Robots – An Integrated Laser Processing Robotic Cell	1	3
11	**Robotics Industrial Applications**	– Robots in the Woodworking Industry – Robots in Spot Welding – Robots in Arc Welding – The Operation of Robotic Welding – Robots in Material Handling – Workpiece Handling and Gripper Selection – Robotic Loading of Machine Tools – Machine Loading Application Cases	1	3
12	**Final Theoretical Exam**	– All Topics	1	3

•Course Content

1. Theoretical Aspect

Order	Topic List / Units	Sub -Topics List	Number of Weeks	Contact Hours
Number of Weeks /and Contact Hours Per Semester			**16**	**48**

2. Practical Aspect

Order	Practical / Tutorials topics	Number of Weeks	Contact Hours
1	None		
Number of Weeks /and Contact Hours Per Semester			

3. Tutorial Aspect:

No.	Tutorial	Number of Weeks	Contact Hours
1	None		
Number of Weeks /and Units Per Semester			

•Teaching Strategies:

- Lectures,
- Self-Learning Problems/Studies,
- Active learning,
- Case study,
- Simulation Exercises,
- Independent Study,
- Analysis and Problem Solving,
- Presentations,
- Research Papers.

•Assessment Methods of the Course:

- Written Exam,
- Reports,
- Assignments,
- Seminar Report,
- Written Research Proposal,
- Survey,
- Experimental and Field Work,

•Assessment Methods of the Course:

- Presentation,
- Written Report.

•Tasks and Assignments:

No.	Assignments/ Tasks	Individual/ Group	Mark	Week Due
1	**Literature Survey Paper** Students will pick a problem related to robotics and automation that interests them. The students will be asked to put themselves in the position of authors of a conference or a journal survey paper. They are supposed to search the literature for approaches to tackle this problem. Then they survey and discuss the relative strengths of each approach. The paper will be 4-6 pages. Student must comply strictly with the formatting instructions using the IEEE template,.	**Individual**	**5**	**7**
2	**Paper Critics** The students must pick one of a highly cited paper related to robotics industrial or non-industrial applications (at least 100 citation as per Google Scholar). The students will be asked to put themselves in the position of a reviewer for a conference or journal. They should give constructive feedback to the authors. They will mention also the good and weak aspects of the paper. For every criticism, students will make a suggestion to improve the paper.	**Individual**	**5**	**12**
3	**Mini-project** Projects can be done individually but preferably in group of 2 to 3 students. Students will be requested to select one of the following project types: ***Type A: System Design and Implementation*** - Students identify a problem in a pertinent area of robotics and automation, industrial or commercial importance for which there are no available system with reasonable cost and capabilities. This system must contain a combination of mechanical, electronic, computer and control components integrated together in order to solve the problem at hand. - Design and develop a new mechatronics system to solve this problem.	**Group 2-3 students or Individual**	**10**	**15**

•Tasks and Assignments:

No.	Assignments/ Tasks	Individual/ Group	Mark	Week Due
	- Analyze experimentally or analytically the performance of the developed system. ***Type B: Empirical Evaluation*** - In this type of projects, the student will pick a problem that interests him/her related to robotics and automation. Student is supposed to search the literature for approaches to tackle this problem, identifies strong and weak points of each approach and selects the most appropriate approach. - He/she must implement and experiment with the selected technique to quantitatively evaluate its performance in tackling the problem. ***Results Delivery:*** - The result of the course project will be a scientific paper (minimum 5 pages) along with part of the source code developed to solve a given problem (if any). - IEEE Manuscript Template must be used.			
Total Score			**20**	

•Learning Assessment:

No.	Assessment Tasks	Week due	Mark
1	**Tasks and Assignments**	**6, 12, 15**	**20**
2	**Midterm Exam (Theoretical)**	**8**	**20**
3	**Final Exam (Theoretical)**	**16**	**60**
Total			**100**

•Learning Resources :

1. Required Textbook(s) :

1- J. Craig, 2017, Introduction to Robotics: Mechanics and Control, 4th Edition, NJ-USA, Pearson Education.
2- James A. Rehg, 2002, Introduction to Robotics in CIM Systems, 5th Edition, NJ-USA, Prentice

•Learning Resources :

Hall.

2. Essential References:

1- Saeed B. Niku, 2020, Introduction to Robotics: Analysis, Control, Applications, 3rd Edition, NY-USA, Wiley.
2- Shimon Y. Nof, 1999, Handbook of Industrial Robotics, 2nd Edition, NY-USA, Wiley.
3- Tsuneo Yoshikawa, 2003, Foundations of Robotics: Analysis and Control, 1st Edition, MA-USA, MT Press.
4- Robert J. Schilling, 2001, Fundamentals of Robotics: Analysis and Control, 1st Edition, New-Delhi, Prentice Hall of India.
5- Mikell P. Groover, 2018, Automation Production Systems and Computer-Integrated Manufacturing, 5th Edition, NJ-USA, Pearson Education.
6- B. Benhabib, 2003, Manufacturing: Design, Production, Automation and Integration, 1st Edition, FL-USA, CRC Press.
7- Mike Wilson, 2014, Implementation of Robot Systems: An Introduction to Robotics, Automation, and Successful Systems Integration in Manufacturing, 1st Edition, MA-USA, Butterworth-Heinemann.
8- Darrell M. West,2018, The Future of Work: Robots, AI, and Automation, 1st Edition, MA-USA, Brookings Institution Press.
9- Tom Taulli, 2020, The Robotic Process Automation Handbook: A Guide to Implementing RPA Systems, 1st Edition, NY-USA, APress Publishing.
10- Ben-Zion Sandler, 1999, Robotics, Designing the Mechanisms for Automated Machinery, 2nd Edition, MA-USA, Academic Press.
11- Craig A Kluever , 2015, Dynamic Systems: Modeling, Simulation, and Control, 1st Edition, NY-USA, Wiley.
12- B. Siciliano and O. Khatib, 2016, Springer Handbook of Robotics, Berlin Heidelberg, Springer.

3. Electronic Materials and Web Sites *etc.*

1- CMTC's Robotics and Automation Consulting Services for Small & Medium-Sized Manufacturers
https://www.cmtc.com/advanced-robotics
2- Industry Today, Advanced Robotics and Automation
https:// www.industrytoday.com/advanced-robotics-and-automation/
3- FIRST®: A Global Robotics Community Preparing Young People For The Future
https:// www.usfirst.org
4- MATE: Marine Advanced Technology Education
https:// www..marinetech.org
5- Journal of Advances in Robotics & Automation
https://www.hilarispublisher.com/advances-in-robotics-automation.html

•الضوابط والسياسات المتبعة في المقرر Course Policies

	بعد الرجوع للوائح الجامعة يتم كتابة السياسة العامة للمقرر فيما يتعلق بالآتي:
1	**سياسة حضور الفعاليات التعليمية Class Attendance:** **- يلتزم الطالب بحضور 75% من المحاضرات ويحرم في حال عدم الوفاء بذلك.** **- يقدم أستاذ المقرر تقريرا بحضور وغياب الطلاب للقسم ويحرم الطالب من دخول الامتحان في حال تجاوز الغياب 25% ويتم اقرار الحرمان من مجلس القسم.**
2	**الحضور المتأخر Tardy:** **- يسمح للطالب حضور المحاضرة إذا تأخر لمدة ربع ساعة لثلاث مرات في الفصل الدراسي، وإذا تأخر زيادة عن ثلاث مرات يحذر شفويا من أستاذ المقرر، وعند عدم الالتزام يمنع من دخول المحاضرة.**
3	**ضوابط الامتحان Exam Attendance/Punctuality:** **- لا يسمح للطالب دخول الامتحان النهائي إذا تأخر مقدار (20) دقيقة من بدء الامتحان** **- إذا تغيب الطالب عن الامتحان النهائي تطبق اللوائح الخاصة بنظام الامتحان في الكلية.**
4	**التعيينات والمشاريع Assignments & Projects:** **- يحدد أستاذ المقرر نوع التعيينات في بداية الفصل ويحدد مواعيد تسليمها وضوابط تنفيذ التكليفات وتسليمها.** **- إذا تأخر الطالب في تسليم التكليفات عن الموعد المحدد يحرم من درجة التكليف الذي تأخر في تسليمه.**
5	**الغش Cheating:** **- في حال ثبوت قيام الطالب بالغش في الامتحان النصفي أو النهائي تطبق عليه لائحة شؤون الطلاب.** **- في حال ثبوت قيام الطالب بالغش او النقل في التكليفات والمشاريع يحرم من الدرجة المخصصة للتكليف.**
6	**الانتحال Plagiarism:** **– في حالة وجود شخص ينتحل شخصية طالب لأداء الامتحان نيابة عنه تطبق اللائحة الخاصة بذلك**
7	**سياسات أخرى Other policies:** **- أي سياسات أخرى مثل استخدام الموبايل أو مواعيد تسليم التكليفات ..... الخ**