Sana'a University
Faculty of Engineering
Electrical Engineering Department
B.Sc. of Computer and Control Engineering

51. Course Plan of Introduction to Robotics

I. Information about Faculty Member Responsible for the Course:

Name of Faculty Member	Prof. Abdurraqeeb Asaad Dr. Adel Al-Shakiri	**Office Hours**					
Location& Telephone No.	Department of Electrical Engineering	**SAT**	**SUN**	**MON**	**TUE**	**WED**	**THU**
E-mail	Ashakiri62@gmail.com						

II. Course Identification and General Information:

1.	Course Title:	Introduction to Robotics				
2.	Course Number & Code:	CCE437				
3.	Credit hours:	C.H				Total
		Th.	Tu.	Pr.	Tr.	
		2	-	2	-	3
4.	Study level/year at which this course is offered:	5^{th} Year/ 1^{st} Semester				
5.	Pre –requisite (if any):	BR103, BR007, ME121				
6.	Co –requisite (if any):	None				
7.	Program (s) in which the course is offered	Computer Engineering and Control				
8.	Language of teaching the course:	English Language.				
9.	System of Study:	Semesters				
10.	Mode of delivery:	Regular Attendance to Classes.				
11.	Location of teaching the course:	Faculty of Engineering.				

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III. Course Description:

This course aims to provide students with the basics of robotics and serial type robots. Robotic becomes the main part that is applicable to many modern industries and control applications. Course topics cover the basic components of robot systems, spatial representations and transformations, forward and inverse kinematics, manipulator dynamics, velocity propagation, Jacobean, trajectory planning, and robot programming and control. Practical lab and course project work develop student's experiences and skills related to different design and implementation practices of robot manipulators as well as the proper robot safety procedures will be emphasized.

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

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

1. Explain systematically the structure of a robotic manipulator and the operation of its main components.
2. Demonstrate safety considerations during installation, maintenance, programming, automatic operations of robotic systems.
3. Identify the main components of the robot including the controller, manipulator arm, teach pendant, standard operator panel, sensors, actuators, and end-of-arm-tooling or vacuum components.
4. Classify robotic systems according to their application, control system, arm geometry, actuators and sensors used, and end-of-arm tooling.
5. Write programs to perform various complex tasks and motions of robotic systems.
6. Search the literature for different information related to the given assignments in robotics.

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V. Course Content:

A – Theoretical Aspect:

Order	Units/Topics List	Sub Topics List	Number of Weeks	Contact Hours
1.	Introduction	– What is a Robot? – What is Robotics? – History of Robotics. – Advantages and Disadvantages of Robots – Robot Degrees of Freedom. – Mass Production and Batch Manufacturing – Flexible Manufacturing Systems – Robotic Safety	1st	2
2.	Robots Components and Specifications	– Basic components of robot systems – Manipulator geometry – Wrists – End effectors – Robot Workspace – Classifying robots by drive control systems – Classifying robots by teaching methods – Specifying robot by repeatability, precision, accuracy	2nd	2

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3.	Position & Orientation Analysis of a Rigid Body	– Robot Coordinates – Robot Reference Frames – Robots Mechanisms – Matrix Representation of a Point, a Vector, and a Frame in Space – Homogeneous Transformation Matrices – Inverse of Transformation Matrices	3rd ,4th	4
4.	Robot Arm Kinematics	– Direct Kinematic Problem – Description of Position and Orientation for Different Robot Configurations – DH Convention – Direct Kinematics Examples – Inverse Kinematic Problem (Type of Solution, Solvability, Multiple Solutions) – Inverse Kinematics Solutions to Known Robot Manipulators**.**	5th ,6th ,7th	6
5.	Mid-Term Exam	– ALL Previous Topics	8th	2
6.	Robot Arm Dynamics	– Lagrange-Euler Formulation – Newton-Euler Formation – Examples of Manipulators Dynamic Models. – Robot Simulations.	9th	2

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7.	Planning of Manipulator Trajectories	– Joint-interpolated Trajectories – Cartesian Path Trajectories – 3rd & 5th Order Polynomial Trajectories Planning – Linear Segments with Parabolic Blends – Collision-Free Path Planning.	10th	2
8.	Control of Robot Manipulators	– Open-Loop and Closed-Loop Control – P, PI, PD, PID Controllers – Control of the Puma Robot Arm – Multiple-Input and Multiple-Output Systems – Model-Based Control Systems – Resolved Motion Control – Adaptive Control	11th	2
9.	End-of-Arm Tooling	– Terms – Power Sources – Standard Grippers: Angular, Parallel – Internal-external Gripping – Vacuum, Magnetic, Flexible, Special Purpose	12th	2
10.	Introduction to Robotics Programming	– Robotics Programming Methods, – Programming as a path in space, – Motion Interpolation, Level & Task Level Languages, – Robot languages.	13th	2

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11.	Robotic Applications-based Image Processing	– Low level & High-level vision, – Sensing & Digitizing, – Template Matching, – Image processing & analysis, – Segmentation, Edge detection, – Object description & recognition, – Interpretation, – Applications.	14th	2
12.	Robot Safety	– Robots Require Respect (3Rs) – People dealing with robots	15th	2
13.	Final Exam	– ALL Topics	16th	2
Number of Weeks /and Units Per Semester			**16**	**32**

B - Practical Aspect:

Order	Tasks/ Experiments	Number of Weeks	Contact Hours
1	**Computer Lab: practices on** – Different computer tools: ROS, MATLAB/Simulink, Robot Studio. – Transformations – Constructing and analyzing different robotic configurations – Kinematic and Dynamic analysis of robot manipulators – Motion analysis of robotic systems. – Different control schemes of robots.	1st ,2nd ,3rd ,4th ,5th ,6th	**12**
2	**Robotics Lab:**	7th ,8th ,9th ,10th	**12**

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	– Set up a robot control system and check basic functions of the controller, – Drive a DC motor using a PWM power amplifier. – Download a user C-code to the robot controller. – Get acquainted with the C language and how it affects the robot. – Create actions based on sensor inputs. – Implement basic functions of sensor-based control on the lab robot	,11th ,12th	
3	**Course Project:** **Starts from week number 4.** – Design and Implementation of a robotic arm for a given task. A report must be prepared and a presentation must be delivered. Students work in groups of at least two.	**13th**	**2**
4	– **Final Lab Exam**	**14th**	**2**
Number of Weeks /and Units Per Semester		**14**	**28**

VI. Teaching strategies of the course:

- Lectures,
- Laboratory Activities & Works,
- Assignments & Homework,
- Interactive class discussions
- Directed self- study,
- Search.

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VII. Assessment methods of the course:

- Examinations
- Homework and Assignments
- Lab & Project Reports,
- Presentations

VIII. Assignments & Reports:

No.	Assignments	Aligned CILOs (symbols)	Week Due	Mark
1	Report on Robots Applications	b2, d1	3rd	1
2	Report on Most-Known Configurations of Industrial Robots	a1, b2, d1	4th	1
3	Report on Actuators & Sensors used for Industrial Robots	a2, b1, b2, d1	5th	1
4	Assignment: Robot manipulators, kinematics and dynamics	a2, b1, b2, d1	6th to 10th	2
5	Assignment: Programming, Control and Planning Methods of Industrial Robots	a2, b1, b2, c1	11th & 12th	2
6	Robot Safety	a2, d1	15th	1
7	Laboratory Reports	a1, a2, b1, b2, c1	3rd to 13th	7
Total				**15**

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

No.	Assessment Method	Week Due	Mark	Proportion of Final Assessment
1.	Quizzes	4th, 10th & 14th	10	6.67%
2.	Reports & Assignments	3rd to 15th	15	10%
3.	Mid-Term Exam (Theoretical)	8th	20	13.33%
4.	Final Lab Exam (including course project Evaluation)	13th & 14th	30	20%
5.	Final Exam	16th	75	50%
Total			**150**	**100%**

X. Learning Resources:

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

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

1. Craig, John J, R., 2005, Introduction to Robotics: Mechanics and Control, 3rd Edition, Pearson Education International Edition, Singapore.
2. Groover, M. P., Weiss, M., Nagel, R. N., and Odrey, N. G. , 1986, Industrial Robotics, Technology, Programming, and Applications. New Delhi: McGraw-Hill.

2- Essential References.

1. Spong M.W., Hutchinson S. & Vidyasagar M, 2004, Robot Dynamics and Control, Second Edition, Wiley, India.
2. Saeed Niku, 2002, Introduction to Robotics: Analysis, Systems, Applications, 1st Edition, NJ, Prentice Hall.
3. Mittal, R. K., & Nagrath, I. J., 2008, Robotics and Control. New Delhi, India: Tata McGraw-Hill.

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4. Lung-S-Wen Tsai, 1999, Robot Analysis, NY, John Wiley & Sons, Inc.
5. K.S. Fu, R.C. Gonzalez, and C.S.G. Lee, 1987, Robotics: Control, Sensing, Vision and Intelligence, NY, McGrawHill.
6. H.Asada and J. Slotive, 1986, Robot Analysis and Control, NY, John Wiley & Sons.
7. Lynch and Park, 2017, Modern Robotics, Cambridge, Cambridge University Press.
8. Thrun, Burgard, and Fox, 2005, Probabilistic Robotics, USA, MIT Press.

3- Electronic Materials and Web Sites *etc*.

Web Sites:

1. Teaching ROBOTC for Innovation First Robots, Carnegie Mellon Robotics Academy. http://www.robotc.net/vex_full/.
2. Introduction to Robotics Course (2DD2410) - KTH
3. https://www.kth.se/social/course/DD2410/
4. Modern Robotics, Lynch and Park, Cambridge University Press, 2017, authors' site (free version, video lectures):
5. http://lynchandpark.org
6. Probabilistic Robotics, Thrun, Burgard, and Fox, MIT Press, 2005, authors' site http://www.probabilistic-robotics.org/
7. Robot Books http://www.robotbooks.com
8. Center for Educational Resources (CERES) Project http://btc.montana.edu/ceres
9. Robotics research forum for academics and practitioners http://www.roboticscommunity.com/
10. Online robotics links http://chinese-school.netfirms.com/robot-resources.html
11. National Robotics Education Foundation (NREF) http://www.the-nref.org/

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	12. Robot Research and Information http://www.autopenhosting.org/robots/research.html 13. RoboRealm: A free application for use in machine vision, image analysis, and robotic vision systems http://www.roborealm.com/ 14. NASA Robotics 15. https://robotics.nasa.gov/links/resources.php **Journals:** 1. IEEE Transactions on Robotics: Peer reviewed academic journal in the field of robotics, though it tends to emphasis mathematical and theoretical approaches. 2. International Journal of Robotics Research: The leading peer reviewed academic journal in robotics with a focus on formal experiments as well as theory. Its articles are detailed and provide extensive explanation of concepts and demonstrations.

	XI. 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 10 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:**

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	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 enquiries.
6	**Plagiarism**: The student will be terminated from the Faculty, if one student attend the exam on another behalf according to the policy, rules and regulations of the university.
7	**Other policies:** • All the teaching materials should be kept out the examination hall. • The mobile phone is not allowed. • There should be a respect between the student and his teacher.

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