EASTERN MEDITERRANEAN UNIVERSITY
FACULTY OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

Course Code: MENG233
Course Name: DYNAMICS
Semester/ Year: Fall 2026-27
Instructor: Prof. Dr. Qasim Zeeshan
Assistant: Mr. Emmanuel Chukwueloka Onyibo
Mr. Garshasp Sarkon
Assessment: Project
Submission Date:

PROJECT: Design and Development of a Robotic Arm

GROUP NO. : ……………………………
STUDENT NO: …………………………. NAME, SURNAME: ……………………………………………………………………..
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SECTIONS:

No.	STUDENT OUTCOMES	COURSE LEARNING OUTCOMES	WEIGHT OF SECTION /100	MARKS OBTAINED	REMARKS
S-0	1, 5, 7	5	10		Abstract, References, Appendices
S-1	1, 5, 7	5	10		
S-2	1, 5, 7	5	10		
S-3	1, 5, 7	5	10		
S-4	1, 5, 7	5	10		
Simulation	1, 5, 7	5	25		
Prototype	1, 5, 7	5	25		
TOTAL:(Out of 100)					

	Course Learning Outcomes	Student Outcomes						
		1	2	3	4	5	6	7
1	Analyze the kinematics of particles							
2	Analyze the kinetics of particles using: (force and acceleration, principle of work and energy, or principle of impulse and momentum)							
3	Analyze the planar kinematics of rigid bodies (Relative motion analysis: velocity and acceleration)							
4	Analyze the planar kinetics of rigid bodies using: (force and acceleration, principle of work and energy, or principle of impulse and momentum)							
5	Use the techniques learned to model and analyze a dynamic system.	X				X		X

Instructions:

1. Late submissions will be penalized with 10 marks/ day.
2. Draw neat, labeled diagrams where necessary.
3. Write relevant equations and write your Assumptions where necessary.
4. Be clear and specific and include units. Give explanatory notes where necessary. Please carry out each step explicitly.
5. Please provide the references using APA Style of Referencing.
6. References should be from the Textbook or from an authentic source.
7. Please include the equations, diagrams, plots and figures in the report.
8. All figures and Tables must be numbered and captioned.
9. Please submit the pdf Soft copy of the report via the MOODLE LMS/ Microsoft Assignment along with the MATLAB codes, Simulink. AVI File. Code/ Simulation etc.
10. The file/ folder uploaded should be named as [MENG233-PROJECT-GROUP NO]. Files with any other name or format will be disregarded. Do not forget the cover page Files with any other name or format will be disregarded. Do not forget the cover page.

ABSTRACT

Abstract and Keywords

An abstract summarizes, usually in one paragraph of 300 words or less, the major aspects of the entire paper/report in a prescribed sequence that includes: 1) the overall purpose of the study and the research problem(s) you investigated; 2) the basic design/approach of the study; 3) major/key findings or trends found as a result of your analysis; and, 4) a brief summary of your interpretations and conclusions.

SECTION 1 - INTRODUCTION

Introduction of the Mechanism
History of the Mechanism
Applications of the Mechanism
*Please provide reference information i.e. using proper citation.

SECTION 2 – MODEL

Working of the Mechanism - Working Principle
*Mathematical Model (Kinematics and/or Kinetics Models) used with reference to the equations in the textbook and other reliable sources.
Model of the Mechanism (can be modelled, designed in CAD Software, SIMSCAPE etc)
Prototype of the Mechanism
Materials and Manufacturing Process
*Prototype can be modelled, designed in CAD Software and manufactured using Plexiglass, Balsawood or 3D Printing.
*Hydraulic, Pneumatic or Motor Actuators can be used accordingly to demonstrate the working of the Mechanism.
*Please use labelled Diagrams, Figures, Graphs, Tables, etc.

SECTION 3 – ANALYSIS

Results - Results of the Velocity, Acceleration, Force, analysis etc. using Figures, Graphs, Tables, etc.
Discuss the Kinematics, Kinetics pf the system.

SECTION 4 - CONCLUSION

The conclusion is intended to help the reader understand why your research should matter to them after they have finished reading the report/paper. A conclusion is not merely a summary of the main topics covered or a re-statement of your research problem, but a synthesis of key points and, if applicable, where you recommend new areas for future research.

REFERENCES

All references on APA Style Format and must also be cited in text in Author (Year) format.

APPENDIX

CAD MODELS, Drawings, Sketches
Prototype of the Mechanism
Simulation (if any)
MATLAB CODES (if any)
SIMULINK MODELS (if any)
SIMSCAPE MODELS (if any)

USE OF ARTIFICIAL INTELLIGENCE

Students are required to explicitly state the use of AI-generated text, data analysis, visuals, or other content in their report under the heading "Use of Artificial Intelligence", which should be placed immediately after the "References" section. This statement must clearly specify the AI tools used (e.g., ChatGPT, Midjourney, Gemini) and the purpose for which they were employed (e.g., generating preliminary text for a literature review, data analysis).

Example Statement: "In this study, [XYZ AI tool] was used for [purpose, e.g., generating preliminary text for a literature review]."

AI-generated content must not exceed 20% of the total word count of the report.

S. No.	**AI Tool Used**	**Section**	**Section No.**	**Page No.**	**Purpose of use**
1	ChatGPT				
2	Claude				
3	Gemini				
4	DeepSeek				

PROJECT GUIDELINES:

Design and Development of a Low-Cost Multi-Degree-of-Freedom Robotic Arm for Ping-Pong Ball Pick-and-Place

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1. Project Overview

This project challenges third-year engineering students to **design, build, and experimentally validate a low-cost multi-degree-of-freedom (DOF) robotic arm** capable of gripping, lifting, transferring, and placing a ping-pong ball with reasonable repeatability and accuracy. The complete system must be developed under a **strict budget constraint of approximately 100 USD**, encouraging students to adopt cost-effective engineering solutions, efficient mechanical designs, and creative problem-solving approaches.

The project integrates multiple engineering disciplines including:

- mechanical design and structural analysis
- actuator selection and torque estimation
- robotic kinematics and motion planning
- embedded system programming
- control implementation and experimental validation

A **4-DOF robotic arm with a simple gripper mechanism** is recommended because it provides sufficient functionality for pick-and-place tasks while remaining feasible within the project's cost and time constraints. The project integrates concepts from **mechanical design, actuator selection, kinematics, embedded control, and experimental validation**. A **4-DOF manipulator with a simple gripper** is recommended because it balances educational complexity with practical feasibility.

Low-cost robotic manipulators have been widely adopted as effective platforms for teaching robotics concepts such as motion control, kinematics, and robot-system integration in undergraduate engineering education (Čehovin Zajc et al., 2023; Markvicka et al., 2023).

To support hands-on learning, students may also refer to practical demonstrations and tutorials that illustrate similar robotic arms and pick-and-place mechanisms. For example:

To support practical learning, students can consult real-world project demonstrations and tutorials. For example, the following project illustrates how a **4-DOF robotic arm with servo motors and Arduino control can perform pick-and-place tasks**:

Build a 4 DOF Robotic Arm with Arduino | Servo + Joystick Control

Such demonstrations show how low-cost servos and microcontrollers can coordinate to produce controlled manipulator motion suitable for educational projects.

Similarly, MATLAB and Simulink can be used to **simulate robotic arms before physical fabrication**, allowing students to analyze kinematics, motion trajectories, and system dynamics. MATLAB's Simscape Multibody environment enables users to construct mechanical systems, perform simulations, and test control algorithms within a virtual environment before hardware implementation (MathWorks).

This type of tutorial demonstrates how affordable servo motors and microcontrollers can be integrated to perform coordinated robotic manipulation tasks.

In addition to hardware development, students can use **MATLAB Simscape Multibody** to simulate the robotic arm prior to fabrication. Simulation enables analysis of link motion, actuator loads, and joint trajectories, reducing development errors and improving design reliability (MathWorks, 2023).

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2. Project Aim

The primary aim of the project is to develop a robotic manipulator that can:

- reach a defined pickup location
- grasp a ping-pong ball without damaging it
- transport it to a designated drop location
- release it accurately in a target zone

The final system should demonstrate **reliable and repeatable pick-and-place operation** while maintaining low cost and mechanical simplicity.

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3. Learning Objectives

Upon completion of this project, students should be able to:

- design articulated robotic mechanisms with multiple joints
- perform basic torque calculations and actuator selection
- model robotic arms using CAD tools
- apply forward and inverse kinematics concepts
- develop embedded control software for servo motors
- design grippers for handling fragile objects
- simulate robotic systems using MATLAB Simscape
- evaluate system performance experimentally

Simulation environments such as MATLAB Simscape allow students to analyze **dynamic motion and joint interactions** before physical construction, providing a valuable learning tool in robotics system development (MathWorks, 2023).

Example Demonstration

A practical example of such a system can be seen in the following project demonstration:

Pick and Place Robot using Arduino | DIY Arduino Project

This example illustrates how **four servo motors can coordinate to perform simple pick-and-place operations**, demonstrating feasibility for low-cost educational systems.

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4. Recommended System Configuration

A practical configuration for the robotic arm includes:

Joint	Degree of Freedom
Base rotation	1
Shoulder	1
Elbow	1
Wrist pitch	1
Gripper open/close	1

This configuration results in a **4-DOF manipulator plus a 1-DOF gripper**, sufficient for performing tabletop pick-and-place operations.

Suggested Performance Targets

Object: Standard ping-pong ball (~2.7 g)
Reach: 20–30 cm
Placement accuracy: within ~1–2 cm
Cycle time: 10–20 seconds
Success rate: at least 80–90% during testing

A practical demonstration of a similar robotic pick-and-place system is illustrated in the following project tutorial:

Such examples demonstrate the feasibility of low-cost servo-driven robotic arms for educational experimentation.

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5. Design Philosophy

Although the ping-pong ball payload is extremely light, the system must be designed to ensure:

- stable motion
- repeatable positioning
- gentle gripping
- structural rigidity

Therefore, the design should prioritize:

- lightweight links
- rigid joints
- balanced mass distribution
- smooth servo control
- compliant gripping surfaces

Low-cost robotic arms typically use hobby servos for actuation due to their affordability and ease of control (Al Tahtawi et al., 2021). High-torque servos such as **MG996R** are appropriate for base and shoulder joints, while smaller servos like **SG90** can be used for wrist and gripper mechanisms.

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6. Role of Simulation Using MATLAB Simscape

Before fabrication, students should model their robotic arm using **MATLAB Simscape Multibody**.

Simscape enables the creation of **3-D multibody models representing links, joints, and actuators**, allowing designers to simulate motion and evaluate mechanical behavior under various operating conditions (MathWorks).

A typical workflow includes:

1. Building the mechanical model
2. Defining joint types and constraints
3. Applying actuator torques or angles
4. Simulating motion trajectories
5. Visualizing robot motion in 3-D

MATLAB also provides a **pick-and-place robot simulation example** demonstrating how forward and inverse kinematics can control manipulator motion during object transfer tasks (MathWorks).

The following tutorial illustrates how such simulations can be implemented in practice:

Pick-and-Place Arm Robot Simulation | MATLAB Simulink Simscape Multibody

These simulations allow students to validate arm reach, trajectory planning, and joint angles before building hardware.

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7. Key Technical Challenges

The project exposes students to realistic engineering challenges.

7.1 Torque and Load Distribution

Even with a light payload, proximal joints must support:

- downstream links
- motors and wiring
- gripper components

Students must estimate joint torques and select appropriate actuators accordingly.

7.2 Structural Rigidity

Low-cost materials such as plywood or acrylic can introduce flexing that reduces positioning accuracy.

7.3 Servo Backlash

Inexpensive hobby servos may exhibit backlash, which affects repeatability.

7.4 Gripper Design

The ping-pong ball is smooth and lightweight, making reliable grasping challenging.

Effective gripper design should include:

- curved finger surfaces
- soft rubber or foam padding
- moderate gripping force

Studies of robotic end-effectors highlight the importance of adapting gripper geometry to the physical characteristics of the manipulated object (Mavrogiannis et al., 2023).

7.5 Motion Coordination

Joint movements must be coordinated to achieve precise end-effector positioning.

Inverse kinematics algorithms or predefined motion sequences can be used to control the robotic arm (Al Tahtawi et al., 2021).

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8. Recommended Materials and Components

Component	Quantity	Estimated Cost (USD)
Arduino Nano / compatible	1	6–8
MG996R high-torque servos	2–3	8–10 each
SG90 micro servos	2	2–3 each
Power supply (5–6 V)	1	8–12
Structural materials (plywood/acrylic/PLA)	set	10–15
Mechanical fasteners and brackets	set	8–12
Rubber pads or foam for gripper	set	3–5
Breadboard and wiring	set	5–7

Estimated total project cost: **75–100 USD**

This component selection balances performance with affordability, enabling students to construct functional robotic systems with minimal cost.

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9. Mechanical Design Recommendations

Link Lengths

Suggested dimensions:

Link 1: 10–12 cm
Link 2: 10–12 cm
Wrist: 5–7 cm

Shorter links reduce torque requirements and improve stability.

Base Design

The base should be rigid and sufficiently heavy to prevent tipping during arm motion.

Gripper Design

A **two-finger parallel gripper** is recommended.

Key design features:

- curved gripping surfaces
- rubber padding for friction
- sufficient closure angle to cradle the ball

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10. Control Strategy

Two control approaches can be implemented.

Option 1: Predefined Motion Sequence

Joint angles are manually defined for key positions:

• home
• approach
• pickup
• lift
• drop
• release

This method is simple and reliable.

Option 2: Coordinate-Based Motion

Students implement simplified inverse kinematics to compute joint angles from Cartesian coordinates.

This approach can be validated using MATLAB simulations before implementation.

MATLAB provides examples of **robot trajectory planning and inverse kinematics for pick-and-place tasks**, which can be adapted for educational robotic arms (MathWorks).

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11. Suggested Development Stages

Stage 1 – Concept Development

Develop alternative arm configurations.

Stage 2 – Preliminary Analysis

Perform:

• torque estimation
• workspace analysis
• servo selection

Stage 3 – CAD Modeling

Model the robotic arm using CAD software.

Stage 4 – Simulation

Import the CAD assembly into Simscape using tools such as the smimport function, which converts mechanical assemblies into simulation models (MathWorks).

Stage 5 – Fabrication

Manufacture structural components and assemble the arm.

Stage 6 – Electronics Integration

Install servos and microcontroller.

Stage 7 – Programming

Implement motion sequences and test each joint.

Stage 8 – Experimental Testing

Conduct repeatability and pick-and-place experiments.

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12. Testing Plan

Testing should follow progressive stages.

Test 1 – Servo Calibration

Verify joint angle limits.

Test 2 – Static Stability

Evaluate structural deflection at maximum reach.

Test 3 – Repeatability

Measure positional deviation for repeated movements.

Test 4 – Gripper Reliability

Test gripping success without arm motion.

Test 5 – Integrated Pick-and-Place

Perform at least **10 complete pick-and-place cycles**.

Performance metrics include:

- success rate
- placement accuracy
- cycle time
- number of dropped objects

13. Risk Mitigation and Cost Control

To maintain feasibility:

- minimize unnecessary sensors
- keep link lengths short
- prototype the gripper early
- maintain rigid structural connections
- reserve budget for replacement components

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14. Possible Enhancements

Optional extensions include:

- joystick control interface
- ultrasonic object detection
- camera-based object recognition
- trajectory optimization algorithms
- advanced simulation-based control

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15. Expected Deliverables

Each student team should submit:

1. **Engineering design report**
2. **Working robotic arm prototype**
3. **Embedded control software**
4. **Experimental testing results**
5. **Final live demonstration**

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16. Project Outcome

The successful completion of this project will produce a **functional low-cost robotic manipulator** demonstrating the principles of robotic motion, manipulation, and system integration.

By combining **hands-on prototyping, simulation tools, and practical tutorials**, students gain valuable experience in designing real robotic systems while working within realistic engineering constraints.

References

Al Tahtawi, A. R., Dewanto, T. P., & Yusuf, T. (2021). Small-scale robot arm design with pick and place mission based on inverse kinematics. *Journal of Robotics and Control*, 2(6), 469–475. https://doi.org/10.18196/jrc.26109

Çehovin Zajc, L., Rezelj, A., & Skočaj, D. (2023). Low-cost open-source robotic platform for education. *IEEE Transactions on Learning Technologies*. Advance online publication. https://doi.org/10.1109/TLT.2022.3228611

Markvicka, E., Henthorn, J., & Liao, T. (2023, June). Designing learning experiences with a low-cost robotic arm. In *2023 ASEE Annual Conference & Exposition Proceedings*. American Society for Engineering Education. https://peer.asee.org/designing-learning-experiences-with-a-low-cost-robotic-arm.pdf

Mavrogiannis, C., Thomason, J., & Okamura, A. M. (2023). Current designs of robotic arm grippers: A comprehensive systematic review. *Robotics*, 12(1), Article 15. https://doi.org/10.3390/robotics12010015

TowerPro. (n.d.). *MG996R servo motor specifications*. https://towerpro.com.tw/product/mg996r/

TowerPro. (n.d.). *SG90 micro servo datasheet*. https://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf