

**Mechanical
Engineering
Department
MCEG 3305**

**Kinematics Design and
Analysis**



Fall 2021

**Dr. Mingli Han
Dr. Chang Duan**

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
MCEG 3305 KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

- I. COURSE DESCRIPTION IN ABET FORMAT**
- II. ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS**
 - Program Outcomes Assessed in Course**
 - Assessment Summary of Class Semester Averages for Outcomes**
 - End of Semester Course Outcomes Assessment Reports**
- III. TESTS**
 - Summary of Topics covered by Test**
 - Original Test Questions & Master Solution/grading scheme used**
 - (Summary of topics can be a separate page or include on the assignment itself)**
 - Above Average (Graded original work)**
 - Average (Graded original work)**
 - Below Average (Graded original work)**
- IV. HOMEWORK ASSIGNMENTS**
 - Summary of Topics Covered by Homework Assignments**
 - Above Average (Graded original work)**
 - Average (Graded original work)**
 - Below Average (Graded original work)**
- V. GRADED FORUM DISCUSSION**
 - Summary of Topics Covered by In-class Exercises**
 - Above Average (Graded original work)**
 - Average (Graded original work)**
 - Below Average (Graded original work)**
- VI. COURSE PROJECT**
 - Summary of Topics Covered by Course Project**
 - Above Average (Graded original work)**
 - Average (Graded original work)**
 - Below Average (Graded original work)**

I. Course Description in ABET Format

MECHANICAL ENGINEERING DEPARTMENT MCEG 3305 Kinematics Design and Analysis

1. **Course number and name:** MCEG 3305 Kinematics Design and Analysis
2. **Credits and contact hours:** 3 credit hours, 5 contact hours
3. **Instructor's or course coordinator's name:** Dr. Mingli Han
Dr. Chang Duan
4. **Text book:** Title: Design of Machinery
Author: Robert L. Norton
Publisher, Year & Edition: McGraw Hill, 2012, 5th Edition
 - a. Other Supplemental material Shigley and Uicker, Theory of Machines and Mechanisms, McGraw Hill.
5. **Specific course information**
 - a. Brief description of the content of the course (catalog description) This course is to provide students with an in-depth study of the displacement, velocity and acceleration of machine parts. This course shall also introduce the students to design methods for mechanisms yielding a desired set of motion characteristics.
 - b. Prerequisites or Co-requisites MCEG 1102 Mechanical Engineering Drawing I
MCEG 2302 Engineering Mechanics II
 - c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program Required
6.
 - a. **Specific goals for the course** specific outcomes of instruction (e.g., The student will be able to explain the significance of current research about a particular topic.)

Students will be able to:
 1. Analyze mechanisms in order to determine their rigid-body dynamic behavior
 2. Synthesize mechanisms in order to accomplish desired motions or tasks
 - b. **Explicitly indicate which of the student outcomes listed in Criterion 3** or any other outcomes are addressed by the course.

The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:

3. Use computer aided engineering software for mechanisms analysis, synthesis and design

Outcome 1

The ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

7 Brief list of topics to be covered

1. Introduction to the kinematics fundamentals (1 class)
2. Position and Displacement (4 classes)
3. Velocity by Components and by Instant Centers (2 classes)
4. Graphical Synthesis (3 classes)
5. Velocity Analysis (5 classes)
6. Acceleration Analysis (3 classes)
7. Mathematical Analysis (2 classes)
8. Design Project (1 classes)
9. Cams (5 classes)
10. Gear Trains (2 classes)

***Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group

II. ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

Outcome 1:

An ability to identify, formulate, and solve complex engineering problems (CEP) by applying principles of engineering, science, and mathematics.

Assessment Summary of Class Semester Averages for Outcomes

Outcomes	1
Semester	Semester Class Average (%)
Fall 2021	78.5
Fall 2020	76.6
Fall 2019	80.1
Fall 2018	88.3
Comments on Trend of Data	The Class Average is decreasing over the last three years.

*Expected Semester Class Average = 70% (or as defined by the program)
Ideal Semester Class Average = 75% (or as defined by the program)

End of Semester Course Assessment Reports Fall 2021 and Last Three Assessment Periods.

Each summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department.
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's critical **evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

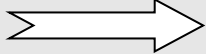
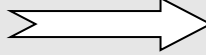
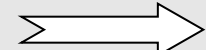
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

**Table 2.1 END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
MCEG 3305 KINEMATICS DESIGN AND ANALYSIS
FALL 2021 SEMESTER**

Report Prepared by: Dr. Chang Duan

Report Date: December 17, 2021

Semester	Analysis Type	Number of Students	Outcome 1* An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematic.			
			Expected Class Average	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Fall 2021	Direct	20	70	70	78.5	85
Fall 2020	Direct	27	70	70	76.6	88.9
Fall 2019	Direct	27	70	70	80.1	92.6
Fall 2018	Direct	36	75/70	70	88.3	97.2
Implementation Summary	Items implemented from previous report or after meeting previous instructor 		Math review tutorials are posted as supplementary material. A self-paced MATLAB tutorial is given in the beginning of the class. Project is assigned earlier so that students have enough time to work on it.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 		Students struggled in some fundamental math problems. Students still have the expectation of the hybrid teaching mode and seems to be less focused in the classroom. The ability of using engineering software varies drastically among students. In particular, the ability of using UG NX for motion simulation and the ability of using MATLAB for calculation, plotting and analysis.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 		Math review (outside of classroom) and quizzes will help student review and improve their math capabilities relate to this course. More tutorial and in-class demonstration will be given to improve the students' ability of using engineering software. Online discussion forum on ecourses can be a good way to engage students outside of the class time.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters 		Class average and expected percent of students declined in recent years, though still meet the expectations.			
Were Expectations Met?	Class Average $\geq 75\%$ and $\geq 70\%$ of Students Performed at or Above Expected Average. 		YES			

*: ABET switched to outcome 1-7 in May 2018. Outcome e is assessed in Fall 2017 and before that. Outcome 1 is assessed in Fall 2018 and onwards.

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

Title of Assignment: TEST 1

TOPICS COVERED IN TEST 1

Test 1 covered the following topics:

1. Degrees of freedom (or mobility)
2. Number synthesis
3. Grashoff condition
4. Vector loop equations
5. Coordinates transformation

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

**SAMPLE TEST 1 QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR TEST 1**

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 1

Oct. 4, 2021

12:00 – 1:30 pm

Solution

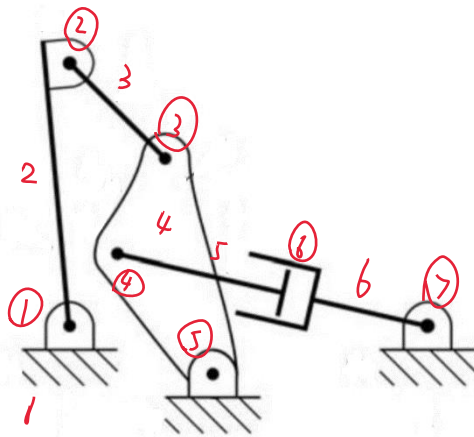
This examination is administered under the University's Code of Student Conduct. All work submitted must be your own. This is an open book examination. Only calculator is allowed, no cellphone, no tablet, and no laptop. Please write your name on every page.

QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	10	
2	10	
3	15	
4	15	
TOTAL	50	

Problem 1 (10 points):

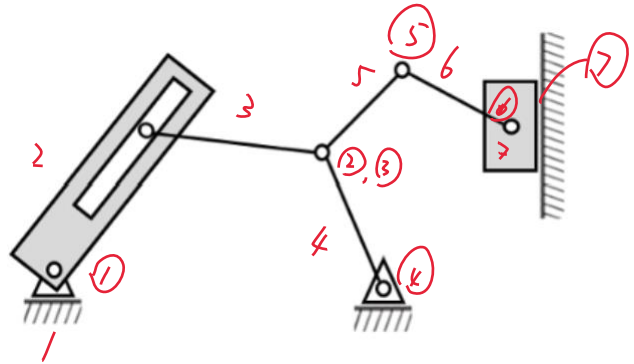
- 1) What is the definition of mobility of a system? (2 points) (Answering DOF will not earn you any point).
- 2) Determine the mobility of the following two planar linkages. In each case, identify links, identify the joints, and show the mobility equation with all corresponding values. (8 points)

Linkage 1:



$$\begin{aligned}
 L &= 6 \\
 J_1 &= 7 \\
 J_2 &= 0 \\
 M &= 3(L-1) - 2J_1 - J_2 \\
 &= 1
 \end{aligned}$$

Linkage 2:



$$\begin{aligned}
 L &= 7 \\
 J_1 &= 7 \\
 J_2 &= 1 \\
 M &= 3(L-1) - 2J_1 - J_2 \\
 &= 18 - 14 - 1 \\
 &= 3
 \end{aligned}$$

Problem 2.

- 1) Using number synthesis, find the number of binary links to produce a 2 degree-of-freedom linkage when the total number of links is 5. (Assuming no multiple joints and half joints involved) (5 points)

$$M = 2, \quad L = 5.$$

$$\text{hence, } L - 3 - M = 0 = T + 2Q + 3P + 4H$$

$$T, Q, P, H \geq 0, \quad \text{thus. } T = Q = P = H = 0$$

$$B = L - T - Q - P - H = 5.$$

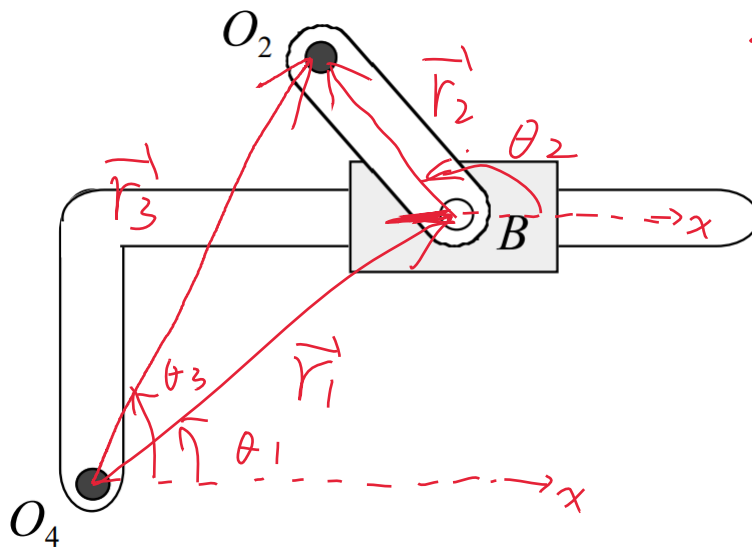
- 2) For a four-bar linkage, assuming the lengths of the four links are the last non-zero four digits of your student ID. For example, if the ID is P10391307, then the lengths are 9, 1, 3, 7. Use Grashof condition to determine the class of this four-bar linkage and predict its rotation behavior. (5 points)

$$S = 1, \quad L = 9, \quad P = 3, \quad Q = 7.$$

$$S + L = P + Q. \quad \text{Grashoff Class II.}$$

Problem 3 For the 3 points O_2 , O_4 , and B , create 3 vectors,

- 1) mark the direction of the vectors (3 points) and angles of the vectors clearly (3 points).
- 2) Write the vector loop equation based on the vectors you defined. (3 points)
- 3) Write the two equations represented by the vector loop equation. (6 points)



$$2) \quad \vec{r}_3 = \vec{r}_1 + \vec{r}_2$$

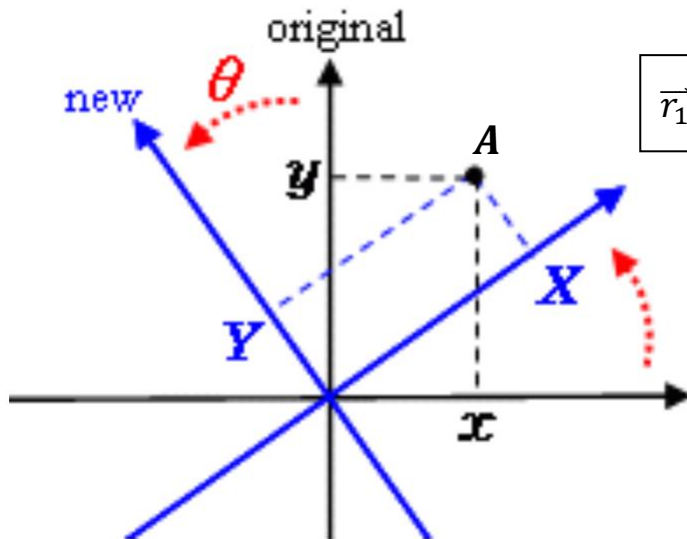
$$3) \quad |r_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} = |r_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

$$|r_3| \cos \theta_3 = |r_1| \cos \theta_1 + |r_2| \cos \theta_2$$

$$|r_3| \sin \theta_3 = |r_1| \sin \theta_1 + |r_2| \sin \theta_2$$

Problem 4 Given the position of point A in the original coordinate system $x = 2, y = 4$,

- 1) Express the position of point A in the original coordinate system in the vector form, denote it as $\vec{r}_1$. Calculate the length and angle of $\vec{r}_1$. (6 pts)
- 2) A new coordinate system is formed by rotating the original coordinate system counterclockwise by angle $\theta = 40^\circ$, calculate the position of point A in the new coordinate system, i.e., find $\vec{r}_2 = \begin{bmatrix} X \\ Y \end{bmatrix}$. (9 pts)



$$\vec{r}_1 = R \vec{r}_2, \text{ where } R = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$

$$1) \quad \vec{r}_1 = \begin{bmatrix} 2 \\ 4 \end{bmatrix}$$

$$|\vec{r}_1| = \sqrt{2^2 + 4^2} = 4.4721$$

$$\theta_1 = \tan^{-1} \frac{4}{2} = 63.43^\circ$$

$$2) \quad \vec{r}_2 = R^{-1} \vec{r}_1 = R^T \vec{r}_1$$

$$= \begin{bmatrix} \cos 40^\circ & \sin 40^\circ \\ -\sin 40^\circ & \cos 40^\circ \end{bmatrix} \begin{bmatrix} 2 \\ 4 \end{bmatrix}$$

$$= \begin{bmatrix} 4.1032 \\ 1.7786 \end{bmatrix}$$

ABOVE AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 1

Oct. 4, 2021

12:00 – 1:30 pm

Student's Name (printed): Tyler Marcel

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QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	10	16
2	10	10
3	15	15
4	15	15
TOTAL	50	50

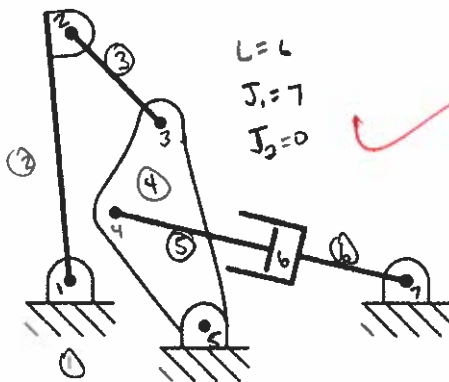
10

Problem 1 (10 points):

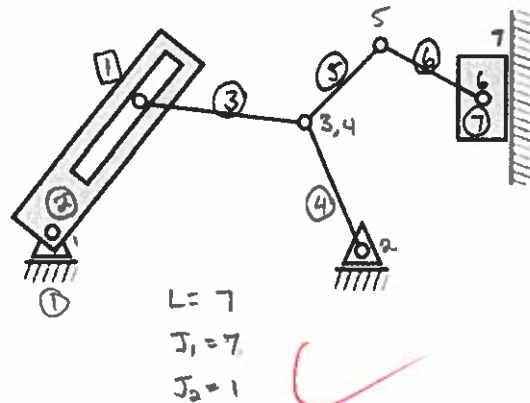
- 1) What is the definition of mobility of a system? (2 points) (Answering DOF will not earn you any point).
- 2) Determine the mobility of the following two planar linkages. In each case, identify links, identify the joints, and show the mobility equation with all corresponding values. (8 points)

L J_1 J_2

Linkage 1:



Linkage 2:



- 1) The number of independent parameters required to determine the position of a linkage system.

$$M = 3(L-1) - 2J_1 - J_2$$

Linkage 1

$$M = 3(6-1) - 2(7) - 0$$

$$M = 15 - 14$$

$$M = 1$$

Linkage 2

$$M = 3(7-1) - 2(7) - 1$$

$$M = 18 - 14 - 1$$

$$M = 3$$

Problem 2.

$$L - 3 - M = T + 2Q + 3P + 4H$$

- 1) Using number synthesis, find the number of binary links to produce a 2 degree-of-freedom linkage when the total number of links is 5. (Assuming no multiple joints and half joints involved) (5 points)

$$L - 3 - M = T + 2Q + 3P + 4H \quad M = 2 \quad L = 5$$

$$5 - 3 - 2 = 0$$

$$T = Q = P = H = 0$$

$$L = B + \overset{0}{T} + \overset{0}{Q} + \overset{0}{P} + \overset{0}{H}$$

$$B = 5$$

- 2) For a four-bar linkage, assuming the lengths of the four links are the last non-zero four digits of your student ID. For example, if the ID is P10391307, then the lengths are 9, 1, 3, 7. Use Grashof condition to determine the class of this four-bar linkage and predict its rotation behavior. (5 points)

3, 3, 7, 5
S P L Q

Class II Case

Triple Rocker

No link can fully rotate

$$S + L > P + Q$$

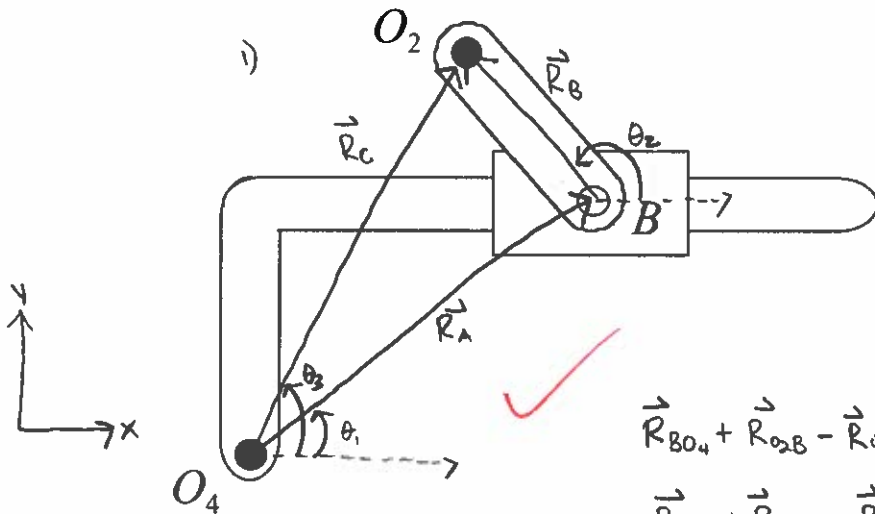
$$3 + 7 > 3 + 5$$

$$10 > 8$$

15 ✓

Problem 3 For the 3 points O_2 , O_4 , and B , create 3 vectors,

- 1) mark the direction of the vectors (3 points) and angles of the vectors clearly (3 points).
- 2) Write the vector loop equation based on the vectors you defined. (3 points)
- 3) Write the two equations represented by the vector loop equation. (6 points)



$$\vec{R}_{BO_4} + \vec{R}_{O_2B} - \vec{R}_{O_2O_4} = 0$$

$$\vec{R}_{B_{O_4}} + \vec{R}_{O_2B} = \vec{R}_{O_2O_4} \quad \text{or} \quad \vec{R}_A + \vec{R}_B = \vec{R}_C$$

$$\vec{R}_A + \vec{R}_B - \vec{R}_C = 0$$

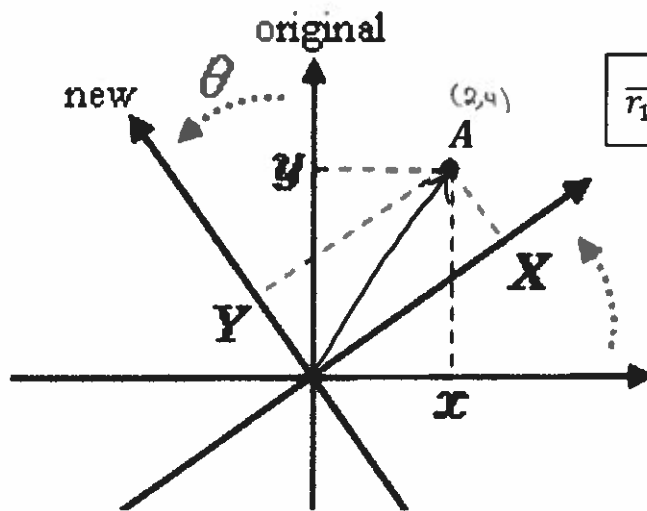
3)

$$a \cos \theta_1 + b \cos \theta_2 - c \cos \theta_3 = 0$$

$$a \sin \theta_1 + b \sin \theta_2 - c \sin \theta_3 = 0$$

15 Problem 4 Given the position of point A in the original coordinate system $x = 2, y = 4$,

- Express the position of point A in the original coordinate system in the vector form, denote it as $\vec{r}_1$. Calculate the length and angle of $\vec{r}_1$. (6 pts)
- A new coordinate system is formed by rotating the original coordinate system counterclockwise by angle $\theta = 40^\circ$, calculate the position of point A in the new coordinate system, i.e., find $\vec{r}_2 = \begin{bmatrix} X \\ Y \end{bmatrix}$. (9 pts)



$$\vec{r}_1 = R\vec{r}_2, \text{ where } R = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$

$$1) R_A = \sqrt{R_x^2 + R_y^2} \quad \vec{r}_1 = \begin{bmatrix} 2 \\ 4 \end{bmatrix}$$

$$R_A = \sqrt{2^2 + 4^2}$$

$$R_A = 4.47 \text{ units?}$$

$$\theta = \arctan\left(\frac{R_y}{R_x}\right)$$

$$\theta = \arctan\left(\frac{4}{2}\right)$$

$$\theta = 63.43^\circ$$

$$2) R = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$

$$R = \begin{bmatrix} \cos 40 & -\sin 40 \\ \sin 40 & \cos 40 \end{bmatrix}$$

$$R = \begin{bmatrix} 0.766 & -0.643 \\ 0.643 & 0.766 \end{bmatrix}$$

$$\vec{r}_1 = R\vec{r}_2 \quad \text{or} \quad R_X = R_x \cos \theta - R_y \sin \theta$$

$$\vec{r}_2 = R^{-1}\vec{r}_1 \quad R_Y = R_x \sin \theta + R_y \cos \theta$$

$$\vec{r}_2 = \begin{bmatrix} 0.766 & 0.643 \\ 0.643 & 0.766 \end{bmatrix} \begin{bmatrix} 2 \\ 4 \end{bmatrix} \quad \vec{r}_2 = \begin{bmatrix} X \\ Y \end{bmatrix}$$

$$\vec{r}_2 = \begin{bmatrix} 4.103 \\ 1.778 \end{bmatrix}$$

AVERAGE

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DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 1

Oct. 4, 2021

12:00 – 1:30 pm

Student's Name (printed): Myles Woodfork

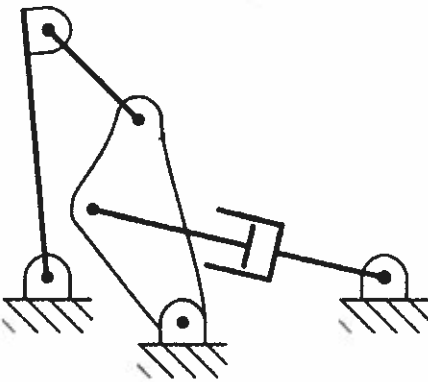
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QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	10	4
2	10	10
3	15	13
4	15	6
TOTAL	50	33

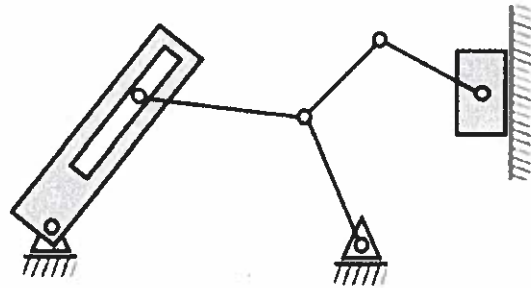
Problem 1 (10 points):

- 1) What is the definition of mobility of a system? (2 points) (Answering DOF will not earn you any point).
- 2) Determine the mobility of the following two planar linkages. In each case, identify links, identify the joints, and show the mobility equation with all corresponding values. (8 points)

Linkage 1:



Linkage 2:



- 1) Mobility of a System: A mechanical system's position in space at any given instant of time.

2) Linkage 1:

$L = 6$ ✓

$$J = 6 \times$$

624

$$M = 3(6-1) - 2(6)$$

$$\cancel{15-3} - \cancel{3} = 15 - 12$$

~~4/18/20-23~~ $\boxed{= 3}$



-2

Linkage 2:

$L = 7$

$J = 6$ ✗

$$M = 3(7-1) - 2(6)$$

$$= 18 - 12$$

= 6

-2

10

Problem 2.

- 1) Using number synthesis, find the number of binary links to produce a 2 degree-of-freedom linkage when the total number of links is 5. (Assuming no multiple joints and half joints involved) (5 points)

$$L=5 \quad M=2$$

~~$$L=5 \quad M=2 \quad T=Q=P=H=0$$~~

~~$$L=5 \quad M=2$$~~

~~$$L=5 \quad M=2 \quad T=Q=P=H=0$$~~

$$L-3-M = T+2Q+3P+4H = 0$$

$$L = B + 0 = 5$$

$$B = 5$$

- 2) For a four-bar linkage, assuming the lengths of the four links are the last non-zero four digits of your student ID. For example, if the ID is P10391307, then the lengths are 9, 1, 3, 7. Use Grashof condition to determine the class of this four-bar linkage and predict its rotation behavior. (5 points)

$$6, 1, 5, 6$$

$$S + L < P + Q$$

$$1 + 6 \leq 5 + 6$$

$$7 < 11$$

Class 1 Kinematic Chain

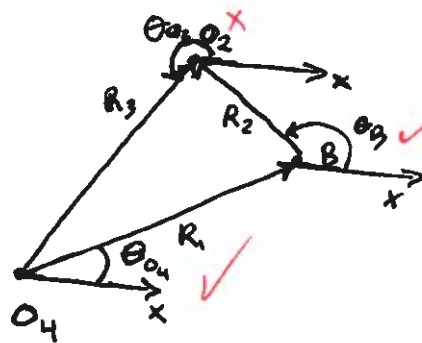
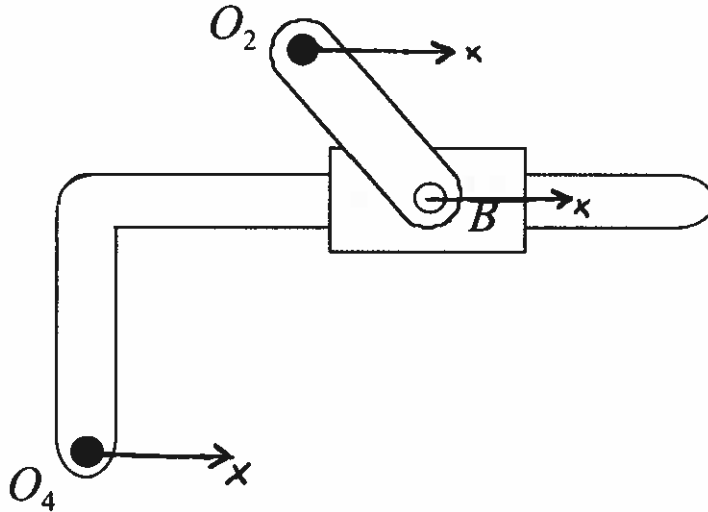
Will either be a Crank Rocker, (S and grounded link rotate)
(both ground links and the coupler fully rotate)
Double Crank, or Grashof Double-

Rocker. (Both ground links oscillate, coupler fully rotates)

13

Problem 3 For the 3 points O_2 , O_4 , and B , create 3 vectors,

- 1) mark the direction of the vectors (3 points) and angles of the vectors clearly (3 points).
- 2) Write the vector loop equation based on the vectors you defined. (3 points)
- 3) Write the two equations represented by the vector loop equation. (6 points)



$$R_1 + R_2 - R_3 = 0$$

or

$$R_B + R_{BO_4} - R_{O_2} = 0$$

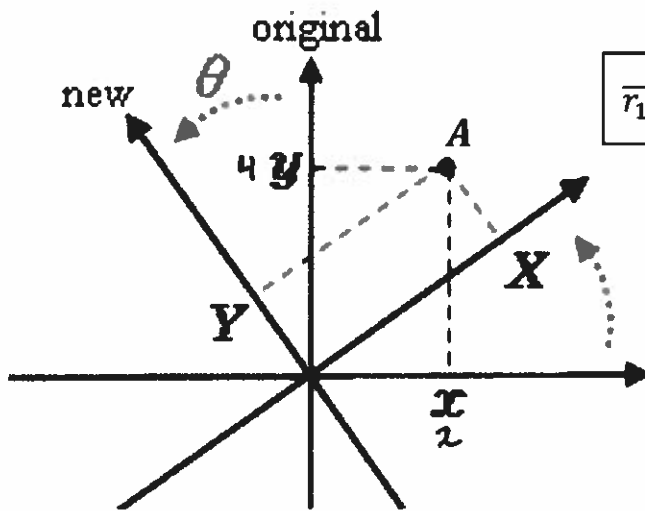
or

$$a e^{j\theta_1} + b e^{j\theta_2} - c e^{j\theta_3} = 0$$

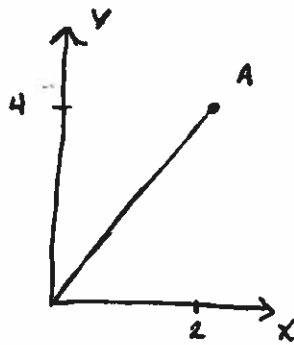
6

Problem 4 Given the position of point A in the original coordinate system $x = 2, y = 4$,

- Express the position of point A in the original coordinate system in the vector form, denote it as $\vec{r}_1$. Calculate the length and angle of $\vec{r}_1$. (6 pts)
- A new coordinate system is formed by rotating the original coordinate system counterclockwise by angle $\theta = 40^\circ$, calculate the position of point A in the new coordinate system, i.e., find $\vec{r}_2 = \begin{bmatrix} X \\ Y \end{bmatrix}$. (9 pts)



$$\vec{r}_1 = R\vec{r}_2, \text{ where } R = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$



$$1. \quad \theta = \tan^{-1}\left(\frac{4}{2}\right)$$

$$= \tan^{-1}(2)$$

$$\theta_1 = 63.4349^\circ$$

$$\vec{r}_1 = \sqrt{2^2 + 4^2}$$

$$= 4.47214$$

2.

$$R = \begin{bmatrix} \cos 40 & -\sin 40 \\ \sin 40 & \cos 40 \end{bmatrix}$$

$$= \begin{bmatrix} 0.766044 & -0.642788 \\ 0.642788 & 0.766044 \end{bmatrix} =$$

Pos. of A

$$R\vec{r}_1 = 4.47214 \begin{bmatrix} 4 \\ 2 \end{bmatrix}$$

BELOW AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 1

Oct. 4, 2021

12:00 – 1:30 pm

Student's Name (printed): Temitayo Ojo

This examination is administered under the University's Code of Student Conduct. All work submitted must be your own. This is an open book examination. Only calculator is allowed, no cellphone, no tablet, and no laptop. Please write your name on every page.

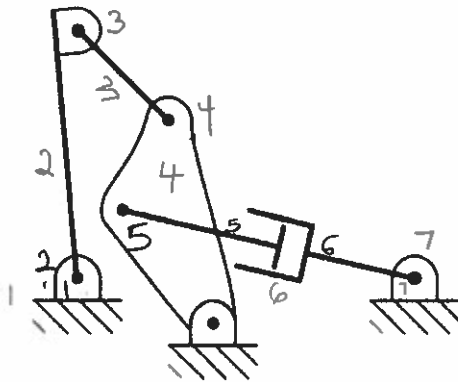
QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	10	3
2	10	3
3	15	12
4	15	4
TOTAL	50	22

3

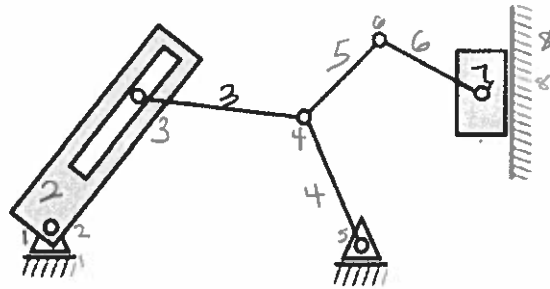
Problem 1 (10 points):

- 1) What is the definition of mobility of a system? (2 points) (Answering DOF will not earn you any point).
- 2) Determine the mobility of the following two planar linkages. In each case, identify links, identify the joints, and show the mobility equation with all corresponding values. (8 points)

Linkage 1:



Linkage 2:



① mobility of a system is the total number of links/joints, etc. of the system X - 2

② Linkage 1:

$$M = 3(L-1) - 2J_1 - J_2$$

$$3(\overset{x}{8}-1) - 2(\overset{x}{6}) - 0$$

$$21 - 12 - 0$$

$$M = 9$$

- 2

Linkage 2:

$$M = 3(\overset{x}{8}-1) - 2(\overset{x}{8}) - \overset{x}{0}$$

$$21 - 16 - 0$$

$$M = 5$$

- 3

3

Problem 2.

- 1) Using number synthesis, find the number of binary links to produce a 2 degree-of-freedom linkage when the total number of links is 5. (Assuming no multiple joints and half joints involved) (5 points)

$$L = 5$$

$$M = 2$$

$$L - 3 - M = T + 2Q + 3P + 4H$$

$$L = B + T + Q + P + H$$

$$5 - 3 - 2 = T + 2Q + 3P + 4H$$

$$5 - 3 - 2 = T + 2Q + 3P + 4H$$

$$Q =$$

$$T =$$

$$P =$$

- 3

- 2) For a four-bar linkage, assuming the lengths of the four links are the last non-zero four digits of your student ID. For example, if the ID is P10391307, then the lengths are 9, 1, 3, 7. Use Grashof condition to determine the class of this four-bar linkage and predict its rotation behavior. (5 points)

Student ID:

P21730452

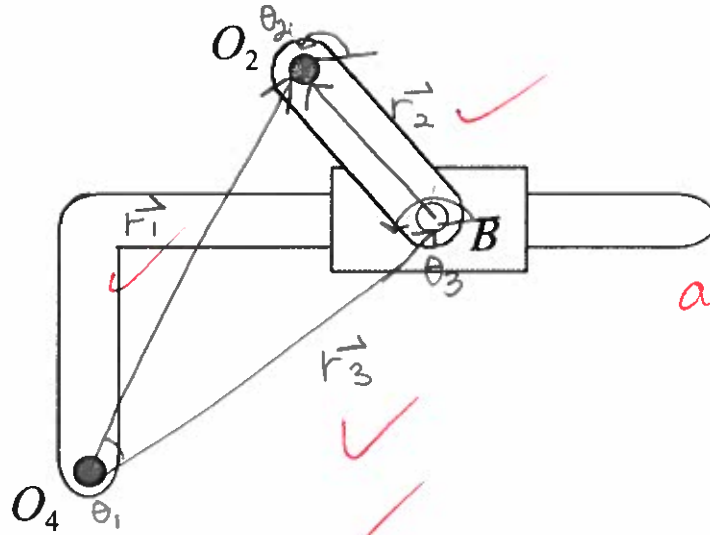
Lengths = 3, 4, 5, 2

- 4

12

Problem 3 For the 3 points O_2 , O_4 , and B , create 3 vectors,

- 1) mark the direction of the vectors (3 points) and angles of the vectors clearly (3 points).
- 2) Write the vector loop equation based on the vectors you defined. (3 points)
- 3) Write the two equations represented by the vector loop equation. (6 points)



$$\vec{r}_1 = \vec{r}_3 + \vec{r}_2$$

$$|\vec{r}_1| = \begin{bmatrix} \cos \theta \\ \sin \theta \end{bmatrix}$$

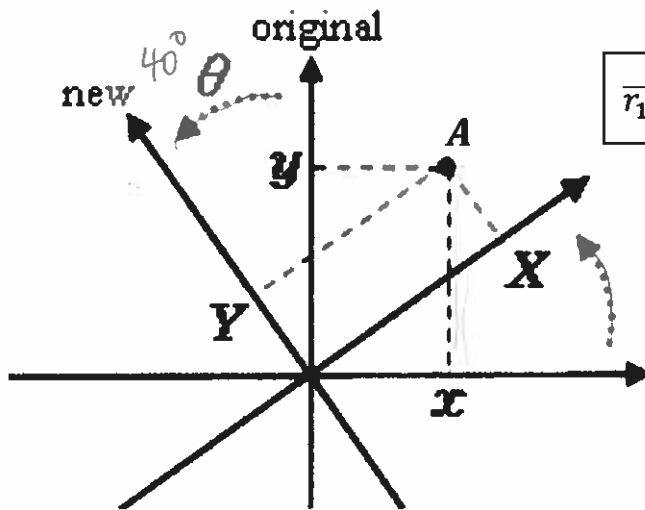
$$O_2 O_4 = B O_4 + O_2 B$$

$$|\vec{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} = |\vec{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} + |\vec{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

$$r_1 \cos \theta_1 = r_3 \cos \theta_3 + r_2 \cos \theta_2$$

$$r_1 \sin \theta_1 = r_3 \sin \theta_3 + r_2 \sin \theta_2$$

- 4 Problem 4 Given the position of point A in the original coordinate system $x = 2, y = 4$,
- 1) Express the position of point A in the original coordinate system in the vector form, denote it as $\vec{r}_1$. Calculate the length and angle of $\vec{r}_1$. (6 pts)
 - 2) A new coordinate system is formed by rotating the original coordinate system counterclockwise by angle $\theta = 40^\circ$, calculate the position of point A in the new coordinate system, i.e., find $\vec{r}_2 = \begin{bmatrix} X \\ Y \end{bmatrix}$. (9 pts)



$$\vec{r}_1 = R\vec{r}_2, \text{ where } R = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$

$$|\vec{r}| \begin{bmatrix} x \\ y \end{bmatrix}$$

$$x = 2$$

$$y = 4$$

① $\vec{r}_1 = R\vec{r}_2$

$$R = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$

$$\tan^{-1} \frac{4}{2} = 26.6^\circ$$

$\left\{ \frac{4}{2} \right\}$

$$\vec{r}_1 = \begin{bmatrix} 2 \\ 4 \end{bmatrix} \checkmark \quad |\vec{r}_1| = ? \quad -3$$

$$= \begin{bmatrix} 2 \cos \theta & -\sin \theta \\ 4 \sin \theta & \cos \theta \end{bmatrix}$$

2) -8

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

Title of Assignment: TEST 2

TOPICS COVERED IN TEST 2

Test 2 covered the following topics:

1. Four-bar linkage position analysis
2. Velocity analysis
3. Acceleration analysis
4. Cam follower classification
5. Cam follower terminology
6. Double-dwell cam design boundary conditions

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

**SAMPLE TEST 2 QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR TEST 2**

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 2

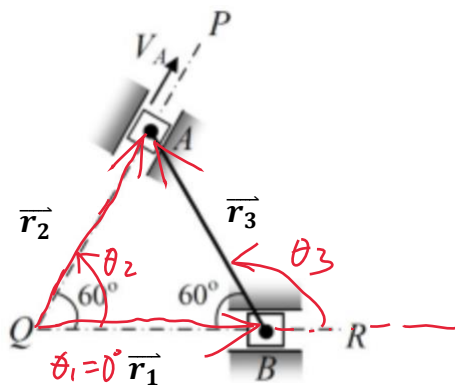
Nov. 3, 2021

Student's Name (printed): _____

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QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	15	
2	15	
3	10	
4	10	
TOTAL	50	

Problem 1 (15 points):



The lengths and angles are given as,

$$|r_1| = 1, |r_2| = 1, |r_3| = 1,$$

$$\theta_1 = 0^\circ, \theta_2 = 60^\circ, \theta_3 = 120^\circ.$$

The rod AB shown in the figure is connected to two sliders at each end through pins. The sliders can slide along QP and QR.

- 1) Mark the directions of the three vectors and their angles according to the given info; (2 pts)
- 2) Write the vector loop equation for velocity analysis; (1 pts)
- 3) Given the linear velocity of link 2 $|\dot{r}_2|$ = the last nonzero digit of your student ID, what are the unknowns in the velocity analysis? (2 pts)
- 4) In the velocity analysis, what quantities are 0? Why? (4 pts)
- 5) Given the linear velocity of link 2 $|\dot{r}_2|$ = the last nonzero digit of your student ID, solve the equations to obtain the numerical value of the unknowns. (6 pts)

$$\dot{\vec{r}}_i = |\dot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

$$2) \quad \dot{\vec{r}}_2 = \dot{\vec{r}}_1 + \dot{\vec{r}}_3$$

$$4) \quad \dot{\theta}_1 = 0, \quad \dot{\theta}_2 = 0, \quad |\dot{r}_3| = 0$$

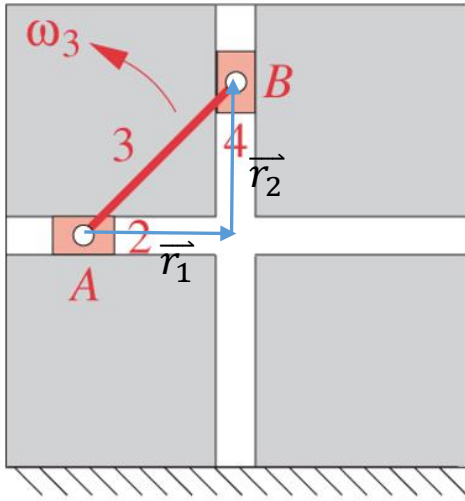
$$3) \quad |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix}$$

$|\dot{r}_1|$ and $\dot{\theta}_3$ are the two unknowns

$$5) \quad \begin{bmatrix} \cos \theta_1 & -\sin \theta_3 \\ \sin \theta_1 & \cos \theta_3 \end{bmatrix} \begin{bmatrix} |\dot{r}_1| \\ \dot{\theta}_3 \end{bmatrix} = |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

$$\dot{\theta}_3 = -1.732 |\dot{r}_2| \quad |\dot{r}_1| = - |\dot{r}_2|$$

Problem 2. (15 points)



Note $\vec{r}_1$ and $\vec{r}_2$ are imaginary vectors, $\vec{r}_3$ starts from A, point to B, A and B are connected by a rigid link.

$$|r_1| = 1, |r_2| = 1, |r_3| = \sqrt{2}, \\ \theta_1 = 0^\circ, \theta_2 = 90^\circ, \theta_3 = 45^\circ$$

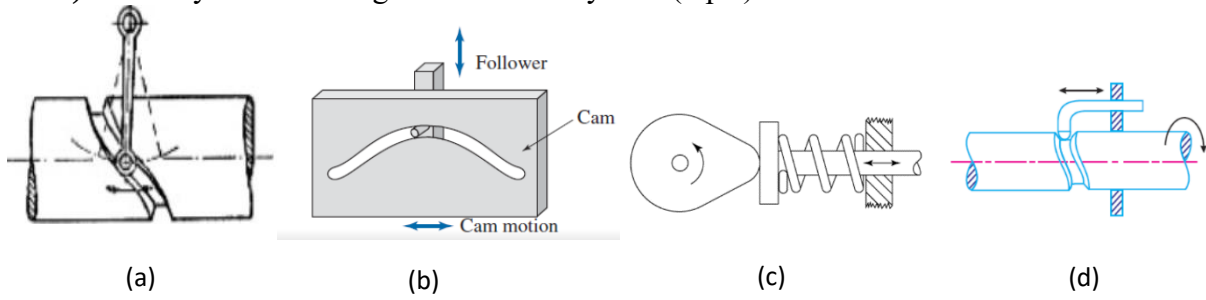
$$\dot{\vec{r}}_i = |\dot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

- 1) Write the vector loop equation. (2 pts)
- 2) What quantities does not change with time? (3 pts)
- 3) Given $\omega_3 = \dot{\theta}_3 =$ second non-zero digit of your student ID, calculate $|\dot{r}_1|$ and $|\dot{r}_2|$ **using velocity vector loop equation**. (6 pts)
- 4) Given $\ddot{\theta}_3 = 0$, list the two equations of acceleration analysis **keeping only nonzero items** (4 points)

$$\ddot{\vec{r}}_i = |\ddot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + 2|\dot{r}_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \ddot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i^2 \begin{bmatrix} -\cos \theta_i \\ -\sin \theta_i \end{bmatrix}$$

Problem 3 (10 points)

1) Classify the following cam follower system (8 pts)



System	Follower motion	Cam motion	Relative motion	Joint closure
(a)	rotating	rotating	radial	form
(b)	translating	translating	radial	form
(c)	translating	rotating	radial	forced
(d)	translating	rotating	axial	form

2) In s diagram, what is its minimum value? (1 pt) 0

3) In s diagram, explain what is Rise, Dwell and Fall? (1 pt)

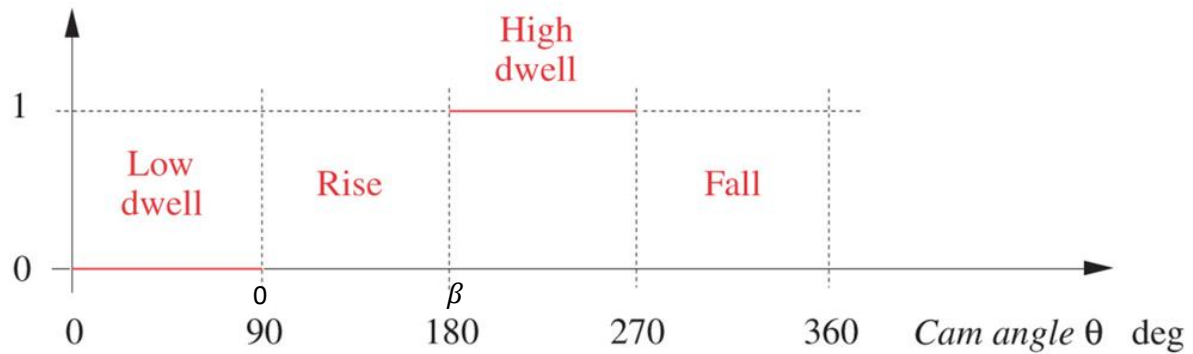
Rise is when s value is increasing.

Dwell is when s value remains unchanged.

Fall is when s value is decreasing.

Problem 4 (10 points)

Motion
mm or in



- 1) The figure above shows a s diagram of a double dwell cam design. When we are asked to design the Rise function from 0 to β , what is the value of β in this case (use radian)? (2 pts) ~~2~~
- 2) What is the fundamental law of cam design? (2 pts)
- 3) To satisfy the fundamental law of cam design, fill in the following table with boundary conditions of s, v, a Rise functions. (3 pts)

	when $\theta = 0$	when $\theta = \beta$
$s =$	0	1
$v =$	0	0
$a =$	0	0

- 4) Given $v = \theta - \beta \sin(\theta)$, calculate a by $\frac{dv}{d\theta}$. (3 pts)

2) The cam-follower function must have continuous velocity and acceleration across the entire interval, thus making the jerk finite.

4)

ABOVE AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 2

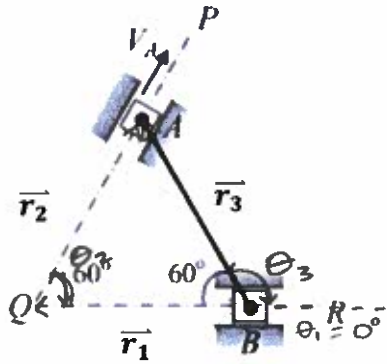
12:00 – 1:30 pm, Nov. 3, 2021

Student's Name (printed): Kiaria Moon

This examination is administered under the University's Code of Student Conduct. All work submitted must be your own. This is an open book examination. Only calculator is allowed, no cellphone, no tablet, and no laptop. Please write your name on every page.

QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	15	14.7
2	15	14
3	10	6.7
4	10	6
TOTAL	50	41.4

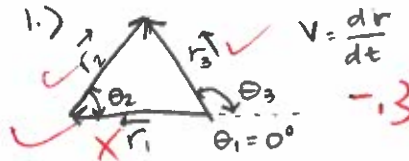
14.7 Problem 1 (15 points):



The lengths and angles are given as,

$$|r_1| = 1, |r_2| = 1, |r_3| = 1,$$

$$\theta_1 = 0^\circ, \theta_2 = 60^\circ, \theta_3 = 120^\circ.$$



The rod AB shown in the figure is connected to two sliders at each end through pins. The sliders can slide along QP and QR.

- 1) Mark the directions of the three vectors and their angles according to the given info; (2 pts)
- 2) Write the vector loop equation for velocity analysis; (1 pts)
- 3) Given the linear velocity of link 2 $|r_2|$ = the last nonzero digit of your student ID, what are the unknowns in the velocity analysis? (2 pts)
- 4) In the velocity analysis, what quantities are 0? Why? (4 pts)
- 5) Given the linear velocity of link 2 $|r_2|$ = the last nonzero digit of your student ID, solve the equations to obtain the numerical value of the unknowns. (6 pts)

$$\dot{\vec{r}}_i = |\dot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

$$\begin{aligned} 2.) \quad \dot{\vec{r}}_3 &= \dot{\vec{r}}_1 + \dot{\vec{r}}_2 \\ |r_3| \begin{bmatrix} \dot{\cos \theta_3} \\ \dot{\sin \theta_3} \end{bmatrix} + |r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} &= |r_1| \begin{bmatrix} \dot{\cos \theta_1} \\ \dot{\sin \theta_1} \end{bmatrix} + |r_1| \dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix} + |r_2| \begin{bmatrix} \dot{\cos \theta_2} \\ \dot{\sin \theta_2} \end{bmatrix} + |r_2| \dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix} \end{aligned}$$

zero zero zero

$$3.) |r_2| = 7$$

Unknowns are $\dot{\theta}_3$ and $|r_1|$ ✓

4.) $\dot{r}_3, \dot{\theta}_1$, and $\dot{\theta}_2$ are zero because $|r_3|, \theta_1$, and θ_2 are constant ✓

5.)

$$|r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

$$|\dot{r}_2| = 7$$

$$\begin{bmatrix} |r_3| - \sin \theta_3 & \cos \theta_3 \\ |r_3| \cos \theta_3 & \sin \theta_3 \end{bmatrix} \begin{bmatrix} \dot{\theta}_3 \\ \dot{r}_1 \end{bmatrix} = |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

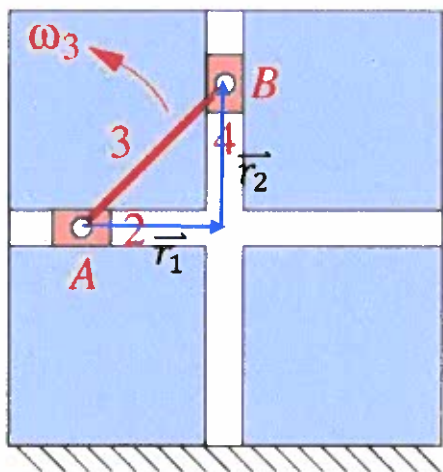
$$\begin{bmatrix} 1 - \sin 120^\circ & \cos 0 \\ 1 \cos 120^\circ & \sin 0 \end{bmatrix} \begin{bmatrix} \dot{\theta}_3 \\ \dot{r}_1 \end{bmatrix} = |7| \begin{bmatrix} \cos 60^\circ \\ \sin 60^\circ \end{bmatrix}$$

$$\begin{bmatrix} -\sqrt{3}/2 & 1 \\ -1/2 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta}_3 \\ \dot{r}_1 \end{bmatrix} = |7| \begin{bmatrix} 1/2 \\ \sqrt{3}/2 \end{bmatrix}$$

$$\begin{bmatrix} -\sqrt{3}/2 & 1 \\ -1/2 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta}_3 \\ \dot{r}_1 \end{bmatrix} = \begin{bmatrix} 3.5 \\ 6.06 \end{bmatrix}$$

$$\begin{bmatrix} \dot{\theta}_3 \\ \dot{r}_1 \end{bmatrix} = \begin{bmatrix} -12.12 \\ -7 \end{bmatrix}$$

14 Problem 2. (15 points)



Note $\vec{r}_1$ and $\vec{r}_2$ are imaginary vectors, $\vec{r}_3$ starts from A, point to B, A and B are connected by a rigid link.

$$|r_1| = 1, |r_2| = 1, |r_3| = \sqrt{2}, \\ \theta_1 = 0^\circ, \theta_2 = 90^\circ, \theta_3 = 45^\circ$$

$$\dot{\vec{r}}_i = |\dot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

- 1) Write the vector loop equation. (2 pts)
- 2) What quantities does not change with time? (3 pts)
- 3) Given $\omega_3 = \dot{\theta}_3 =$ second non-zero digit of your student ID, calculate $|\dot{r}_1|$ and $|\dot{r}_2|$ using velocity vector loop equation. (6 pts)
- 4) Given $\ddot{\theta}_3 = 0$, list the two equations of acceleration analysis keeping only nonzero items (4 points)

$$\ddot{\vec{r}}_i = |\ddot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + 2|\dot{r}_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \ddot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i^2 \begin{bmatrix} -\cos \theta_i \\ -\sin \theta_i \end{bmatrix}$$

$$1.) \vec{r}_3 = \vec{r}_1 + \vec{r}_2$$

$$2.) |r_3|, \theta_1, \text{ and } \theta_2 \text{ are constant}$$

$$3.) \omega_3 = \dot{\theta}_3 = 4$$

$$|\dot{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} + |r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_1| \dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix} + |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix} + |r_2| \dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix}$$

$\dot{r}_3, \dot{\theta}_1, \dot{\theta}_2$ are zero

so,

$$|r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

$$\begin{bmatrix} \cos 0 & \cos 90 \\ \sin 0 & \sin 90 \end{bmatrix} \begin{bmatrix} \dot{r}_1 \\ \dot{r}_2 \end{bmatrix} = (\sqrt{2})(4) \begin{bmatrix} -\sin 45 \\ \cos 45 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{r}_1 \\ \dot{r}_2 \end{bmatrix} = \begin{bmatrix} -4 \\ 4 \end{bmatrix}$$

$$\begin{bmatrix} \dot{r}_1 \\ \dot{r}_2 \end{bmatrix} = \begin{bmatrix} -4 \\ 4 \end{bmatrix}$$

4. $\ddot{\theta}_3 = 0$ $\ddot{r}_3, \ddot{\theta}_1$, and $\ddot{\theta}_2$ are zero

so,

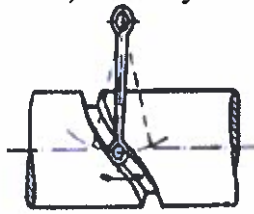
$$|r_3| \ddot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} + |r_3| \dot{\theta}_3^2 \begin{bmatrix} -\cos \theta_3 \\ -\sin \theta_3 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

-1

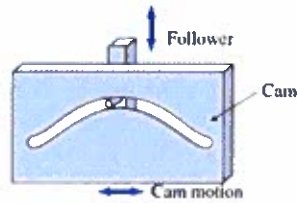
6.7

Problem 3 (10 points)

1) Classify the following cam follower system (8 pts)



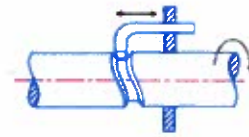
(a)



(b)



(c)



(d)

System	Follower motion	Cam motion	Relative motion	Joint closure
(a)	Oscillating ✓	rotating ✓	/	Form ✓
(b)	translating ✓	rotating ✗	/	Form ✓
(c)	translating ✓	rotating ✓	/	Force ✓
(d)	Oscillating ✓	rotating ✓	/	Form ✓

- 2) In s diagram, what is its minimum value? (1 pt) 0 can not be negative value
 3) In s diagram, explain what is Rise, Dwell and Fall? (1 pt)

Rise:

Dwell: no output motion for a specified period of input motion

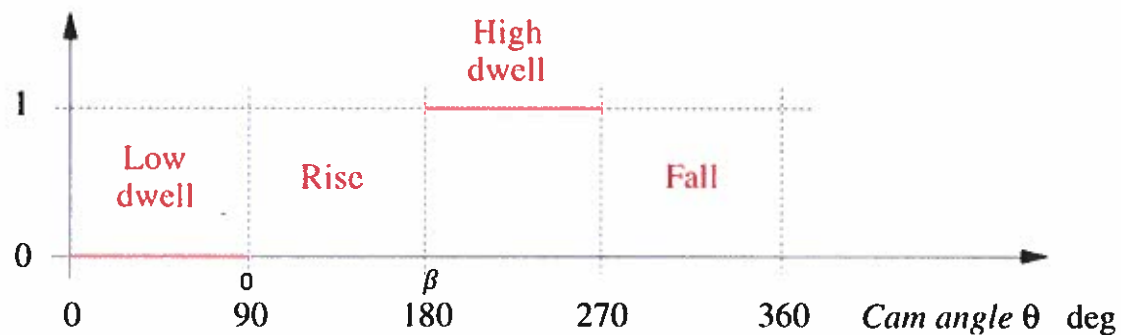
Fall:

- 0.6

- 3

6

Problem 4 (10 points)

Motion
mm or in

- 1) The figure above shows a s diagram of a double dwell cam design. When we are asked to design the Rise function from 0 to β , what is the value of β in this case (use radian)? (2 pts) $\pi/2$ radians ✓
- 2) What is the fundamental law of cam design? (2 pts)
- 3) To satisfy the fundamental law of cam design, fill in the following table with boundary conditions of s, v, a Rise functions. (3 pts)

	when $\theta = 0$	when $\theta = \beta$
$s =$	0 ✓	h ✓
$v =$	0 ✓	0 ✓
$a =$	$\pi^3/\beta^2 \cdot h$ ✓	$\pi^3/\beta \cdot h/2$ ✓

- 4) Given $v = \theta - \beta \sin(\theta)$, calculate a by $\frac{dv}{d\theta}$. (3 pts)

2.) Fundamental Law of Cam Design: The cam follower function must have continuous velocity and acceleration across the entire interval, thus making the jerk finite ✓

4.)

-3

AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 2

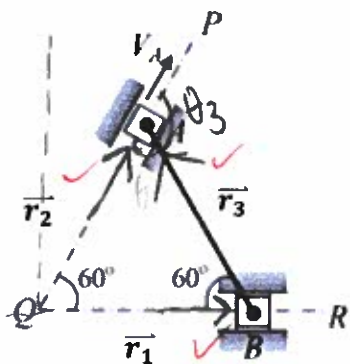
12:00 – 1:30 pm, Nov. 3, 2021

Student's Name (printed): Seyi Oluwashina

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QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	15	12
2	15	12
3	10	7.5
4	10	3.5
TOTAL	50	35

12 Problem 1 (15 points):



The lengths and angles are given as,

$$|r_1| = 1, |r_2| = 1, |r_3| = 1,$$

$$\theta_1 = 0^\circ, \theta_2 = 60^\circ, \theta_3 = 120^\circ.$$

The rod AB shown in the figure is connected to two sliders at each end through pins. The sliders can slide along QP and QR.

- 1) Mark the directions of the three vectors and their angles according to the given info; (2 pts)
- 2) Write the vector loop equation for velocity analysis; (1 pts)
- 3) Given the linear velocity of link 2 $|\dot{r}_2|$ = the last nonzero digit of your student ID, what are the unknowns in the velocity analysis? (2 pts)
- 4) In the velocity analysis, what quantities are 0? Why? (4 pts)
- 5) Given the linear velocity of link 2 $|\dot{r}_2|$ = the last nonzero digit of your student ID, solve the equations to obtain the numerical value of the unknowns. (6 pts)

$$\dot{\vec{r}}_i = |\dot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

$$2) \dot{\vec{r}}_1 + \dot{\vec{r}}_2 = \dot{\vec{r}}_3$$

$$3) \dot{\vec{r}}_1 = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_1| \dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix}$$

$$\dot{\vec{r}}_2 = |\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix} + |r_2| \dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix}$$

$$\dot{\vec{r}}_3 = |\dot{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} + |r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix}$$

Unknowns = $|\dot{r}_1|$ and $\dot{\theta}_3$

- 1) $\dot{\theta}_1 = 0$
 $\dot{\theta}_2 = 0$
 $\dot{r}_3 = 0$
- Because $\theta_1 = \text{constant}$ so $\dot{\theta}_1 = 0$
 $r_3 = \text{constant}$ so $\dot{r}_3 = 0$
 Because $\theta_2 = \text{constant}$ so $\dot{\theta}_2 = 0$

$$5) \dot{r}_1 \cos \theta_1 + \dot{r}_2 \cos \theta_2 + r_3 \dot{\theta}_3 \sin \theta_3$$

$$\dot{r}_1 \sin \theta_1 - \dot{r}_2 \sin \theta_2 - r_3 \dot{\theta}_3 \cos \theta_3$$

$$\dot{r}_1 \cos \theta_1 + r_3 \dot{\theta}_3 \sin \theta_3 = 1$$

$$r_3 \dot{\theta}_3 \cos \theta_3 = 1.7$$

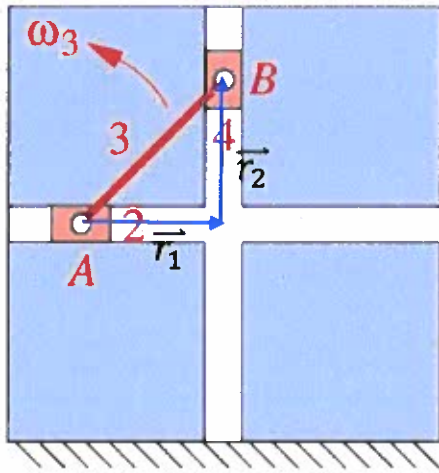
$$\dot{r}_1 + 0.866 \dot{\theta}_3 = 1$$

$$-\dot{\theta}_3 0.5 = 1.7$$

$$\dot{\theta}_3 = -3.4$$

$$\dot{r}_1 = 3.9$$

12 Problem 2. (15 points)



Note $\vec{r}_1$ and $\vec{r}_2$ are imaginary vectors, $\vec{r}_3$ starts from A, point to B, A and B are connected by a rigid link.

$$|r_1| = 1, |r_2| = 1, |r_3| = \sqrt{2}, \\ \theta_1 = 0^\circ, \theta_2 = 90^\circ, \theta_3 = 45^\circ$$

$$\dot{\vec{r}}_i = |r_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

- 1) Write the vector loop equation. (2 pts)
- 2) What quantities does not change with time? (3 pts)
- 3) Given $\omega_3 = \dot{\theta}_3 =$ second non-zero digit of your student ID, calculate $|\dot{\vec{r}}_1|$ and $|\dot{\vec{r}}_2|$ using velocity vector loop equation. (6 pts)
- 4) Given $\ddot{\theta}_3 = 0$, list the two equations of acceleration analysis keeping only nonzero items (4 points)

$$\dot{\theta}_3 = 2$$

$$\ddot{\vec{r}}_i = |\ddot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + 2|\dot{r}_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \ddot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i^2 \begin{bmatrix} -\cos \theta_i \\ -\sin \theta_i \end{bmatrix}$$

$$1) r_1 + r_2 = r_3 \quad \checkmark$$

$$2) \theta_1, \theta_2, |r_3|$$

$$3) \dot{r}_1 \cos \theta_1 + \dot{r}_2 \cos \theta_2 + r_3 \dot{\theta}_3 \sin \theta_3 \\ - \dot{r}_1 \sin \theta_1 - \dot{r}_2 \sin \theta_2 - r_3 \dot{\theta}_3 \cos \theta_3$$

$$\dot{r}_1 + r_3 \dot{\theta}_3 \sin \theta_3$$

$$- \dot{r}_2 - r_3 \dot{\theta}_3 \cos \theta_3$$

$$\dot{r}_1 = - \dot{\theta}_3 = -2 \quad \checkmark$$

$$\dot{r}_2 = \dot{\theta}_3 = 2$$

$$4) \ddot{r}_1 + \sqrt{2} [\ddot{\theta}_3 \sin \theta_3 + \dot{\theta}_3^2 \cos \theta_3]$$

$$\ddot{r}_2 - \sqrt{2} [\ddot{\theta}_3 \cos \theta_3 - \dot{\theta}_3^2 \sin \theta_3]$$

$$\Rightarrow \ddot{r}_1 + \sqrt{2} \dot{\theta}_3^2 \cos \theta_3 = 0 \quad \times$$

$$\ddot{r}_2 - \sqrt{2} \dot{\theta}_3^2 \sin \theta_3 = 0$$

- 3

$$\dot{\vec{r}}_1 = |\dot{\vec{r}}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + r_1 \dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix}$$

$$\dot{\vec{r}}_2 = |\dot{\vec{r}}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix} + r_2 \dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix}$$

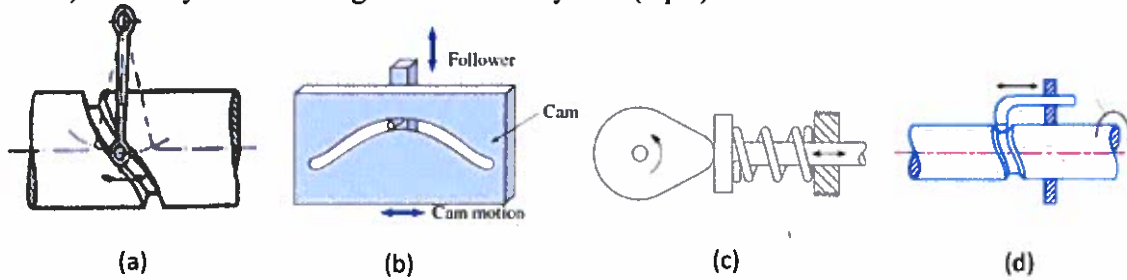
$$\dot{\vec{r}}_3 = |\dot{\vec{r}}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} + r_3 \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix}$$

Student's Name: Seyi Oluwashina

7.5

Problem 3 (10 points)

1) Classify the following cam follower system (8 pts)



System	Follower motion	Cam motion	Relative motion	Joint closure
(a)	Translating x	Translating x	radial ✓	Form closed ✓
(b)	Translating ✓	Translating ✓	Axial x	Form closed ✓
(c)	Translating ✓	rotating ✓	Axial x	Force closed ✓
(d)	Translating ✓	rotating ✓	radial x	Form closed ✓

-2.5

2) In s diagram, what is its minimum value? (1 pt)

3) In s diagram, explain what is Rise, Dwell and Fall? (1 pt)

2) Minimum value = 0

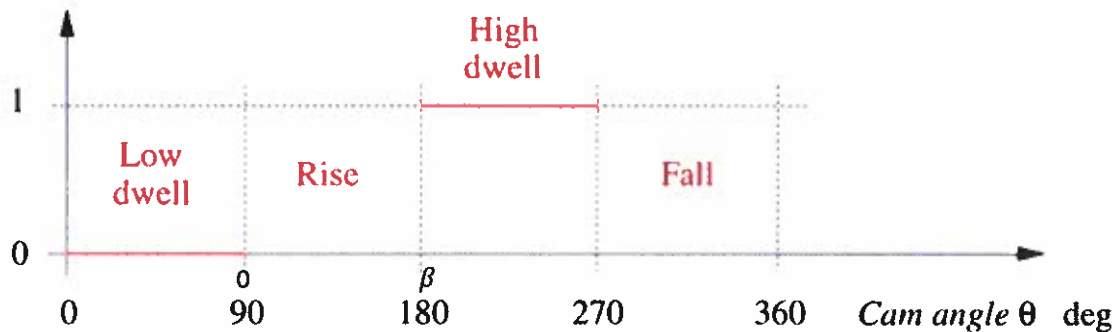
3) Rise - Increase in motion with cam angle

Dwell - Constant motion

Fall - Decrease in motion

3.5 Problem 4 (10 points)

Motion
mm or in



- 1) The figure above shows a s diagram of a double dwell cam design. When we are asked to design the Rise function from 0 to β , what is the value of β in this case (use radian)? (2 pts)
- 2) What is the fundamental law of cam design? (2 pts)
- 3) To satisfy the fundamental law of cam design, fill in the following table with boundary conditions of s, v, a Rise functions. (3 pts)

	when $\theta = 0$	when $\theta = \beta$
$s =$	0 ✓	$\frac{\pi}{2} k_v$ ✗
$v =$	k_v ✓	k_v ✗
$a =$	0 ✓	0 ✓

-1.5

- 4) Given $v = \theta - \beta \sin(\theta)$, calculate a by $\frac{dv}{d\theta}$. (3 pts)

1) $\frac{\beta}{2}$ ✗ -2

2) Cam Follower function must have continuous velocity and acceleration across the interval thus making the jerk finite

1) $v = \theta - \beta \sin(\theta)$

$$\int dv = \int \theta - \beta \sin(\theta) d\theta$$

$$= \int \theta - \beta \int \sin d\theta \quad \text{✗ -3}$$

$$a = \frac{\theta^2}{2} + \beta \cos \theta$$

BELOW AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Test 2

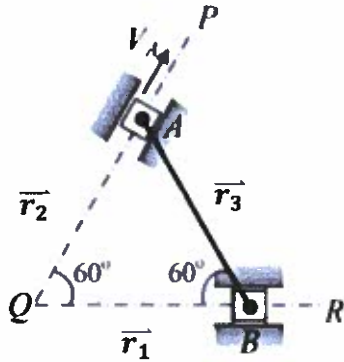
12:00 – 1:30 pm, Nov. 3, 2021

Student's Name (printed): Edwin Godfrey #

This examination is administered under the University's Code of Student Conduct. All work submitted must be your own. This is an open book examination. Only calculator is allowed, no cellphone, no tablet, and no laptop. Please write your name on every page.

QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	15	2.7
2	15	4
3	10	4
4	10	4.5
TOTAL	50	15.2

2.7 Problem 1 (15 points):



The lengths and angles are given as,

$$|r_1| = 1, |r_2| = 1, |r_3| = 1,$$

$$\theta_1 = 0^\circ, \theta_2 = 60^\circ, \theta_3 = 120^\circ.$$

The rod AB shown in the figure is connected to two sliders at each end through pins. The sliders can slide along QP and QR.

1) Mark the directions of the three vectors and their angles according to the given info; (2 pts)

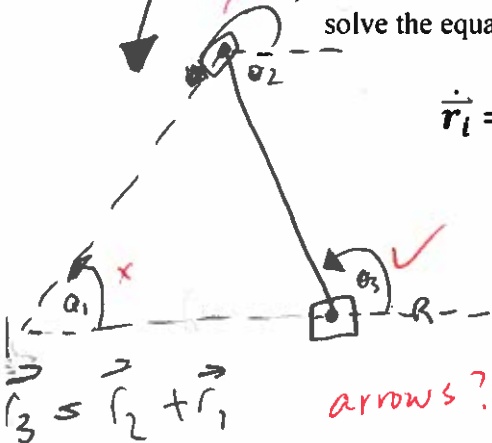
2) Write the vector loop equation for velocity analysis; (1 pts)

3) Given the linear velocity of link 2 $|r_2|$ = the last nonzero digit of your student ID, what are the unknowns in the velocity analysis? (2 pts) ⁻²

4) In the velocity analysis, what quantities are 0? Why? (4 pts) $\dot{\theta}_1 = 0$, because it's 0 in position ⁻³

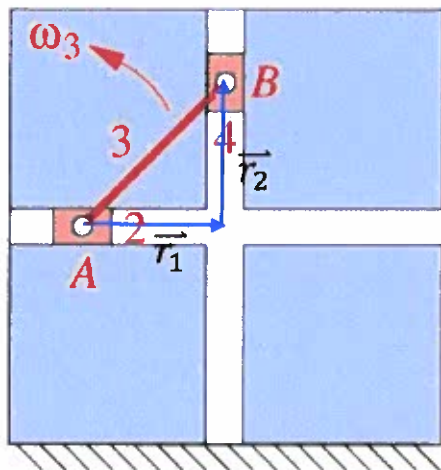
5) Given the linear velocity of link 2 $|r_2|$ = the last nonzero digit of your student ID, solve the equations to obtain the numerical value of the unknowns. (6 pts) ⁻⁶

$$\dot{r}_i = |r_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$



-1.3

4 Problem 2. (15 points)



Note $\vec{r}_1$ and $\vec{r}_2$ are imaginary vectors, $\vec{r}_3$ starts from A, point to B, A and B are connected by a rigid link.

$$|r_1| = 1, |r_2| = 1, |r_3| = \sqrt{2}, \\ \theta_1 = 0^\circ, \theta_2 = 90^\circ, \theta_3 = 45^\circ$$

$$\dot{\vec{r}}_i = |r_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix}$$

- Write the vector loop equation. (2 pts)
- What quantities does not change with time? (3 pts) $\theta_1 = 0, \dot{\theta}_1 = 0, \ddot{\theta}_1 = 0$ -2
- Given $\omega_3 = \dot{\theta}_3 =$ second non-zero digit of your student ID, calculate $|\dot{\vec{r}}_1|$ and $|\dot{\vec{r}}_2|$ using velocity vector loop equation. (6 pts) 2nd non-zero of student ID = 1
- Given $\ddot{\theta}_3 = 0$, list the two equations of acceleration analysis keeping only nonzero items (4 points) -9

$$\ddot{\vec{r}}_i = |\ddot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + 2|\dot{r}_i| \dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \ddot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i| \dot{\theta}_i^2 \begin{bmatrix} -\cos \theta_i \\ -\sin \theta_i \end{bmatrix}$$

1) Vector loop equation
 $\vec{r}_3 = \vec{r}_1 + \vec{r}_2$ ✓

$$2 \times 2 \quad 2 \times 1 \\ A' = B$$

$$\sqrt{2} \begin{bmatrix} \cos 0 \\ \sin 0 \end{bmatrix} = 1 \begin{bmatrix} \cos 0 \\ \sin 0 \end{bmatrix} + 1 \begin{bmatrix} \cos 0 \\ \sin 0 \end{bmatrix}$$

$$\sqrt{2} \begin{bmatrix} \cos(45) \\ \sin(45) \end{bmatrix} = 1 \begin{bmatrix} \cos(0) \\ \sin(0) \end{bmatrix} + 1 \begin{bmatrix} \cos(90) \\ \sin(90) \end{bmatrix}$$

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$3) \dot{\vec{r}}_1 = |\dot{r}_1| \begin{bmatrix} \cos 0 \\ \sin 0 \end{bmatrix} + \vec{r}_1 \cdot 0 \begin{bmatrix} -\sin 0 \\ \cos 0 \end{bmatrix}$$

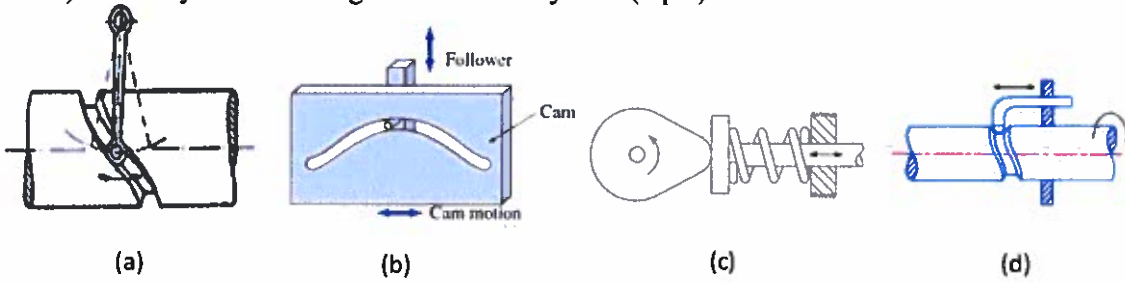
$$\vec{r}_1 = 1 \begin{bmatrix} \cos 0 \\ \sin 0 \end{bmatrix}$$

$$= \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$4) \ddot{\vec{r}}_1 = |\ddot{r}_1| \begin{bmatrix} \cos 0 \\ \sin 0 \end{bmatrix} + 2|\dot{r}_1| \dot{\theta}_1 \begin{bmatrix} -\sin 0 \\ \cos 0 \end{bmatrix}$$

4 Problem 3 (10 points)

1) Classify the following cam follower system (8 pts)

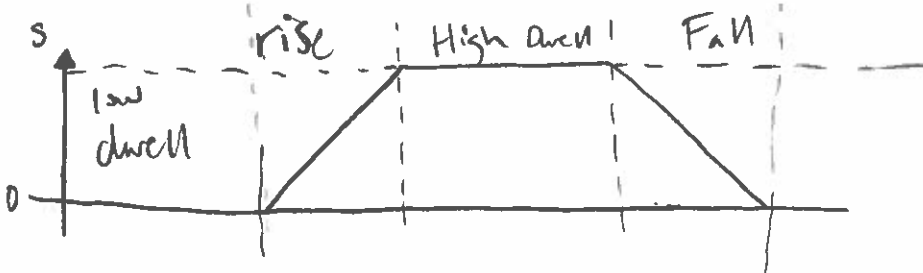


System	Follower motion	Cam motion	Relative motion	Joint closure
(a)	roller	Axial	CEP	form ✓
(b)	roller	radial	CPM	form ✓
(c)	flat-faced	radial	CEP	force ✓
(d)	mushroom	Axial	CPM	form ✓

-6

2) In s diagram, what is its minimum value? (1 pt)

3) In s diagram, explain what is Rise, Dwell and Fall? (1 pt)



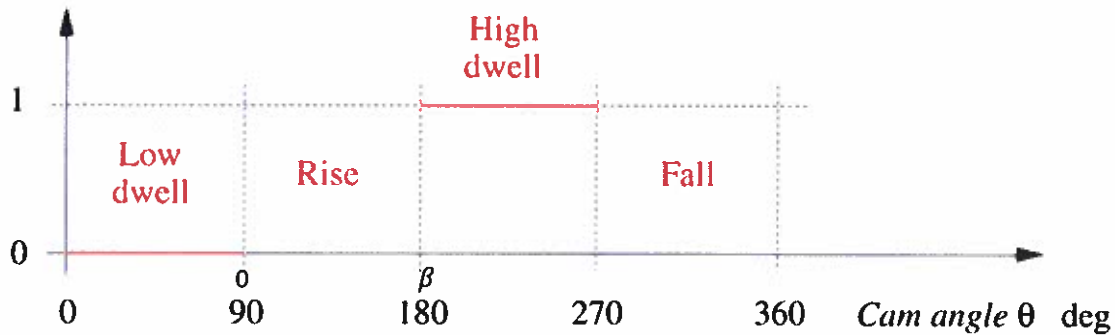
2) the minimum value is 0° ✓

3) Rise: Output motion goes up (increases)

Dwell: no output motion for a specified period of input motion.

Fall: Output goes down (decreases) ✓

4.5 Problem 4 (10 points)
Motion
mm or in



- 1) The figure above shows a s diagram of a double dwell cam design. When we are asked to design the Rise function from 0 to β , what is the value of β in this case (use radian)? (2 pts) $\beta = \pi$ X -2
- 2) What is the fundamental law of cam design? (2 pts)
- 3) To satisfy the fundamental law of cam design, fill in the following table with boundary conditions of s, v, a Rise functions. (3 pts)

	when $\theta = 0$	when $\theta = \beta$
$s =$	0	h
$v =$	0	0
$a =$	0	C

- 4) Given $v = \theta - \beta \sin(\theta)$, calculate a by $\frac{dv}{d\theta}$. (3 pts)

$$a = \frac{dv}{d\theta}$$

$$dv = \left(\sin \right) \left(2\pi \frac{\theta}{\beta} \right) d\theta$$

$$\int dv = -\left(\frac{\beta}{2\pi} \right) \cos \left(2\pi \frac{\theta}{\beta} \right) + k_1$$

2) Any cam designed for operation at other than very low speeds must be designed with the following constraints:

The cam function must be continuous through the first and second derivatives of displacement across the entire interval (360 degrees)

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

Title of Assignment: Final Exam

TOPICS COVERED IN FINAL EXAM

Final exam covered the following topics:

1. Cam design using SVAJ diagram
2. Fundamental law of cam design
3. Cam design using combined functions
4. Cam design using polynomial function
5. Gear parameters calculation (diametral pitch, circular pitch, base pitch, gear ratio)
6. Compound gear train concept and velocity ratio calculation

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

**SAMPLE FINAL EXAM QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR FINAL EXAM**

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Final Exam

December 06, 2021

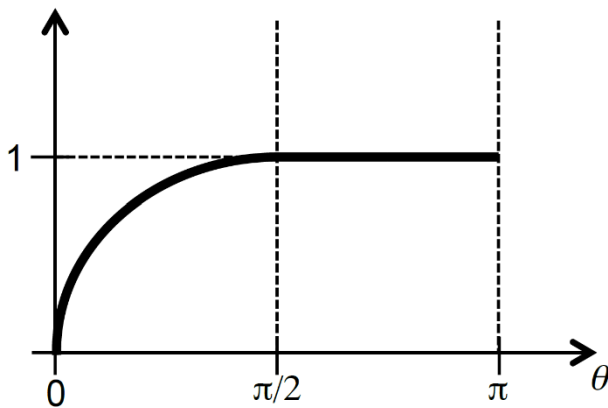
12 – 2 pm

Solution

This examination is administered under the University's Code of Student Conduct. All work submitted must be your own. This is an open book examination. Only calculator is allowed, no cellphone, no tablet, and no laptop. Please write your name on every page.

QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	25	
2	25	
3	25	
4	25	
TOTAL	100	

Problem 1. (25 points)



The figure above shows the v diagram of a cam design, $v = \sin \theta$, for $0 \leq \theta \leq \frac{\pi}{2}$; and $v = 1$, for $\frac{\pi}{2} \leq \theta \leq \pi$. Given $s = 1$ at $\theta = \frac{\pi}{2}$.

- 1) Find the a function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (8 pts)
- 2) Find the s function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (10 pts)
- 3) What is the fundamental law of cam design? (3 pts) If this function is used as a rise function between a low dwell and high dwell (meaning before $\theta = 0$, there is a low dwell, after $\theta = \pi$, there is a high dwell), does it satisfy the fundamental law of cam design? (2 pts) why? (2 pts)

1) For $0 \leq \theta \leq \frac{\pi}{2}$, $a = \frac{dv}{d\theta} = \cos \theta$,

For $\frac{\pi}{2} \leq \theta \leq \pi$, $a = \frac{dv}{d\theta} = 0$.

2) For $0 \leq \theta \leq \frac{\pi}{2}$, $s = \int v d\theta = \int \sin \theta d\theta = -\cos \theta + K_1$

when $\theta = \frac{\pi}{2}$, $s = -\cos \frac{\pi}{2} + K_1 = K_1 \stackrel{BC}{=} 1 \Rightarrow K_1 = 1$

$s = 1 - \cos \theta$.

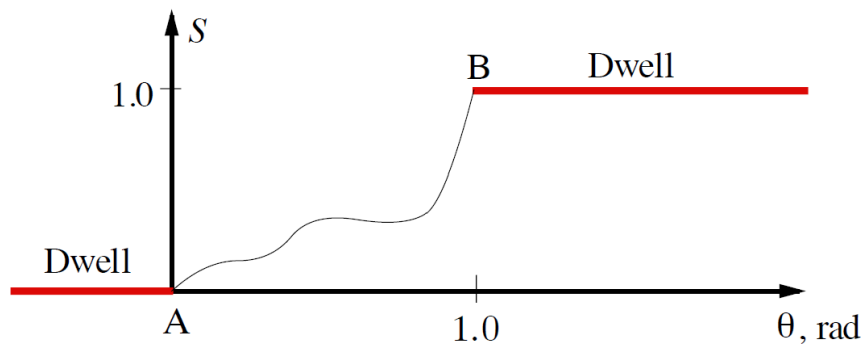
For $\frac{\pi}{2} \leq \theta \leq \pi$, $s = \int v d\theta = \int 1 d\theta = \theta + K_2$

when $\theta = \frac{\pi}{2}$, $s = \frac{\pi}{2} + K_2 \stackrel{BC}{=} 1 \Rightarrow K_2 = 1 - \frac{\pi}{2}$

$s = \theta + 1 - \frac{\pi}{2}$.

3) The cam-follower function must have continuous velocity and acceleration across the entire interval. No. $v \neq 0$ at $\theta = \pi$.

Problem 2 (25 points)



Assume that s is the cam-follower displacement and θ is the cam angle. The rise is $h = 1$ after 1.0 radian of rotation, and the rise begins and ends at a dwell. If the **position, velocity, and acceleration** are continuous at $\theta = 0$, and the **position and velocity** are continuous at $\theta = \beta = 1$, use polynomial function to design a rise function s from 0 to $\beta = 1$ using the boundary conditions given above. Note: Use the minimum possible number of terms.

- 1) How many boundary conditions are given? (2 pts) What will be the order of the polynomial function? (2 pts)
- 2) Write the general form of the s function, and the corresponding v and a functions. (6 pts)
- 3) Bring in the boundary conditions and list the equations to be solved. (7 pts)
- 4) Solve all the unknowns. (8 pts)

1)

	s	v	a
$\theta = 0$	0	0	0
$\theta = 1 = \beta$	1	0	

5 BCs. order of the polynomial is 4.

2)

$$s = C_0 + C_1\left(\frac{\theta}{\beta}\right) + C_2\left(\frac{\theta}{\beta}\right)^2 + C_3\left(\frac{\theta}{\beta}\right)^3 + C_4\left(\frac{\theta}{\beta}\right)^4$$

$$v = \frac{1}{\beta} \left[C_1 + 2C_2\left(\frac{\theta}{\beta}\right) + 3C_3\left(\frac{\theta}{\beta}\right)^2 + 4C_4\left(\frac{\theta}{\beta}\right)^3 \right]$$

$$a = \frac{1}{\beta^2} \left[2C_2 + 6C_3\left(\frac{\theta}{\beta}\right) + 12C_4\left(\frac{\theta}{\beta}\right)^2 \right]$$

$$3) \text{ when } \theta = 0, \quad S = C_0 \stackrel{BC}{=} 0 \Rightarrow C_0 = 0.$$

$$\text{when } \theta = 0, \quad V = \frac{1}{\beta} C_1 \stackrel{BC}{=} 0 \Rightarrow C_1 = 0$$

$$\text{when } \theta = 0, \quad A = \frac{1}{\beta^2} 2C_2 \stackrel{BC}{=} 0 \Rightarrow C_2 = 0$$

$$\text{when } \theta = \beta, \quad S = C_3 + C_4 = 1 \quad (1)$$

$$\text{when } \theta = \beta, \quad V = \frac{1}{\beta} (3C_3 + 4C_4) = 0$$

$$\Rightarrow 3C_3 + 4C_4 = 0 \quad (2)$$

From (1) and (2)

$$C_3 = 4, \quad C_4 = -3$$

$$\text{Thus} \quad S = 4 \left(\frac{\theta}{\beta} \right)^3 - 3 \left(\frac{\theta}{\beta} \right)^4$$

Problem 3 (25 pts)

A zero-eccentricity cam with a reciprocating radial roller follower is to be designed such that the displacement of the follower is $s = 15[1 - \cos(2\theta)]$ (unit: mm). The prime circle radius is $R_b = 40$ mm, and the roller follower radius is $R_f = 12$ mm. For the cam rotation angle $\theta = 30^\circ$, determine the following:

- 1) The expression of $v = \frac{ds}{d\theta}$
- 2) The expression of $a = \frac{dv}{d\theta}$
- 3) The pitch circle radius $R_p = R_b + R_f$
- 4) The pressure angle

$$\phi = \tan^{-1} \frac{v - \epsilon}{s + \sqrt{R_p^2 - \epsilon^2}}$$

- 5) The pitch radius of curvature

$$\rho_{pitch}(\theta) = \frac{[(R_p + s)^2 + v^2]^{\frac{3}{2}}}{(R_p + s)^2 + 2v^2 - a(R_p + s)}$$

$$1) v = \frac{ds}{d\theta} = 30 \sin(2\theta)$$

$$2) a = \frac{dv}{d\theta} = 60 \cos(2\theta)$$

$$3) R_p = R_b + R_f = 52 \text{ mm}$$

$$4) \theta = 30^\circ. \quad s(\theta) = 7.5$$

$$v(\theta) = 25.98$$

$$a(\theta) = 30.$$

$$\phi = \tan^{-1} \cdot \frac{25.98}{7.5 + 52} = 23.59^\circ$$

$$5) \rho = \frac{[(52 + 7.5)^2 + 25.98^2]^{\frac{3}{2}}}{(52 + 7.5)^2 + 2 \cdot 25.98^2 - 30(52 + 7.5)} = 88.13$$

Problem 4 (25 points)

The following figure shows a compound gear train.

Gear 2: $N_2 = 12$ teeth and $P_d = 12$

Gear 3: $d_3 = 2.5$ in.

Gear 4: $N_4 = 15$ teeth

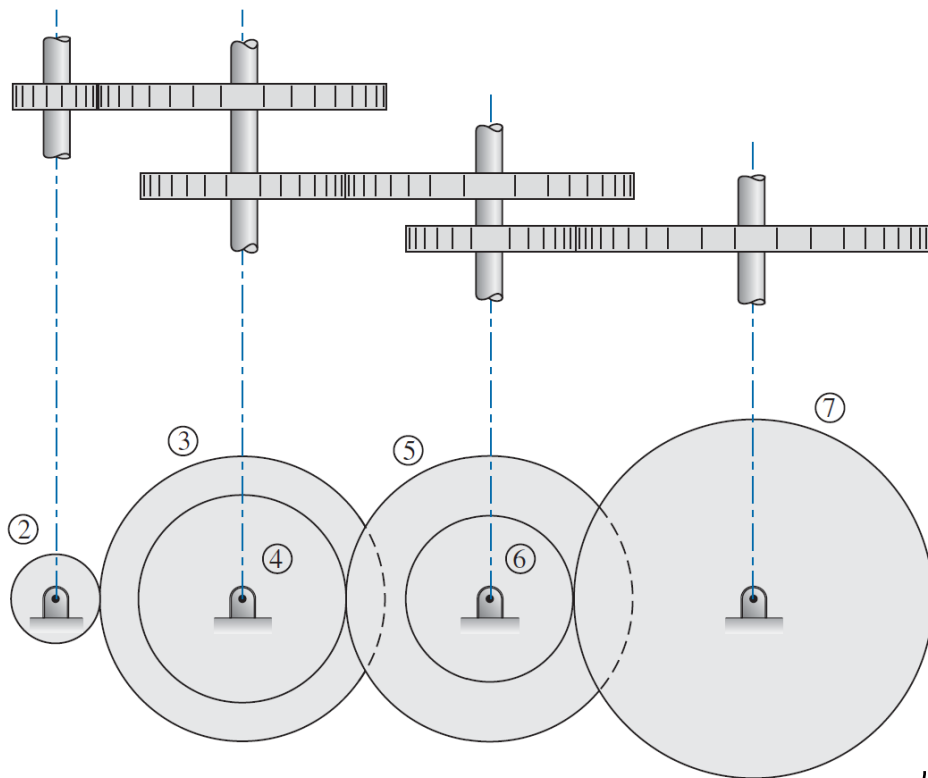
Gear 5: $d_5 = 3.0$ in. and $P_d = 10$

Gear 6: $d_6 = 1.5$ in. and $P_d = 8$

Gear 7: $N_7 = 32$ teeth

Answer the following questions:

- 1) What is a compound gear train? (5 pts)
- 2) Find the velocity of gear 7 as gear 2 drives at 1800 rpm. (13 pts)
- 3) Find the pitch diameter of each gear. (7 pts)



1) Compound gear train is one in which at least one shaft carries more than one gear.

2)

$$M_V = \frac{\omega_7}{\omega_2} = - \frac{N_2 \times N_4 \times N_6}{N_3 \times N_5 \times N_7}$$

$$= - \frac{d_2 \times d_4 \times d_6}{d_3 \times d_5 \times d_7}$$

$$= - \frac{1 \times 1.5 \times 1.5}{2.5 \times 3 \times 4} = -0.075$$

$$\omega_7 = 1800 \times (-0.075) = -135 \text{ rpm}$$

3)

$$d_2 = \frac{N_2}{P_d} = 1$$

$$d_4 = \frac{N_4}{P_d} = 1.5$$

$$d_7 = \frac{N_7}{P_d} = 1.5$$

ABOVE AVERAGE

PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MCEG 3305 Kinematics Design and Analysis

Fall 2021

Final Exam

December 06, 2021

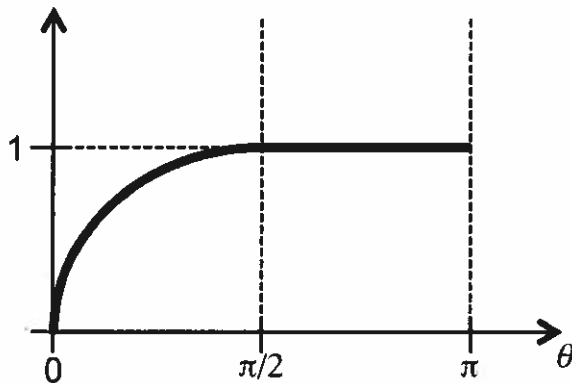
12 – 2 pm

Student's Name (printed): Angel Randall

This examination is administered under the University's Code of Student Conduct. All work submitted must be your own. This is an open book examination. Only calculator is allowed, no cellphone, no tablet, and no laptop. Please write your name on every page.

QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	25	20
2	25	22
3	25	24
4	25	22
TOTAL	100	88

Problem 1. (25 points)



The figure above shows the v diagram of a cam design, $v = \sin \theta$, for $0 \leq \theta \leq \frac{\pi}{2}$; and $v = 1$, for $\frac{\pi}{2} \leq \theta \leq \pi$. Given $s = 1$ at $\theta = \frac{\pi}{2}$.

- 1) Find the a function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (8 pts)
- 2) Find the s function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (10 pts)
- 3) What is the fundamental law of cam design? (3 pts) If this function is used as a rise function between a low dwell and high dwell (meaning before $\theta = 0$, there is a low dwell, after $\theta = \pi$, there is a high dwell), does it satisfy the fundamental law of cam design? (2 pts) why? (2 pts)

$$1) a = \frac{dv}{d\theta}$$

$$a = \cos \theta, \text{ for } 0 \leq \theta \leq \frac{\pi}{2}$$

$$a = 0, \text{ for } \frac{\pi}{2} \leq \theta \leq \pi$$

$$2) s = \int v d\theta$$

~~$$s = \int \sin \theta d\theta$$~~

$$s = \int \sin \theta d\theta$$

$$s = -\cos \theta + k_1, \text{ for } 0 \leq \theta \leq \frac{\pi}{2}$$

$$s = \int 1 d\theta$$

$$s = \theta + k_2, \text{ for } \frac{\pi}{2} \leq \theta \leq \pi$$

3) The cam function must be continuous through the first and second derivatives of displacement across the entire interval (360°); the jerk function must be finite across the entire interval (360°).

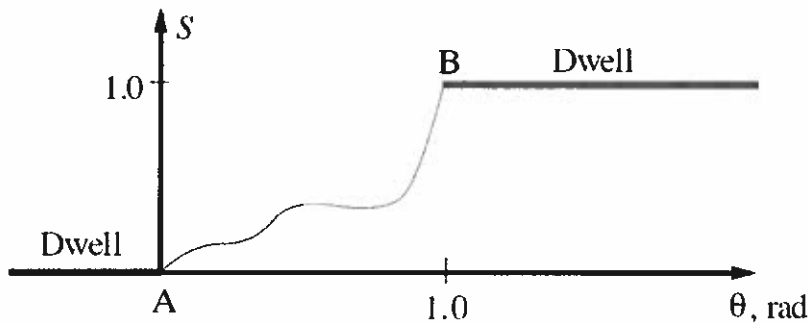
If the function was used as described, it would satisfy the law of cam design by having no discontinuities.

$$k_1 = ?$$

$$k_2 = ?$$

- 3

Problem 2 (25 points)



Assume that s is the cam-follower displacement and θ is the cam angle. The rise is $h = 1$ after 1.0 radian of rotation, and the rise begins and ends at a dwell. If the **position, velocity, and acceleration** are continuous at $\theta = 0$, and the **position and velocity** are continuous at $\theta = \beta = 1$, use polynomial function to design a rise function s from 0 to $\beta = 1$ using the boundary conditions given above. Note: Use the minimum possible number of terms.

- 1) How many boundary conditions are given? (2 pts) What will be the order of the polynomial function? (2 pts)
- 2) Write the general form of the s function, and the corresponding v and a functions. (6 pts)
- 3) Bring in the boundary conditions and list the equations to be solved. (7 pts)
- 4) Solve all the unknowns. (8 pts)

	$\theta = 0$	$\theta = \beta = 1$
$s =$	0 ✓	h ✓
$v =$	0 ✓	0 ✓
$a =$	0 ✓	0 ✗

1) 6 Boundary Conditions are given

k represents # of boundary conditions

N represents order of polynomial function

so $N = k - 1$, $N = 5$

4 and

5 on

next page →

← general form

2) $s = C_0 + C_1x + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5$

$v = \frac{1}{\beta} \left[C_1 + 2C_2\left(\frac{\theta}{\beta}\right) + 3C_3\left(\frac{\theta}{\beta}\right)^2 + 4C_4\left(\frac{\theta}{\beta}\right)^3 + 5C_5\left(\frac{\theta}{\beta}\right)^4 \right]$

$a = \frac{1}{\beta^2} \left[2C_2 + 6C_3\left(\frac{\theta}{\beta}\right) + 12C_4\left(\frac{\theta}{\beta}\right)^2 + 20C_5\left(\frac{\theta}{\beta}\right)^3 \right]$

equations to be solved are underlined in green

4) @ $\theta=0, s=0$

$$0 = C_0 + 0 + 0 \dots$$

$$C_0 = 0$$

@ $\theta=0, v=0$

$$0 = \frac{1}{\beta} (C_1 + 0 + 0 \dots)$$

$$C_1 = 0$$

@ $\theta=0, a=0$

$$0 = \frac{1}{\beta^2} (C_2 + 0 + 0 \dots)$$

$$C_2 = 0$$

@ $\theta=\beta, s=h$

$$\underline{h = C_3 + C_4 + C_5}$$

@ $\theta=\beta, v=0$

$$\underline{0 = \frac{1}{\beta} (3C_3 + 4C_4 + 5C_5)}$$

@ $\theta=\beta, a=0$

$$\underline{0 = \frac{1}{\beta^2} (6C_3 + 12C_4 + 20C_5)}$$

5) $C_3 = 10h$

$$C_4 = -15h$$

$$C_5 = 6h$$

-2

$$s = h \left[10 \left(\frac{\theta}{\beta} \right)^3 - 15 \left(\frac{\theta}{\beta} \right)^4 + 6 \left(\frac{\theta}{\beta} \right)^5 \right]$$

$$v = \frac{1}{\beta} \left[30 \left(\frac{\theta}{\beta} \right)^2 - 60 \left(\frac{\theta}{\beta} \right)^3 + 30 \left(\frac{\theta}{\beta} \right)^4 \right]$$

$$a = \frac{1}{\beta^2} \left[60 \left(\frac{\theta}{\beta} \right) - 180 \left(\frac{\theta}{\beta} \right)^2 + 120 \left(\frac{\theta}{\beta} \right)^3 \right]$$

Problem 3 (25 pts)

A zero-eccentricity cam with a reciprocating radial roller follower is to be designed such that the displacement of the follower is $s = 15[1 - \cos(2\theta)]$ (unit: mm). The prime circle radius is $R_b = 40$ mm, and the roller follower radius is $R_f = 12$ mm. For the cam rotation angle $\theta = 30^\circ$, determine the following:

- 1) The expression of $v = \frac{ds}{d\theta}$
- 2) The expression of $a = \frac{dv}{d\theta}$
- 3) The pitch circle radius $R_p = R_b + R_f$
- 4) The pressure angle

$$\phi = \tan^{-1} \frac{v - \epsilon}{s + \sqrt{R_p^2 - \epsilon^2}}$$

- 5) The pitch radius of curvature

$$\rho_{pitch}(\theta) = \frac{[(R_p + s)^2 + v^2]^{\frac{3}{2}}}{(R_p + s)^2 + 2v^2 - a(R_p + s)}$$

derivative ↓
↑ integrate

$\epsilon = ?$

$$1) s = 15[1 - \cos 2\theta]$$

$$v = \frac{ds}{d\theta}$$

~~$v = 30 \sin 2\theta$~~

$$v = 30 \sin 2\theta$$

$$3) R_p = R_b + R_f$$

$$R_p = 40 \text{ mm} + 12 \text{ mm}$$

$$R_p = 52 \text{ mm}$$

$$2) a = \frac{dv}{d\theta}$$

$$a = 60 \cos 2\theta$$

$$4) \phi = \tan^{-1} \frac{v - \epsilon}{s + \sqrt{R_p^2 - \epsilon^2}}$$

Assumption: $\epsilon = 1$

$\epsilon = 0$

$$\phi = \tan^{-1} \frac{30 \sin 2(30^\circ) - 1}{15[1 - \cos 2(30^\circ)] + \sqrt{52^2 - 1^2}}$$

$$\phi = 22.8^\circ$$

$$\rho_{pitch}(\theta) = \frac{[(R_p + s)^2 + v^2]^{\frac{3}{2}}}{(R_p + s)^2 + 2v^2 - a(R_p + s)}$$

~~$\rho_{pitch}(\theta) = \frac{[(52 + 15[1 - \cos 2(30^\circ)])^2 + (30 \sin 2(30^\circ))^2]^{\frac{3}{2}}}{(52 + 15[1 - \cos 2(30^\circ)])^2 + 2(30 \sin 2(30^\circ))^2 - 60 \cos 2(30^\circ)(52 + 15[1 - \cos 2(30^\circ)])}$~~
see #5 on back of this page

$$5) \rho_{pitch}(\theta) = \frac{[(R_p + s)^2 + v^2]^{3/2}}{(R_p + s)^2 + 2v^2 - a(R_p + s)}$$

$$= \frac{[(52\text{mm} + 15[1 - \cos 2(30^\circ)])^2 + 30 \sin^2(30^\circ)]^{3/2}}{(52\text{mm} + 15[1 - \cos 2(30^\circ)])^2 + 2(30 \sin^2(30^\circ)) - 60 \cos 2(30^\circ)(52\text{mm})}$$

$$(52\text{mm} + 15[1 - \cos 2(30^\circ)])^2 + 2(30 \sin^2(30^\circ)) - 60 \cos 2(30^\circ)(52\text{mm})$$

wowwww, yikes

$$52\text{mm} + 15[1 - \cos 2(30^\circ)]$$

okay, so

$$s = 15[1 - \cos 2(30^\circ)] = 7.5$$

$$v = 30 \sin^2(30^\circ) = 25.981$$

$$a = 60 \cos 2(30^\circ) = 30$$

so that

$$= \frac{[(52\text{mm} + 7.5)^2 + 25.981^2]^{3/2}}{(52\text{mm} + 7.5)^2 + 2(25.981)^2 - 30(52\text{mm} + 7.5)}$$

easier to see

$$\rho_{pitch}(\theta) = 88.1^\circ$$



Problem 4 (25 points)

The following figure shows a compound gear train.

units are inches!

Gear 2: $N_2 = 12$ teeth and $P_d = 12$

Gear 3: pitch diameter $d_3 = 2.5$ in. and $P_d = 12$

Gear 4: $N_4 = 15$ teeth and $P_d = 10$

Gear 5: pitch diameter $d_5 = 3$ in. and $P_d = 10$

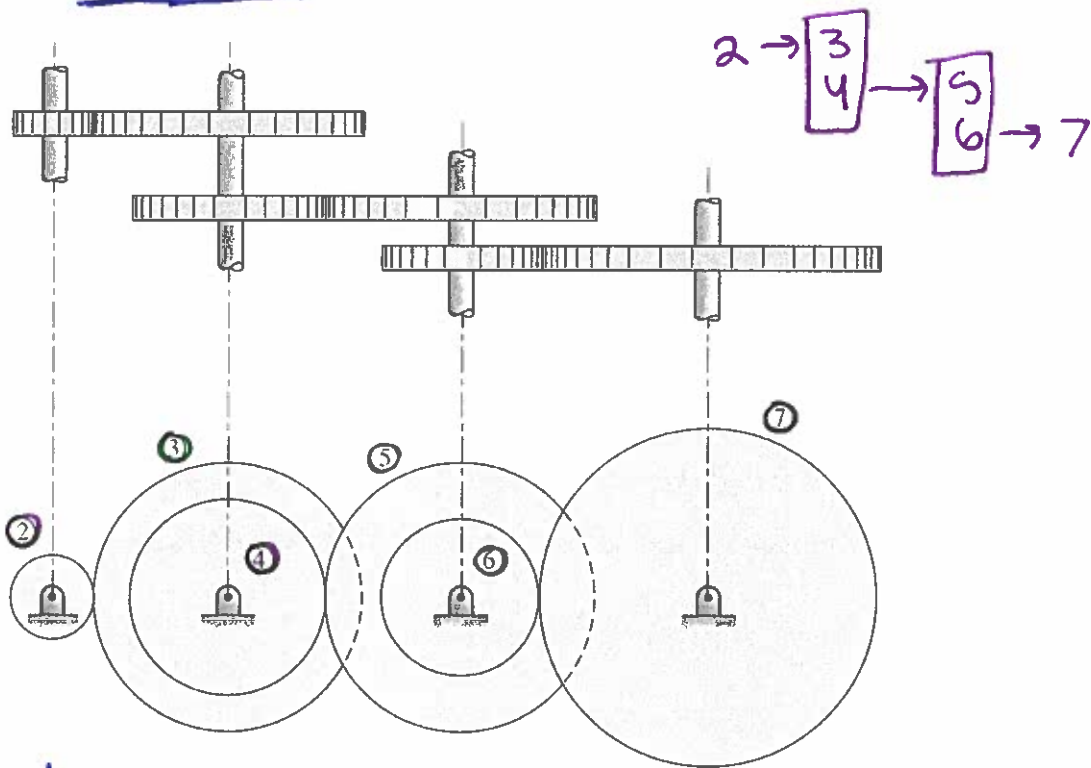
Gear 6: pitch diameter $d_6 = 1.5$ in. and $P_d = 8$

Gear 7: $N_7 = 32$ teeth and $P_d = 8$

~~2 4 3~~
~~4~~

Answer the following questions:

- 1) What is a compound gear train? (5 pts)
- 2) Find the pitch diameter of Gear 2, Gear 4 and Gear 7. (6pts)
- 3) Find the number of teeth of Gear 3, Gear 5 and Gear 6. (6 pts)
- 4) Find the velocity of gear 7 as gear 2 drives at 1800 rpm. (8 pts)



1) A compound gear train is one in which at least one shaft carries more than one gear.

2) $P_d = \frac{n}{d}$ find d

Gear 2: $12 = \frac{12}{d_2} = 7$ ~~7~~ $d_2 = 1 \text{ in}$ ✓

Gear 4: $10 = \frac{15}{d_4} = 7$ ~~7~~ ~~1.5~~ $d_4 = 1.5 \text{ in}$ ✓

Gear 7: $8 = \frac{32}{d_7} = 7$ $d_7 = 4 \text{ in}$ ✓

#3 & #4 on next page →

$$3) \quad Pd = \frac{N}{d} \quad \text{Gear 3: } 12 = \frac{N_3}{2.5 \text{ in}} \Rightarrow N_3 = 30 \text{ teeth}$$

$$\text{find } N \quad \text{Gear 5: } 10 = \frac{N_5}{3 \text{ in}} \Rightarrow N_5 = 30 \text{ teeth}$$

$$\text{Gear 6: } 8 = \frac{N_6}{1.5 \text{ in}} \Rightarrow N_6 = 12 \text{ teeth}$$

~~2 → 3~~
~~4 → 5~~
~~6 → 7~~

$$4) \quad \begin{array}{l} 2 \rightarrow 3 \\ 4 \rightarrow 5 \\ 6 \rightarrow 7 \end{array}$$

even #, positive
odd #, negative

$$\left\{ \begin{array}{l} N_3 = N_4, \text{ so } \frac{N_3}{N_4} = 1 \\ N_5 = N_6, \text{ so } \frac{N_5}{N_6} = 1 \end{array} \right.$$

$$\cancel{m_v = \left(-\frac{N_2}{N_3} \right) \left(-\frac{N_4}{N_5} \right)}$$

$$m_v = \left(-\frac{N_2}{N_3} \right) \left(-\frac{N_3}{N_4} \right) \left(-\frac{N_4}{N_5} \right) \left(-\frac{N_5}{N_6} \right) \left(-\frac{N_6}{N_7} \right)$$

$$-1 \cdot -1 = 1$$

$$m_v = \left(-\frac{N_2}{N_5} \right) \left(-\frac{N_4}{N_5} \right) \left(-\frac{N_6}{N_7} \right) \quad \times$$

$$m_v = \frac{-N_2}{N_7} = \frac{\omega_7}{\omega_2}$$

-3

"angular velocity between gears of a gearset remain constant throughout the mesh"

the velocity of gear 7 = 1800 rpm

AVERAGE

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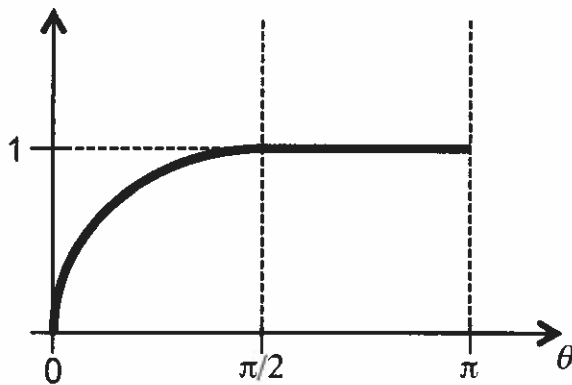
12 – 2 pm

Student's Name (printed): Temitayo Oju

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QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	25	9
2	25	20
3	25	18
4	25	25
TOTAL	100	72

Problem 1. (25 points)



The figure above shows the v diagram of a cam design, $v = \sin \theta$, for $0 \leq \theta \leq \frac{\pi}{2}$; and $v = 1$, for $\frac{\pi}{2} \leq \theta \leq \pi$. Given $s = 1$ at $\theta = \frac{\pi}{2}$.

- 1) Find the a function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (8 pts)
- 2) Find the s function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (10 pts)
- 3) What is the fundamental law of cam design? (3 pts) If this function is used as a rise function between a low dwell and high dwell (meaning before $\theta = 0$, there is a low dwell, after $\theta = \pi$, there is a high dwell), does it satisfy the fundamental law of cam design? (2 pts) why? (2 pts)

① $a = \frac{dv}{d\theta} = -\cos \theta + K_1$
when $\theta = 0$

$\frac{\pi}{2} = \pi$
 $a = \frac{dv}{d\theta} = 0$

② $s = 0$
when $\theta = 0$

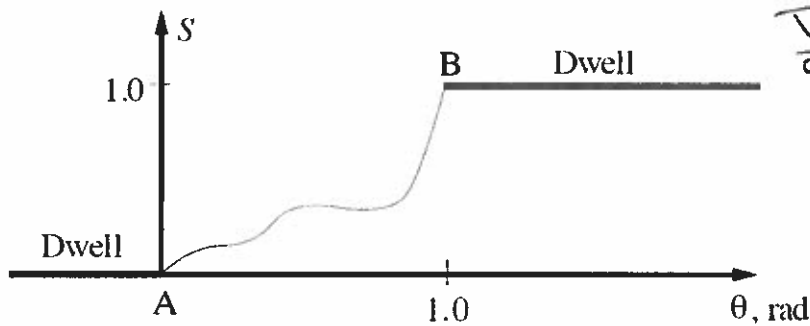
$\frac{\pi}{2} = \pi$
 $s = 0$

- ③ Fundamental law of cam design states $s \propto \theta^2$ must have continuous Velocity and acceleration in the entire interval thus making the jerk finite.

It doesn't satisfy the fundamental law.

Why? because it was not continuous all the way to acceleration.

Problem 2 (25 points)



	$\theta = 0$	$\theta = \beta$
s	0	1
v	0	0
a	0	0

Assume that s is the cam-follower displacement and θ is the cam angle. The rise is $h = 1$ after 1.0 radian of rotation, and the rise begins and ends at a dwell. If the **position, velocity, and acceleration** are continuous at $\theta = 0$, and the **position and velocity** are continuous at $\theta = \beta = 1$, use polynomial function to design a rise function s from 0 to $\beta = 1$ using the boundary conditions given above. Note: Use the minimum possible number of terms.

- 1) How many boundary conditions are given? (2 pts) What will be the order of the polynomial function? (2 pts)
- 2) Write the general form of the s function, and the corresponding v and a functions. (6 pts)
- 3) Bring in the boundary conditions and list the equations to be solved. (7 pts)
- 4) Solve all the unknowns. (8 pts)

① Boundary conditions are 5.

The order of the polynomials would be 4.

② $s = C_0 + C_1\left(\frac{\theta}{\beta}\right) + C_2\left(\frac{\theta}{\beta}\right)^2 + C_3\left(\frac{\theta}{\beta}\right)^3 + C_4\left(\frac{\theta}{\beta}\right)^4$

$v = \frac{1}{\beta} \left[C_1\left(\frac{1}{\beta}\right) + 2C_2\left(\frac{1}{\beta^2}\right)\theta + 3C_3\left(\frac{1}{\beta^3}\right)\theta^2 + 4C_4\left(\frac{1}{\beta^4}\right)\theta^3 \right]$

$a = \frac{1}{\beta^2} \left[2C_2\left(\frac{\theta}{\beta}\right) + 6C_3\left(\frac{\theta}{\beta}\right) + 12C_4\left(\frac{\theta}{\beta}\right)^2 \right]$

③ when $\theta = 0$

$s = C_0 = 0$

when $\theta = 0$

$v = \frac{1}{\beta} C_1 = 0$

when $\theta = 0$

$a = \frac{1}{\beta^2} 2C_2 = 0$

when $\theta = \beta$ bc

$s = C_3 + C_4 = 1$

when $\theta = \beta$ bc

$v = 3C_3 + 4C_4 = 0$

④

$\begin{bmatrix} 1 & 1 \\ 3 & 4 \end{bmatrix} \begin{bmatrix} C_3 \\ C_4 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 3 \\ -2 \end{bmatrix}$

Problem 3 (25 pts)

A zero-eccentricity cam with a reciprocating radial roller follower is to be designed such that the displacement of the follower is $s = 15[1 - \cos(2\theta)]$ (unit: mm). The prime circle radius is $R_b = 40$ mm, and the roller follower radius is $R_f = 12$ mm. For the cam rotation angle $\theta = 30^\circ$, determine the following:

- 1) The expression of $v = \frac{ds}{d\theta}$
- 2) The expression of $a = \frac{dv}{d\theta}$
- 3) The pitch circle radius $R_p = R_b + R_f$
- 4) The pressure angle

$$s = 15[1 - \cos(2\theta)] = 7.5 \text{ mm}$$

$$\phi = \tan^{-1} \frac{v - e}{s + \sqrt{R_p^2 - e^2}}$$

- 5) The pitch radius of curvature

$$\rho_{\text{pitch}}(\theta) = \frac{[(R_p + s)^2 + v^2]^{\frac{3}{2}}}{(R_p + s)^2 + 2v^2 - a(R_p + s)}$$

$$\phi = 30^\circ$$

$$R_b = 40 \text{ mm}$$

$$R_f = 12 \text{ mm}$$

$$\textcircled{1} v = \frac{ds}{d\theta} = 15[1 - \cos(2\theta)] = 30 \sin(2\theta) = 30 \sin(60^\circ) = 25.98 \text{ mm/rad}$$

$$\textcircled{2} a = \frac{dv}{d\theta} = 2(30 \cos(2\theta)) = 60 \cos(60^\circ) = 30 \text{ mm/rad}^2$$

$$\textcircled{3} R_p = R_b + R_f$$

$$40 \text{ mm} + 12 \text{ mm}$$

$$= 52 \text{ mm}$$

$$\textcircled{4} \phi = \tan^{-1} \frac{v - e}{s + \sqrt{R_p^2 - e^2}} = \tan^{-1} \frac{25.98 - 0}{7.5 + \sqrt{52^2 - 0^2}} = 0.722 \text{ rad} = 41.2^\circ$$

$$\textcircled{5} \rho_{\text{pitch}}(\theta) = \frac{[(52 + 7.5)^2 + (25.98)^2]^{\frac{3}{2}}}{(52 + 7.5)^2 + 2(25.98)^2 - 30(52 + 7.5)}$$

Problem 4 (25 points)

The following figure shows a compound gear train.

Gear 2: $N_2 = 12$ teeth and $P_d = 12$

Gear 3: pitch diameter $d_3 = 2.5$ in. and $P_d = 12$

Gear 4: $N_4 = 15$ teeth and $P_d = 10$

Gear 5: pitch diameter $d_5 = 3$ in. and $P_d = 10$

Gear 6: pitch diameter $d_6 = 1.5$ in. and $P_d = 8$

Gear 7: $N_7 = 32$ teeth and $P_d = 8$

$$\frac{T_4}{O_4} = \frac{T_2}{O_2}$$

$$P_d = \frac{N}{d_p}$$

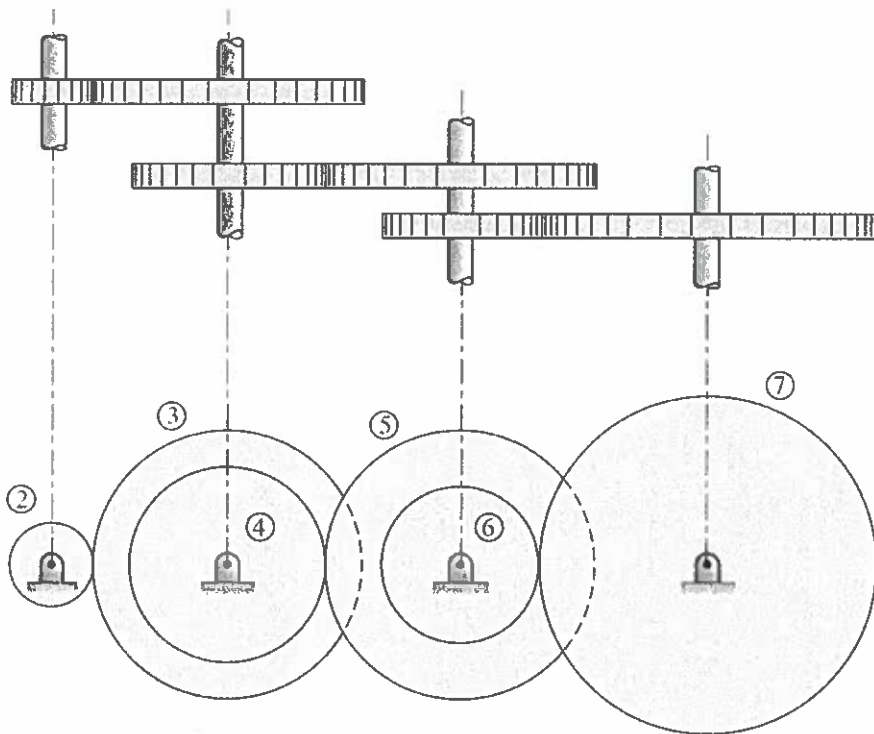
$$m = \frac{d_p}{N}$$

$$P_c = \frac{ndp}{N}$$

$$d_b = d_p \cos \phi \quad P_b = \frac{ndb}{N}$$

Answer the following questions:

- 1) What is a compound gear train? (5 pts)
- 2) Find the pitch diameter of Gear 2, Gear 4 and Gear 7. (6pts)
- 3) Find the number of teeth of Gear 3, Gear 5 and Gear 6. (6 pts)
- 4) Find the velocity of gear 7 as gear 2 drives at 1800 rpm. (8 pts)



① compound gear train is in which one shaft carries one or more gears. The ratio should be greater than 10:1.

② Pitch diameter

$$\text{Gear 2} = d_p 12 = \frac{12}{d_p} d_p = \frac{12 d_p}{12} = \frac{12}{12} = d_p = 1 \text{ in (Gear 2)}$$

$$\text{Gear 4} = d_p 10 = \frac{15}{d_p} d_p = \frac{10 d_p}{10} = \frac{15}{10} = d_p = 1.5 \text{ in (Gear 4)}$$

$$\text{Gear 7} = d_p 8 = \frac{32}{d_p} d_p = \frac{8 d_p}{8} = \frac{32}{8} = d_p = 4 \text{ in (Gear 7)}$$

$$Pd = \frac{N}{dp}$$

$$\textcircled{3} \text{ Gear 3 } \left(\frac{2}{5}\right)2 = \frac{N}{2/5} \cdot 2/5 = 30 \text{ teeth.}$$

$$\text{Gear 5 } \left(\frac{3}{8}\right)10 = \frac{N}{3/8} \cdot 3/8 = 30 \text{ teeth.}$$

$$\text{Gear 6 } \left(\frac{1}{5}\right)8 = \frac{N}{1/5} \cdot 1/5 = 12 \text{ teeth.}$$

$\textcircled{4}$ Find velocity Gear 7 as gear 2 drives at 1800 rpm.

$$m_v = \frac{\omega_{out}}{\omega_{in}} = \frac{\omega_1}{\omega_2} = \left(-\frac{N_2}{N_3}\right) \left(-\frac{N_4}{N_5}\right) \left(-\frac{N_6}{N_7}\right)$$

$$= \left(-\frac{12}{30}\right) \left(-\frac{15}{30}\right) \left(-\frac{12}{32}\right)$$

$$= -0.075$$

BELOW AVERAGE

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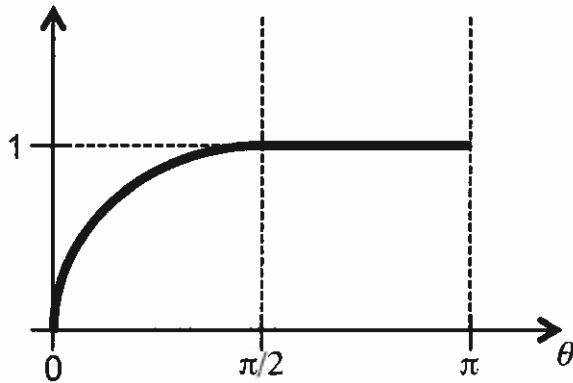
12 – 2 pm

Student's Name (printed): Tyler Valentine

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QUESTION #	MAXIMUM POINTS	POINTS SECURED
1	25	11
2	25	16
3	25	7
4	25	5
TOTAL	100	39

Problem 1. (25 points)



The figure above shows the v diagram of a cam design, $v = \sin \theta$, for $0 \leq \theta \leq \frac{\pi}{2}$; and $v = 1$, for $\frac{\pi}{2} \leq \theta \leq \pi$. Given $s = 1$ at $\theta = \frac{\pi}{2}$.

- 1) Find the a function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (8 pts) - 8
- 2) Find the s function for $0 \leq \theta \leq \frac{\pi}{2}$ and $\frac{\pi}{2} \leq \theta \leq \pi$ respectively. (10 pts) - 2
- 3) What is the fundamental law of cam design? (3 pts) If this function is used as a rise function between a low dwell and high dwell (meaning before $\theta = 0$, there is a low dwell, after $\theta = \pi$, there is a high dwell), does it satisfy the fundamental law of cam design? (2 pts) why? (2 pts) - 4

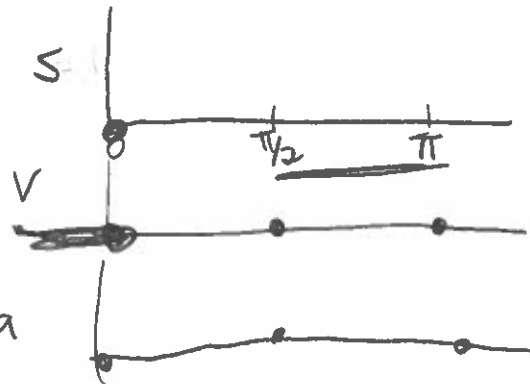
$$v = \sin \theta \quad 0 \leq \theta \leq \frac{\pi}{2}$$

$$v = 1 \quad \frac{\pi}{2} \leq \theta \leq \pi$$

$$s = \cos \theta + K_1 \quad 0 \leq \theta \leq \frac{\pi}{2}$$

$$s = \theta + K_2 \quad \frac{\pi}{2} \leq \theta \leq \pi$$

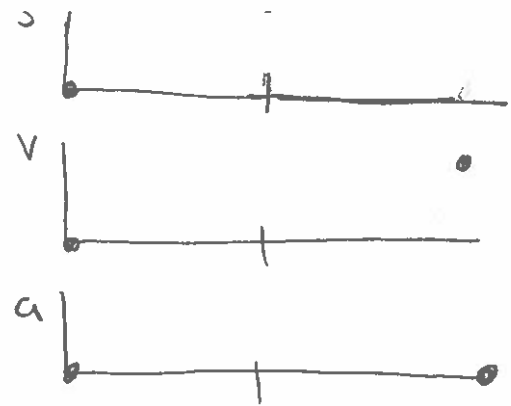
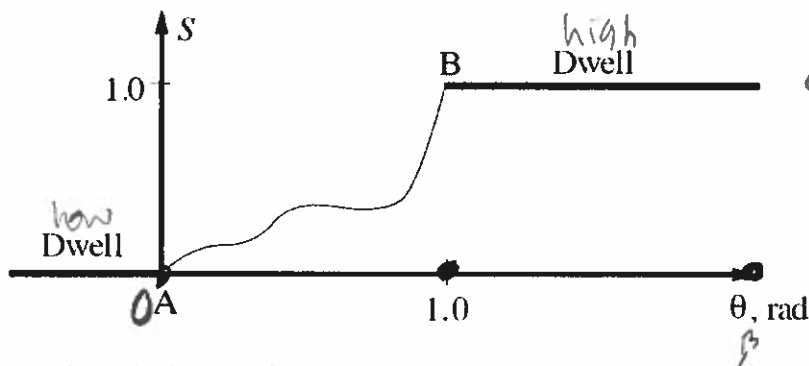
$$a =$$



$$K_1; K_2 = ?$$

Fundamental law of cam design: Velocity and acceleration must be continuous for finite jerk

Problem 2 (25 points)



Assume that s is the cam-follower displacement and θ is the cam angle. The rise is $h = 1$ after 1.0 radian of rotation, and the rise begins and ends at a dwell. If the **position, velocity, and acceleration** are continuous at $\theta = 0$, and the **position and velocity** are continuous at $\theta = \beta = 1$, use polynomial function to design a rise function s from 0 to $\beta = 1$ using the boundary conditions given above. Note: Use the minimum possible number of terms.

- 1) How many boundary conditions are given? (2 pts) What will be the order of the polynomial function? (2 pts)
- 2) Write the general form of the s function, and the corresponding v and a functions. (6 pts)
- 3) Bring in the boundary conditions and list the equations to be solved. (7 pts)
- 4) Solve all the unknowns. (8 pts)

$$s = C_0 + C_1\left(\frac{\theta}{\beta}\right) + C_2\left(\frac{\theta}{\beta}\right)^2 + C_3\left(\frac{\theta}{\beta}\right)^3 + C_4\left(\frac{\theta}{\beta}\right)^4 + C_5\left(\frac{\theta}{\beta}\right)^5 + C_6\left(\frac{\theta}{\beta}\right)^6$$

$$v = \frac{ds}{d\theta} = \frac{1}{\beta} \left[0 + C_1 + 2C_2\left(\frac{\theta}{\beta}\right) + 3C_3\left(\frac{\theta}{\beta}\right)^2 + 4C_4\left(\frac{\theta}{\beta}\right)^3 + 5C_5\left(\frac{\theta}{\beta}\right)^4 + 6C_6\left(\frac{\theta}{\beta}\right)^5 \right]$$

$$a = \frac{dv}{d\theta} = \frac{1}{\beta^2} [2C_2 + 6C_3\left(\frac{\theta}{\beta}\right) + 12C_4\left(\frac{\theta}{\beta}\right)^2 + 20C_5\left(\frac{\theta}{\beta}\right)^3 + 30C_6\left(\frac{\theta}{\beta}\right)^4]$$

	$\theta = 0$	$\theta = \beta$
s	0 ✓	1 ✓
v	0 ✓	0 ✓
a	0 ✓	0 ✗

-1

when $\theta = 0$

$$s = C_0 = 0$$

$$v = \frac{1}{\beta} (C_1 + 0) = 0$$

$$a = \frac{1}{\beta^2} (2C_2 + 0) = 0$$

when $\theta = \beta$

$$s = h = C_3 + C_4 + C_5$$

$$v = \frac{1}{\beta} (3C_3 + 4C_4 + 5C_5)$$

$$a = \frac{1}{\beta^2} (6C_3 + 12C_4 + 20C_5)$$

3) -2

4) -4

Problem 3 (25 pts)

A zero-eccentricity cam with a reciprocating radial roller follower is to be designed such that the displacement of the follower is $s = 15[1 - \cos(2\theta)]$ (unit: mm). The prime circle radius is $R_b = 40$ mm, and the roller follower radius is $R_f = 12$ mm. For the cam rotation angle $\theta = 30^\circ$, determine the following:

- 1) The expression of $v = \frac{ds}{d\theta}$
- 2) The expression of $a = \frac{dv}{d\theta}$
- 3) The pitch circle radius $R_p = R_b + R_f$
- 4) The pressure angle

$$\phi = \tan^{-1} \frac{v - e}{s + \sqrt{R_p^2 - e^2}}$$

- 5) The pitch radius of curvature

$$\rho_{pitch}(\theta) = \frac{[(R_p + s)^2 + v^2]^{\frac{3}{2}}}{(R_p + s)^2 + 2v^2 - a(R_p + s)}$$

$$s = 15[1 - \cos(2\theta)]$$

$$v = \frac{ds}{d\theta} = [1 - \sin(\theta) \cdot \cos] \quad \times - \times$$

$$a = \frac{dv}{d\theta} = \quad \times - 5$$

$$R_p = R_b + R_f = 12 + 40 = 52 \quad \checkmark$$

$$\phi = \tan^{-1} \frac{v - e}{s + \sqrt{R_p^2 - e^2}}$$

for

- 5

$$\frac{[(52 + s)^2 + v^2]^{\frac{3}{2}}}{(52 + s)^2 + 2v^2 - a(52 + s)} \quad - 4$$

$$s = \frac{ds}{d\theta}$$

$$\frac{ds}{d\theta} \frac{d\theta}{dt} = \frac{ds}{d\theta} \frac{d\theta}{dt} = \frac{v}{d\theta} \omega = v\omega$$

$$v\omega = v\omega$$

$$v = v$$

Problem 4 (25 points)

The following figure shows a compound gear train.

Gear 2: $N_2 = 12$ teeth and $P_d = 12$

Gear 3: pitch diameter $d_3 = 2.5$ in. and $P_d = 12$

Gear 4: $N_4 = 15$ teeth and $P_d = 10$

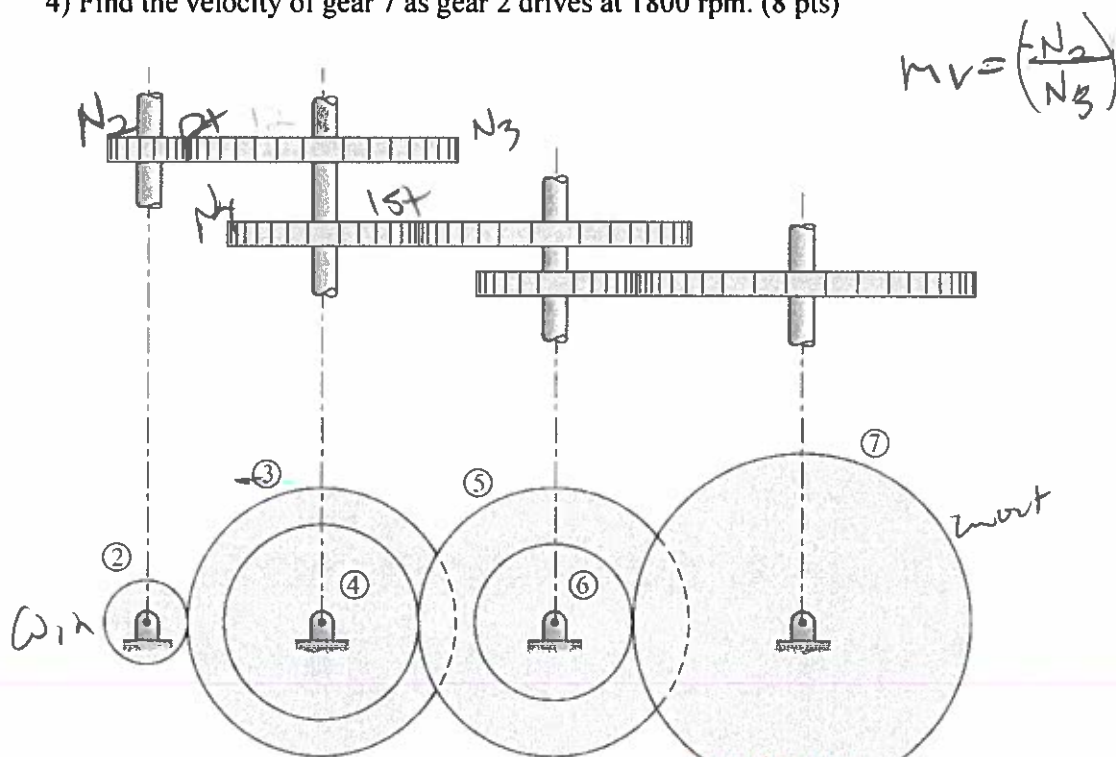
Gear 5: pitch diameter $d_5 = 3$ in. and $P_d = 10$

Gear 6: pitch diameter $d_6 = 1.5$ in. and $P_d = 8$

Gear 7: $N_7 = 32$ teeth and $P_d = 8$

Answer the following questions:

- 1) What is a compound gear train? (5 pts)
- 2) Find the pitch diameter of Gear 2, Gear 4 and Gear 7. (6pts)
- 3) Find the number of teeth of Gear 3, Gear 5 and Gear 6. (6 pts)
- 4) Find the velocity of gear 7 as gear 2 drives at 1800 rpm. (8 pts)



$$MV = \left(\frac{-N_2}{N_3} \right)$$

1) a compound gear train is one where ^{at least} one shaft carries more than one gear ✓

2) -6

3) -6

4) -8

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

HOMEWORK 1

TOPICS COVERED IN HOMEWORK 1

- 1. Degree of freedom**
- 2. Number synthesis**
- 3. Grashoff condition**

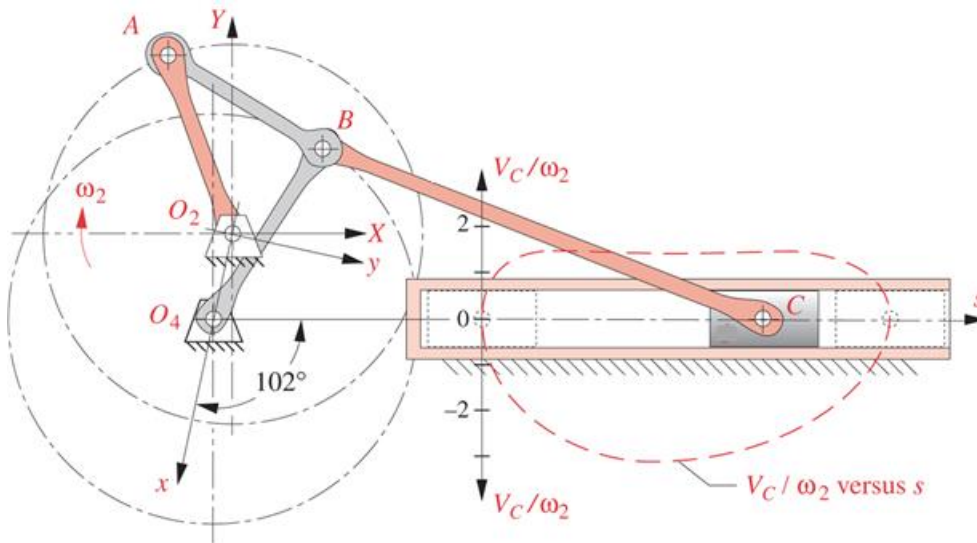
MCEG 3053 Kinematics Design and Analysis

Homework #1 Due 09/08/2021 midnight

Use this page as your cover page

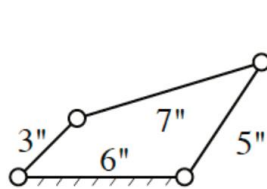
Student's name: _____ Grade: _____

Problem 1. Find the mobility of the mechanism shown in the following figure.

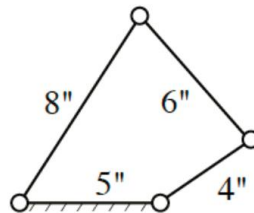


Problem 2. Use number synthesis to find all the possible link combinations for mobility $M = 1$ for eight links ($L = 8$), to hexagonal order using only revolute joints.

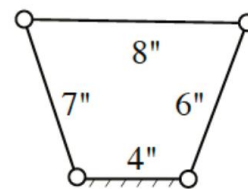
Problem 3. Determine the Grashof condition for the four-bar linkages below. Indicate whether they are crank-rocker, double-crank, double-rocker, or triple-rocker mechanisms.



(a)



(b)



(c)

ABOVE AVERAGE

MCEG 3053 Kinematics Design and Analysis

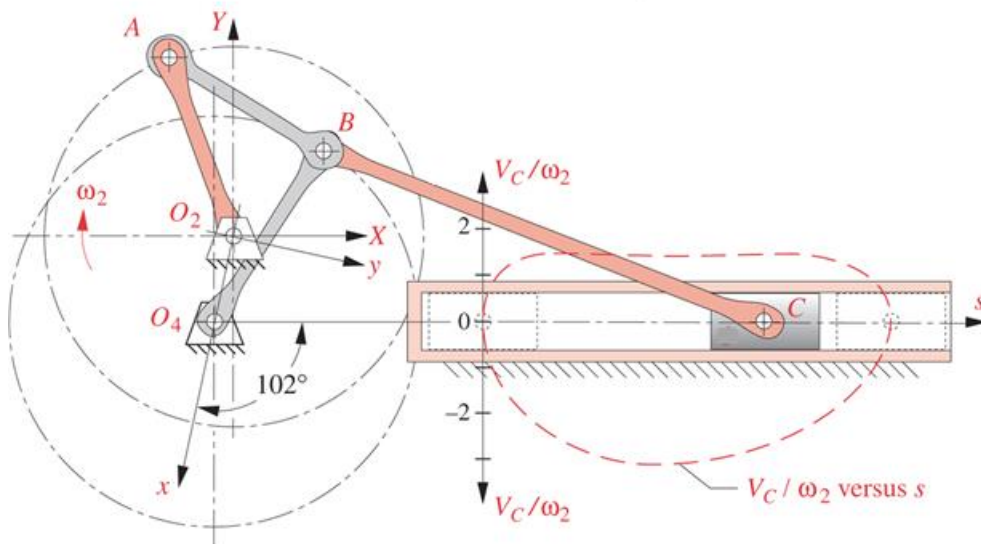
Homework #1 Due 09/08/2021 midnight

Use this page as your cover page

Student's name: Zion Brown

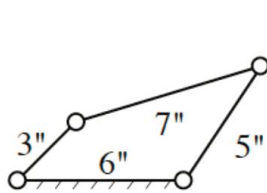
Grade: 90

Problem 1. Find the mobility of the mechanism shown in the following figure.

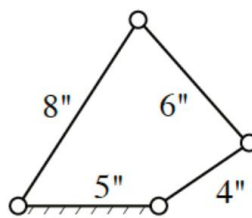


Problem 2. Use number synthesis to find all the possible link combinations for mobility $M = 1$ for eight links ($L = 8$), to hexagonal order using only revolute joints.

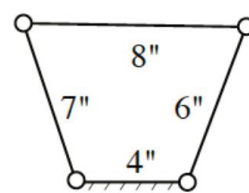
Problem 3. Determine the Grashof condition for the four-bar linkages below. Indicate whether they are crank-rocker, double-crank, double-rocker, or triple-rocker mechanisms.



(a)

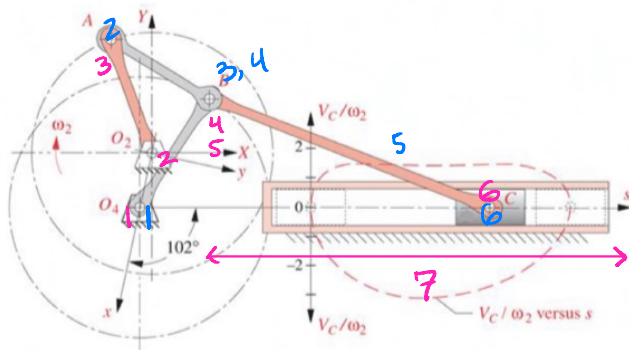


(b)



(c)

Problem 1. Find the mobility of the mechanism shown in the following figure.



Problem 1

$$L = 6$$

$$J_1 = 7$$

$$J_2 = 0$$

Mobility

$$M = 3(L - 1) - 2J_1 - J_2$$

$$= 3(6 - 1) - 2(7) - 0$$

$$15 - 14$$

$$M = 1$$

— = Links

— = J_1

Problem 2

Problem 2. Use number synthesis to find all the possible link combinations for mobility $M = 1$ for eight links ($L = 8$), to hexagonal order using only revolute joints.

Given
 $M = 1$
 $L = 8$

$$L - 3 - M = T + 2Q + 3P + 4H$$

$$L = B + T + Q + P + H$$

Possibilities

$$1 \quad 4 = T + 2Q + 3P + 4H, \quad Q = 2, \quad T = 0, P = 0, H = 0, \quad 8 = B + T + 2 + P + H, \quad B = 6$$

$$\text{if } Q = 2, P = 0, H = 0, T = 0, B = 6, L = 8$$

$$2 \quad 4 = T + 2Q + 3P + 4H, \quad T = 4, \quad P = 0, H = 0, \quad 8 = B + 4 + 0 + 0 + 0, \quad B = 4$$

$$\text{if } T = 4, P = 0, H = 0, B = 4, L = 8$$

$$3 \quad 4 = T + 2Q + 3P + 4H, \quad H = 1, \quad P = 0, T = 0, Q = 0, \quad 8 = B + 0 + 0 + 0 + 1, \quad B = 7$$

$$\text{if } H = 1, P = 0, T = 0, Q = 0, B = 7, L = 8$$

$$4 \quad 4 = T + 2Q + 3P + 4H, \quad P = 1, \quad T = 1, Q = 0, H = 0, \quad 8 = B + 1 + 0 + 1 + 0, \quad B = 6$$

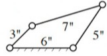
$$\text{if } P = 1, T = 1, H = 0, Q = 0, B = 6, L = 8$$

$$5 \quad 4 = T + 2Q + 3P + 4H, \quad Q = 1, \quad T = 2, P = 0, H = 0, \quad 8 = B + 2 + 1 + 0 + 0, \quad B = 5$$

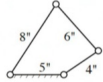
$$\text{if } Q = 1, T = 2, P = 0, H = 0, B = 5, L = 8$$

Problem 3

Problem 3. Determine the Grashof condition for the four-bar linkages below. Indicate whether they are crank-rocker, double-crank, double-rocker, or triple-rocker mechanisms.



(a)



(b)



(c)

a) Crank - Rocker

b) ~~Double~~ - Rocker

c) Double Crank

Show the grashoff condition

triple

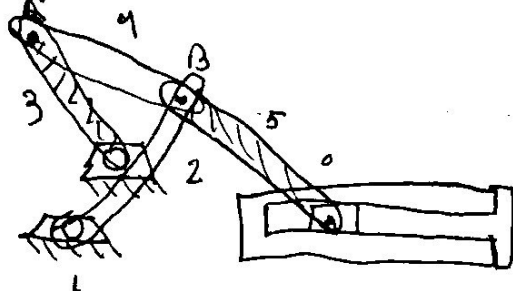
- / 0

AVERAGE

85

Hu #1 MCEG 3053 P04 Zyon Villano

P1



$$\begin{aligned}
 F &= 3(L-1) - 2J_r - J_e \\
 L &= 6 \quad J_r = 7 \\
 &= 3(6-1) - 2(7) = 0 \\
 F &= 1
 \end{aligned}$$

P2

Use # synthesis ... $M=1$ $L=8$ revolute
radial joints

$$\begin{aligned}
 M &= 3(L-1) - 2j \\
 1 &= 3(8-1) - 2j \\
 j &= 10
 \end{aligned}$$

of binary joints 10

$$L = B + T + Q \quad \text{not necessary}$$

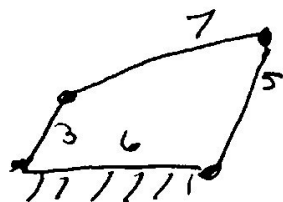
$$L - 3 - m = T + 2Q \quad \text{not necessary}$$

$T:0$	$Q:2$	$B+T+Q$	$B=2$
$T:2$	$Q:1$	$B+T+Q=2$	$B=3$
$T:4$	$Q:0$	$2 \quad 1$	$B=4$
		$4 \quad 0$	

in complete

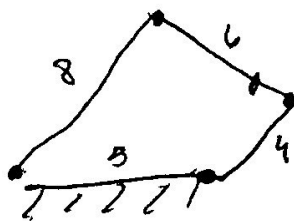
-10

P3 Grashof's Determine the Grashof condition...



$$\begin{aligned} S &= 3 \\ C &= 7 \\ P &= 6 \\ Q &= 5 \end{aligned}$$

Crank rocker

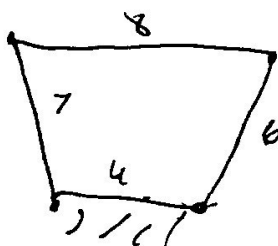


$$\begin{aligned} S &= 4 \\ C &= 6 \\ P &= 8 \\ Q &= 5 \end{aligned}$$

~~Double rocker~~

~~triple~~

-5



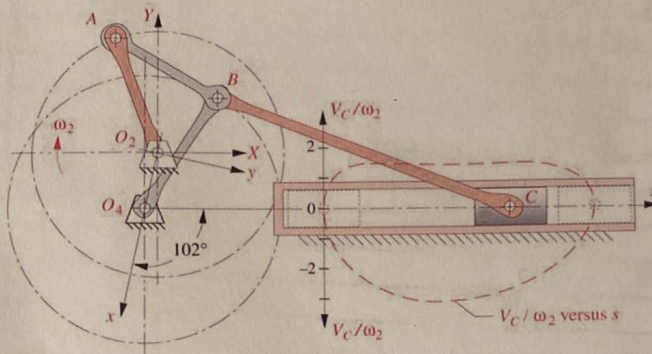
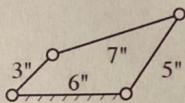
$$\begin{aligned} S &= 4 \\ C &= 8 \\ P &= 7 \\ Q &= 6 \end{aligned}$$

Double crank

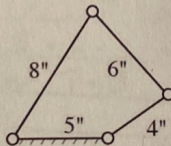


BELOW AVERAGE

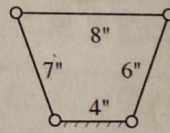
Use this page as your cover page

Student's name: Idris AgboolaGrade: 70**Problem 1.** Find the mobility of the mechanism shown in the following figure.**Problem 2.** Use number synthesis to find all the possible link combinations for mobility $M = 1$ for eight links ($L = 8$), to hexagonal order using only revolute joints.**Problem 3.** Determine the Grashof condition for the four-bar linkages below. Indicate whether they are crank-rocker, double-crank, double-rocker, or triple-rocker mechanisms.

(a)



(b)



(c)

Problem #1

$L = 6$

$J_1 = 7$ $J_2 = 0$

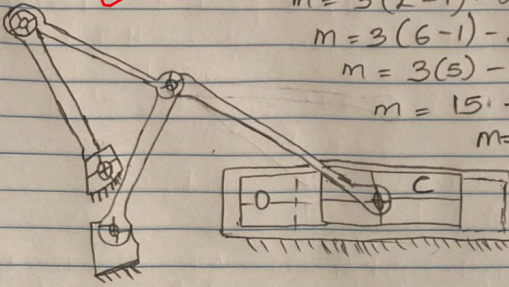
$m = 3(L-1) - 2J_1 - J_2$

$m = 3(6-1) - 2(7) - 0$

$m = 3(5) - 14$

$m = 15 - 14$

$m = 1$



Problem #2

$M = 1$

$L = 8$

$L - 3 - m = T + 2Q + 3P + 4H$

$8 - 3 - 1 = T + 2Q$

$4 = T + 2Q = 4 = (2 + 2(0)) = 4 = 4$

If $Q = 1$ then $T = 2$, $B = L - (T + Q + P + H)$

$B = 8 - 2 - 1 = 5$

If $Q = 2$ then $T = 0$, $B = L - (T + Q + P + H)$

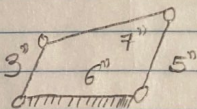
$B = 8 - 2 = 6$

incomplete

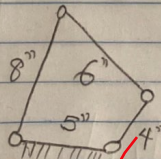
why?

-20

Problem #3

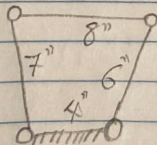


(a) Crank - Rocker



(b)

double-rocker



(c)

Double Crank

show grashoff condition

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

HOMEWORK 2

TOPICS COVERED IN HOMEWORK 2

- 1. Four-bar linkage position analysis**
- 2. Position analysis using MATLAB**
- 3. Linkage synthesis (two-position)**

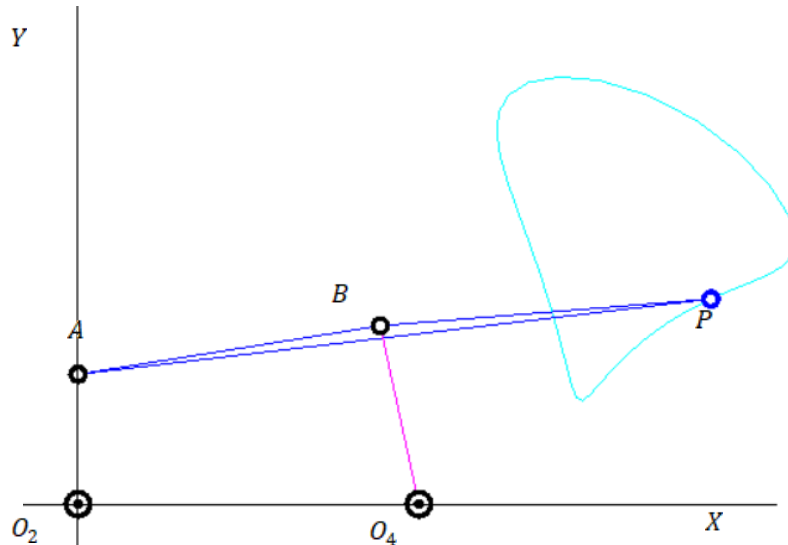
MCEG 3305 Kinematics Design and Analysis

Homework #2 Due 09/29/2021

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Student's name: _____ Grade: _____

Problem 1 (50 points): The following figure shows a movie camera film-advance mechanism,



- 1) The lengths of the four-bar linkage is given as $d = 1.444$, $a = 0.55$, $b = 1.297$, $c = 0.773$. The unit is inch.
- 2) Using Grashof condition to classify this linkage and predict its motion.
- 3) P is a point on the coupler AB . $p = 2.7$, $\delta_3 = -2.33^\circ$ where p is the distance between P and A , δ_3 is the angle rotating AB to AP .
- 4) calculate and plot the angular displacement of links 3 and 4 and the path coordinates of point P with respect to the angle of the input crank O_2A for one revolution.

Hint: You can use the MATLAB script on Canvas as a basis. Using the script (only the OPEN configuration, not the CROSSED), you should be able to find the angular displacement of links 3 and 4 (θ_3 and θ_4) given the angle of the input crank O_2A (θ_2).

Now if you use this script manually, you can have sth. like

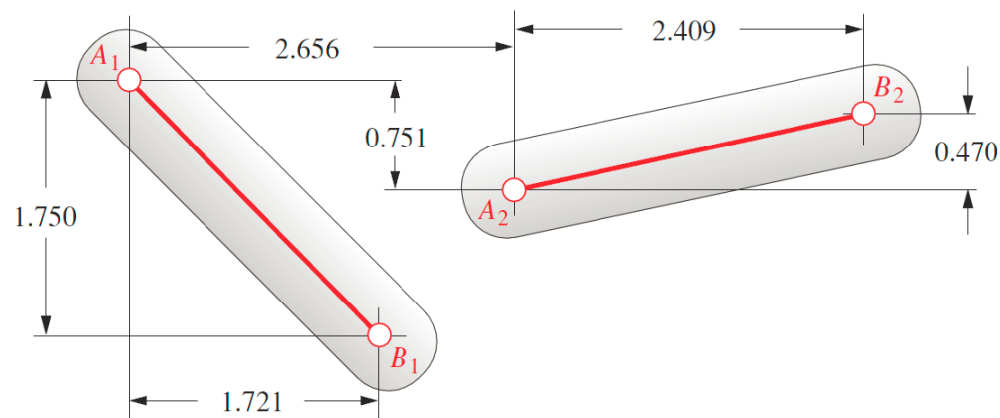
θ_2	θ_3	θ_4
0°		
5°		
10°		
$\vdots$		
360°		

Now you can plot θ_3 and θ_4 with respect to θ_2

Hint: It will be easier if you know how to turn the script into a function, and plot the results using MATLAB. (+1 bonus point if you do that)

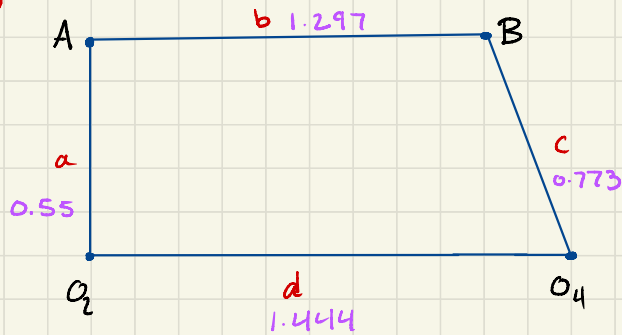
To find the position of point P , you need to use the equation that we talked about in class to find any point on the link (in this case, coupler) AND make that part of the MATLAB script. So for every θ_2 , you will also have a coordinates of P calculated. Lastly, plot the trajectory of point P .

Problem 2 (P5.1 and P3.3, 50 points) Consider the two positions provided in the figure. (a) Using graphical method to determine the corresponding pivot. (b) Analytically, find the coordinates of the pivot. (c) Design a crank-rocker four-bar linkage to give the two positions rocker motion (Example 3-2, p.105).



ABOVE AVERAGE

1)



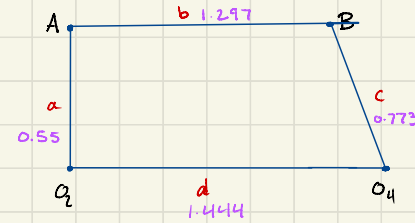
Given

$$d = 1.444$$

$$a = 0.55$$

$$b = 1.297 \text{ inch}$$

$$c = 0.773$$



95/100

* 1, 3, and 4 are on MATLAB

Analysis

$$\therefore a = 0.55 \text{ in } \& d = 1.44 \text{ in}$$

→ Grashof Equation

• For at least one link to be capable of making a full revolution

$$s + l \leq p + q$$

$$\rightarrow a + d < b + c$$

$$0.55 + 1.444 \quad 1.297 + 0.773$$

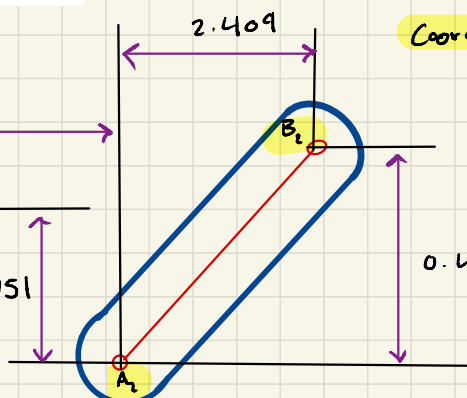
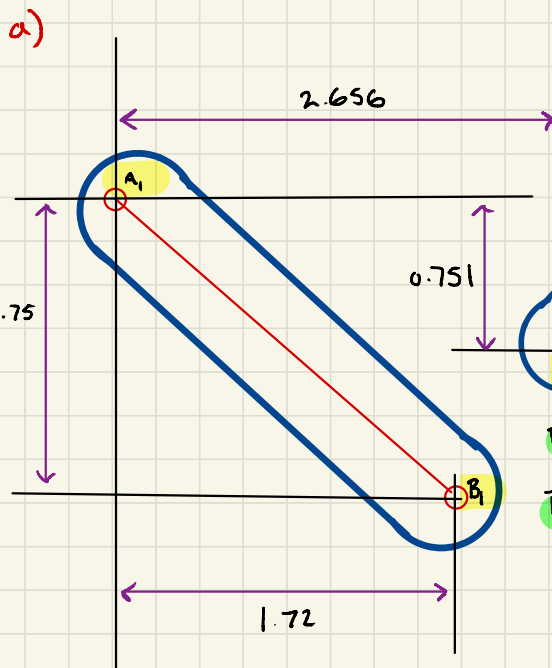
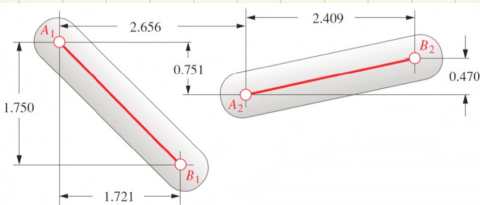
$$\rightarrow 1.994 < 2.07$$

2) → Crank Rocker Mechanism Grashof Class I

ANSWER

* Because. The shortest link is adjacent to the ground

Problem 2 (P5.1 and P3.3, 50 points) Consider the two positions provided in the figure. (a) Using graphical method to determine the corresponding pivot. (b) Analytically, find the coordinates of the pivot. (c) Design a crank-rocker four-bar linkage to give the two positions rocker motion (Example 3-2, p.105).



$P(1.923, 1.923)$ Measured Value
The point P is a pivot point

b) The coordinate of the pivot slope line A_1, A_2

$$m_1 = \frac{y_2 - y_1}{x_2 - x_1} \rightarrow \frac{-0.751 - 0}{2.656 - 1} = m = 0.28276$$

Normal slope to A_1, A_2

$$m_1 = \frac{-1}{-0.28276} = 3.53662$$

Equation of Normal slope

$$y = 3.53662x + c$$

Coordinate of Midpoint

$$\rightarrow \left[\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right] \rightarrow \left[\frac{2.656 + 1}{2}, \frac{0.75 + 0}{2} \right] = (1.828, -0.3735)$$

Normal passes slope

$$y = 1.828 \times 3.56 + E = -0.375$$

$$E = 6.840$$

slope of line $B_1 B_2$

$$m_2 = \frac{-0.75 + 0.47 - (-1.75)}{2.656 + 2.409 - 1.721}$$

$$m_2 = 0.43929$$

Slope of Normal

$$m_2 = \frac{-1}{0.43929} = -2.27636$$

Equation of normal

$$y = 2.27638x + F$$

Coordinate of Midpoint B_1, B_2

$$\left[\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right]$$

$$= 3.393, -1.0155$$

$$= -2.27638 \times F = -1.0155$$

$$F = 6.70825$$

→ substitute

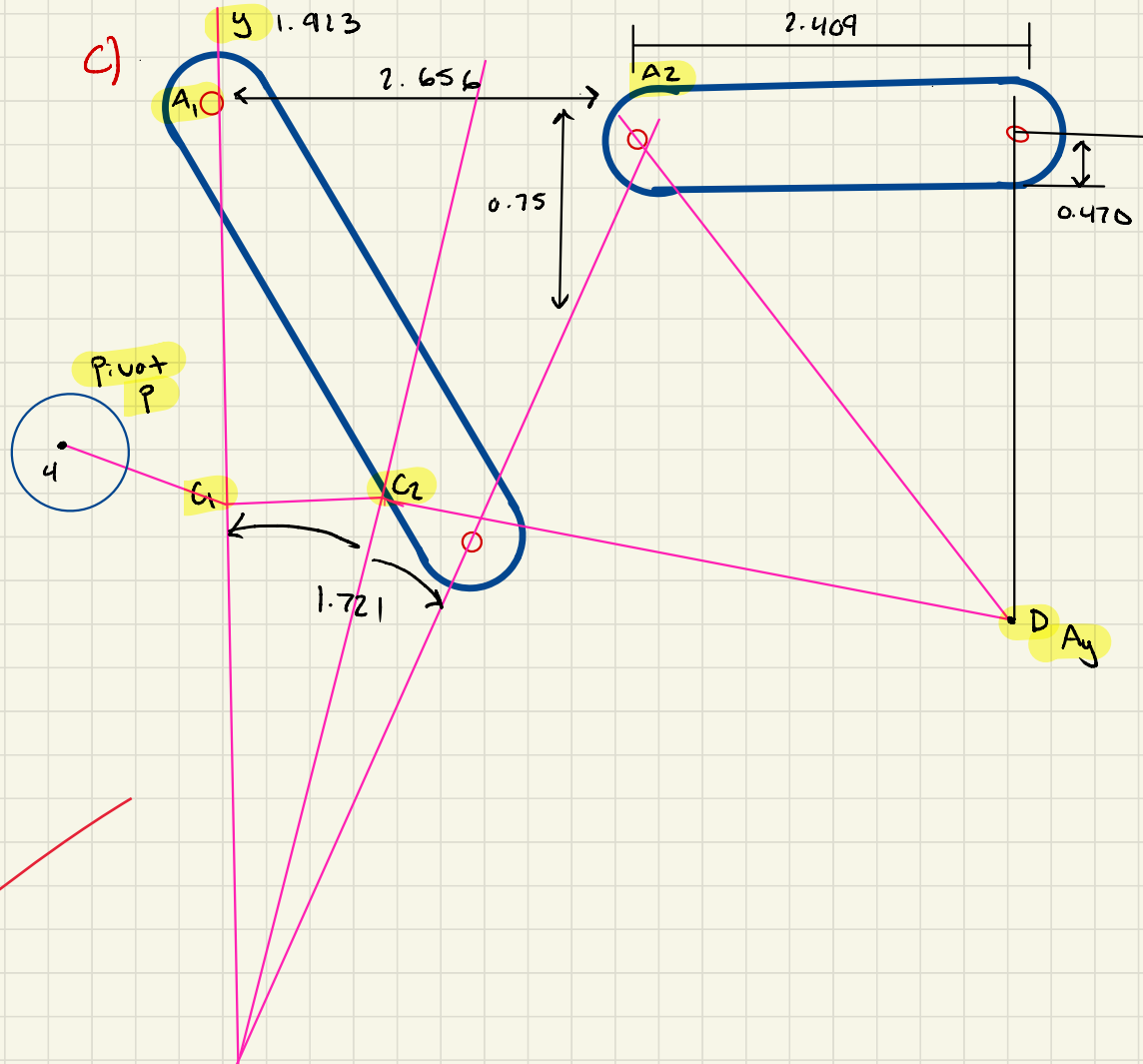
$$y = -2.27638 + 6.70825$$

x-intersection point P

$$y = 3.53662x - 5.07213$$

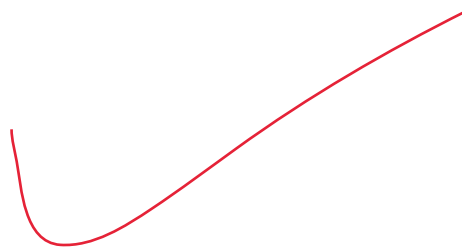
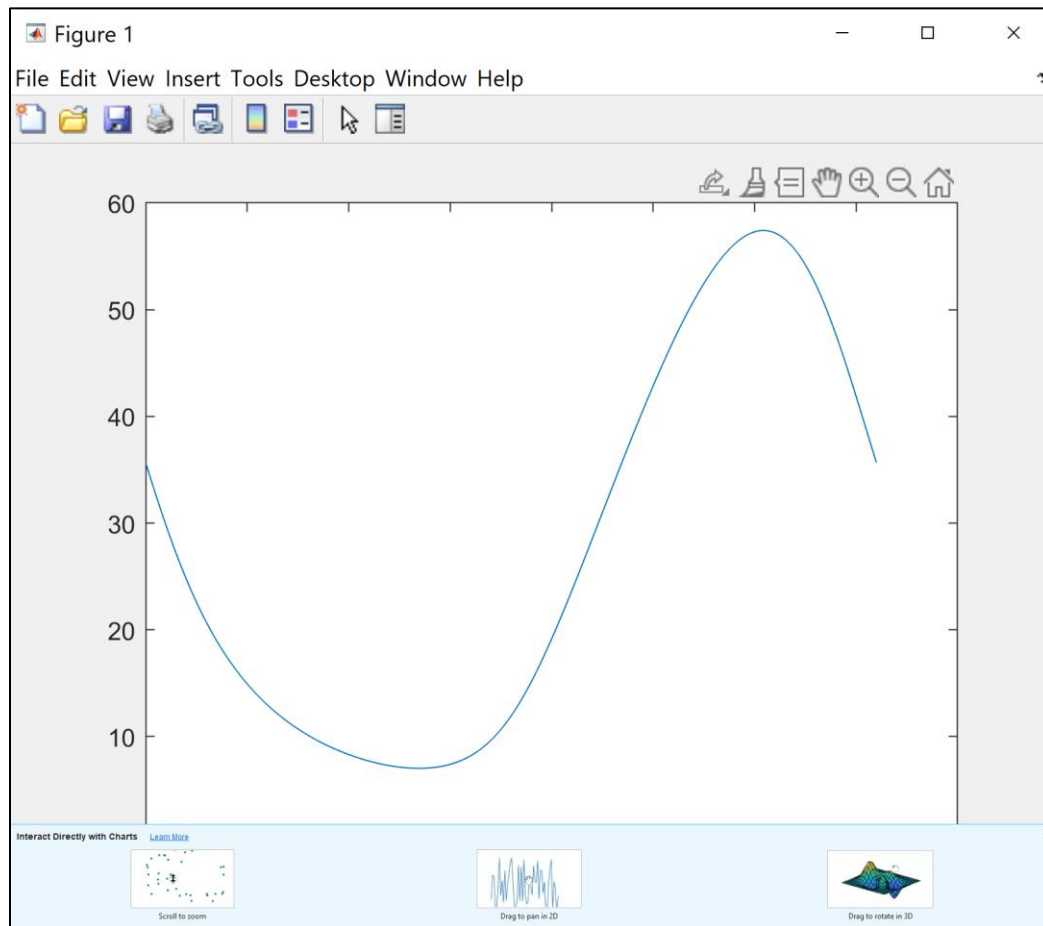
$$y = -2.2768x - 16.70825$$

$$\therefore \rightarrow x = 2026 \quad y = 2095$$



Zion H. Brown
September 29, 2021
Kinematics HW 2
My MATLAB Code is in the submission folder.

Plot: theta2 vs theta3open

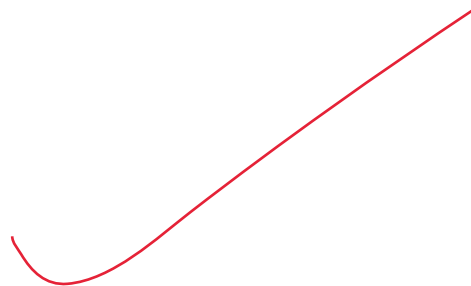
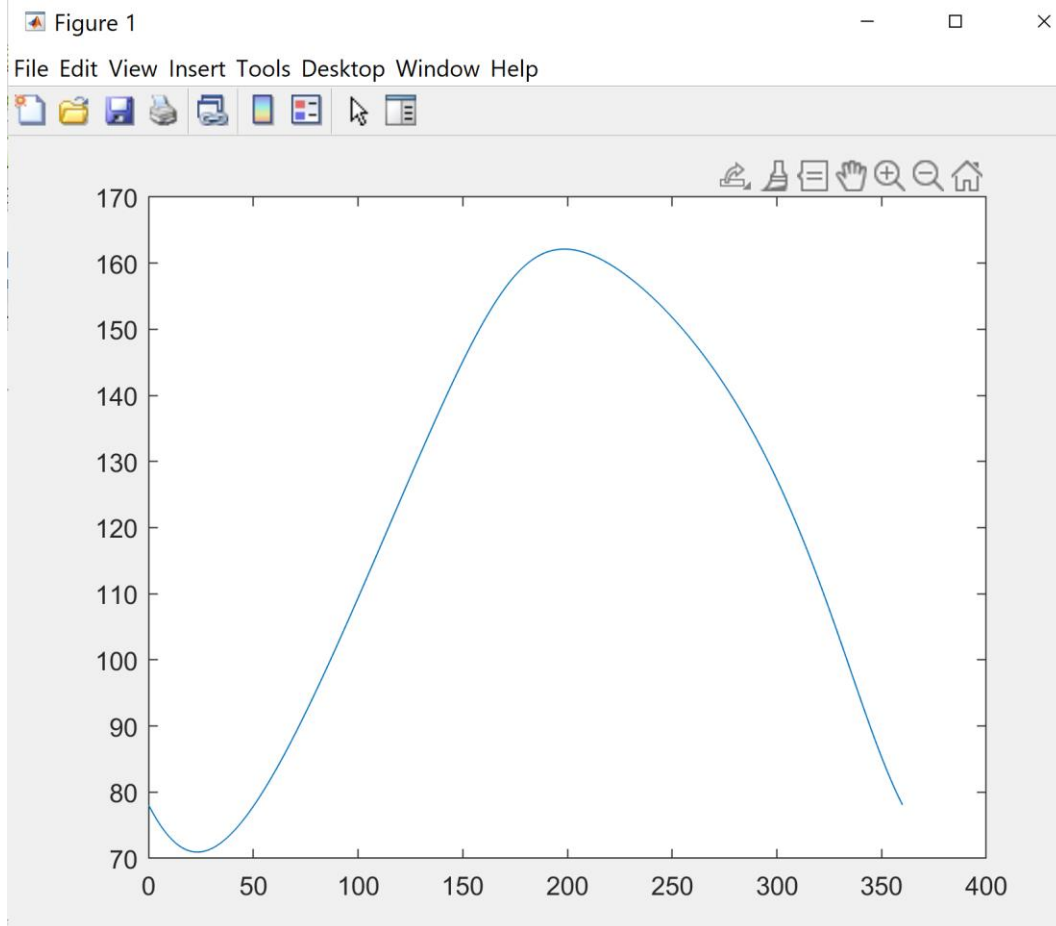


Zion H. Brown

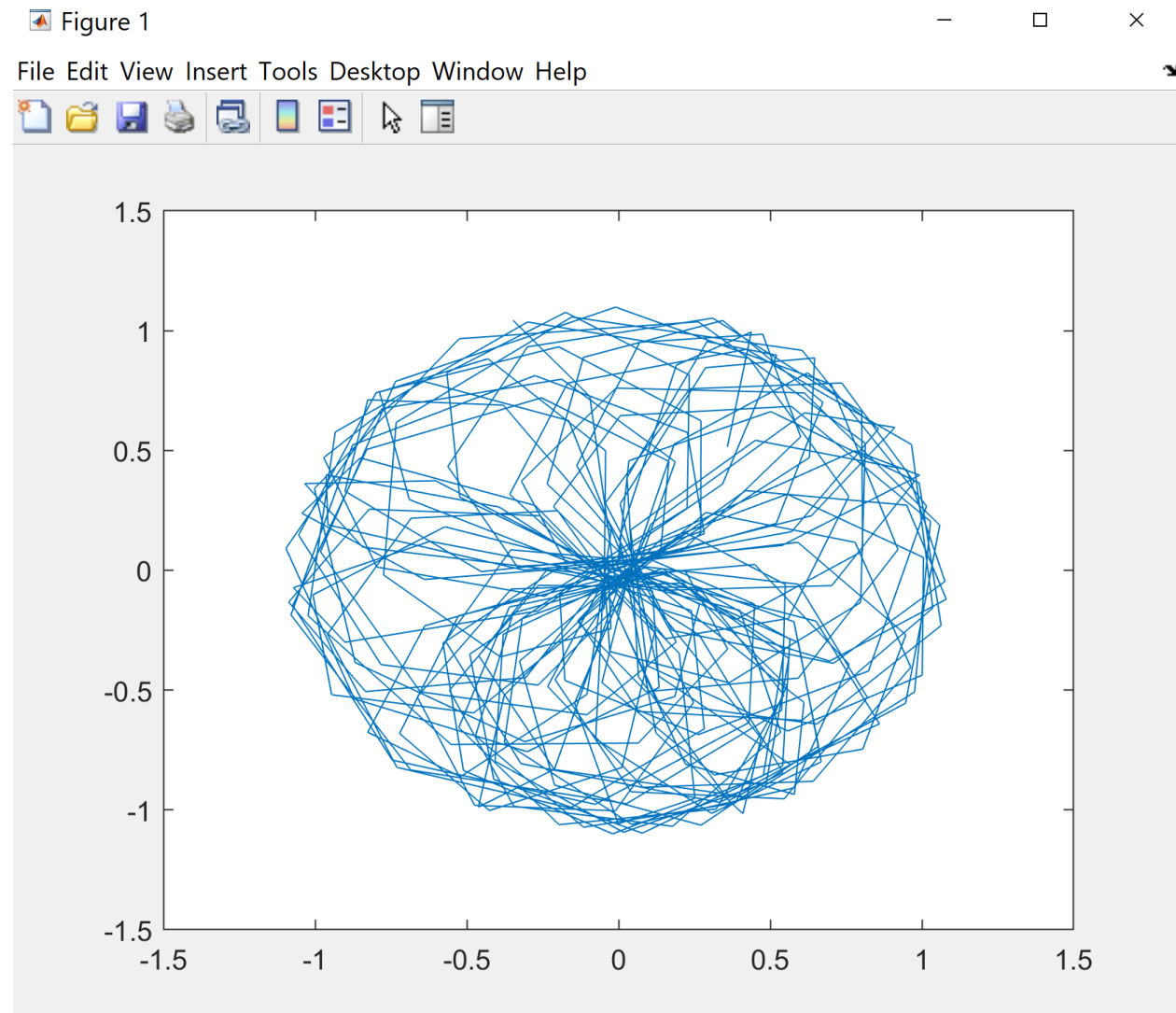
September 29, 2021

Kinematics HW 2

Plot: θ_2 vs θ_{4open}



Zion H. Brown
September 29, 2021
Kinematics HW 2
Plot: RPax vs RPay



X

-5

AVERAGE

MCEG 3053 Kinematics Design and Analysis

Homework #2 Due 09/29/2021

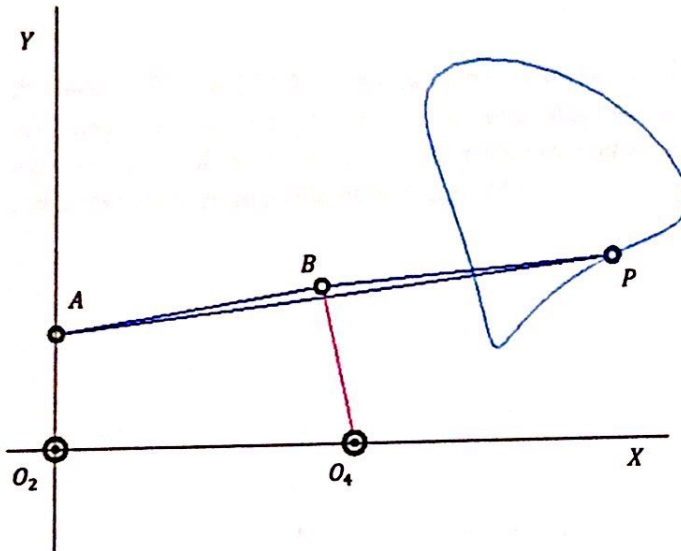
Use this page as your cover page

82/100

Student's name: Wendell Smith

Grade: _____

Problem 1 (50 points): The following figure shows a movie camera film-advance mechanism,



- 1) The lengths of the four-bar linkage is given as $d = 1.444$, $a = 0.55$, $b = 1.297$, $c = 0.773$. The unit is inch.
- 2) Using Grashof condition to classify this linkage and predict its motion.
- 3) P is a point on the coupler AB . $p = 2.7$, $\delta_3 = -2.33^\circ$ where p is the distance between P and A , δ_3 is the angle rotating AB to AP .
- 4) calculate and plot the angular displacement of links 3 and 4 and the path coordinates of point P with respect to the angle of the input crank O_2A for one revolution.

Hint: You can use the MATLAB script on Canvas as a basis. Using the script (only the OPEN configuration, not the CROSSED), you should be able to find the angular displacement of links 3 and 4 (θ_3 and θ_4) given the angle of the input crank O_2A (θ_2).

Now if you use this script manually, you can have sth. like

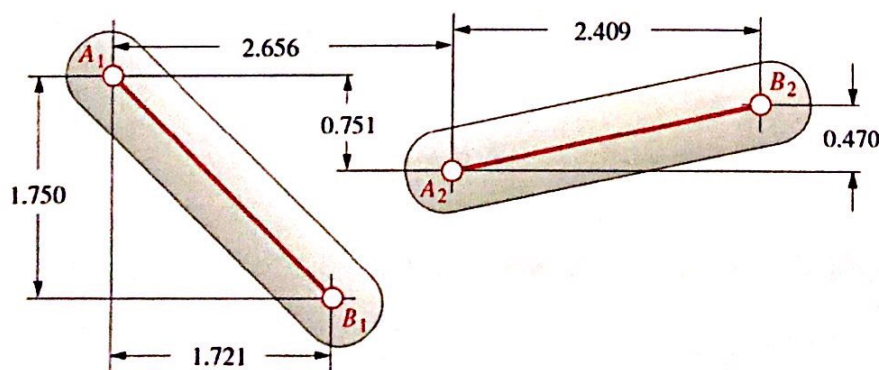
θ_2	θ_3	θ_4
0°	36.3°	62.7°
5°	33.1°	59.7°
10°	30.3°	57.5°
$\vdots$	20.3°	57.3°
360°	36.3°	62.7°

Now you can plot θ_3 and θ_4 with respect to θ_2

Hint: It will be easier if you know how to turn the script into a function, and plot the results using MATLAB. (+1 bonus point if you do that)

To find the position of point P , you need to use the equation that we talked about in class to find any point on the link (in this case, coupler) AND make that part of the MATLAB script. So for every θ_2 , you will also have a coordinates of P calculated. Lastly, plot the trajectory of point P .

Problem 2 (P5.1 and P3.3, 50 points) Consider the two positions provided in the figure. (a) Using graphical method to determine the corresponding pivot. (b) Analytically, find the coordinates of the pivot. (c) Design a crank-rocker four-bar linkage to give the two positions rocker motion (Example 3-2, p.105).



Wardell Smith
HW # 2

9/27/2021

① Given: $d = 1.444$, $a = 0.55$, $b = 1.297$, $c = 0.773$
(inches)

Find: Grashof condition

Solution: Grashof condition

$$S = 0.55 \text{ in}$$

$$L = 1.444 \text{ in}$$

$$P = 0.773 \text{ in}$$

$$Q = 1.297 \text{ in}$$

$$S + L = .55 + 1.444 = 1.994 \text{ in}$$

$$P + Q = .773 + 1.297 = 2.07 \text{ in}$$

$$1.994 \text{ in} < 2.07 \text{ in}$$

Grashof Class 1

$\therefore P = \text{point on coupler AB}$

$$p = 2.7, \theta_3 = -2.33^\circ$$

find: Calculate and plot the angular displacement of
link 3 and 4 & the path of coordinates of point P
with respect to O_2A (input crank angle) one rev.

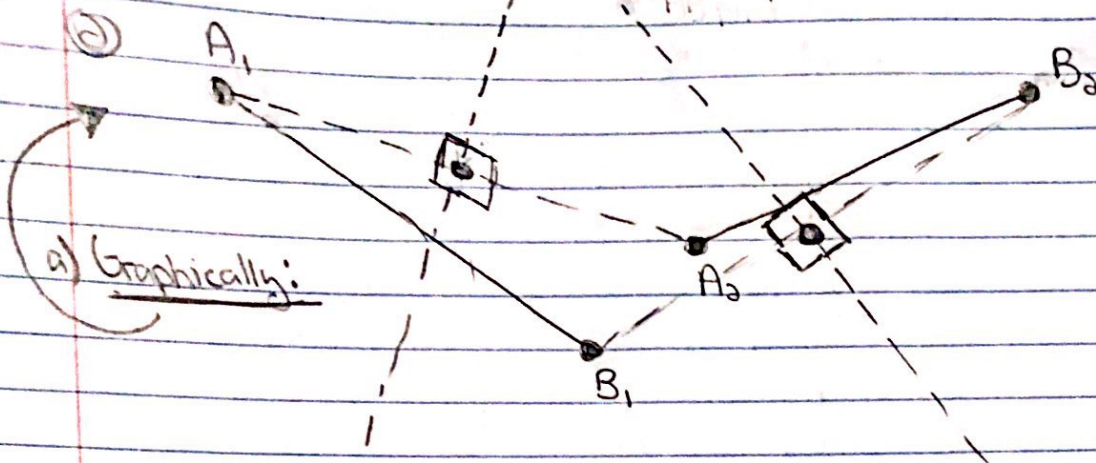
Angular displacement of links 3, 4 given the input
crank ϕ_2 .

See chart on page 1!

plots?

-15

9/27/2021



b) Analytically:

$$\begin{bmatrix} 2(A_{1x} - A_{2x}) & 2(A_{1y} - A_{2y}) \\ 2(B_{1x} - B_{2x}) & 2(B_{1y} - B_{2y}) \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} (A_{1x}^2 + A_{1y}^2) - (A_{2x}^2 + A_{2y}^2) \\ (B_{1x}^2 + B_{1y}^2) - (B_{2x}^2 + B_{2y}^2) \end{bmatrix}$$

$$\begin{aligned} A_{1x} &= 2.656, A_{2x} = 2.409; B_{1x} = 3.344, B_{2x} = 2.409 \\ A_{1y} &= 1.75, A_{2y} = .751; B_{1y} = 1.75, B_{2y} = .47 \end{aligned}$$

$$\begin{bmatrix} 2(2.656 - 2.409) & 2(1.75 - .751) \\ 2(3.344 - 2.409) & 2(1.75 - .47) \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} (2.656)^2 + (1.75)^2 - (2.409)^2 - (.751)^2 \\ (3.344)^2 + (1.75)^2 - (2.409)^2 - (.47)^2 \end{bmatrix}$$

$$\begin{bmatrix} .494 & 1.998 \\ .935 & 2.56 \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 10.12 - 6.37 \\ 14.25 - 6.02 \end{bmatrix}$$

$$\begin{bmatrix} .494 & 1.998 \\ .935 & 2.56 \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 3.75 \\ 8.23 \end{bmatrix}$$

$$\begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 3.75 \\ 8.23 \end{bmatrix} - \begin{bmatrix} .494 & 1.998 \\ .935 & 2.56 \end{bmatrix}$$

c) Design crank-rocker four bar linkage:

BELOW AVERAGE

MCEG 3053 Kinematics Design and Analysis

Homework #2 Due 09/29 2021

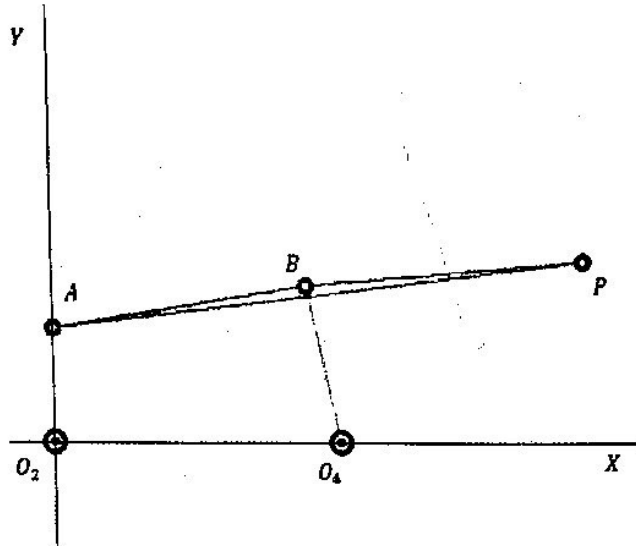
Use this page as your cover page

50

Student's name: _____

Grade: _____

Problem 1 (50 points): The following figure shows a movie camera film-advance mechanism,



- 1) The lengths of the four-bar linkage is given as $d = 1.444$, $a = 0.55$, $b = 1.297$, $c = 0.773$. The unit is inch.
- 2) Using Grashof condition to classify this linkage and predict its motion.
- 3) P is a point on the coupler AB . $p = 2.7$, $\delta_3 = -2.33^\circ$ where p is the distance between P and A , δ_3 is the angle rotating AB to AP .
- 4) calculate and plot the angular displacement of links 3 and 4 and the path coordinates of point P with respect to the angle of the input crank O_2A for one revolution.

Hint: You can use the MATLAB script on Canvas as a basis. Using the script (only the OPEN configuration, not the CROSSED), you should be able to find the angular displacement of links 3 and 4 (θ_3 and θ_4) given the angle of the input crank O_2A (θ_2).

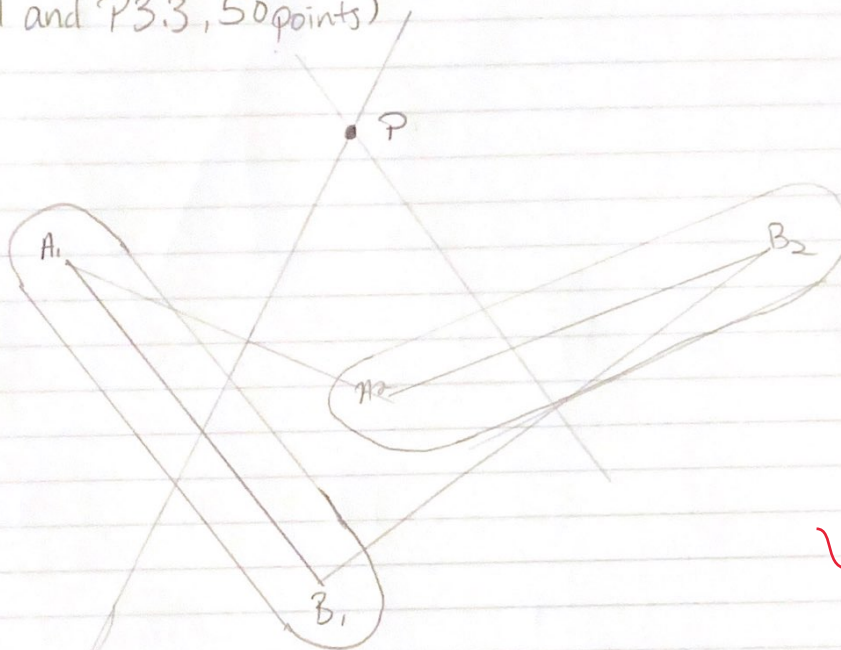
Now if you use this script manually, you can have sth like

θ_2	θ_3	θ_4
0°		
5°		
10°		
$\vdots$		
360°		

Christopher Medlow

2. (P5.1 and P3.3, 50 points)

a.)



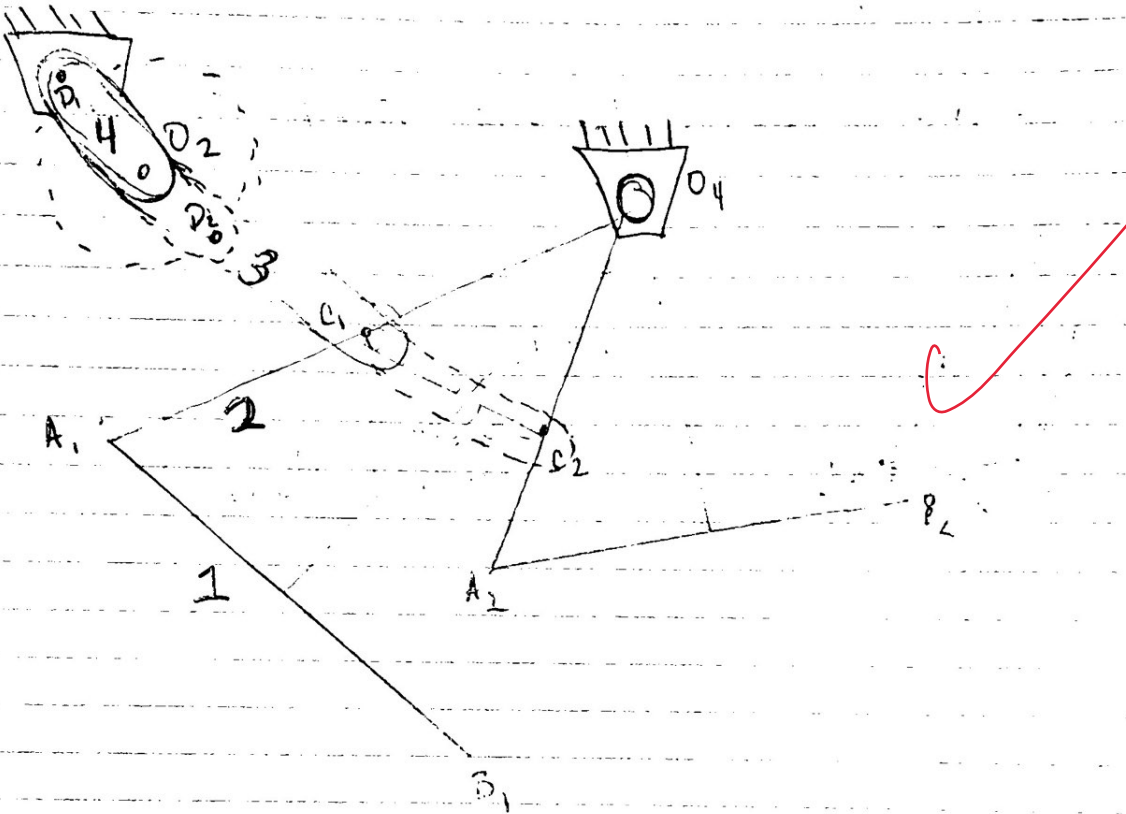
b.) $A_1 \begin{bmatrix} 0 \\ 1.750 \end{bmatrix}$ $B_1 \begin{bmatrix} 1.721 \\ 0 \end{bmatrix}$ $A_2 \begin{bmatrix} 2.656 \\ 0.999 \end{bmatrix}$ $B_2 \begin{bmatrix} 5.065 \\ 1.464 \end{bmatrix}$

$$\begin{bmatrix} 2(0 - 2.656) & 2(1.750 - 0.999) \\ 2(1.721 - 5.065) & 2(0 - 1.464) \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} (0^2 + 1.750^2) - (2.656^2 + 0.999^2) \\ (1.721^2 + 0^2) - (5.065^2 + 1.464^2) \end{bmatrix}$$

$$\begin{bmatrix} -5.312 & 1.502 \\ -6.688 & -2.938 \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 3.0625 - 8.052337 \\ 2.96184 - 27.8122 \end{bmatrix} = \begin{bmatrix} -4.9898 \\ -24.8503 \end{bmatrix}$$

$$P_x = 2.0284$$

$$P_y = 3.85142$$



Professor, on 9/29/21 I woke up with a cold so I chose to stay in my room for the day and scheduled a Covid Test. My intention was to ask you in class if you could go more in depth with how to use the MATLAB function. I asked other students and many claimed they were lost/confused about it. This HW is halfway done. If you could help us gather a better understanding and allow a late submission for MATLAB part it would be greatly appreciated!

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

HOMEWORK 3

TOPICS COVERED IN HOMEWORK 3

- 1. Velocity analysis**
- 2. Acceleration analysis**

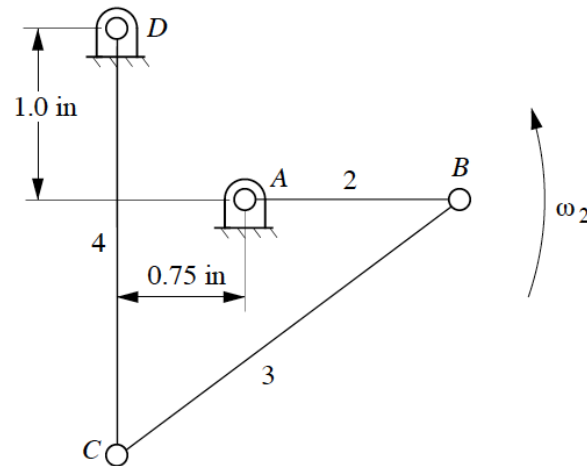
MCEG 3305 Kinematics Design and Analysis

Homework #3 Due 10/20/2021

Use this page as your cover page

Student's name: _____ Grade: _____

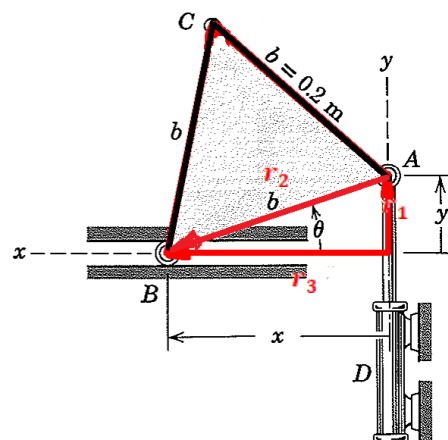
Problem 1. (50 points): In the four-bar mechanism below, link 2 is rotating CCW at the rate of 4 rad/s (constant). In the position shown, link 2 is horizontal and link 4 is vertical. Determine the angular velocity of links 3 and 4.



Link lengths: $AB = 1.25$ in, $BC = 2.5$ in

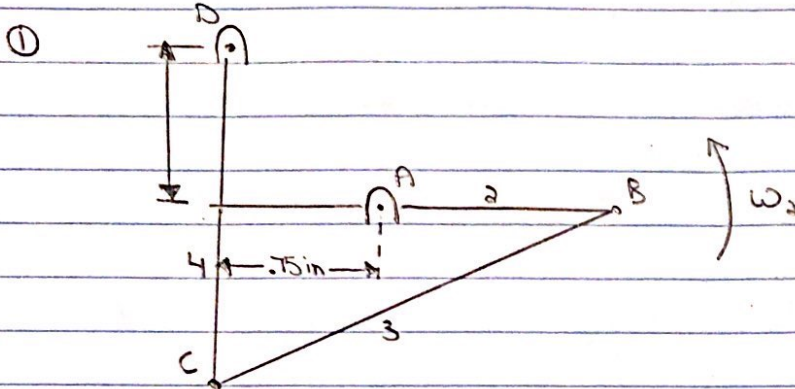
Problem 2 (50 points).

Motion of the equilateral triangular plate ABC in its plane is controlled by the hydraulic cylinder D . If the piston rod in the cylinder is moving upward at the constant rate of 0.3 m/s during an interval of its motion, for the instant when $\theta = 30^\circ$, calculate (a) the velocity and acceleration of the center of the roller B in the horizontal guide and (b) the angular velocity and angular acceleration of edge AB .



ABOVE AVERAGE

Wendell Smith
MECE 3305
HW # 3



$$AB = 1.25 \text{ in}, \quad BC = 2.5 \text{ in}$$

~~1.25~~ 2.5

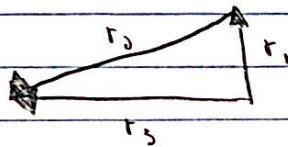
- ② The piston rod in the cylinder is moving upward at the constant rate of .3 m/s during an interval of its motion, for the instant when $\theta = 30^\circ$, calculate
- the velocity and acceleration of the center of the roller B in the horizontal guide.
 - The angular velocity and angular acceleration of edge AB.

$$|\dot{r}_1| = .3 \text{ m/s (constant)}$$

$$a) |\dot{r}_3|, |\ddot{r}_3|$$

$$b) \dot{\theta}_2, \ddot{\theta}_2$$

③



position analysis

$$r_1 + r_2 - r_3 = 0$$

$$|r_1| = 0.2 \sin 30^\circ \quad \theta_1 = 90^\circ \text{ (constant)}$$

$$= 0.1$$

$$|r_2| = 0.2 \text{ (constant)} \quad \theta_2 = 210^\circ$$

$$|r_3| = 0.2 \cos 30^\circ \quad \theta_3 = 180^\circ \text{ (constant)}$$

$$= 0.1732$$

velocity analysis

$$\dot{r}_1 + \dot{r}_2 + \dot{r}_3 = 0$$

$$|\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |\dot{r}_2| \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix} = |\dot{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix}$$

cont. →

$$|\dot{r}_3| \begin{bmatrix} \cos \phi_3 \\ \sin \phi_3 \end{bmatrix} = |r_2| \dot{\phi}_2 \begin{bmatrix} -\sin \phi_2 \\ \cos \phi_2 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \phi_1 \\ \sin \phi_1 \end{bmatrix}$$

$$\begin{bmatrix} \cos \phi_3 & |r_2| \sin \phi_2 \\ \sin \phi_3 & -|r_2| \cos \phi_2 \end{bmatrix} \begin{bmatrix} |\dot{r}_3| \\ \dot{\phi}_2 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \phi_1 \\ \sin \phi_1 \end{bmatrix}$$

$$\begin{bmatrix} \cos 180^\circ & 0.2 \sin 210^\circ \\ \sin 180^\circ & -0.2 \cos 210^\circ \end{bmatrix} \begin{bmatrix} |\dot{r}_3| \\ \dot{\phi}_2 \end{bmatrix} = .3 \begin{bmatrix} \cos 90^\circ \\ \sin 90^\circ \end{bmatrix}$$

$$\begin{bmatrix} |\dot{r}_3| \\ \dot{\phi}_2 \end{bmatrix} = \begin{bmatrix} \cos 180^\circ & 0.2 \sin 210^\circ \\ \sin 180^\circ & -0.2 \cos 210^\circ \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ .3 \end{bmatrix}$$

$$= \begin{bmatrix} -.1732 \\ 1.7321 \end{bmatrix}$$

Acceleration Analysis

$$\ddot{r}_1 + \ddot{r}_2 = \ddot{r}_3$$

$$\text{constants} \rightarrow \phi_1, |r_2|, \phi_2, |\dot{r}_1|$$

$$\ddot{r}_1 = |\ddot{r}_1| \begin{bmatrix} \cos \phi_1 \\ \sin \phi_1 \end{bmatrix} = 0$$

$$|r_2| \ddot{\phi}_2 \begin{bmatrix} -\sin \phi_2 \\ \cos \phi_2 \end{bmatrix} + |r_2| \dot{\phi}_2^2 \begin{bmatrix} \cos \phi_2 \\ \sin \phi_2 \end{bmatrix} = |\ddot{r}_3| \begin{bmatrix} \cos \phi_3 \\ \sin \phi_3 \end{bmatrix}$$

$$|\ddot{r}_3| \begin{bmatrix} \cos \phi_3 \\ \sin \phi_3 \end{bmatrix} - |r_2| \dot{\phi}_2^2 \begin{bmatrix} -\sin \phi_2 \\ \cos \phi_2 \end{bmatrix} = |r_2| \ddot{\phi}_2 \begin{bmatrix} -\cos \phi_2 \\ -\sin \phi_2 \end{bmatrix}$$

cont. $\rightarrow$

$$\begin{bmatrix} \cos \theta_3 & |r_2| \sin \theta_2 \\ \sin \theta_3 & -|r_2| \cos \theta_2 \end{bmatrix} \begin{bmatrix} \ddot{r}_3 \\ \ddot{\theta}_2 \end{bmatrix} = |r_2| \ddot{\theta}_2 \begin{bmatrix} -\cos \theta_2 \\ -\sin \theta_2 \end{bmatrix}$$

$$\begin{bmatrix} \cos 180 & .2 \sin 210 \\ \sin 180 & -.2 \cos 210 \end{bmatrix} \begin{bmatrix} \ddot{r}_3 \\ \ddot{\theta}_2 \end{bmatrix} = 0.2 (1.7321)^2 \begin{bmatrix} -\cos 20 \\ -\sin 20 \end{bmatrix}$$

$$\begin{bmatrix} \ddot{r}_3 \\ \ddot{\theta}_2 \end{bmatrix} = \begin{bmatrix} \cos 180 & .2 \sin 210 \\ \sin 180 & -.2 \cos 210 \end{bmatrix} \begin{bmatrix} -1.7321 \\ -1 \end{bmatrix}$$

$$= \begin{bmatrix} -.6929 \\ 1.7321 \end{bmatrix}$$

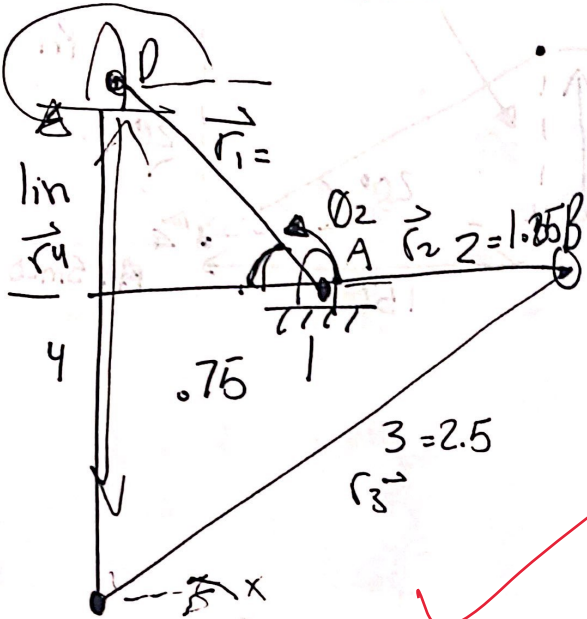
AVERAGE

Problem 1

Given:

HW#3

85



$$r_1 = \sqrt{.75^2 + 1^2} = 1.25$$

$$r_2 = 1.25$$

$$r_3 = 2.5$$

$$r_4 = ?$$

$$\theta_1 = \tan^{-1}(.75) = 53.13^\circ$$

$$\theta_2 = 0$$

$$\theta_3 = ?$$

$$\theta_4 = 270^\circ$$

$$\vec{r}_1 + \vec{r}_4 = \vec{r}_2 + \vec{r}_3 \rightarrow \begin{bmatrix} r_1 \cos \theta_1 + r_4 \cos \theta_4 \\ r_1 \sin \theta_1 + r_4 \sin \theta_4 \end{bmatrix} = \begin{bmatrix} r_2 \cos \theta_2 + r_3 \cos \theta_3 \\ r_2 \sin \theta_2 + r_3 \sin \theta_3 \end{bmatrix}$$

numbers/ unknowns

$$\begin{bmatrix} -.75 + |r_4| \cdot 0 \\ 1 + |r_4| \cdot (-1) \end{bmatrix} = \begin{bmatrix} 1.25 + 2.5 \cos \theta_3 \\ 0 + 2.5 \sin \theta_3 \end{bmatrix}$$

$$\begin{aligned} (1) \quad & -.75 = 1.25 + 2.5 \cos \theta_3 \\ & -1.25 = 2.5 \cos \theta_3 \\ & -.796 = \cos \theta_3 = 142^\circ \end{aligned}$$

$$\begin{aligned} (2) \quad & 1 + |r_4| \cdot (-1) = 2.5 \sin \theta_3 \\ & 1 + r_4 \cdot (-1) = 1.53 \\ & r_4 = 2.5 \end{aligned}$$

Velocity
in complete

10

son cah toa

$$\theta = 30^\circ$$

Problem # 2

$$\omega = 0.3 \text{ m/s} \quad \dot{r}_1 = 0.3 \text{ m/s}$$

a.) velocity & acceleration of b

b.) angular velocity & angular acceleration at edge AB

Given: $\theta_1 = 30^\circ$
 $|r_1| = 0.2 \sin 30 = 0.1 \text{ m}$

$$|r_2| = 0.2 \text{ m}$$

$$\theta_2 = 270 - 60 = 210^\circ$$

$$|r_3| = 0.2 \cos 30 = 0.173$$

$$\theta_3 = 180^\circ$$

Answer

Velocity Analysis

$$\vec{r}_1 + \vec{r}_2 = \vec{r}_3$$

$$\theta_1, \theta_3, |r_2| - \text{constant}$$

$$= 0 \quad \dot{\theta}_1 = 0 \quad \dot{\theta}_3 = 0 \quad \dot{r}_2 \neq 0$$

$$|r_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_2| \dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix} = |r_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix}$$

$$|\dot{r}_1| = 0.3 \text{ m/s}$$

$$\begin{bmatrix} \cos \theta_3 & |r_2| \sin \theta_2 \\ \sin \theta_3 & -|r_2| \cos \theta_2 \end{bmatrix} \begin{bmatrix} |\dot{r}_3| \\ \dot{\theta}_2 \end{bmatrix} = \begin{bmatrix} |\dot{r}_1| \cos \theta_1 \\ |\dot{r}_1| \sin \theta_1 \end{bmatrix}$$

$$\begin{bmatrix} -1 & -0.1 \\ 0 & 0.173 \end{bmatrix} \begin{bmatrix} |\dot{r}_3| \\ \dot{\theta}_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0.3 \end{bmatrix} = \begin{bmatrix} |\dot{r}_3| \\ \dot{\theta}_2 \end{bmatrix} = \begin{bmatrix} -0.1732 \\ 1.732 \end{bmatrix}$$

Acceleration analysis

$$\vec{r}_1 + \vec{r}_2 = \vec{r}_3$$

$$\ddot{\theta}_1 = 0 \quad \ddot{\theta}_3 = 0, \quad \ddot{r}_1 = 0$$

Acceleration Analysis

$$\ddot{\vec{r}}_1 + \ddot{\vec{r}}_2 = \ddot{\vec{r}}_3$$

$$\ddot{\theta}_1 = 0 \quad |\ddot{\vec{r}}_1| = 0$$

$$\ddot{\theta}_3 = 0$$

$$|\ddot{\vec{r}}_2| = 0$$

$$|r_2| \ddot{\theta}_2 \begin{bmatrix} \sin \theta_2 \\ \cos \theta_2 \end{bmatrix} + |r_2| \dot{\theta}_2^2 \begin{bmatrix} -\cos \theta_2 \\ \sin \theta_2 \end{bmatrix} = |\dot{\vec{r}}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix}$$

$$\begin{bmatrix} \cos \theta_3 & |r_2| \sin \theta_2 \\ \sin \theta_3 & -|r_2| \cos \theta_2 \end{bmatrix} \begin{bmatrix} |\dot{\vec{r}}_3| \\ \dot{\theta}_2 \end{bmatrix} = \begin{bmatrix} -|r_2| \dot{\theta}_2^2 \cos \theta_2 \\ -|r_2| \dot{\theta}_2^2 \sin \theta_2 \end{bmatrix}$$

bring in numbers

$$\begin{bmatrix} -1 & -.1 \\ 0 & .1732 \end{bmatrix} \begin{bmatrix} |\dot{\vec{r}}_3| \\ \dot{\theta}_2 \end{bmatrix} = \begin{bmatrix} .5196 \\ .3 \end{bmatrix}$$

$$\boxed{|\dot{\vec{r}}_3| = [-.693]} \quad \times$$

Problem # 2

continue

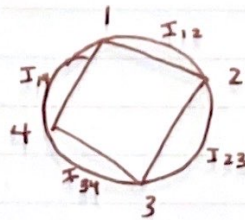
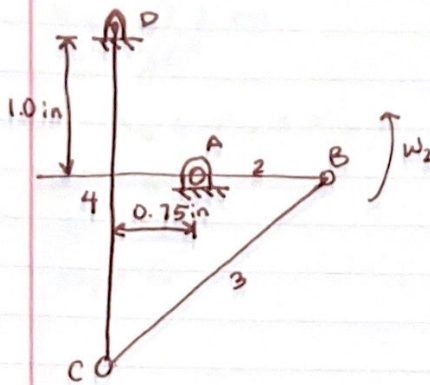
-5

BELOW AVERAGE

60/100

Kiarla
moon

Problem 1



link 2 rotating CCW
@ rate of 4 rad/s (constant)

AB = 1.25 in, BC = 2.5 in

Instantaneous centers

$$\binom{n}{2} = \frac{n!}{2!(n-2)!} = \frac{n(n-1)}{2} \rightarrow \frac{4(4-1)}{2} = \frac{4(3)}{2} = 6$$

$$\frac{\omega_2}{\omega_3} = \frac{I_{13} I_{23}}{I_{12} I_{23}} \rightarrow \frac{4}{\omega_3} = \frac{0.75 + 1.25}{1.25}$$

$$\omega_3 = 2.5 \text{ rad/s CCW}$$

Same side as relative I centers

$$V_{I_{34}} = I_{13} \cdot I_{34} \cdot \omega_3 = I_{14} \cdot I_{34} \cdot \omega_4$$

$$\frac{\omega_3}{\omega_4} = \frac{I_{14} I_{34}}{I_{13} I_{34}}$$

$$I_{13} I_{34} = \sqrt{(2.5)^2 + (1.25 + 0.75)^2} = 1.5 \text{ in}$$

$$\frac{2.5}{\omega_4} = \frac{1 + 1.5}{1.5} \Rightarrow \omega_4 = 1.5 \text{ rad/s}$$

link 3 & 4

$$I_{14} = I_{13} = I_{34}$$

$$\omega_4 = 1.5 \text{ rad/s (CCW)}$$

not using
vector loop

Problem 2

$$v_1 = 0.3 \text{ m/s}$$

$$v_3 = 0.2 \text{ m}$$

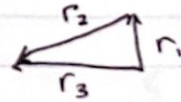
$$\theta = 30^\circ$$

$$v_3 = v_1 + v_2$$

$$\theta_2 = 30^\circ$$

$$\theta_1 = 90^\circ$$

$$\theta_3 = 0$$



KM



40

Problem 2

$$AB = BC = CA = b = 0.2 \text{ m}$$

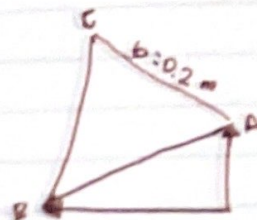
$$\theta = 30^\circ$$

constant rate of 0.3 m/s

$$y = b \sin \theta$$

$$x = b \cos \theta$$

$$x^2 + y^2 = b^2$$



KM

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

HOMEWORK 4

TOPICS COVERED IN HOMEWORK 4

- 1. Cam design using polynomial function**

MCEG 3305 Kinematics Design and Analysis

Homework #4 Due 11/17/2021

Use this page as your cover page

Student's name: _____ Grade: _____

Problem 1. Design the rise function for double-dwell cam using polynomial function.

Problem: Consider the following double-dwell cam specification

 dwell at zero displacement for 90 degrees (low dwell)

 rise h in 90 degrees

 dwell at h for 90 degrees (high dwell)

 fall h in 90 degrees

 cam ω 2π rad/sec

Boundary conditions:

	when $\theta = 0$	when $\theta = \beta$
$s =$	0	h
$v =$	0	0
$a =$	0	0
$j =$	0	0

Hint: The procedure is similar to Example 8-5 (page 431) on the textbook.

ABOVE AVERAGE

MCEG 3305 Kinematics Design and Analysis

Homework #4 Due 11/17/2021

Use this page as your cover page

Student's name: _____

Grade: 100

Problem 1. Design the rise function for double-dwell cam using polynomial function.

Problem: Consider the following double-dwell cam specification

dwell at zero displacement for 90 degrees (low dwell)

rise h in 90 degrees

dwell at h for 90 degrees (high dwell)

fall h in 90 degrees

cam ω 2π rad/sec

Boundary conditions:

	when $\theta = 0$	when $\theta = \beta$
$s =$	0	h
$v =$	0	0
$a =$	0	0
$j =$	0	0

Hint: The procedure is similar to Example 8-5 (page 431) on the textbook.

Chris Medlow

①

HW #11

1.

$$s = C_0 + C_1 \left(\frac{\theta}{\beta}\right) + C_2 \left(\frac{\theta}{\beta}\right)^2 + C_3 \left(\frac{\theta}{\beta}\right)^3 + C_4 \left(\frac{\theta}{\beta}\right)^4 + C_5 \left(\frac{\theta}{\beta}\right)^5 + C_6 \left(\frac{\theta}{\beta}\right)^6 + C_7 \left(\frac{\theta}{\beta}\right)^7$$

$$v = \frac{1}{\beta} \left[C_1 + 2C_2 \left(\frac{\theta}{\beta}\right) + 3C_3 \left(\frac{\theta}{\beta}\right)^2 + 4C_4 \left(\frac{\theta}{\beta}\right)^3 + 5C_5 \left(\frac{\theta}{\beta}\right)^4 + 6C_6 \left(\frac{\theta}{\beta}\right)^5 + 7C_7 \left(\frac{\theta}{\beta}\right)^6 \right]$$

$$a = \frac{1}{\beta^2} \left[2C_2 + 6C_3 \left(\frac{\theta}{\beta}\right) + 12C_4 \left(\frac{\theta}{\beta}\right)^2 + 20C_5 \left(\frac{\theta}{\beta}\right)^3 + 30C_6 \left(\frac{\theta}{\beta}\right)^4 + 42C_7 \left(\frac{\theta}{\beta}\right)^5 \right]$$

$$j = \frac{1}{\beta^3} \left[6C_3 + 24C_4 \left(\frac{\theta}{\beta}\right) + 60C_5 \left(\frac{\theta}{\beta}\right)^2 + 120C_6 \left(\frac{\theta}{\beta}\right)^3 + 210C_7 \left(\frac{\theta}{\beta}\right)^4 \right]$$

$$C \theta = \beta \quad s = h$$

$$h = C_4 \left(\frac{\theta}{\beta}\right)^4 + C_5 \left(\frac{\theta}{\beta}\right)^5 + \dots = C_4 + C_5 + C_6 + C_7 = h$$

$$C \theta = \beta \quad v = 0$$

$$0 = \frac{1}{\beta} [4C_4 + 5C_5 + 6C_6 + 7C_7] \Rightarrow 4C_4 + 5C_5 + 6C_6 + 7C_7 = 0$$

$$C \theta = \beta \quad a = 0$$

$$6C_4 + 10C_5 + 15C_6 + 21C_7 = 0$$

$$C \theta = \beta \quad j = 0$$

$$4C_4 + 10C_5 + 20C_6 + 35C_7 = 0$$

$$C_4 = 35h \quad C_5 = 84h \quad C_6 = 70h \quad C_7 = -20h$$

$$s = h \left(35 \left(\frac{\theta}{\beta}\right)^4 - 84 \left(\frac{\theta}{\beta}\right)^5 + 70 \left(\frac{\theta}{\beta}\right)^6 - 20 \left(\frac{\theta}{\beta}\right)^7 \right)$$

AVERAGE

Use this page as your cover page

Student's name: Temitayo OjoGrade: 90**Problem 1.** Design the rise function for double-dwell cam using polynomial function.

Problem: Consider the following double-dwell cam specification

dwell at zero displacement for 90 degrees (low dwell)

rise h in 90 degreesdwell at h for 90 degrees (high dwell)fall h in 90 degreescam ω 2π rad/sec

Boundary conditions:

	when $\theta = 0$	when $\theta = \beta$
$s =$	0	h
$v =$	0	0
$a =$	0	0
$j =$	0	0

8 BCS.

7 Polynomials.

Hint: The procedure is similar to Example 8-5 (page 431) on the textbook.

$$\theta = 0 \rightarrow s = 0; v = 0; a = 0; j = 0$$

$$\theta = \beta \rightarrow s = h; v = 0; a = 0; j = 0$$

$$s = c_0 + c_1\left(\frac{\theta}{\beta}\right) + c_2\left(\frac{\theta}{\beta}\right)^2 + c_3\left(\frac{\theta}{\beta}\right)^3 + c_4\left(\frac{\theta}{\beta}\right)^4 + c_5\left(\frac{\theta}{\beta}\right)^5 + c_6\left(\frac{\theta}{\beta}\right)^6 + c_7\left(\frac{\theta}{\beta}\right)^7$$

$$v = \frac{1}{\beta} \left[c_1 + 2c_2\left(\frac{\theta}{\beta}\right) + 3c_3\left(\frac{\theta}{\beta}\right)^2 + 4c_4\left(\frac{\theta}{\beta}\right)^3 + 5c_5\left(\frac{\theta}{\beta}\right)^4 + 6c_6\left(\frac{\theta}{\beta}\right)^5 + 7c_7\left(\frac{\theta}{\beta}\right)^6 \right]$$

$$a = \frac{1}{\beta^2} \left[2c_2 + 6c_3\left(\frac{\theta}{\beta}\right) + 12c_4\left(\frac{\theta}{\beta}\right)^2 + 20c_5\left(\frac{\theta}{\beta}\right)^3 + 30c_6\left(\frac{\theta}{\beta}\right)^4 + 42c_7\left(\frac{\theta}{\beta}\right)^5 \right]$$

$$j = \frac{1}{\beta^3} \left[6c_3 + 24c_4\left(\frac{\theta}{\beta}\right) + 60c_5\left(\frac{\theta}{\beta}\right)^2 + 120c_6\left(\frac{\theta}{\beta}\right)^3 + 210c_7\left(\frac{\theta}{\beta}\right)^4 \right]$$

$$\theta = 0, s = c_0 \stackrel{BC}{=} 0 \Rightarrow c_0 = 0$$

$$\theta = 0, v = \frac{1}{\beta} c_1 \stackrel{BC}{=} 0 \Rightarrow c_1 = 0$$

$$\theta = 0, a = \frac{1}{\beta^2} 2c_2 \stackrel{BC}{=} 0 \Rightarrow c_2 = 0$$

$$\theta = 0, j = \frac{1}{\beta^3} 6c_3 \stackrel{BC}{=} 0 \Rightarrow c_3 = 0$$

$$\theta = \beta, s = c_4 + c_5 + c_6 + c_7 = h$$

$$\theta = \beta, v = \frac{1}{\beta} [4c_4 + 5c_5 + 6c_6 + 7c_7] = 0$$

$$\theta = \beta, a = \frac{1}{\beta^2} [12c_4 + 20c_5 + 30c_6 + 42c_7] = 0$$

$$\theta = \beta, j = \frac{1}{\beta^3} [24c_4 + 60c_5 + 120c_6 + 210c_7] = 0$$

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 4 & 5 & 6 & 7 \\ 12 & 20 & 30 & 42 \\ 24 & 60 & 120 & 210 \end{bmatrix} \begin{bmatrix} c_4 \\ c_5 \\ c_6 \\ c_7 \end{bmatrix} = \begin{bmatrix} h \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$c_4, c_5, c_6, c_7 = ?$$

$$s = ?$$

BELOW AVERAGE

HW#4

50/100

Given: double dwell cam

dwell @ 0 displacement for 90° (low)

rise h in 90°

dwell @ h for 90° (high) $2\pi \text{ rad/sec} = 1 \text{ rev/sec}$

fall h in 90°

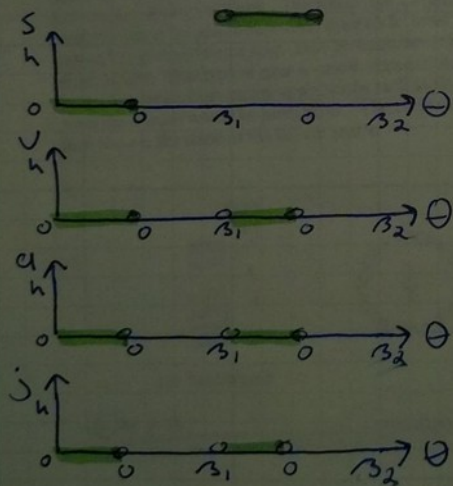
cam ω $2\pi \text{ rad/sec}$

Find: rise function using polynomial function

Assume: B.C.

	$\theta = 0$	$\theta = \beta$
$s =$	0	h
$v =$	0	0
$a =$	0	0
$j =$	0	0

Solution:



~~$$s = C_0 + C_1\left(\frac{\theta}{\beta}\right) + C_2\left(\frac{\theta}{\beta}\right)^2 + C_3\left(\frac{\theta}{\beta}\right)^3 + C_4\left(\frac{\theta}{\beta}\right)^4 + C_5\left(\frac{\theta}{\beta}\right)^5$$~~

$$0 = C_0 + 0 + 0 + \dots$$

$$C_0 = 0$$

$$0 = \frac{1}{\beta} (C_1 + 0 + 0 + \dots)$$

$$C_1 = 0$$

$$0 = \frac{1}{\beta^2} (C_2 + 0 + 0 + \dots)$$

$$C_2 = 0$$

$$h = C_3 + C_4 + C_5$$

$$0 = \frac{1}{\beta} (3C_3 + 4C_4 + 5C_5)$$

$$0 = \frac{1}{\beta^2} (6C_3 + 12C_4 + 20C_5)$$

$$C_3 = 10h$$

$$C_4 = -15h$$

$$C_5 = 6h$$

$$s = h \left[10\left(\frac{\theta}{\beta}\right)^3 - 15\left(\frac{\theta}{\beta}\right)^4 + 6\left(\frac{\theta}{\beta}\right)^5 \right]$$

$$s = C_0 + C_1\left(\frac{\theta}{\beta}\right) + C_2\left(\frac{\theta}{\beta}\right)^2 + C_3\left(\frac{\theta}{\beta}\right)^3 + C_4\left(\frac{\theta}{\beta}\right)^4 + C_5\left(\frac{\theta}{\beta}\right)^5$$

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

GRADED DISCUSSION FORUM # 1

TOPICS COVERED IN GRADED DISCUSSION FORUM #1

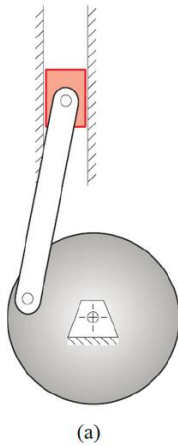
- 1. Degree of freedom**
- 2. Number synthesis**

Degree of Freedom and Number Synthesis

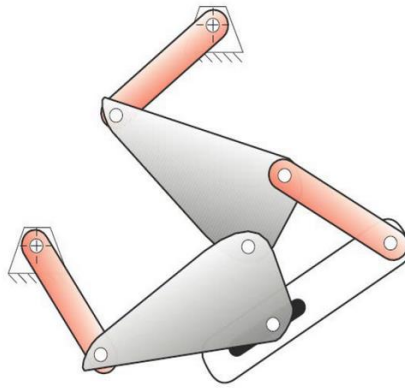
Aug 31 at 11:33am

1 30

Problem 1. Find the mobility of the following two mechanisms.



(a)



(b)

Problem 2. Use number synthesis to find all the possible link combinations for 2-DOF, for 7 links, to hexagonal order, using only revolute joints.

ABOVE AVERAGE

DOF and Number Synthesis Discussion

2/2

1. Mobility for mechanism (a)

$$L = 4 \quad J_1 = 4 \quad J_2 = 0$$

$$M = 3(L-1) - 2J_1 - J_2$$

$$= 3(4-1) - 2(4) - 0$$

$$= 9 - 8$$

$$M = 1$$

Mobility for mechanism (b)

$$L = 7 \quad J_1 = 7 \quad J_2 = 1$$

$$M = 3(L-1) - 2J_1 - J_2$$

$$= 3(7-1) - 2(7) - 1$$

$$= 18 - 14 - 1$$

$$M = 3$$

$$2. L = B + T + Q + P + H$$

$$L - 3 - M = T + 2Q + 3P + 4H \quad (M=2)$$

$$7 - 3 - 2 = \underline{2} = T + 2Q + 3P + 4H$$

$$T = 0, 1, 2 \quad + \quad Q = 0, 1$$

$$Q = 0: T = 2$$

$$L = B + T + Q = 7$$

$$= B + 2 + 0 = 7, \text{ Therefore } B = 5$$

$$Q = 1: T = 0$$

$$L = B + T + Q = 7$$

$$= B + 0 + 1 = 7, \text{ Therefore } B = 6$$

AVERAGE

Guy Green

ME63305 Dr. Duan
MW 12-1:30

1.4/2

Degree of Freedom
+
Number Synthesis

Problem 1.)

a.) $N = 3(L-1) - 2J_1 - J_2$

$L = 3$

$J_1 = 3$

$J_2 = 0$

$N = 0$

b.) $L = 7$

$J_1 = 8$

$J_2 = 0$

$N = 2$

Problem 2) Possible Link Combinations For 2-DOF

Given: DOF = 2
 $L = 7$

$$J = \frac{3}{2}(L-1) - \frac{1}{2}N$$
$$= \frac{3}{2}(7-1) - \frac{1}{2}(2)$$
$$= 8$$

$$N = 2(J)$$
$$= 2(8)$$
$$= 16$$

$T = 0, 1, 2$ $Q = 0, 1$

$Q = 0, T = 2$

$Q = 1, T = 0$

$T = 2 - 2Q$
 $T = 2$

$B = L - T - Q$
 $B = 5$

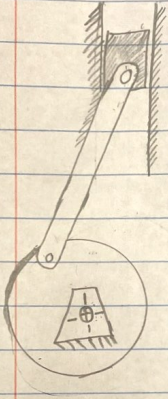
$L - 3 - M = T + 2Q + 3P + 4H$

$7 - 3 - 2 = T + 2Q$

$2 = T + 2Q$

BELOW AVERAGE

1/2

Kinematic Analysis DesignHomework #1Idris Agbala

$$L=4 \quad J_1=3 \quad J_2=0$$

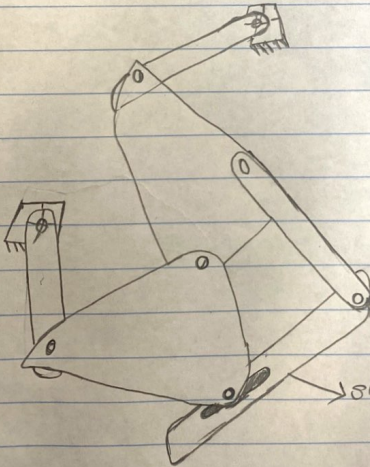
$$M = 3(L-1) - 2J_1 - J_2$$

$$M = 3(4-1) - 2(3) - 0$$

$$M = 3(3) - 6$$

$$M = 9 - 6$$

$$= 3$$



$$L=7 \quad J_1=8 \quad J_2=0$$

$$M = 3(L-1) - 2J_1 - J_2$$

$$M = 3(7-1) - 2(8) - 0$$

$$M = 3(6) - 16$$

$$M = 18 - 16$$

$$M = 2$$

→ sliding full joint

2 missing

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

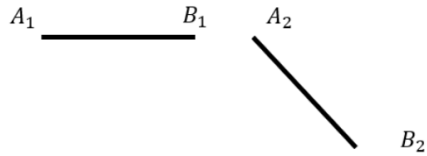
GRADED DISCUSSION FORUM # 2

TOPICS COVERED IN GRADED DISCUSSION FORUM #2

- 1. Linkage synthesis**



- 1) Graphically find the pivot that makes link AB move from position A_1B_1 to A_2B_2 .



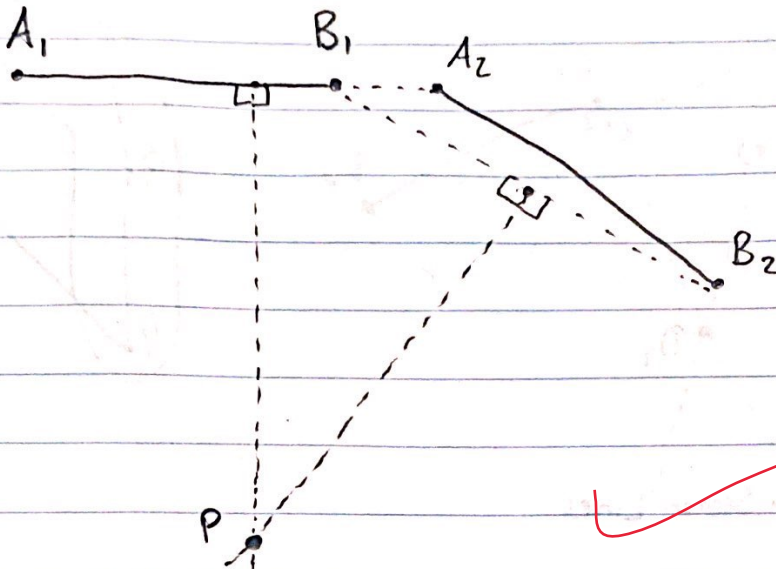
- 2) If $A_1 = \begin{bmatrix} 0 \\ 4 \end{bmatrix}$, $B_1 = \begin{bmatrix} 5 \\ 4 \end{bmatrix}$, $A_2 = \begin{bmatrix} 6 \\ 4 \end{bmatrix}$, $B_2 = \begin{bmatrix} 9 \\ 0 \end{bmatrix}$ find the location of the pole.

ABOVE AVERAGE

2/2

Tyler Marcel

1)



2)

$$\begin{bmatrix} 2(0-6) & 2(4-4) \\ 2(5-9) & 2(4-0) \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} (0^2+4^2) - (6^2+4^2) \\ (5^2+4^2) - (9^2+0^2) \end{bmatrix}$$

$$\begin{bmatrix} -12 & 0 \\ -8 & 8 \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} -36 \\ -40 \end{bmatrix}$$

$$\begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 3 \\ -2 \end{bmatrix}$$

$$-12P_x = -36$$

$$P_x = 3$$

$$-8P_x + 8P_y = -40$$

$$-8(3) + 8P_y = -40$$

$$8P_y = -16$$

$$P_y = -2$$

$$\begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 3 \\ -2 \end{bmatrix}$$

AVERAGE

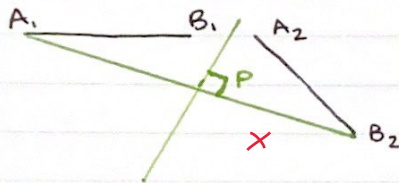
September 22, 2021

1. 3/2

Linkage Synthesis

Kiaria Moon

1.



- 7

2. If $A_1 = \begin{bmatrix} 0 \\ 4 \end{bmatrix}$, $B_1 = \begin{bmatrix} 5 \\ 4 \end{bmatrix}$, $A_2 = \begin{bmatrix} 6 \\ 4 \end{bmatrix}$, $B_2 = \begin{bmatrix} 9 \\ 0 \end{bmatrix}$ find the location of the pole.

$$A_1 \begin{bmatrix} A_{1x} \\ A_{1y} \end{bmatrix} = \begin{bmatrix} 0 \\ 4 \end{bmatrix}$$

$$B_1 \begin{bmatrix} B_{1x} \\ B_{1y} \end{bmatrix} = \begin{bmatrix} 5 \\ 4 \end{bmatrix}$$

$$A_2 \begin{bmatrix} A_{2x} \\ A_{2y} \end{bmatrix} = \begin{bmatrix} 6 \\ 4 \end{bmatrix}$$

$$B_2 \begin{bmatrix} B_{2x} \\ B_{2y} \end{bmatrix} = \begin{bmatrix} 9 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} 2(0-4) & 2(4-4) \\ 2(5-9) & 2(4-0) \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} (0^2+4^2) - (6^2+4^2) \\ (5^2+4^2) - (9^2-0^2) \end{bmatrix}$$

$$= \begin{bmatrix} -12 & 0 \\ -8 & 8 \end{bmatrix} \begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} -36 \\ -40 \end{bmatrix}$$

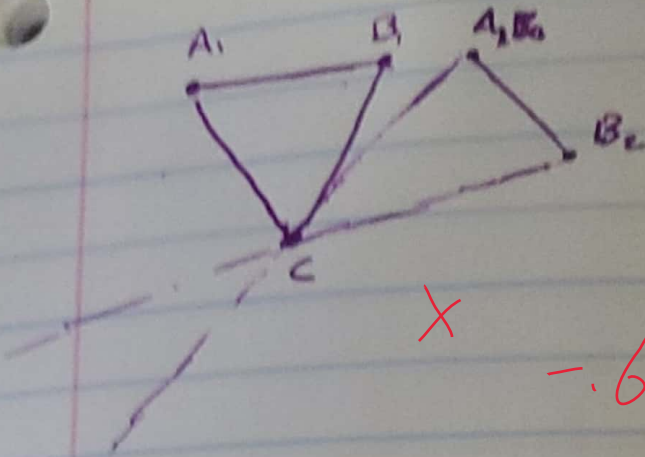
$$\begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} -12 & 0 \\ -8 & 8 \end{bmatrix}^{-1} \begin{bmatrix} -36 \\ -40 \end{bmatrix}$$

$$* P = [A]^{-1}[B]$$

$$\begin{bmatrix} P_x \\ P_y \end{bmatrix} = \begin{bmatrix} 3 \\ -2 \end{bmatrix}$$

BELOW AVERAGE

1.1/2



$$A_1 \begin{bmatrix} 0 \\ 4 \end{bmatrix}$$

$$\begin{bmatrix} 2(0-4) & 2(4-4) \\ 2(5-4) & 2(4-0) \end{bmatrix}$$

$$\begin{bmatrix} -12 & 0 \\ -8 & 8 \end{bmatrix}$$

$$\begin{bmatrix} (0^2+4^2)-(6^2+4^2) \\ (5^2+4^2)-(9^2+0^2) \end{bmatrix} = \begin{bmatrix} 16-52 \\ 41-81 \end{bmatrix} = \begin{bmatrix} -36 \\ -40 \end{bmatrix}$$

$$\begin{bmatrix} 8 & 0 \\ 8 & -12 \end{bmatrix} \frac{1}{(-12 \cdot 8) - (8 \cdot 0)} = \frac{1}{-96}$$

$$= -\frac{1}{96} \begin{bmatrix} 8 & 0 \\ 8 & -12 \end{bmatrix} = \begin{bmatrix} -\frac{8}{96} & 0 \\ -\frac{8}{96} & \frac{-12}{96} \end{bmatrix} = \begin{bmatrix} -\frac{1}{12} & 0 \\ \frac{1}{12} & -\frac{1}{8} \end{bmatrix}$$

$$\begin{bmatrix} -\frac{1}{12} & 0 \\ \frac{1}{12} & -\frac{1}{8} \end{bmatrix} \begin{bmatrix} -36 \\ -40 \end{bmatrix} = \begin{bmatrix} 3 \\ -8 \end{bmatrix} = \begin{bmatrix} 3 \\ 8 \end{bmatrix}$$

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

GRADED DISCUSSION FORUM # 3

TOPICS COVERED IN GRADED DISCUSSION FORUM #3

1. Vector loop equation

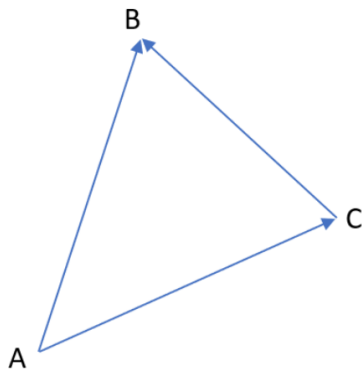


Vector Loop Equation

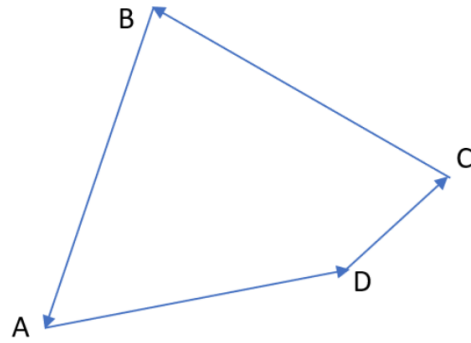
Chang Duan

Sep 8 at 8:15pm

26



(1)



(2)

In this discussion, for (1) and (2) respectively, please

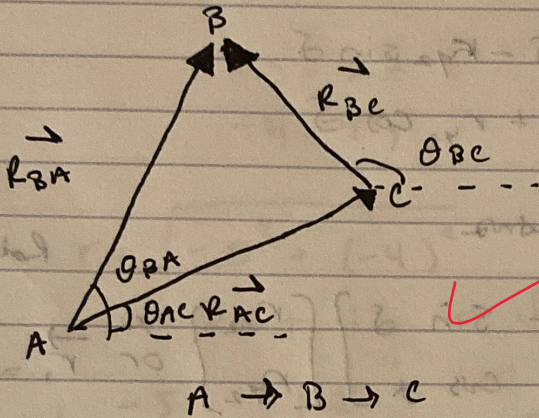
1. notate the different vectors;
2. mark their angles;
3. write the vector loop equation.

ABOVE AVERAGE

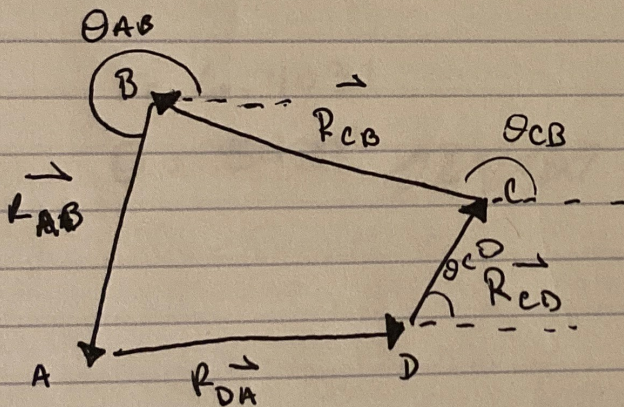
2/2

Discussion Assignment

1. Notate the different vectors
2. Mark their angles
3. Write the vector loop equation



$$r_{AB} - r_{BC} - r_{CA} = 0$$



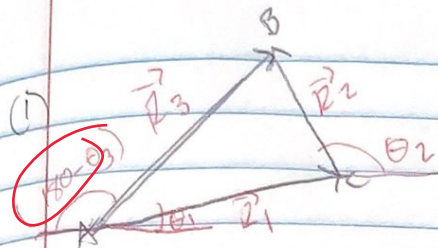
$$r_{CD} + r_{CB} + r_{AB} + r_{DA} = 0$$

AVERAGE

9/14/21

Vector loop discussion

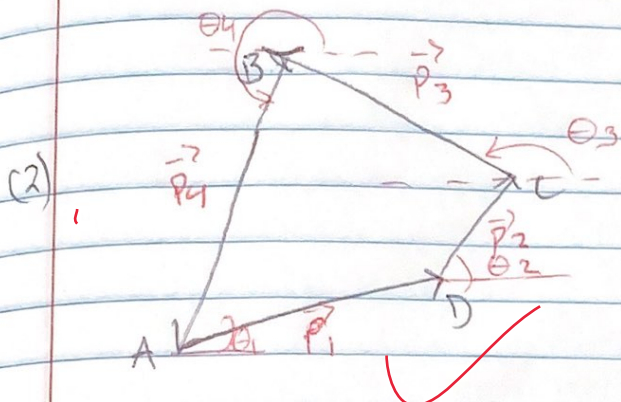
1.5/2



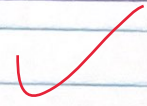
$\sum \pi_i = 0$
closed loop

$$\vec{r}_1 + \vec{r}_2 + (-\vec{r}_3) = 0 \quad -1.5$$

$$\vec{r}_1 + \vec{r}_2 + \vec{r}_3 = 0 \quad \times$$



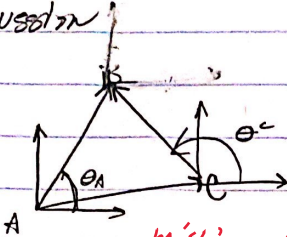
$$\vec{r}_1 + \vec{r}_2 + \vec{r}_3 + \vec{r}_4 = 0$$



BELOW AVERAGE

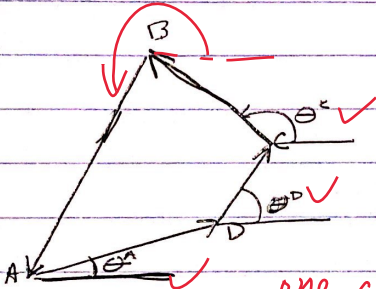
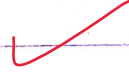
1.2/2

Discussion



missing one angle

$$R_{AB} = \frac{1}{2} CA + R_{BC}$$



$$R_{CD} = R_{AB} + R_{CB}$$

one angle wrong

-.6

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

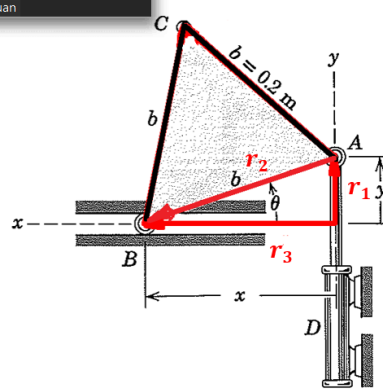
GRADED DISCUSSION FORUM # 4

TOPICS COVERED IN GRADED DISCUSSION FORUM #4

- 1. Velocity analysis**
- 2. Acceleration analysis**



Problem. Motion of the equilateral triangular plate ABC in its plane is controlled by the hydraulic cylinder D . If the piston rod in the cylinder is moving upward at the constant rate of 0.3 m/s during an interval of its motion, for the instant when $\theta = 30^\circ$, calculate (a) the velocity and acceleration of the center of the roller B in the horizontal guide and (b) the angular velocity and angular acceleration of edge AB .



Please ignore the calculation required. It is provided to show the context only. Answer the following questions in this discussion instead:

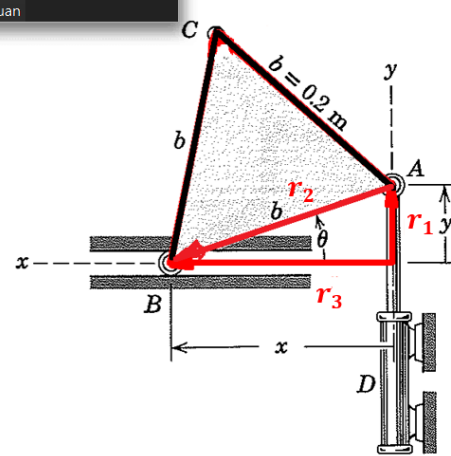
1. What is the vector loop equation for position analysis?
2. What is the vector loop equation for velocity analysis? What are the unknowns?
3. What quantities does not change with time?
4. What is the vector loop equation for acceleration analysis? What are the unknowns?

ABOVE AVERAGE

2/2

Brandon Hunter 3/16

Problem. Motion of the equilateral triangular plate ABC in its plane is controlled by the hydraulic cylinder D . If the piston rod in the cylinder is moving upward at the constant rate of 0.3 m/s during an interval of its motion, for the instant when $\theta = 30^\circ$, calculate (a) the velocity and acceleration of the center of the roller B in the horizontal guide and (b) the angular velocity and angular acceleration of edge AB .



Position

$ r_1 $	$\theta_1 = \text{constant}$
$ r_2 = \text{constant}$	θ_2
$ r_3 $	$\theta_3 = \text{constant}$

known

$|r_1|$
 $|r_2| = \text{constant}$
 $|r_3|$

$\theta_1 = \text{constant}$
 θ_2
 $\theta_3 = \text{constant}$

known

$ \dot{r}_1 = 0.3 \text{ m/s}$	$\dot{\theta}_1 = 30^\circ$
$ \dot{r}_2 = 0$	$\dot{\theta}_2 = \text{unknown}$
$ \dot{r}_3 = \text{unknown}$	$\dot{\theta}_3 = 0$

velocity

$|\dot{r}_1| = \text{constant}$

$ \ddot{r}_1 = 0$	$ \ddot{\theta}_1 = 0$
$ \ddot{r}_2 = 0$	$ \ddot{\theta}_2 = \text{unknown}$
$ \ddot{r}_3 = \text{unknown}$	$ \ddot{\theta}_3 = 0$

Acceleration



Position analysis

$$\vec{r}_3 = \vec{r}_1 + \vec{r}_2$$

$$|r_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} = |r_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix}$$

Velocity analysis

$$\dot{\vec{r}}_3 = \dot{\vec{r}}_1 + \dot{\vec{r}}_2$$

$$|\dot{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} + |r_3| \dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix}$$

$$|\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_1| \dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix}$$

$$|\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix} + |r_2| \dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix}$$

$$\underline{|\dot{r}_3|} \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} = |\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + |r_1| \dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix} + |r_2| \underline{\dot{\theta}_2} \begin{bmatrix} \sin \theta_2 \\ \cos \theta_2 \end{bmatrix}$$

$|\dot{r}_3|$ & $\dot{\theta}_2$ are unknown

Acceleration Analysis

$$\ddot{\vec{r}}_3 = \ddot{\vec{r}}_1 + \ddot{\vec{r}}_2$$

$$\ddot{\vec{r}}_i = |\ddot{r}_i| \begin{bmatrix} \cos \theta_i \\ \sin \theta_i \end{bmatrix} + 2|\dot{r}_i|\dot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i|\ddot{\theta}_i \begin{bmatrix} -\sin \theta_i \\ \cos \theta_i \end{bmatrix} + |r_i|\dot{\theta}_i^2 \begin{bmatrix} -\cos \theta_i \\ -\sin \theta_i \end{bmatrix}$$

$$|\dot{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} + 2|\dot{r}_3|\dot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} + |r_3|\ddot{\theta}_3 \begin{bmatrix} -\sin \theta_3 \\ \cos \theta_3 \end{bmatrix} + |r_3|\dot{\theta}_3^2 \begin{bmatrix} -\cos \theta_3 \\ -\sin \theta_3 \end{bmatrix}$$

$$|\dot{r}_1| \begin{bmatrix} \cos \theta_1 \\ \sin \theta_1 \end{bmatrix} + 2|\dot{r}_1|\dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix} + |r_1|\ddot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix} + |r_1|\dot{\theta}_1^2 \begin{bmatrix} -\cos \theta_1 \\ -\sin \theta_1 \end{bmatrix}$$

$$|\dot{r}_2| \begin{bmatrix} \cos \theta_2 \\ \sin \theta_2 \end{bmatrix} + 2|\dot{r}_2|\dot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix} + |r_2|\ddot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix} + |r_2|\dot{\theta}_2^2 \begin{bmatrix} -\cos \theta_2 \\ -\sin \theta_2 \end{bmatrix}$$

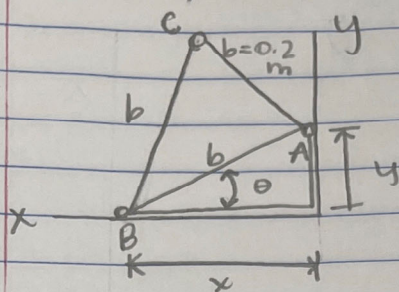
$$|\dot{r}_3| \begin{bmatrix} \cos \theta_3 \\ \sin \theta_3 \end{bmatrix} = 2|\dot{r}_1|\dot{\theta}_1 \begin{bmatrix} -\sin \theta_1 \\ \cos \theta_1 \end{bmatrix} + |r_2|\ddot{\theta}_2 \begin{bmatrix} -\sin \theta_2 \\ \cos \theta_2 \end{bmatrix} + |r_2|\dot{\theta}_2^2 \begin{bmatrix} -\cos \theta_2 \\ -\sin \theta_2 \end{bmatrix}$$

$|\dot{r}_3|$ & $\ddot{\theta}_2$ are unknown

AVERAGE

1.5/2

Velocity / Acceleration Analysis:



1) Vector loop equation (position)

$$r_2 \sin \theta_2 - r_1 = 0, r_2 \cos \theta_2 - r_3 = 0$$

2) v.l.e. (velocity)

$r_2 \dot{\theta}_2 \cos \theta_2 - \dot{r}_1 = 0; r_2 \dot{\theta}_2 \sin \theta_2 + \dot{r}_3 = 0$, We have to find R and we have the angle in the problem.

3) What quantities don't change with time?

$$\dot{r}_2 + \dot{r}_1$$

4) v.l.e. acceleration

$$r_2 [\ddot{\theta}_2 \cos \theta_2 + \dot{\theta}_2^2 \sin \theta_2] + \ddot{r}_3 = 0$$

$$r_2 [-\ddot{\theta}_2 \sin \theta_2 + \dot{\theta}_2^2 \cos \theta_2] - \ddot{r}_1 = 0$$

$$\ddot{\theta}_2 \cos \theta_2 - \dot{\theta}_2^2 \sin \theta_2 = 0$$

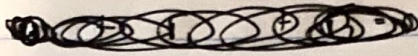
We must find $\ddot{\theta}_2 + \ddot{r}_3$

BELOW AVERAGE

0.6/2

~~Discussion~~ ^{velocity} Discussion

1)



$$r_3 = r_2 \cos \theta$$

$$r_1 = r_2 \sin \theta$$

-0.2

2)

$$\dot{y} = b (\dot{\theta} \cos \theta)$$

$$\dot{x} = -b \dot{\theta} \sin \theta$$

y, x, θ , $\sin \theta$ (unknown)

X

-0.5

3)

r_2

length

X

-0.5

4)

$$\ddot{x} = -b \dot{\theta}^2 \cos \theta$$

$$\ddot{y} = -b \dot{\theta}^2 \sin \theta$$

x, $\dot{\theta}$, $\ddot{\theta}$, $\ddot{y}$

-0.2

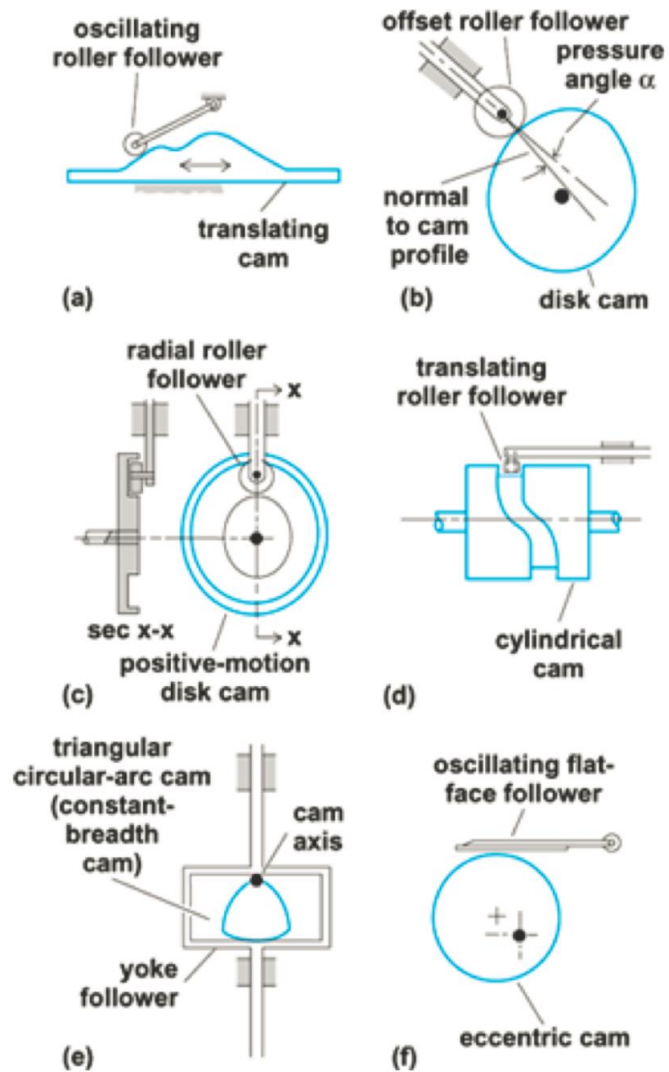
**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

GRADED DISCUSSION FORUM # 5

TOPICS COVERED IN GRADED DISCUSSION FORUM #5

1. Cam classification

Classify the following cam-follower systems:



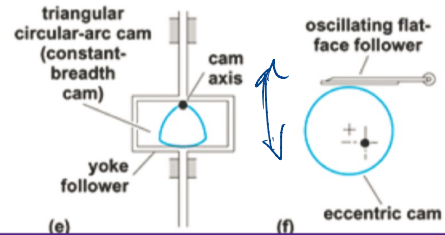
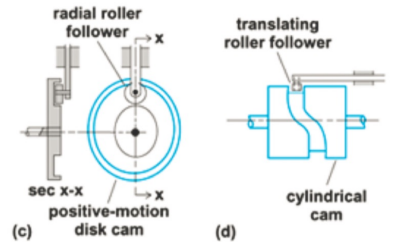
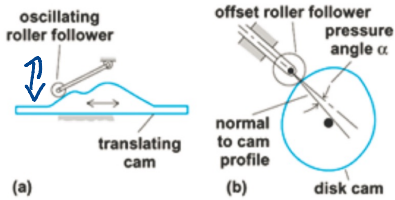
System	Follower motion	Follower shape	Cam motion	Cam shape	Relative motion	Joint closure
(a)						
(b)						
(c)						
(d)						
(e)						
(f)						

ABOVE AVERAGE

Classify the following cam-follower systems:

Zion Brown

2/2



System	Follower motion	Follower shape	Cam motion	Cam shape	Relative motion	Joint closure
(a)	Oscillating	Roller	Translating	Wedge	axial	Forced
(b)	Translating	Roller	Rotating	Disc	Radial	Forced
(c)	Translating	Roller	Rotating	Grooved	Radial	Form
(d)	Translation	Roller	Rotating	Cylindrical	Axial	Form
(e)	Translating	Yoke	Rotating	Tri Disc	Radial	Form
(f)	Oscillating	Flat Face	Rotating	Eccentric Disc	Radial	Forced



AVERAGE

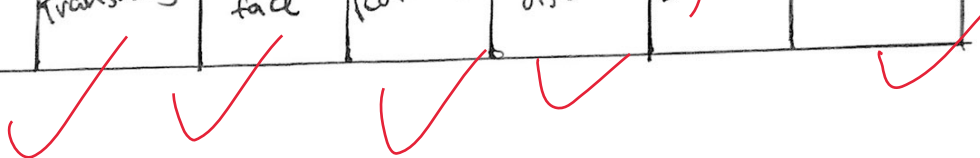
Muhammed Zaidi
P21822726

Cam Classification Discussion

MCEG 3305-POH

1.8/2

System	Follower motion	Follower shape	Cam motion	Cam shape	Relative motion	Joint closure
a)	Oscillating	Roller	Translating	wedged	Perpendicular	Force
b)	Translating	Roller	Rotating	Disc	Offset inclined	Force
c)	Translating	Roller	Rotating	grooved	Radial	Form
d)	Translating	Roller	Rotating	Cylindrical	Axial	Form
e)	Translating	Yoke	Rotating	triangular	Radial	Force X
f)	Translating	Flat face	Rotating	offset disc	Eccentric	Force



BELOW AVERAGE

1/2

System	Follower motion	Follower shape	Cam motion	Cam shape	Relative motion	Joint closure
(a)	Oscillating ✓	Roller	Linear	Linear cam ✓	Constant accel	OFE
(b)	Reciprocating ✓	Roller	Rotating	Flat cam ✓	harmonic	OFE
(c)	oscillating ✗	Roller	Rotating	Grooved plate ✓	constant velocity	box
(d)	Translating ✓	Roller	Rotating	cylindrical ✓	constant velocity	box
(e)	oscillating ✗	Faced	Rotating	Triangular ✓	Constant velocity	box
(f)	oscillating ✓	Flat Face ✓	Rotating	P-CAM ✗	F Feature	OFE

✓

✓

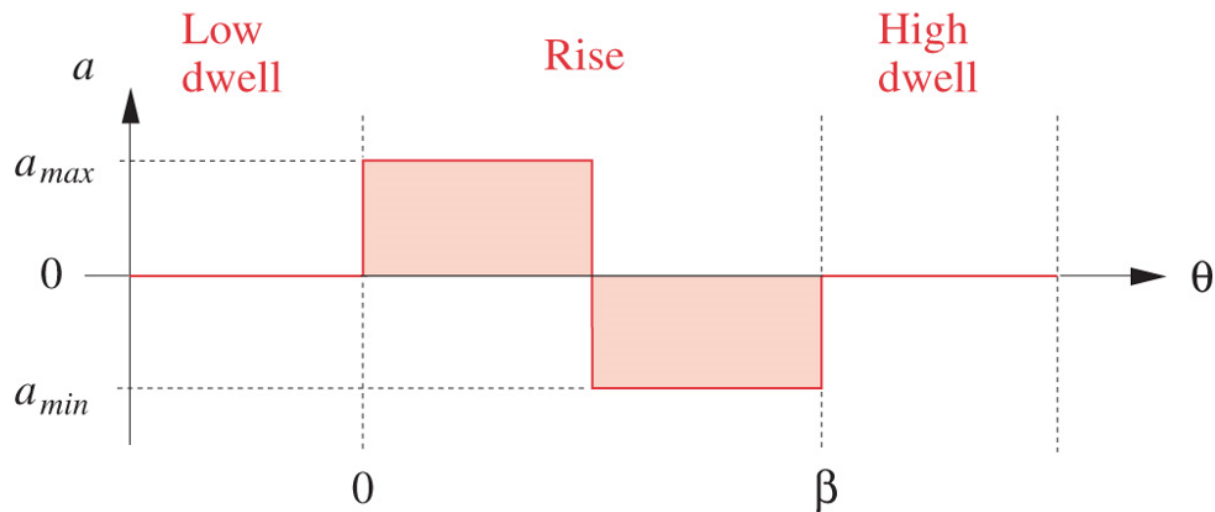
✓

**KINEMATICS DESIGN AND ANALYSIS
FALL 2021**

GRADED DISCUSSION FORUM # 6

TOPICS COVERED IN GRADED DISCUSSION FORUM #6

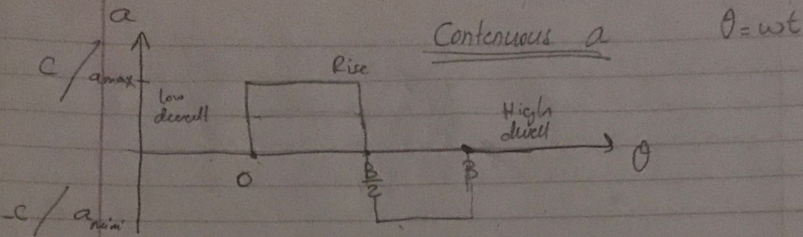
- 1. Cam design by constant acceleration**



This figure shows the a diagram for a double dwell cam design. Constant acceleration function is used for the rise function where $a_{max} = C$, $a_{min} = -C$. Answer the following questions:

1. What are the boundary conditions for v ?
2. What are the boundary conditions for s ? (assuming s needs to rise to h at the end of the rise)
3. Find the v function for 0 to $\frac{\beta}{2}$ and $\frac{\beta}{2}$ to β respectively by integrating a function and apply boundary conditions.
4. Find the s function for 0 to $\frac{\beta}{2}$ and $\frac{\beta}{2}$ to β respectively by integrating v function and apply boundary conditions. Hint, at $\theta = \frac{\beta}{2}$, $s = \frac{h}{2}$. You can also express C in terms of h .

ABOVE AVERAGE



$$a_{max} = c \text{ for } 0 \text{ to } \frac{B}{2}$$

$$a_{min} = -c \text{ for } \frac{B}{2} \text{ to } B$$

In general $a = \frac{dv}{d\theta}$

$$a = \frac{dv}{d\theta}$$

$$v = \int a d\theta = \int c d\theta$$

$$= c\theta + k_1$$

$$v = \int a d\theta = \int -c d\theta$$

$$= -c\theta + k_3$$

at $\theta = B$ and $v = 0$

at $\theta = 0$ and $v = 0$

$\theta = \frac{B}{2}$ and $v = 0$ BCS

$$v(0) = c(0) + k_1 = 0$$

$$v = c\theta$$

$$v(0) = -c\theta + k_3 = 0$$

$$k_3 = c\theta$$

$$v = -c\theta + c\theta$$

$$s = \int v d\theta = \int c\theta d\theta$$

$$= \frac{1}{2} c\theta^2 + k_2$$

$$s = \int v d\theta = \int -c\theta + c\theta d\theta$$

$$= -\frac{1}{2} c\theta^2 + c\theta^2 + k_4$$

at $\theta = 0$, $s = 0$

at $\theta = B$ and $s = h$

$$s(0) = \frac{1}{2} c(0)^2 + k_2 = 0$$

$$k_2 = 0$$

$$s(B) = -\frac{1}{2} c(B)^2 + c(B)^2 + k_4 = h$$

$$= -\frac{1}{2} c(B^2) + cB^2 + k_4 = h$$

when $\theta = \frac{B}{2}$ and $s = \frac{h}{2}$

$$k_4 = -\frac{1}{2} cB^2 + h = -\frac{1}{2} \left(\frac{4h}{B^2} \right) B^2 + h$$

$$= -h + h$$

$$s\left(\frac{B}{2}\right) = \frac{1}{2} c \left(\left(\frac{B}{2}\right)^2 \right) = \frac{h}{2}$$

$$c = \frac{4h}{B^2}$$

$$s = -\frac{1}{2} c\theta^2 + c\theta^2 - h$$

$$= -\frac{2h}{B^2} \theta^2 + \frac{4h}{B^2} \theta - h$$

AVERAGE

Discussion:

1) boundary conditions for v

$$\Theta=0, v=0, \Theta=\beta, v=0$$

2) boundary condition for s

$$\Theta=0, s=0, \Theta=\beta, s=h$$

3) v functions integrating a

$$a=c \quad \frac{\partial v}{\partial t}=c \quad v=ct+k \quad v=ct \quad a=-c$$

$$\Rightarrow \frac{\partial v}{\partial t} = -c \quad v=-ct+k$$

$$0 = -c \frac{\beta}{\omega} + k \Rightarrow k = \frac{c\beta}{\omega} \Rightarrow v = -ct + \frac{c\beta}{\omega}$$

4) v function integrating v

$$v=ct \Rightarrow \frac{\partial s}{\partial t}=ct \quad s=\frac{ct^2}{2}$$

$$v=-ct + \frac{c\beta}{\omega} \Rightarrow s = -\frac{ct^2}{2} + \frac{c\beta t}{\omega} + k$$

$$h = -\frac{c(\frac{\beta}{\omega})^2}{2} + \frac{c\beta(\frac{\beta}{\omega})}{\omega} + k, \quad k = h - \frac{c(\frac{\beta}{\omega})^2}{2}$$

$$s = -\frac{ct^2}{2} + \frac{c\beta t}{\omega} + h - \frac{c(\frac{\beta}{\omega})^2}{2}$$

$$\frac{h}{2} = \frac{c(\frac{\beta}{\omega})^2}{2} \Rightarrow c = \frac{4h\omega^2}{\beta^2}$$

BELOW AVERAGE

$$1/2$$

$$1. V_{max} = \frac{1}{2} c \left(\frac{B}{2W} \right)^2$$

$$V_{max} = \frac{B^2 c}{4W^2}$$

✓ - . 2

$$2. s = 0 + \frac{1}{2} ct^2$$

$$s = \frac{c}{2} t^2$$

- . 2

When $h=0, s=0, t=0$
and

When $h \rightarrow \frac{h}{2}, t = \frac{B}{2W}, s = \frac{1}{2} c \left(\frac{B}{2W} \right)^2$

$$3. \frac{h}{2} = \frac{1}{2} c \cdot \frac{B^2}{4W^2}$$

$$W = \frac{B}{2} \sqrt{\frac{c}{h}}$$

✗ - . 3

$$4. V_{max} = C \times \frac{B}{2W} \sqrt{\frac{c}{h}} = \sqrt{hc}$$

- . 3

$$V = \sqrt{ch} - ct$$

✗

KINEMATICS DESIGN AND ANALYSIS SEMESTER PROJECT FALL 2021

PROJECT TITLE Four-bar Linkage Simulation and Analysis

TOPICS COVERED IN PROJRCT

- 1. Grashoff condition**
- 2. Linkage modelling using NX**
- 3. Linkage motion simulation using NX**
- 4. Linkage position, velocity and acceleration analysis using MATLAB**

MCEG3305: Kinematics Design and Analysis

Fall 2021

Project: Pedal Bin Mechanism Design and Analysis

I. Project description

This is a group project to design and analyze the pedal bin mechanism using Siemens NX and MATLAB. You need to model and simulate your mechanism using Siemens NX and perform position, velocity, and acceleration analysis with MATLAB.

II. The pedal bin mechanism:

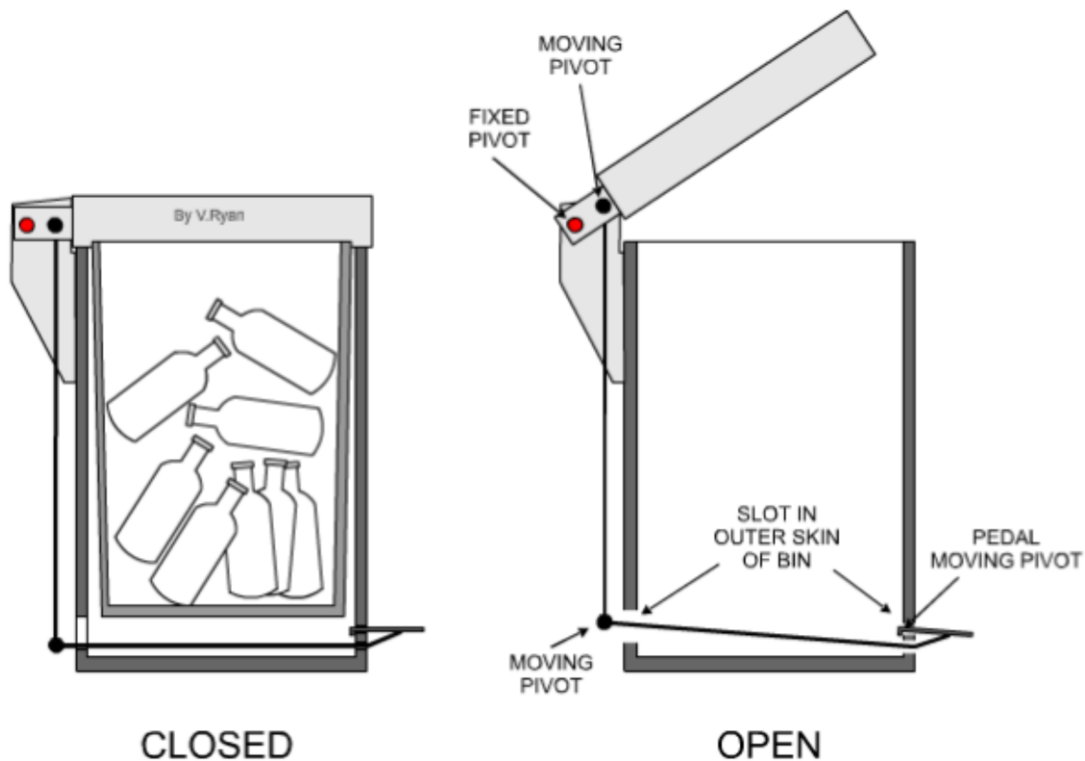


Figure 1. The pedal bin mechanism [1]

Figure 1 shows the closed and open position of the pedal bin mechanism. It shows the fixed and moving pivots.

III. Design Tasks:

1. Determine the dimension of the pedal bin mechanism;
2. Create the pedal bin using NX;
3. Create the assembly of the mechanism;
4. Create the links and joints for the motion analysis;
5. Select input/driver joint, assuming an angular velocity and perform the motion analysis;
6. Note the angles of the pedal and the lids for the open and closed positions;
7. Create a mpeg video or other sort of animation to demonstrate your motion;
8. Analyze the position, velocity and acceleration of the linkage using MATLAB;

9. Plot the position, velocity and acceleration and compare the results with the motion simulation.

IV. Deliverable Results:

1. Proposal report: maximum 2 pages; Due date: Oct. 20.

The proposal must describe:

- A. Proposed work schedule.
- B. Tasks distribution. (What will each group member work on?)

2. Final Project Presentations (Nov. 24): Every group will be asked to give a 10-minute presentation using PowerPoint.

3. Final Report and soft copy of your project (Due: Dec. 1)

A. A final report in electronic format should be documented in Word format. There is no specific format and page limitation, but your report should include the following contents:

- Abstract (100-150 words);
- Introduction (design objectives);
- Project description (mechanism's functional requirements, design constraints, design parameters, etc.);
- NX models and motion (models of components, drafting of major components, assembly, extreme positions, motion analysis and simulation, etc.);
- Position, velocity, and acceleration analysis using MATLAB (equations used, MATLAB code, MATLAB plots; comparison with the NX motion, etc.)
- Conclusion and suggestion; and
- Reference, if any.

B. Please submit

Electronic version of the report, presentation, and your project as one compressed file to Canvas.

4. Taskstream submission (Due: Dec. 1)

Submit the final report to Taskstream in response to Outcome 1 Assignment 1

V. Point Distribution:

Category		Points
Proposal		30
Quality, completeness and results (120 pts)	Create NX model	20
	Assembly of the mechanism	10
	Motion demonstration	30
	Determine input/output joint for position analysis	10
	Analyze the position, velocity and acceleration of the linkage using MATLAB	30
	Plot the position, velocity and acceleration and compare the results with the motion simulation.	20
Final presentation		50
Final report	Format	30
	Phrasing and clarity	30
	Neatness	20
Taskstream submission		20
Peer evaluation		100
Total		400

Reference:

[1] Ryan, V., "The pedal mechanism 1", <https://technologystudent.com/rmprep09/ped1.html>
(March 28, 2021)

**ABOVE AVERAGE
PROJECT REPORT**

**MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



MCEG 3305 Kinematics Design and Analysis

Fall 2021 Section P04

Project Report on

“Kinematics Pedal Bin Trashcan Design”

**Conducted on
November 29, 2021**

**Submitted by
Zion Brown, Kiaria Moon, Temitayo Ojo (Group 3)**

**On
December 1, 2021**

**To
Dr. Chang Duan
*Kinematics Design and Analysis Instructor***

Category		Points	Score
Proposal		30	28
Quality, completeness and results (120 pts)	Create NX model	20	18
	Assembly of the mechanism	10	10
	Motion demonstration	30	24
	Determine input/output joint for position analysis	10	10
	Analyze the position, velocity and acceleration of the linkage using MATLAB	30	28
	Plot the position, velocity and acceleration and compare the results with the motion simulation.	20	20
Final presentation		50	48
Final report	Format	30	28
	Phrasing and clarity	30	27
	Neatness	20	18
Taskstream submission		20	20
Peer evaluation		100	80
Total		400	359

Letter of Transmittal

Kiaria Moon
Mechanical Engineering Student
Prairie View, Texas 77446
Cell: 832-504-0097
E-mail: kmoon1@pvamu.edu

Dr. Chang Duan
Measurement Laboratory Instructor
Prairie View A&M University
C.L. Wilson Engineering Building
Room 105H

October 20th, 2021

Dear Dr. Duan:

The following pages are a detailed report for MCEG 3305 Kinematics Design and Analysis Project "Pedal Bin Mechanism Design and Analysis". This report addresses the use of Matlab for performing position, velocity, and acceleration analysis as well as the use of Siemens NX Unigraphics to model, assemble, and simulate a pedal bin trash can mechanism. The lab was performed on October 20, 2021 and was submitted on December 1, 2021.

If you have any questions or concerns, please call, or email me at any time.

Sincerely,

Kiaria Moon
Enclosure: Lab Report

ABSTRACT

The purpose of this project includes the use of NX Unigraphics to model, assemble, and simulate a pedal bin mechanism and perform in-depth examination of its motion. For this experiment the group used hand calculations and MATLAB to perform position, velocity, and acceleration analysis.

The methods used included linkage analysis. In this analysis the team determined the lengths of the four links. The measurements were then used to complete analysis in MATLAB and used for modeling and simulating the mechanism for NX. In NX Unigraphics we set design constraints for a crank-rocker and modeled the four-bar linkage like a mechanism that controls a pedal bin trash can.

Conclusions drawn from this project:

- The trash bin mechanism open and closed as expected and the MATLAB code returns the correct angular velocity and acceleration values for θ_3 and θ_4 . The team was to complete the simulation objective and demonstrate the model transition from one extreme (completely closed) to the next extreme (completely open).



TABLE OF CONTENT

ABSTRACT	i
LIST OF FIGURES	ii
LIST OF TABLES	iii
1. Project Introduction	6
1.1 Design Objectives	6
2. Project Description	7
2.1 Mechanism's Functional Requirements	7
2.2 Design Constraints and Parameters	8
3. NX Models and Motion Simulation	9
3.1 Models of components	9
3.2 Component Assembly	10
3.3 Extreme Positions, Motion Analysis, and Simulation	11
4. Position, Velocity, and Acceleration Analysis using MATLAB	12
4.1 Equations and Analysis	12
4.2 MATLAB code	14
4.3 MATLAB Plots and comparison with the NX Motion	16
5. Conclusions and Recommendations	19

does
not
match.
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start
at page 1



LIST OF FIGURES

Figure 1.1 Pedal Bin Moment Demonstration	6
Figure 1.2 Pedal Bin Opened and Closed Positions	6
Figure 2.1 Four-Bar linkage with Vectors	7
Figure 2.2 Walmart Trashcan	7
Figure 2.3 Linkage Identification	8
Figure 2.4 Angular Velocity Assumption	8
Figure 3.1 Link 1.....	9
Figure 3.2 Link 2.....	9
Figure 3.3 Link 3	9
Figure 3.4 Link 4	10
Figure 3.5 Isometric Views of the Linkage Mechanism	10
Figure 3.6 Completely Open	11
Figure 3.7 Completely Closed	11
Figure 4.1 Four-Bar Linkage Crossed Configuration	12
Figure 4.2 Four bar linkage Function	15
Figure 4.3 Call to Function	16
Figure 4.4 θ_2 vs θ_3	16
Figure 4.5 θ_2 vs $\dot{\theta}_3$	16
Figure 4.6 θ_2 vs $\dot{\theta}_3$	17
Figure 4.7 θ_2 vs θ_4	17
Figure 4.8 θ_2 vs $\dot{\theta}_4$	18
Figure 4.9 θ_2 vs $\ddot{\theta}_4$	18



CHAPTER 1

Project Introduction

1.1 Design Objectives

The project team was tasked with designing a pedal bin mechanism for a trashcan. Early in the project, it was observed that the mechanism that controls the movement could be represented as a four-bar linkage. The design was to satisfy the general movement of a trash can, that is, the opening and closing movement of the lid caused by the depression of the attached foot pedal.

To satisfy the design requirement successfully, the project team included assumptions regarding the length of the four-bar links, angular velocity, and constant acceleration. In addition, the team also constrained the design by including two extreme positions; fully open and completely closed. Lastly, the project team chose an input angle to complete the subsequent analysis.

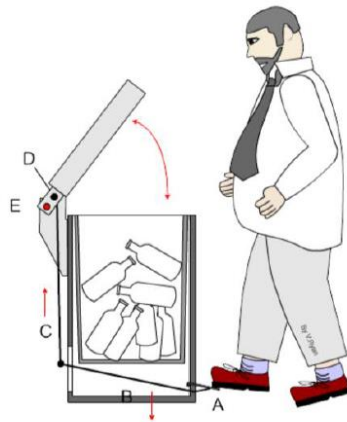


Figure 1.1 Pedal Bin Moment Demonstration

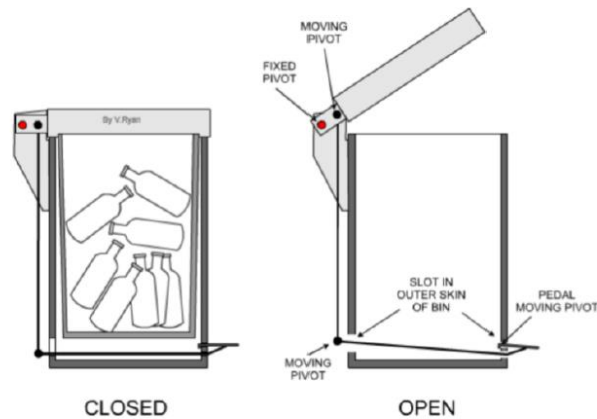


Figure 1.2 Pedal Bin Opened and Closed Positions

CHAPTER 2

Project Description

2.1 Mechanism's Functional Requirements

To successfully satisfy the design objectives, the project team made several assumptions regarding the function's requirements of varying components. The assumptions made had to align with the functional capabilities of the components as seen in an actual trashcan.

The first assumption the team made was the lengths of the links in the four-bar mechanism. The proposed trashcan had to be designed with the correct proportions to resemble an actual trashcan you would see in real life. The team used the dimensions of a trashcan found in a local Walmart seen in figure xxx to make this assumption. The lengths are described as:

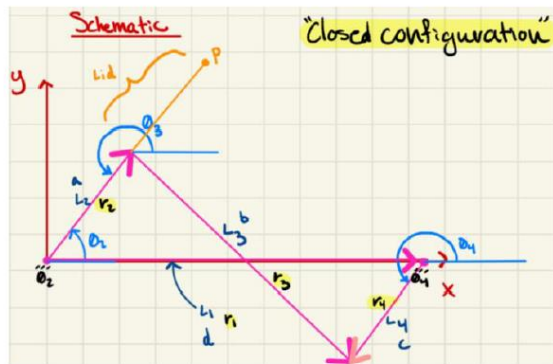


Figure 2.1 Four-Bar linkage with Vectors



Figure 2.2 Walmart Trashcan

Lengths

$$L_1 = r_1 = 25 \text{ in}$$

$$L_2 = r_2 = 1.5 \text{ in}$$

$$L_3 = r_3 = 21 \text{ in}$$

$$L_4 = r_4 = 10.5 \text{ in}$$

Using the assumed link lengths, the team then found the predicted motion of the linkage using its Grashof Condition:

Grashof Condition

$$S + L < P + Q$$

$$25 \text{ in} < 31.5 \text{ in}$$

Crank Rocker

Because the mechanism is a crank-rocker one, link can make a complete revolution. In reality, no link will make a full revolution the designed four-bar linkage, but one link still includes the ability to make a full revolution.

The next step was to design the angular velocity that the lid (link 2) opens. The project team assumed an angular velocity of 1.57 radians/second. The angular velocity value was derived from the two extreme positions assumed by the project team. The analysis is described below:

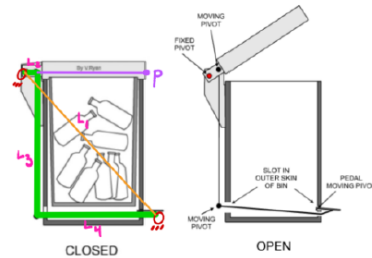


Figure 2.3 Linkage Identification

Angular Velocity

'Fully Open' = 135°

‘Completely Closed’ = 45°

Because the lid moves from closed to open:

$$135^\circ - 45^\circ = 90^\circ$$

$$90^\circ \times \frac{\pi}{180} = 1.57 \text{ radians CCW}$$

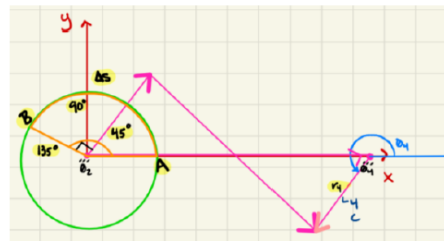


Figure 2.4 Angular Velocity Assumption

The last assumption the team made was a constant acceleration of link 2 as 0 radians/second². By keeping the acceleration constant, the team was able to neglect many of the complexities associated with a varying acceleration parameter.



CHAPTER 3

NX Models and Motion Simulation

3.1 Models of components

The model was constructed by assembling four links. The links were designed in NX with units of inches. The links were sketched and then extruded to 1 inch. the links also included holes on each end; the holes acted as pivots and allowed the links to oscillate/translate (only at the moving pivots) Link 1 is the fixed link in our design.

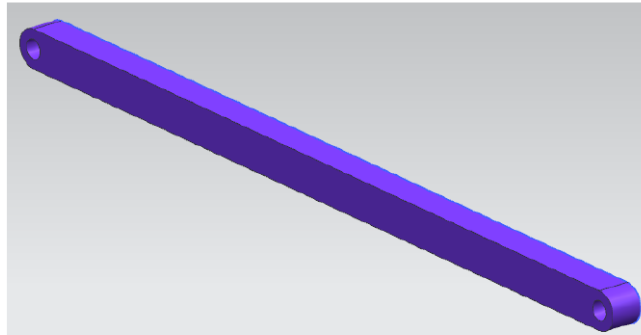


Figure 3.1 Link 1

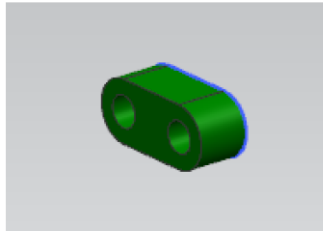


Figure 3.2 Link 2

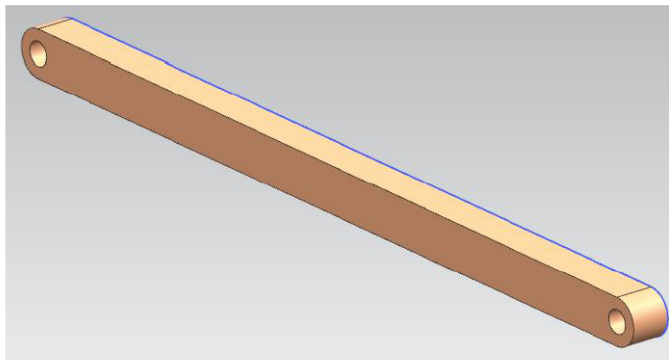


Figure 3.3 Link 3

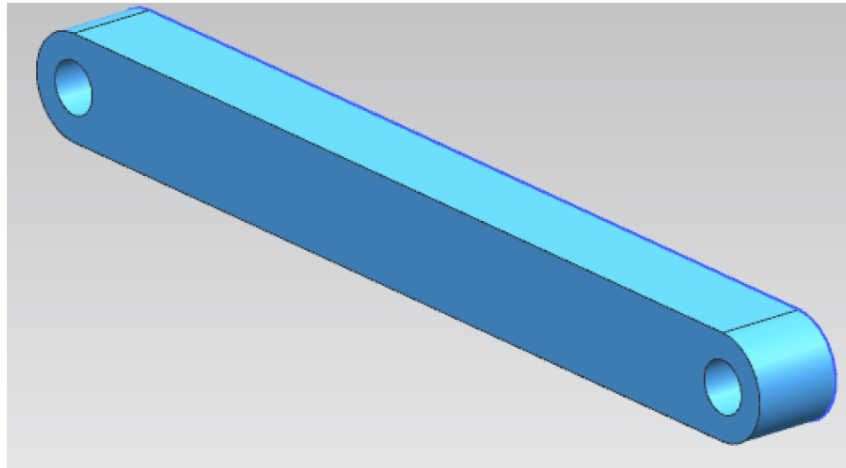


Figure 3.4 Link 4

3.2 Component Assembly

The model of the four-bar linkage was assembled by using the assembly feature in NX. The links were put together via the touch align feature and constrained centerline to centerline.

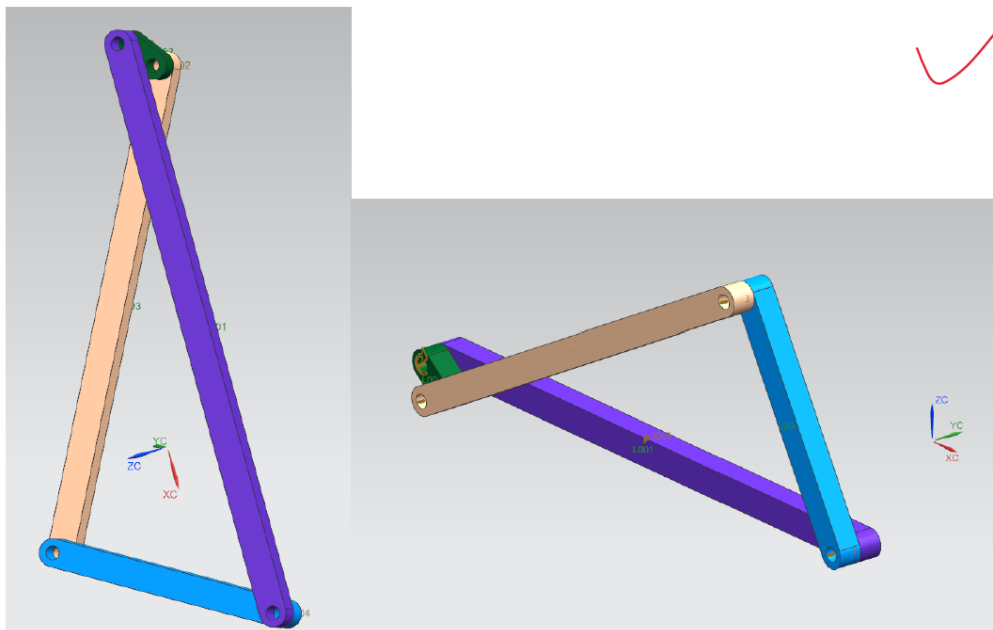


Figure 3.5 Isometric Views of the Linkage Mechanism

3.3 Extreme Positions, Motion Analysis, and Simulation

The project team used the CAD model to visualize the extreme positions in our design; completely open and fully closed. Motion analysis was also completed in NX. The project team set the angular velocity value of link 2 as 1.57 radians/second. Due to the units of angular velocity being radians/second, the time value set to one second to stay consistent.

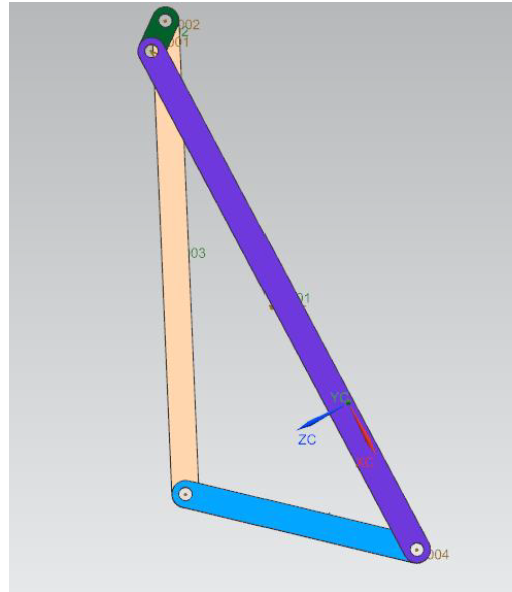


Figure 3.6 Completely Open

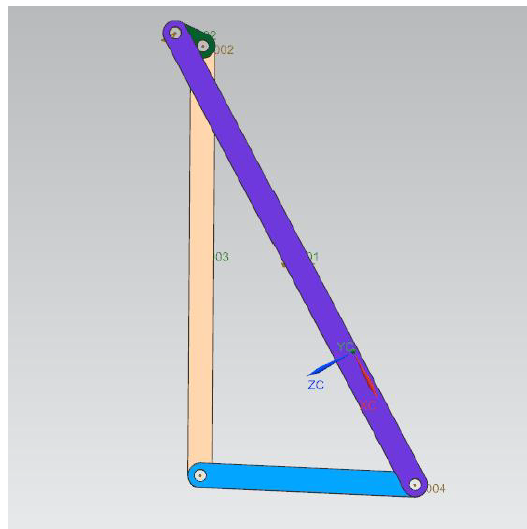


Figure 3.7 Fully Closed



CHAPTER 4

Position, Velocity, and Acceleration Analysis using MATLAB

This chapter will display the position, velocity, and acceleration analysis completed by the project team. Each function will include the knowns, unknowns, related analysis, and the result. Please note, the following numerical examples showcase the results for the “completely closed configuration” or, theta 2 at 45°. The complete MATLAB code can be found in section 4.2.

4.1 Equations and Analysis

Position Analysis

The position analysis was completed via ‘Crossed Configuration’ MATLAB code. No hand calculation steps were taken by the team. Instead, the team altered the code to calculate the results pertaining to only the crossed configuration. The team used figure xxx to note the configuration as crossed.

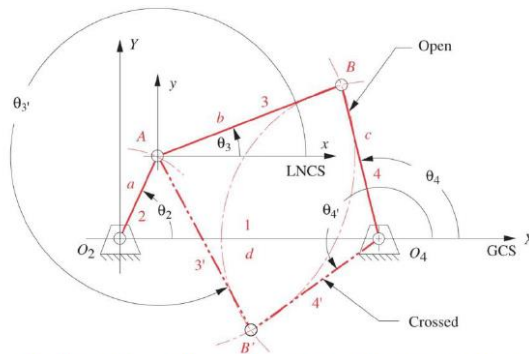


Figure 4.1 Four-Bar Linkage Crossed Configuration

Known

$L_1 = r_1 = 25$ in
 $L_2 = r_2 = 1.5$ in
 $L_3 = r_3 = 21$ in
 $L_4 = r_4 = 10.5$ in

Unknown

θ_3
 θ_4

Analysis

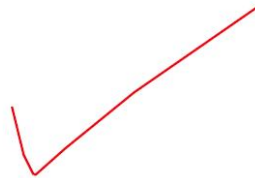
*Position Analysis was completed via ‘Crossed Configuration’ MATLAB Code

$$r_2 + r_3 = r_1 + r_4 \rightarrow -r_1 + r_2 + r_3 - r_4 = 0$$

$$-|r_1| \begin{bmatrix} \cos\theta_1 \\ \sin\theta_1 \end{bmatrix} + |r_2| \begin{bmatrix} \cos\theta_2 \\ \sin\theta_2 \end{bmatrix} + |r_3| \begin{bmatrix} \cos\theta_3 \\ \sin\theta_3 \end{bmatrix} - |r_4| \begin{bmatrix} \cos\theta_4 \\ \sin\theta_4 \end{bmatrix} = 0$$

Results

$\theta_3 = 331.5^\circ$
 $\theta_4 = 238.5^\circ$



Velocity Analysis

To calculate the unknown velocity variables, the team took the derivative of position with respect to time. The angular velocity assumption of link 2 was include in this calculation as a known variable. Due to the lengths of the links being constant, their respective derivatives are zero in the velocity analysis.

Known

$$L_1 = r_1 = 25 \text{ in}$$

$$L_2 = r_2 = 1.5 \text{ in}$$

$$L_3 = r_3 = 21 \text{ in}$$

$$L_4 = r_4 = 10.5 \text{ in}$$

$$\theta_3 = 331.5^\circ$$

$$\theta_4 = 238.5^\circ$$

Unknown

$$\dot{\theta}_3$$

$$\dot{\theta}_4$$

Analysis

$$-\dot{r}_1 + \dot{r}_2 + \dot{r}_3 - \dot{r}_4 = 0$$

$$-\cancel{|r_1| \begin{bmatrix} \cos\theta_1 \\ \sin\theta_1 \end{bmatrix}} - \cancel{|r_1|\dot{\theta}_1 \begin{bmatrix} -\sin\theta_1 \\ \cos\theta_1 \end{bmatrix}} + \cancel{|r_2| \begin{bmatrix} \cos\theta_2 \\ \sin\theta_2 \end{bmatrix}} + |r_2|\dot{\theta}_2 \begin{bmatrix} -\sin\theta_2 \\ \cos\theta_2 \end{bmatrix} \\ + \cancel{|r_3| \begin{bmatrix} \cos\theta_3 \\ \sin\theta_3 \end{bmatrix}} + |r_3|\dot{\theta}_3 \begin{bmatrix} -\sin\theta_3 \\ \cos\theta_3 \end{bmatrix} - \cancel{|r_4| \begin{bmatrix} \cos\theta_4 \\ \sin\theta_4 \end{bmatrix}} - |r_4|\dot{\theta}_4 \begin{bmatrix} -\sin\theta_4 \\ \cos\theta_4 \end{bmatrix} = 0$$

$$|r_2|\dot{\theta}_2 \begin{bmatrix} -\sin\theta_2 \\ \cos\theta_2 \end{bmatrix} + |r_3|\dot{\theta}_3 \begin{bmatrix} -\sin\theta_3 \\ \cos\theta_3 \end{bmatrix} - |r_4|\dot{\theta}_4 \begin{bmatrix} -\sin\theta_4 \\ \cos\theta_4 \end{bmatrix} = 0$$

$$(1.5)(1.57) \begin{bmatrix} -\sin(45^\circ) \\ \cos(45^\circ) \end{bmatrix} + (21)(\dot{\theta}_3) \begin{bmatrix} -\sin(331.5^\circ) \\ \cos(331.5^\circ) \end{bmatrix} - (10.5)(\dot{\theta}_4) \begin{bmatrix} -\sin(238.5^\circ) \\ \cos(238.5^\circ) \end{bmatrix} = 0$$

Results

$$x = A^{-1} \times b \rightarrow \begin{bmatrix} \dot{\theta}_3 \\ \dot{\theta}_4 \end{bmatrix} = \begin{bmatrix} -0.0263 \\ -0.2153 \end{bmatrix}$$



Acceleration Analysis

To calculate the unknown acceleration variables, the team took the derivative of velocity with respect to time. The acceleration constant of link 2 was include in this calculation as a known variable. Due to the lengths of the links being constant, their respective derivatives are zero in the velocity analysis. As a result, the zeros in the velocity analysis are the same zeros in the acceleration analysis. In addition, the constant acceleration assumption of 0 radians/second².

Known

$L_1 = r_1 = 25$ in
 $L_2 = r_2 = 1.5$ in
 $L_3 = r_3 = 21$ in
 $L_4 = r_4 = 10.5$ in
 $\Theta_3 = 331.5^\circ$
 $\Theta_4 = 238.5^\circ$
 $\dot{\theta}_3 = -0.0263$
 $\dot{\theta}_4 = -0.2153$

Analysis

$$-\ddot{r}_1 + \ddot{r}_2 + \ddot{r}_3 - \ddot{r}_4 = 0$$

Distributing negative coefficients

$$\begin{aligned}
 &|r_2|\ddot{\theta}_2 \begin{bmatrix} -\sin\theta_2 \\ \cos\theta_2 \end{bmatrix} + |r_2|\dot{\theta}_2^2 \begin{bmatrix} -\cos\theta_2 \\ -\sin\theta_2 \end{bmatrix} \\
 &+ |r_3|\ddot{\theta}_3 \begin{bmatrix} -\sin\theta_3 \\ \cos\theta_3 \end{bmatrix} + |r_3|\dot{\theta}_3^2 \begin{bmatrix} -\cos\theta_3 \\ -\sin\theta_3 \end{bmatrix} \\
 &- |r_4|\ddot{\theta}_4 \begin{bmatrix} -\sin\theta_4 \\ \cos\theta_4 \end{bmatrix} - |r_4|\dot{\theta}_4^2 \begin{bmatrix} -\cos\theta_4 \\ -\sin\theta_4 \end{bmatrix} = 0
 \end{aligned}
 \rightarrow
 \begin{aligned}
 &|r_2|\ddot{\theta}_2 \begin{bmatrix} -\sin\theta_2 \\ \cos\theta_2 \end{bmatrix} + |r_2|\dot{\theta}_2^2 \begin{bmatrix} -\cos\theta_2 \\ -\sin\theta_2 \end{bmatrix} \\
 &- |r_3|\ddot{\theta}_3 \begin{bmatrix} \sin\theta_3 \\ \cos\theta_3 \end{bmatrix} - |r_3|\dot{\theta}_3^2 \begin{bmatrix} \cos\theta_3 \\ \sin\theta_3 \end{bmatrix} \\
 &+ |r_4|\ddot{\theta}_4 \begin{bmatrix} \sin\theta_4 \\ \cos\theta_4 \end{bmatrix} + |r_4|\dot{\theta}_4^2 \begin{bmatrix} \cos\theta_4 \\ \sin\theta_4 \end{bmatrix} = 0
 \end{aligned}$$

$$\begin{bmatrix} (-21) \times \sin(331.5^\circ) & (10.5) \times \sin(238.5^\circ) \\ (21) \times \cos(331.5^\circ) & (-10.5) \times \cos(238.5^\circ) \end{bmatrix} \begin{bmatrix} \ddot{\theta}_3 \\ \ddot{\theta}_4 \end{bmatrix}$$

$$= \begin{bmatrix} 1.5(\sin(45^\circ) \times 0 + \cos(45^\circ) (1.57)^2 + 21 \times \cos(331.5^\circ) (-0.0263)^2 - 10.5 \times \cos(238.5^\circ) (-0.2153)^2 \\ -1.5(\sin(45^\circ) \times 0 - \sin(45^\circ) (1.57)^2 + 21 \times \sin(331.5^\circ) (-0.0263)^2 - 10.5 \times \sin(238.5^\circ) (-0.2153)^2 \end{bmatrix}$$

Unknown

$\ddot{\theta}_3$
 $\ddot{\theta}_4$

Results

$$x = A^{-1} \times b \rightarrow \begin{bmatrix} \ddot{\theta}_3 \\ \ddot{\theta}_4 \end{bmatrix} = \begin{bmatrix} 0.1947 \\ -0.1040 \end{bmatrix}$$

4.2 MATLAB Code

```

Users > Zion > Documents > Kin Project Code
Editor - C:\Users\Zion\Documents\Kin Project Code\kmsc2.m
kmsc2.m  testcodeout.m  +
1 function [theta3crossed, theta4crossed, theta3dot, theta4dot, theta3doubledot, theta4doubledot] = kmsc2(theta2)
2
3 d = 25; a = 1.5; b = 21; c = 10.5; alpha2 = 0; w2 = 1.57;
4
5 % d=L1=r1, a=L2=r2, b=L3=r3, c=L4=r4 theta2dot=w2=2.35
6 % theta2 = 135;
7 K1 = d/a; K2 = d/c;
8 K3 = (a^2 - b^2 + c^2 + d^2) / (2*a*c);
9
10 A = cosd(theta2) - K1 - K2*cosd(theta2) + K3;
11 B = -2*sind(theta2);
12 C = K1 - (K2+1)*cosd(theta2) + K3;
13
14 theta4crossed = 2*atan2d(-B+sqrt(B^2-4*A*C), 2*A)+360;
15 if theta4crossed > 180
16     theta4crossed = theta4crossed - 360;
17     disp('Theta 4:')
18     disp(theta4crossed)
19 elseif theta4crossed < -180
20     theta4crossed = theta4crossed + 360;
21     disp('Theta 4:')
22     disp(theta4crossed)
23 end
24

```

```

26 K4 = d/b;
27 K5 = (c^2 - d^2 - a^2 - b^2)/(2*a*b);
28
29 D = cosd(theta2) - K1 + K4*cosd(theta2) + K5;
30 E = -2*sind(theta2);
31 F = K1 + (K4-1)*cosd(theta2) + K5;
32
33 theta3crossed = 2*atan2d(-E+sqrt(E^2-4*D*F),2*D)+360;
34
35 if theta3crossed > 180
36     theta3crossed = theta3crossed - 360;
37     disp('Theta 3:')
38     disp(theta3crossed)
39 elseif theta3crossed < -180
40     theta3crossed = theta3crossed + 360;
41     disp('Theta 3:')
42     disp(theta3crossed)
43 end
44 %Velocity Analysis r2 & b matrix
45 vel2_1= [-sind(theta2); cosd(theta2)];
46 b_1 = (1.5*w2)*(vel2_1);
47
48 % Because the matrix is moved to the other side of the equal sign the
49 % matrix has to flip. The team multiplied the b matrix by negative 1 to
50 % flip the matrix
51
52 bbb_1 = (b_1*-1);
53
54 %a matrix
55 a_1= [(21)*(-sind(theta3crossed)), (-10.5)*(-sind(theta4crossed)); (21)*(cosd(theta3crossed)), (-10.5)*(cosd(theta4crossed))];
56
57 %Inverse Calculation x=A^-1*b
58 Velocity_vector = inv(a_1)*(bbb_1);
59
60 theta3dot= Velocity_vector(1);
61 disp('theta3 dot is')
62 disp(theta3dot)
63
64 theta4dot= Velocity_vector(2);
65 disp('theta4 dot is')
66 disp(theta4dot)
67
68 %Acceleration Analysis
69 aa_1= [(-21)*(sind(theta3crossed)), (10.5)*(sind(theta4crossed)); (21)*(cosd(theta3crossed)), (-10.5)*(cosd(theta4crossed))];
70 bb_1= [(1.5*(sind(theta2)*(alpha2)+cosd(theta2)*(w2^2)))+(21*cosd(theta3crossed)*(theta3dot^2)-10.5*cosd(theta4crossed)*(theta4dot^2))];
71
72 Acceleration_Vector = inv(aa_1)*(bb_1);
73
74
75 theta3doubledot = Acceleration_Vector(1);
76 disp('Theta 3 double dot:')
77 disp(theta3doubledot)
78 theta4doubledot = Acceleration_Vector(2);
79 disp('Theta 4 double dot:')
80 disp(theta4doubledot)
81 end

```

Figure 4.2 Four bar linkage Function

```

Editor - C:\Users\Zion\Documents\Kin Project Code\testcodeout.m
kmsc2.m  testcodeout.m  +
1 theta2 = 45:1:135;
2 for i = 1:length(theta2)
3     [theta3crossed(i), theta4crossed(i), theta3dot(i), theta4dot(i), theta3doubledot(i), theta4doubledot(i)] = kmsc2(theta2(i));
4     hey1 = theta2(i);
5     disp('theta 2 value')
6     disp(hey1)
7     disp('-----')
8 end
9

```

Figure 4.3 Call to Function

***Please note lines 65 and 66 are too long to be included in the screenshot. The complete code will be attached with the submission.**

4.3 MATLAB Plots and comparison with the NX Motion

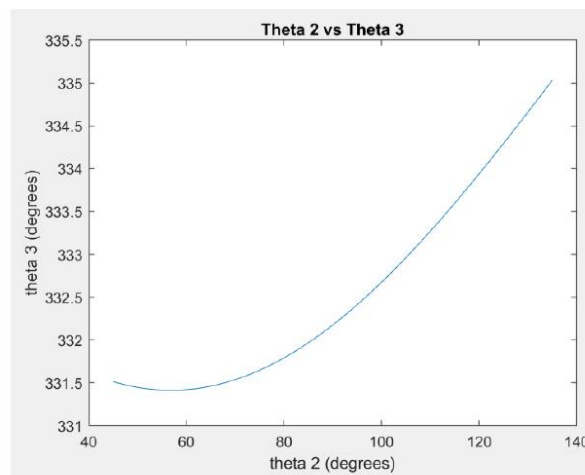


Figure 4.4 theta2 vs theta3

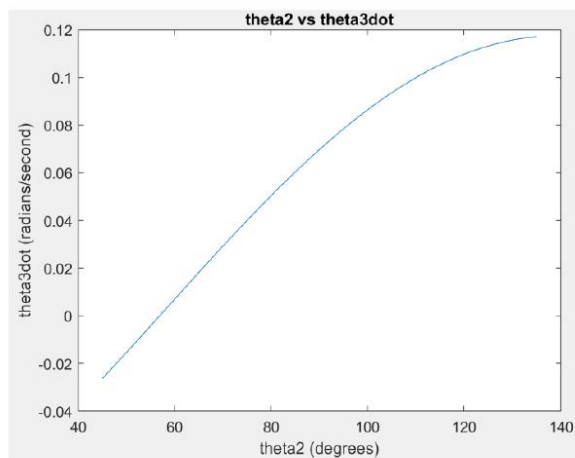


Figure 4.5 theta2 vs theta3dot

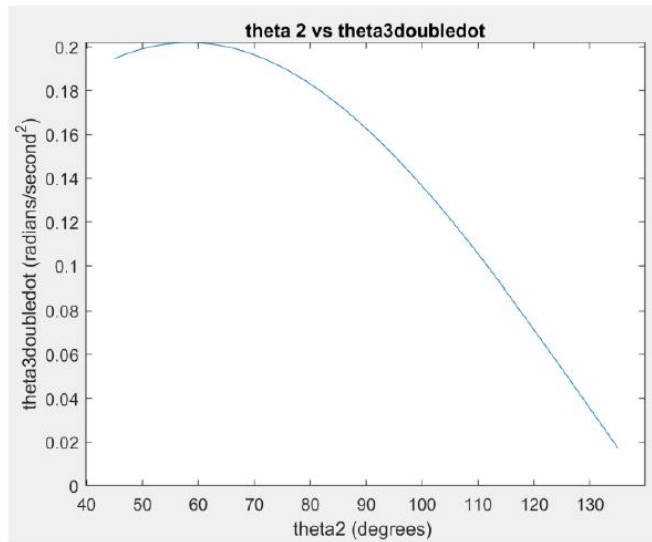


Figure 4.6 theta2 vs theta3dot

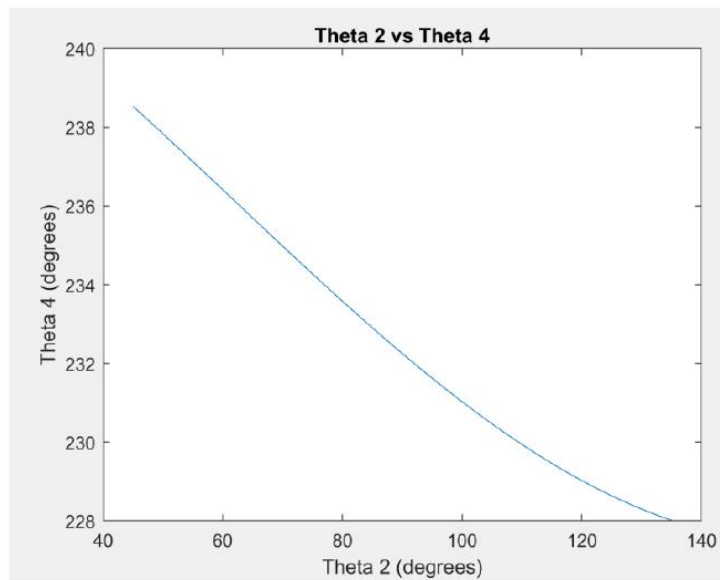


Figure 4.7 theta2 vs theta4



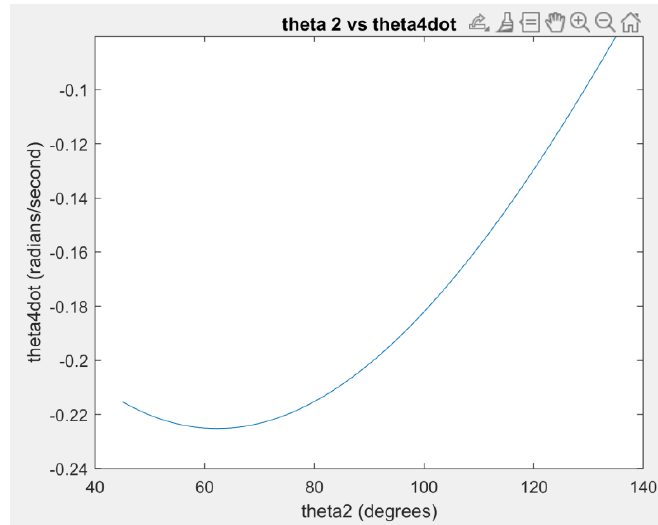


Figure 4.8 theta2 vs theta4 dot

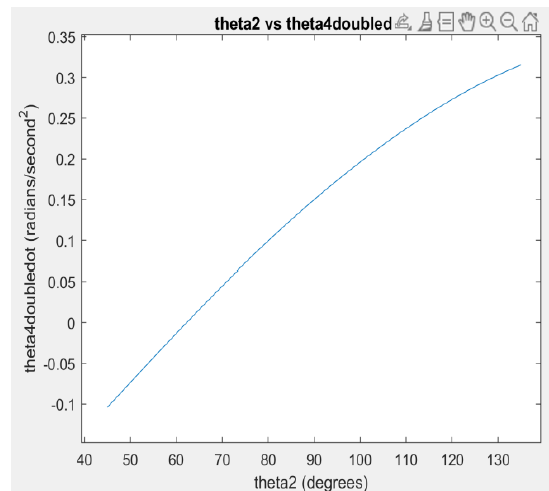


Figure 4.9 theta2 vs theta4 double dot

The plots illustrate the resulting variables when related to an increasing input angle, θ_2 . For each respective variable, θ_3 and θ_4 , the resulting plots; position, velocity, and acceleration are each inversely related to each other. It can be observed that:

*Note the following explains the general trends observed by the plots (not completely linear trends).

- As θ_2 increased: position θ_3 increased ,and position θ_4 decreased
- As θ_2 increased: Angular velocity $\dot{\theta}_3$ increased ,and Angular Velocity $\dot{\theta}_4$ increased
- As θ_2 increased: Acceleration $\ddot{\theta}_3$ increased ,and Acceleration $\ddot{\theta}_4$ increased

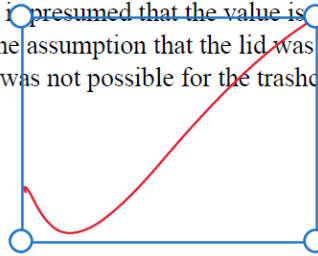
CHAPTER 5

Conclusion

From the completed analysis and resulting plots, the project team successfully satisfied the project's design objectives. The trash can open and close based on the angular velocity and constant acceleration assumption. While the trashcan lid moves from open to close, the designed four-bar linkage and MATLAB code return the correct angular velocity and acceleration values of θ_3 and θ_4 . In addition, the team was able to complete the simulation objective. The team utilized NX Unigraphics to demonstrate the model transitioning from one extreme position to the next extreme position without the user's aid. The model simulated transitioning between both positions in one second, accurately relating the unit of angular velocity ($\frac{\text{radians}}{\text{second}}$).

Recommendations

One proposed recommendation is to find a solution to measure the initial angle made by link 2 and link 1 in the NX model. When assembling the links, NX auto constrained theta 2 to a value slightly less than 45° . The team could not alter this constraint. Thus, the simulation did not represent the 45° to 135° entirely. It is presumed that the value is auto constrained to approximately 38° . The team kept the assumption that the lid was completely closed at 45° because any angle smaller than 45° was not possible for the trashcan lid.



AVERAGE
PROJECT REPORT

MCEG 3305 Kinematic Design and Analysis

FINAL REPORT

THE PEDAL BIN MECHANISM



Prairie View A&M University

Roy G. Perry College of Engineering

Dr. Chang Duan

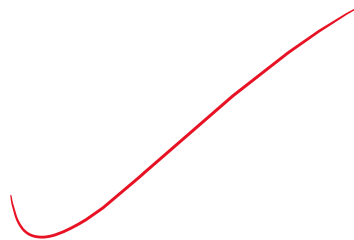
Kinematic Design and Analysis instructor

Idris Agboola, Cameau Poort, Edwin Godfrey II, Winston Wright

Category		Points	Score
Proposal		30	30
Quality, completeness and results (120 pts)	Create NX model	20	20
	Assembly of the mechanism	10	10
	Motion demonstration	30	30
	Determine input/output joint for position analysis	10	10
	Analyze the position, velocity and acceleration of the linkage using MATLAB	30	8
	Plot the position, velocity and acceleration and compare the results with the motion simulation.	20	5
Final presentation		50	38
Final report	Format	30	20
	Phrasing and clarity	30	25
	Neatness	20	15
Taskstream submission		20	20
Peer evaluation		100	80
Total		400	311

Abstract

The findings of the group on designing the pedal bin mechanism with Siemens NX and analyzing position, velocity, and acceleration with MATLAB are presented in this study. The pedal bin mechanism is a simple and frequent design for high-end domestic trash bins that are more expensive due to its quality mild steel construction. A series of linked narrow pieces of steel is required for proper operation. The first linkage moves downwards as the foot is pressed on the pedal, while the second linkage moves upwards. The lid's moving pivot is attached to the second linkage. Finally, the pivot is secured, allowing the lid to rotate. This linkage is a form of mechanism that emerges from pivots and levers being able to move freely. The team used a detailed schematic of the pedal mechanism to create the final model, which was based on the measurements provided in the report's NX Models and Motion section. The team must also examine many design needs and restrictions in addition to the models and performance charts. The group employed many engineering principles to overcome the project's complexity and offer a final simulation because it required a professional team and multiple machinery and equipment.



Lists of Figures

Figure #

Introduction.....	1
Design Objectives.....	1.1
Project description.....	1.2
Requirements.....	2.1
Constraints.....	2.2
Components of the pedal bin.....	3.1
The pedal bin mechanism	3.2
Position Analysis.....	3.3
Velocity Analysis.....	3.4
Acceleration Analysis.....	4.1
Conclusion.....	4.2
References	

Introduction

~~Fig 1.1 Design Objectives:~~

- Determining the dimension of the pedal bin mechanism
- Creating the pedal bin using NX
- Creating the assembly of the mechanism
- Creating the links and joints for the motion analysis
- Selecting input/driver joint, assuming an angular velocity and performing the motion analysis
- Note the angles of the pedal and the lids for the open and closed positions
- Creating a mpeg video or other sort of animation to demonstrate motion
- Analyze the position, velocity and acceleration of the linkage using MATLAB
- Plotting the position, velocity and acceleration and comparing the results with motion Simulation

~~Fig 1.2 Project descriptions:~~

- Using Siemens NX and MATAB, this group project will design and analyze the pedal bin mechanism. With NX, we were able to model and simulate the pedal bin mechanism, and with MATLAB, we were able to examine the location, velocity, and acceleration. A linkage is a sort of mechanism that contains fixed pivots, moving pivots, and levers. The fixed and moveable pivots that allow the pedal bin mechanism to close and open are shown in Figure 1.1. The design functions have a number of requirements, including ~~but not limited to~~ tools/equipment requirements, labor training requirements, and material needs.

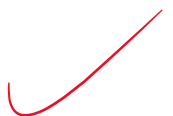


Fig 2.1 Requirement:

- Our group wants to provide an attractive pedal bin design that is easy to use, and an adequate sign compared to the competition. NX and MATLAB are essential to us testing the results for our position analysis on our design. These pedal bins are essential to every household and business as well. They allow no hands to be used when throwing away trash. Which in the time we are in now with trying to contain the spread of covid this is something very essential in stopping the spread of the virus. The bin has the foot pedal which is where the name originates from and that needs to be efficient and not break. There are 2 links in the system that are used to open the top of the pedal bin when the foot pedal is hit. In our design we chose to make the circular body of the pedal bin a #304 stainless steel sheet to preserve the material and keep it from rusting. The last thing you want in an indoor trash can is rust as this will be near little kids as well as household pets. This also saves money one less reason to get a new trash can.

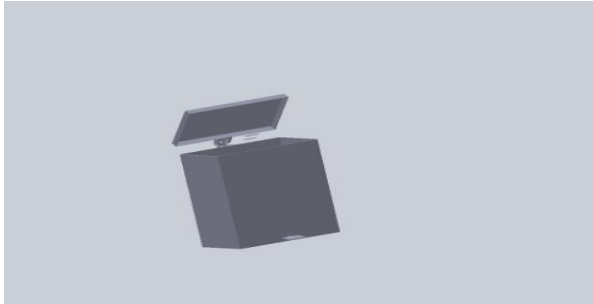
Fig 2.2 Constraints:

- A major constraint in designing the pedal bin mechanism for the waste bin is keeping the estimated cost affordable to manufacture. Keeping the Estimated price under £3.00 may be challenging considering this can be a relatively expensive mechanism. This is due to the range of equipment needed and the cost of employment of a semi-skilled workforce.

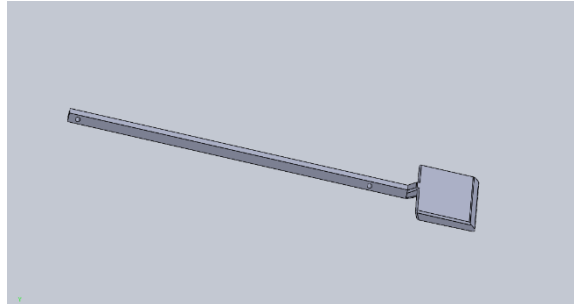
Fig 3.1 Components of the pedal Bin

- **Bin Assembly (Animation)**

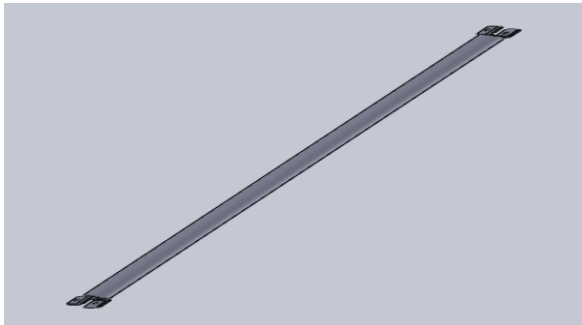
Pedal bin



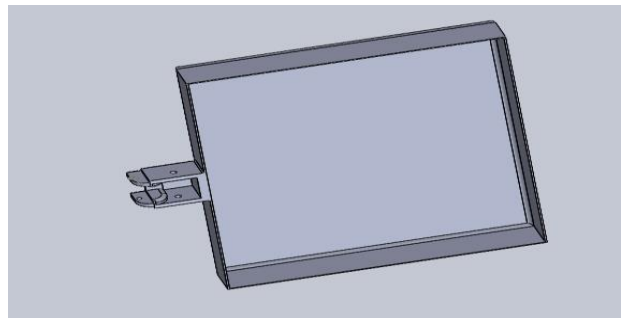
Foot Pedal



Rod



lid



Waste Basket

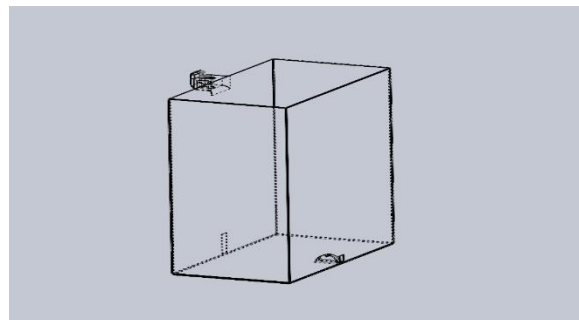
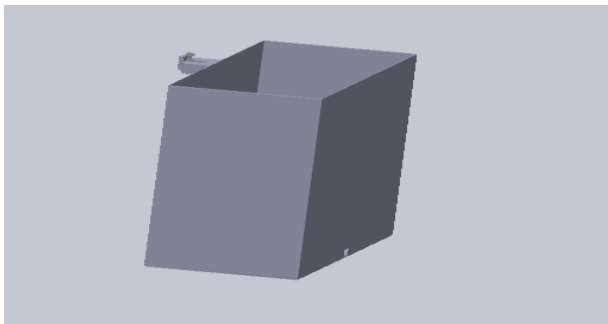
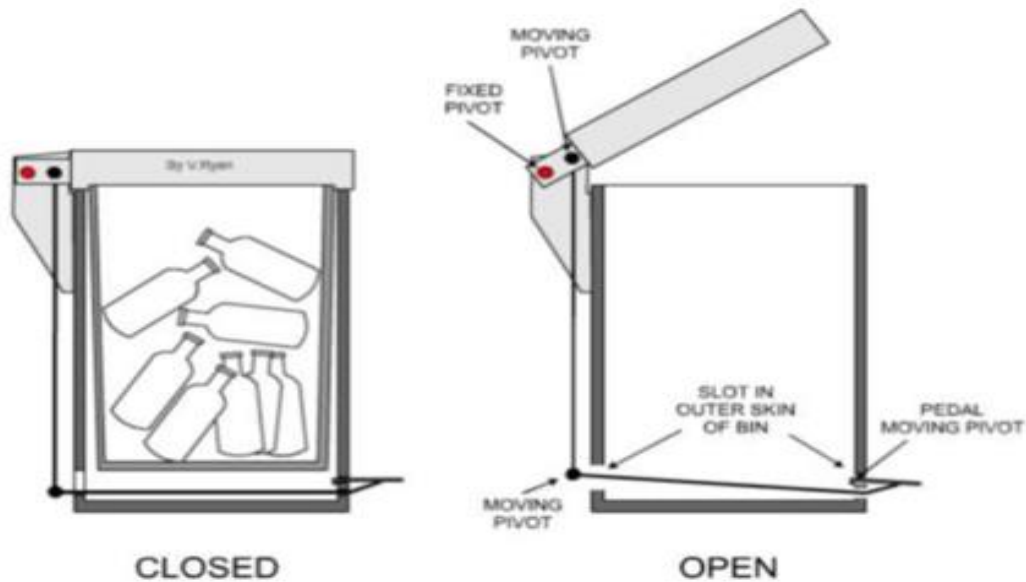


Figure # table missing

Fig 3. 2NX Models and Motion

II. The pedal bin mechanism:

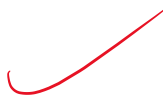


*dimension and linkage identification
not presented*

Fig 3.3 Position Analysis

Matlab Code

```
a = 15.6;
b = 21.9;
c = 35;
d = 1.9;
theta_2 = 90;
K_1 = d/a;
K_2 = d/c;
K_3 = (a^2 + c^2 + d^2 - b^2)/(2*a*c);
K_4 = d/b;
K_5 = (c^2 - d^2 - a^2 - b^2)/(2*a*b);
A_p = cosd(theta_2) - K_1 - K_2*cosd(theta_2) + K_3;
B_p = -2*sind(theta_2);
C_p = K_1 - (K_2 + 1)*cosd(theta_2);
D_p = cosd(theta_2) - K_1 + K_4*cosd(theta_2) + K_5;
E_p = -2*sind(theta_2);
F_p = K_1 + (K_4 - 1)*cosd(theta_2) + K_5;
theta_3_open = 2*atand(-E_p - sqrt(E_p^2 - 4*D_p*F_p)/(2*D_p));
theta_3_crossed = 2*atand(-E_p + sqrt(E_p^2 - 4*D_p*F_p)/(2*D_p));
theta_4_open = 2*atand(-B_p - sqrt(B_p^2 - 4*A_p*C_p)/(2*A_p));
theta_4_crossed = 2*atand(-B_p + sqrt(B_p^2 - 4*A_p*C_p)/(2*A_p));
omega_2 = 25; theta_3 = theta_3_crossed;
j = sqrt(-1);
```



open or crossed. must be one of them
not both

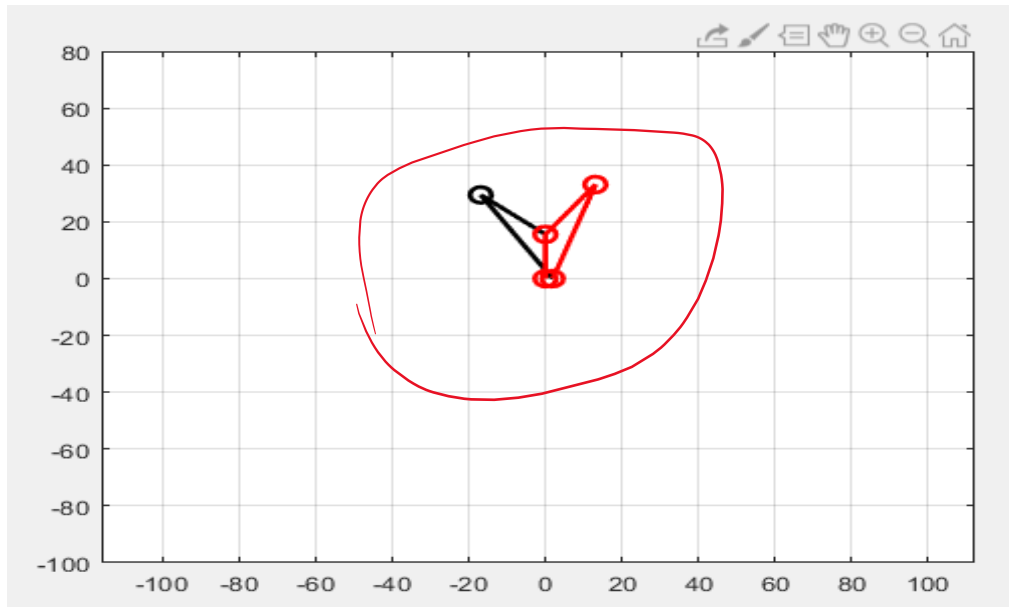


Figure 3.4 Velocity Analysis

$$\omega_3 = ((a \cdot \omega_2) / b) * (\sin(\theta_4 - \theta_2) / \sin(\theta_3 - \theta_4));$$

$$\omega_4 = ((a \cdot \omega_2) / c) * (\sin(\theta_2 - \theta_3) / \sin(\theta_4 - \theta_3));$$

$$V_A = a \cdot \omega_2 * (-\sin(\theta_2) + j \cdot \cos(\theta_2));$$

$$V_{Ax} = a \cdot \omega_2 * (-\sin(\theta_2));$$

$$V_{Ay} = a \cdot \omega_2 * (j \cdot \cos(\theta_2));$$

$$V_{BA} = b \cdot \omega_3 * (-\sin(\theta_3) + j \cdot \cos(\theta_3));$$

$$V_{BAx} = b \cdot \omega_3 * (-\sin(\theta_3));$$

$$V_{BAy} = b \cdot \omega_3 * (j \cdot \cos(\theta_3));$$

$$V_B = c \cdot \omega_4 * (-\sin(\theta_4) + j \cdot \cos(\theta_4));$$

$$V_{Bx} = c \cdot \omega_4 * (-\sin(\theta_4));$$

$$V_{By} = c \cdot \omega_4 * (j \cdot \cos(\theta_4));$$

Fig 4.1 Acceleration Analysis

```

A_a = c*sind(theta_4);

B_a = b*sind(theta_3);

C_a = a*alpha_2*sind(theta_2) + a*(omega_2^2)*cosd(theta_2) + b*(omega_3^2)*cosd(theta_3) +
c*(omega_4^2)*cosd(theta_4);

D_a = c*cosd(theta_4);

E_a = b*cosd(theta_3);

F_a = a*alpha_2*cosd(theta_2) + a*(omega_2^2)*sind(theta_2) + b*(omega_3^2)*sind(theta_3) +
c*(omega_4^2)*sind(theta_4);

alpha_3 = (C_a*D_a - A_a*F_a)/(A_a*E_a - B_a*D_a);

alpha_4 = (C_a*E_a - B_a*F_a)/(A_a*E_a - B_a*D_a);

A_A = a*alpha_2*(-sind(theta_2) + j*cosd(theta_2)) - a*(omega_2^2)*(cosd(theta_2) + j*sind(theta_2));

A_Ax = -a*alpha_2*sind(theta_2) - a*(omega_2^2)*cosd(theta_2);

A_Ay = a*alpha_2*cosd(theta_2) - a*(omega_2^2)*sind(theta_2);

A_BA = b*alpha_3*(-sind(theta_3) + j*cosd(theta_3)) - b*(omega_3^2)*(cosd(theta_3) + j*sind(theta_3));

A_BAx = -b*alpha_3*sind(theta_3) - b*(omega_3^2)*cosd(theta_3);

A_BAy = b*alpha_3*cosd(theta_3) - b*(omega_3^2)*sind(theta_3);

A_B = c*alpha_4*(-sind(theta_4) + j*cosd(theta_4)) - c*(omega_4^2)*(cosd(theta_4) + j*sind(theta_4));

A_Bx = -c*alpha_4*sind(theta_4) - c*(omega_4^2)*cosd(theta_4);

A_By = c*alpha_4*cosd(theta_4) - b*(omega_4^2)*sind(theta_4);

```

velocity and acceleration

No plots, no results.

Fig 4.2 Conclusions:

In conclusion, the pedal bin mechanism is an invention that has already been created long before as our group uses these designs in household trashcans worldwide. The job as mechanical engineers are to innovate a more efficient way for them to work. Whether it be by changing dimension, material, etc for the bin. In our design we use the dimensions 35.10”H as the height of our bin and we believe that with the materials used and manufacturing processes we can deliver a bigger pedal at half the price of the competition. That is what sets our design apart from the competition. The current competition is charging \$430 for there 20L bin that has a height of 24.8”H [1]. Therefore, compared to the competition our product will increase in sales at a higher rate.

References

Design of Machinery 5th edition, Robert L. Norton

**BELOW AVERAGE
PROJECT REPORT**

Myles Woodfork
Austin Smith
Chris Nylander
12/1/2021
Kinematics and Design
Dr. Chang Duan

Fall 2021 Project Report

Abstract and Description

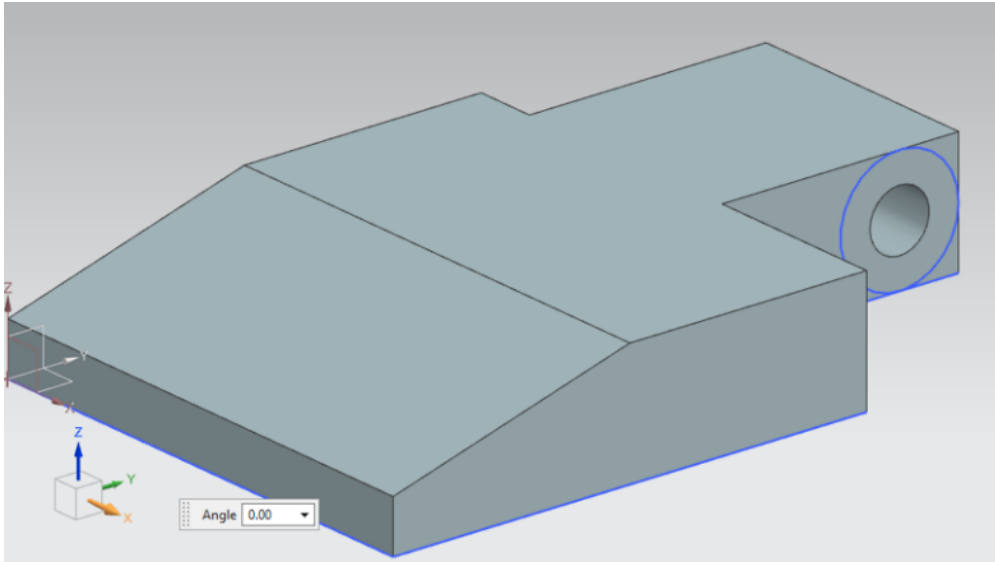
In this project, we were instructed to, as a group create a moving functional model of a trash bin using NX or AutoCAD. After which we were to use processes taught to us in class to do a Position, Velocity, and Acceleration Analysis on it, and write a code solving for each using the coding software, MatLab. All of which were to be presented in a PowerPoint to the class and instructor for grading. For the model of the bin, we had 7 pieces making up the full model: the pedal, a linking bar under the bin, a hinge, another bar behind the bin, the top, and the bin itself. All of these were made individually in their own NX files, then stripped together to make the full mechanism.

Once the full mechanism was made, we then had to rig it all up so that the top could move inversely with the pedal being moved up and down. Once that was made to specifications and recorded, the operation moved onto MatLab. Where we were instructed to perform position analysis, as well as velocity and acceleration analyses and transfer them into code using the software. Once done, we formatted it all into a powerpoint in order of how each happened: the models, the full model and animation, the analyses, and lastly the code.

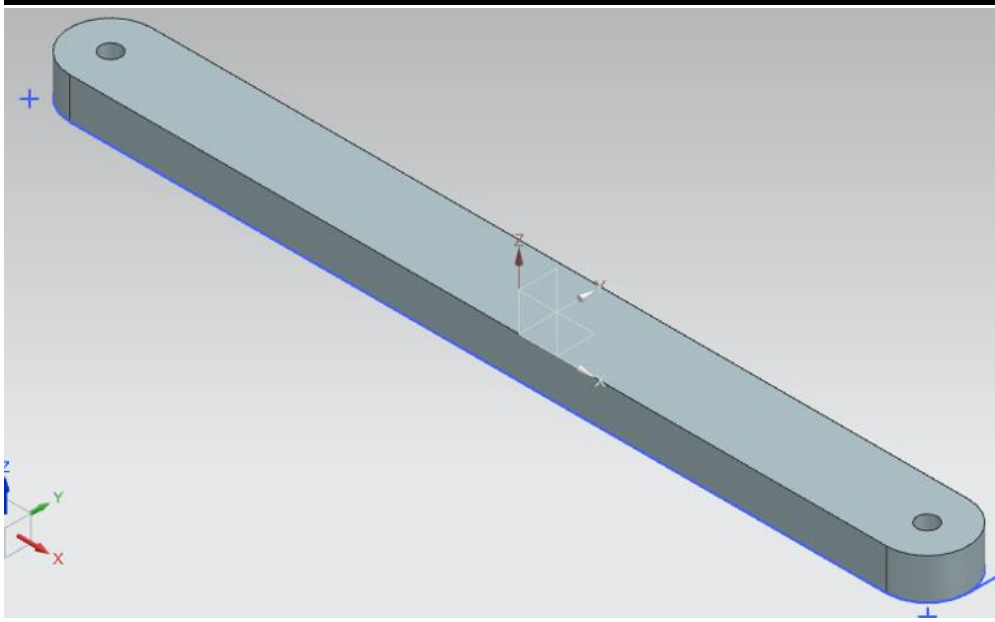


Category		Points	Score
Proposal		30	28
Quality, completeness and results (120 pts)	Create NX model	20	20
	Assembly of the mechanism	10	10
	Motion demonstration	30	25
	Determine input/output joint for position analysis	10	7
	Analyze the position, velocity and acceleration of the linkage using MATLAB	30	8
	Plot the position, velocity and acceleration and compare the results with the motion simulation.	20	5
Final presentation		50	36
Final report	Format	30	20
	Phrasing and clarity	30	15
	Neatness	20	15
Taskstream submission		20	20
Peer evaluation		100	80
Total		400	289

Models



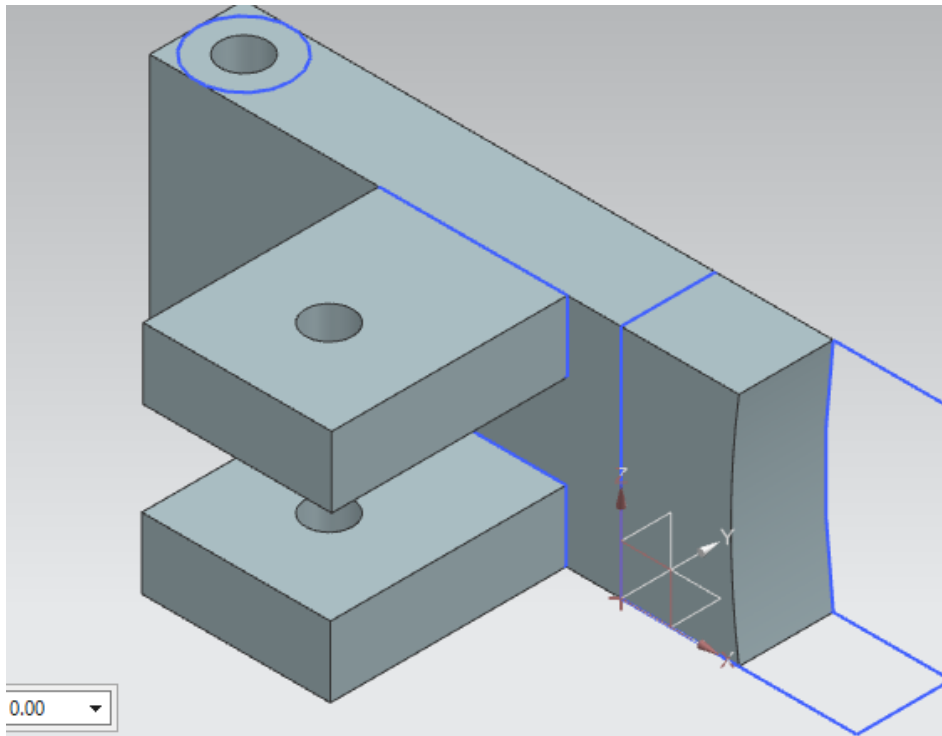
Pedal



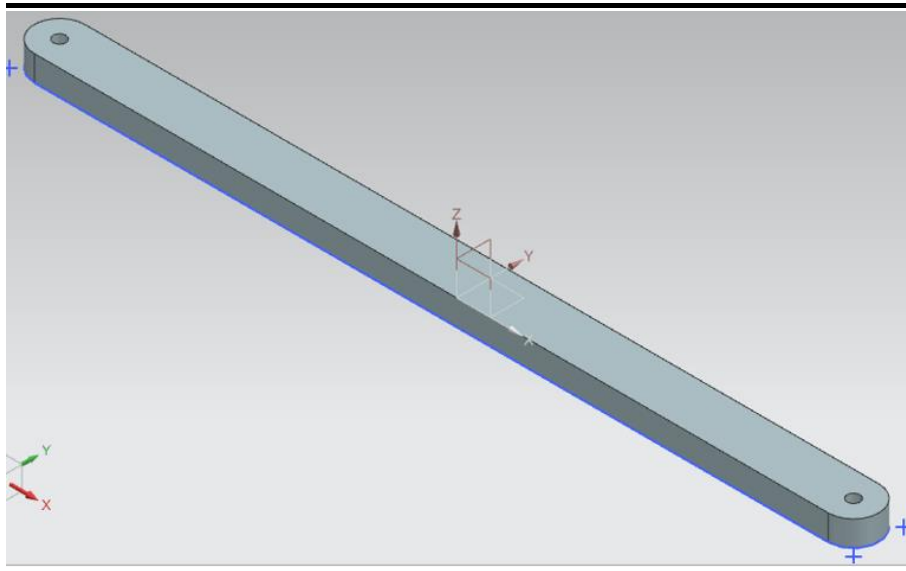
Link

(Underneath)

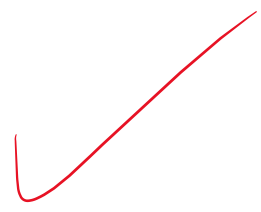


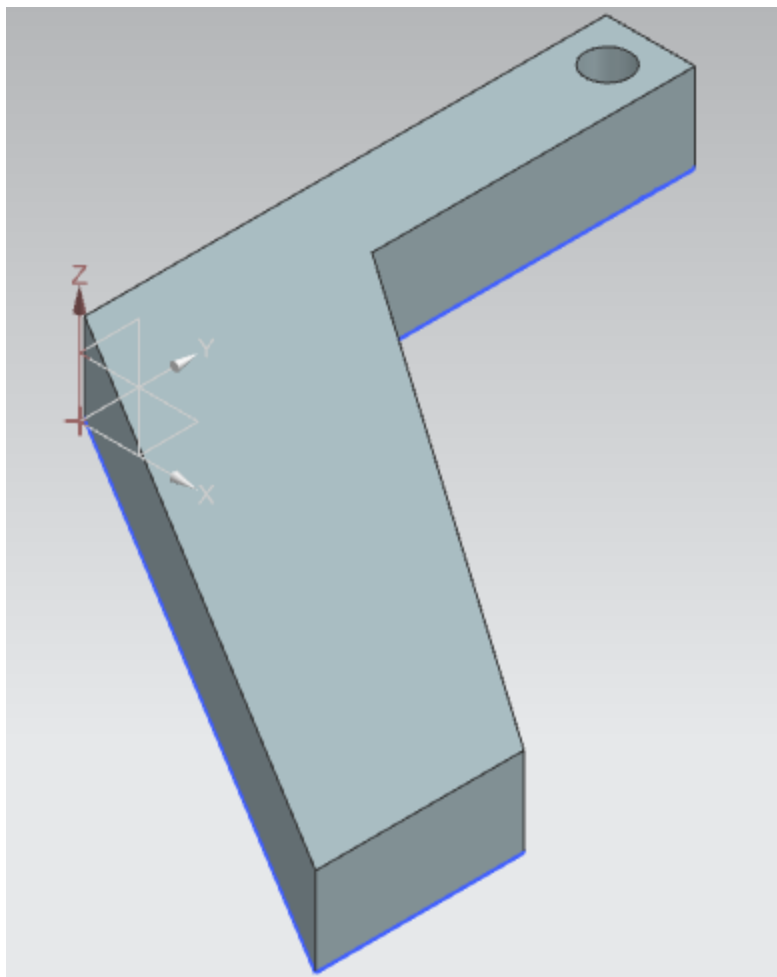


Hinge

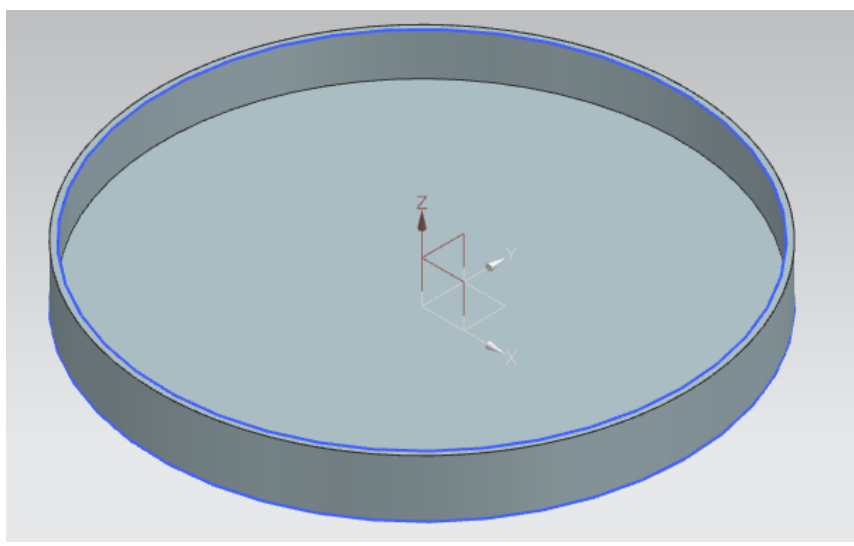


Bar



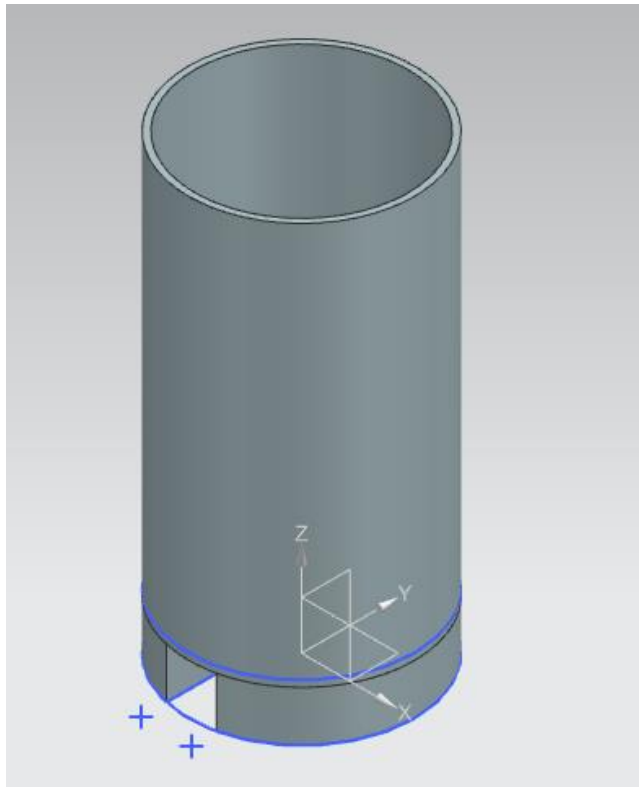


Arm

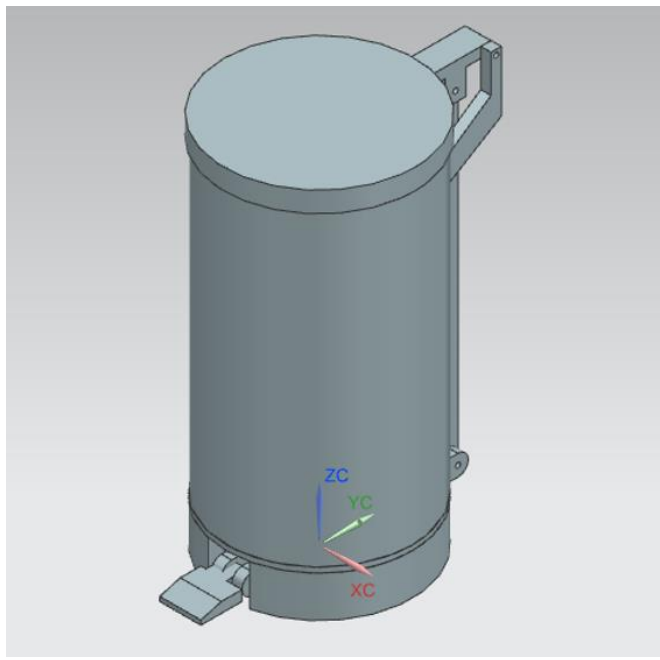


Top

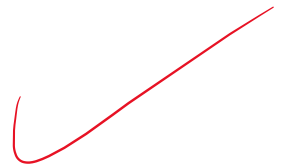




Bin (Body)



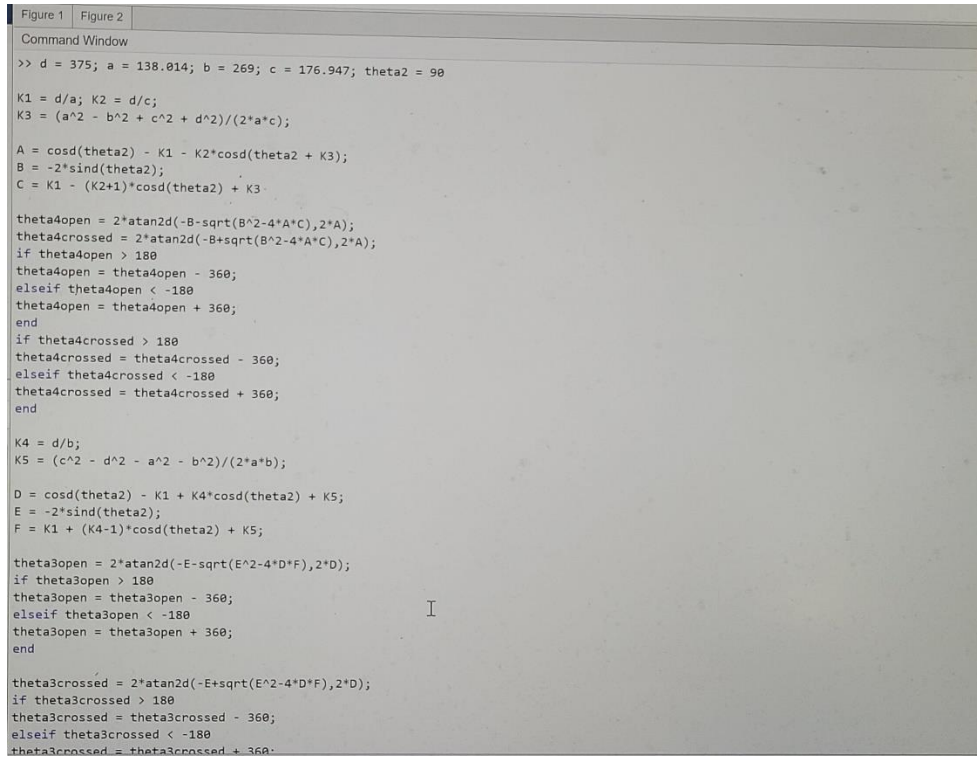
Full Assembled Trash Bin



Animated Assembly

(Included in Presentation)

Code for Analyses



```
Figure 1 | Figure 2
Command Window
>> d = 375; a = 138.014; b = 269; c = 176.947; theta2 = 90

K1 = d/a; K2 = d/c;
K3 = (a^2 - b^2 + c^2 + d^2)/(2*a*c);

A = cosd(theta2) - K1 - K2*cosd(theta2 + K3);
B = -2*sind(theta2);
C = K1 - (K2+1)*cosd(theta2) + K3;

theta4open = 2*atan2d(-B+sqrt(B^2-4*A*C),2*A);
theta4crossed = 2*atan2d(-B+sqrt(B^2-4*A*C),2*A);
if theta4open > 180
theta4open = theta4open - 360;
elseif theta4open < -180
theta4open = theta4open + 360;
end
if theta4crossed > 180
theta4crossed = theta4crossed - 360;
elseif theta4crossed < -180
theta4crossed = theta4crossed + 360;
end

K4 = d/b;
K5 = (c^2 - d^2 - a^2 - b^2)/(2*a*b);

D = cosd(theta2) - K1 + K4*cosd(theta2) + K5;
E = -2*sind(theta2);
F = K1 + (K4-1)*cosd(theta2) + K5;

theta3open = 2*atan2d(-E+sqrt(E^2-4*D*F),2*D);
if theta3open > 180
theta3open = theta3open - 360;
elseif theta3open < -180
theta3open = theta3open + 360;
end

theta3crossed = 2*atan2d(-E+sqrt(E^2-4*D*F),2*D);
if theta3crossed > 180
theta3crossed = theta3crossed - 360;
elseif theta3crossed < -180
theta3crossed = theta3crossed + 360;
end
```

dimension and linkage identification
not present

```

Figure 1 | Figure 2
Command Window
K4 = d/b;
K5 = (c^2 - d^2 - a^2 - b^2)/(2*a*b);

D = cosd(theta2) - K1 + K4*cosd(theta2) + K5;
E = -2*sind(theta2);
F = K1 + (K4-1)*cosd(theta2) + K5;

theta3open = 2*atan2d(-E-sqrt(E^2-4*D*F),2*D);
if theta3open > 180
    theta3open = theta3open - 360;
elseif theta3open < -180
    theta3open = theta3open + 360;
end

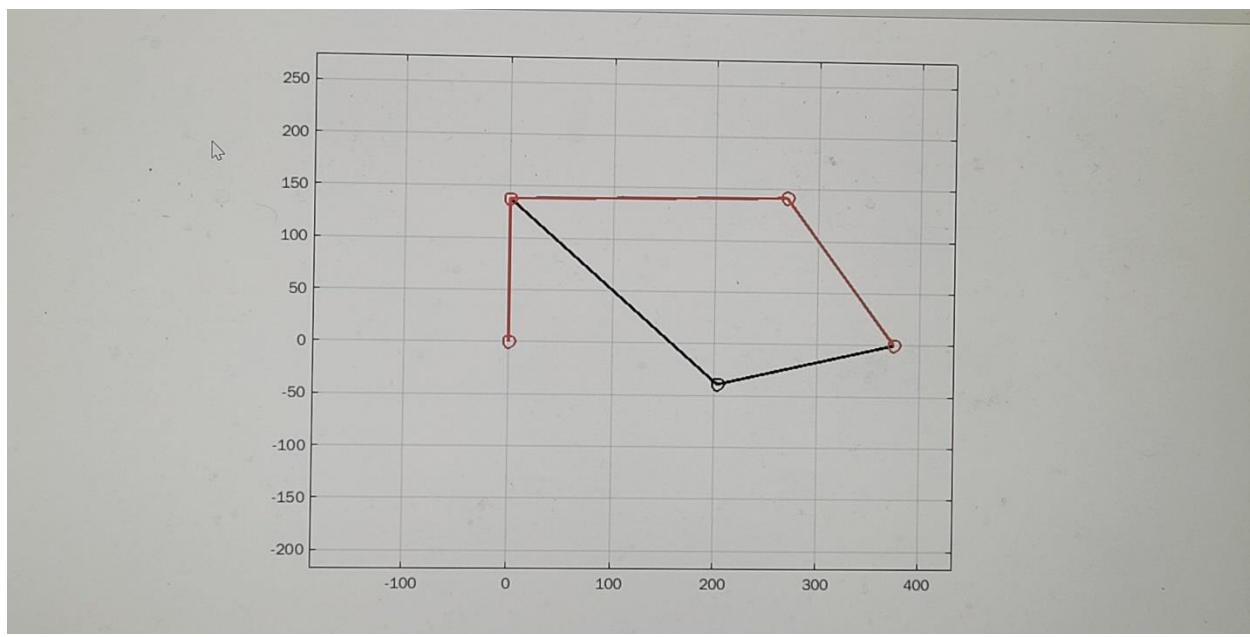
theta3crossed = 2*atan2d(-E+sqrt(E^2-4*D*F),2*D);
if theta3crossed > 180
    theta3crossed = theta3crossed - 360;
elseif theta3crossed < -180
    theta3crossed = theta3crossed + 360;
end

figure;
plot ([0 a*cosd(theta2) a*cosd(theta2)+b*cosd(theta3crossed) d], [0 a*sind(theta2) a*sind(theta2)+b*sind(theta3crossed) 0], '-ko', 'LineWidth',2,'MarkerSize',8);
hold on;
plot ([0 a*cosd(theta2) a*cosd(theta2)+b*cosd(theta3open) d], [0 a*sind(theta2) a*sind(theta2)+b*sind(theta3open) 0], '-ro', 'LineWidth',2,'MarkerSize',8);
grid on;
axis([-20 160 -100 80]);
axis equal

theta2 =
    90

C =
    5.1458

```



One position.

Crossed.
not both

Conclusion

In all, this was a very eye opening project, and served as a great way to use what we had learned previously in a semi-realistic scenario. It also served as a great eye opener to the things we might not have known prior to doing this project.

Velocity and acceleration analysis
missing.