ME2021 – Mechanics of Machines I

Lecture 01:
INTRODUCTION TO MECHANISMS AND KINEMATICS

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Introduction

This module develops the

- knowledge to **motion of a particle or multibody system**,
- knowledge to **analyse kinematics, kinetics and dynamic of planer mechanisms, gear transmission systems** and
- knowledge to **analyse power transmission devices**.

Outline

1. **Introduction:** Kinematic analysis of 2D Link mechanisms, Kinematic pairs, degree of freedom of a kinematic chain, mechanism mobility analysis using Grubler's criterion, Commonly employed mechanisms: four-bar mechanism and Grashof's Criterion, Slider crank mechanism and inversions.
2. **Kinematic Analysis of planer mechanisms** (Analytical approach using vector loop method)
3. **Gears and Gear Trains:** Friction gearing, common types of toothed gears, involute gear teeth, speed-ratio, simple gear train, compound gear trains, planetary gear trains, kinematic analysis of multiple stage planetary gear trains, differentials.
4. **Static force analysis for planer mechanisms**. Two force and Three force members, static force analysis using force polygon method.
5. **Kinetic analysis of planer mechanisms**, free body diagram, D'Alembert's principle, dynamic equilibrium

Recommended Text

- *Waldron, K.J., and Kinzel, G.L.*, **"Kinematics, Dynamics, and Design of Machinery"**, *3rd edition, Wiley.*
- *W.L. Cleghorn,* **"Mechanisms and Machines"** *2nd edition, Oxford University Press, 2015.*
- *John J. Uicker, Gordon R. Pennock and Joseph E. Shigley,* **"Theory of Machines and Mechanisms"***, Oxford University Press*

Learning Outcomes

LO1: Explain the significance, effect and control of mechanical vibrations in the design and operation of mechanical plant.

LO2: Identify kinematic loops in a mechanism; apply closed-form position analysis methods.

LO3: Differentiate loop closure equations to perform velocity and acceleration analysis.

LO4: Simulate mechanism motion using computer software.

LO5: Understand, motion limits, instantaneous center of rotation and singularities.

LO6: Understand tooth gear transmission, compound, planetary gear trains and differentials.

LO7: Construct free body diagrams of mechanism links, and derive statics or inverse dynamics equations in matrix-vector form.

LO8: Determine mechanism forces and torques using graphical methods.

LO9: Simulate mechanism static and/or dynamic forces and torques using computer software.

LO10: Use D'Alembert's principle and perform dynamic analysis for planer mechanisms.

Course Description

Assessment Criteria

- Continuous assessment will carry 35% of the total marks.
  - ✓ Labs, Assignments, Quizzes **20%**
    - ✓ Test 1 – March 1,2019
    - ✓ Test 2 – April 3, 2019
  - ✓ Midterm Examination **15%**
- Final Examination **65%**

Lectures	Wednesday: 8.30 – 10.30	*EA2*
	Wednesday:10.30 – 12.30	*E106*
	Friday: 13.30 – 14.30	*E101*
Tutorials	Friday: 14.30 – 15.30	*E101*
Laboratory	**Mechanical:** Monday 8.30 – 10.30, Friday 10.30 – 12.30 **Mechatronics:** Monday 15.30 – 17.30, Friday 15.30 – 17.30	*Mechanics Laboratory (3rd Floor)*

Unit Study Calendar - 2019

Week	Dates	Description	Lecture (hrs.)	Tutorials (hrs.)
1	5-8 Feb	Introduction to Mechanics, commonly employed mechanisms, planer mechanisms, Kinematic Chains and Kinematic Pairs, mechanism mobility using Grubler's criterion	3	1
2	11-15 Feb	Mechanism inversion, types of four bar and slider crank mechanisms, Grahsof's criterion, Introduction to Kinematic analysis. Instantaneous center of rotation, Kennedy's theorem, analysis of velocities, brief introduction to polygon method	3	1
3	18-22 Feb	Mechanics of rigid bodies and planer mechanisms, displacement analysis, relative velocity between two points undergoing planer motion,	3	1
4	25 -1 Mar	Planer Mechanism, special cases of relative velocity expressions, relative acceleration between two points undergoing planer motion	3	Test 1 (Mar 1)
5	4-8 Mar	Analytical Kinematic Analysis of planer mechanisms (Loop closure equation), position, velocity and acceleration representation.	3	1
6	11-15 Mar	Analysis of Four Bar chain, Slider crank mechanism	3	1
7	18-22 Mar	Solution under different input conditions, analytical solution for slider crank inversion,	3	1

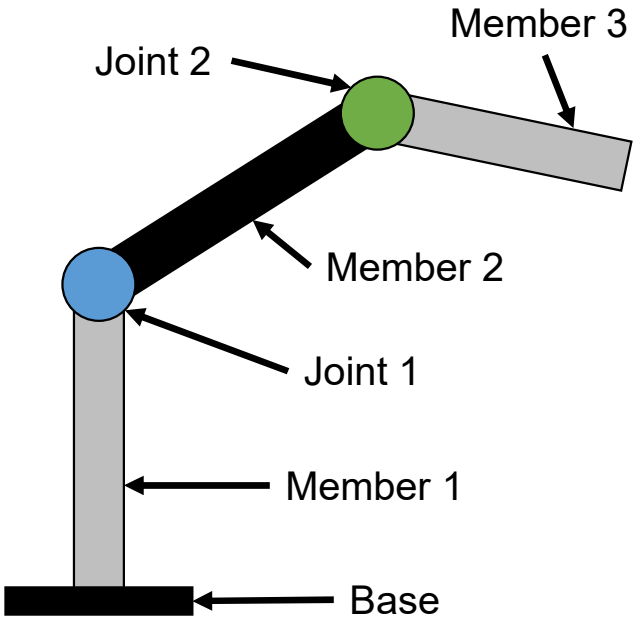
Unit Study Calendar - 2019

Week	Dates	Description	Lecture (hrs.)	Tutorials (hrs.)
8	25-29 Mar	**Mid-semester exam**		Mid Exam
9	1-5 Apr	Kinematics for Gears	3	1
10	8-12 Apr	Gears, friction gearing, common types of toothed gears, gear geometry, Simple and compound gear trains, planetary gear trains, tabular analysis of planetary gear trains, differentials.	3	1
11	15-19 Apr	**New Year Holidays**	3	1
12	22-26 Apr	Static force analysis of planer mechanisms, graphical method, Static force analysis, vector approach	3	1
13	29-3 May	Dynamic Analysis of Planer Mechanisms and Virtual work	3	Test 2 (Apr 3)
14	6-10 May	Dynamic Analysis of Planer mechanisms,	3	1
15	13-17 May	Unbalance forces and couples, balancing of rotors.	3	1

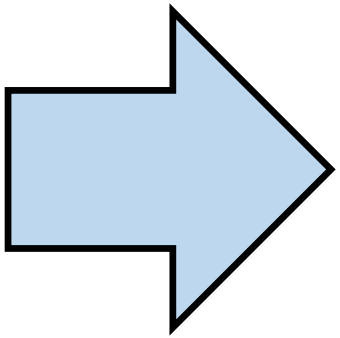
Lecture 01:
Introduction to Mechanisms and Kinematics

Introduction

- Mechanism is a machine composed of several **Members** and **Joints.**

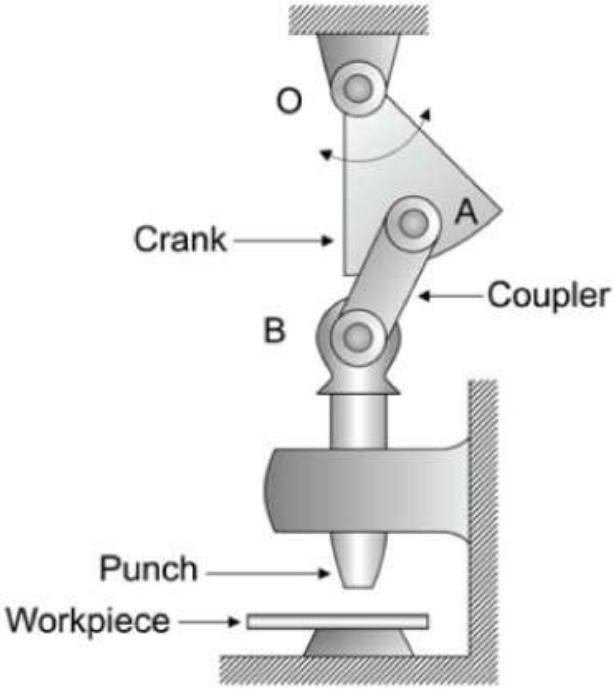


Power Source
1. **Motion**
2. **Force**

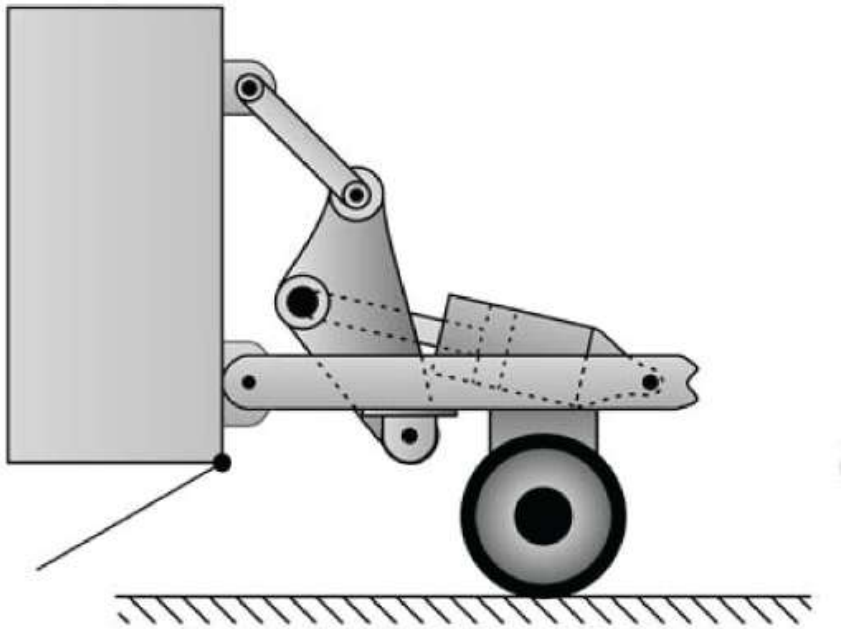


Output

Example – Punch Mechanism



Example – Dump Truck



Dump truck

ME2021 – Mechanics of Machines I

Lecture 02:
INTRODUCTION TO MECHANISMS AND KINEMATICS

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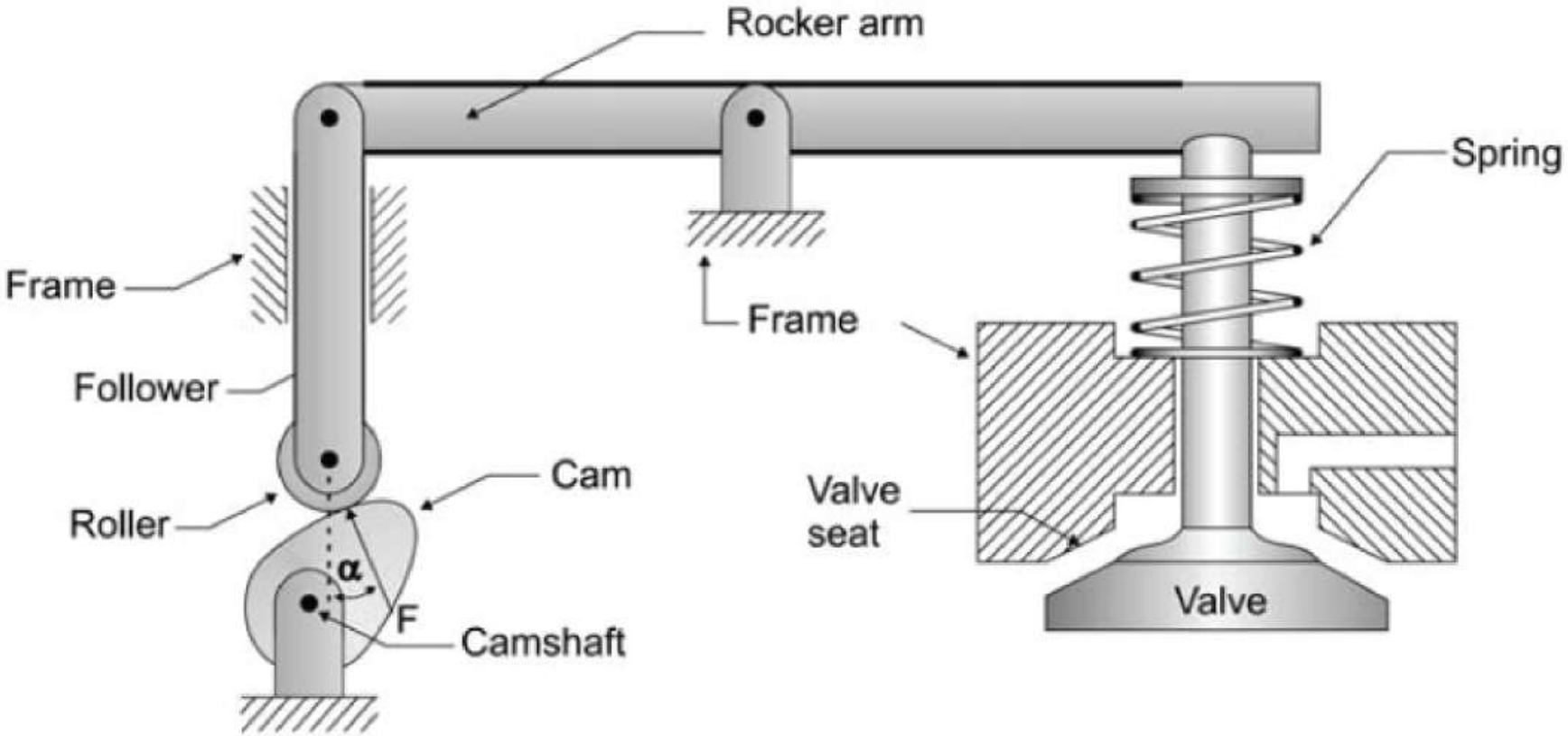
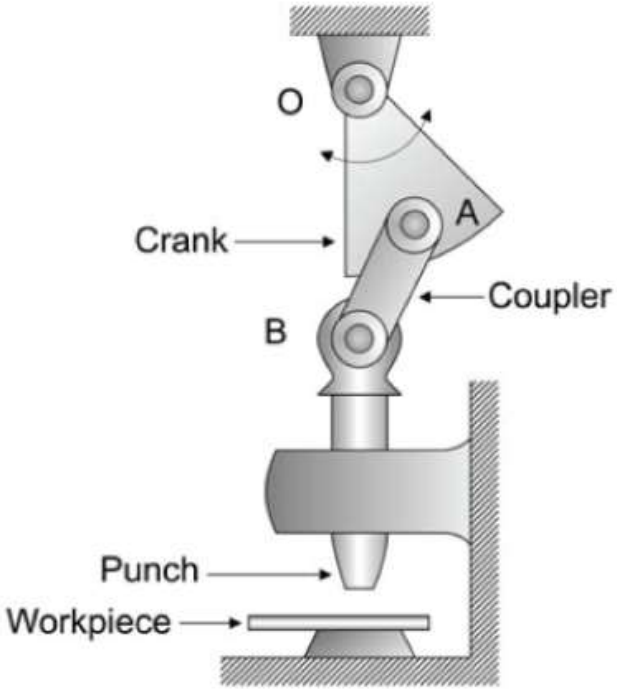
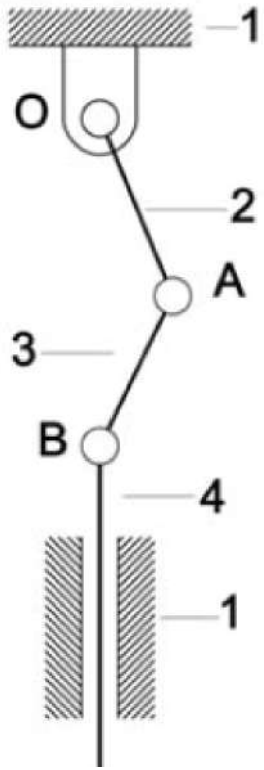
Example – Cam Operating Valve

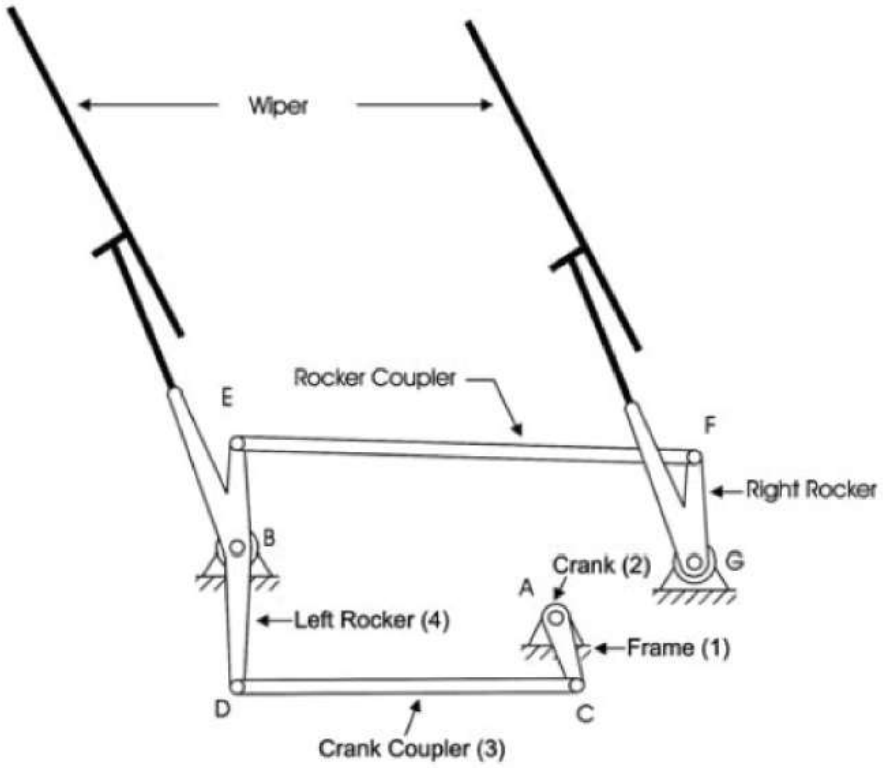


Example – Punch Mechanism

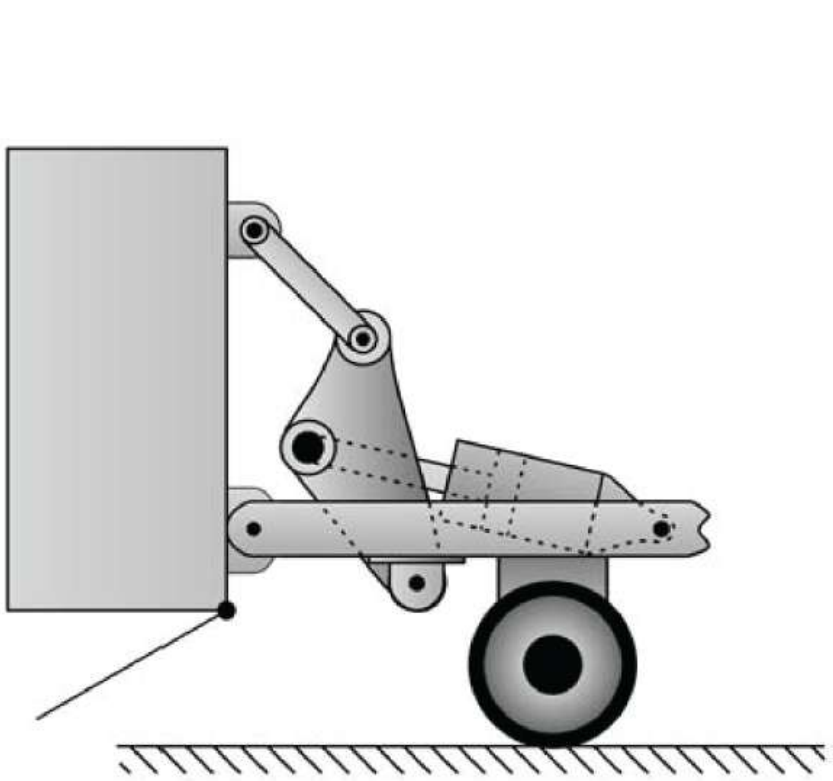




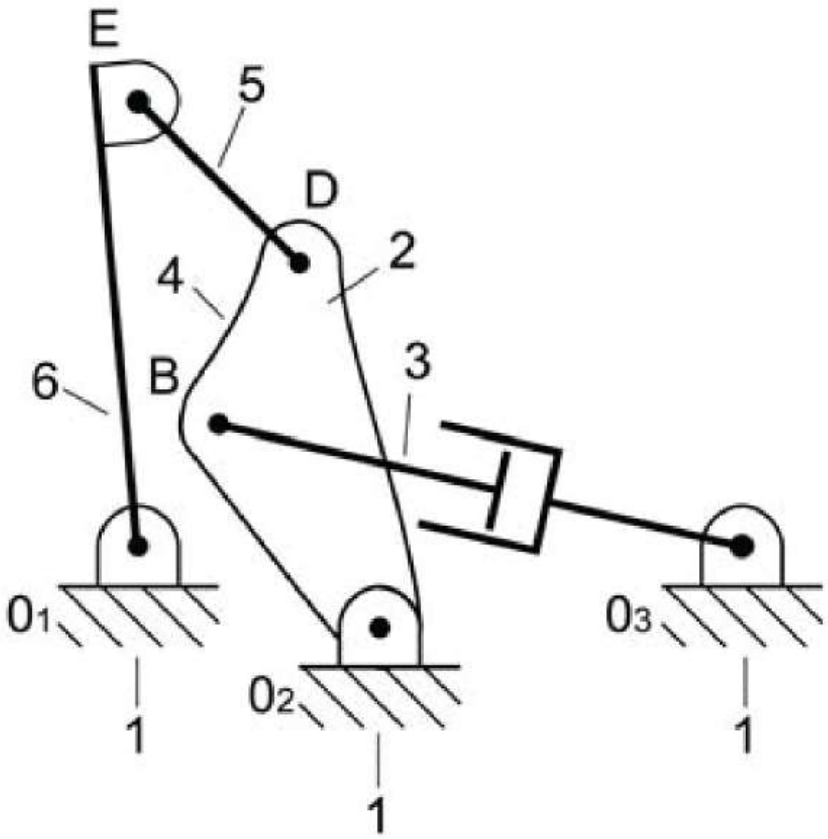
Example – Windshield wiper mechanism



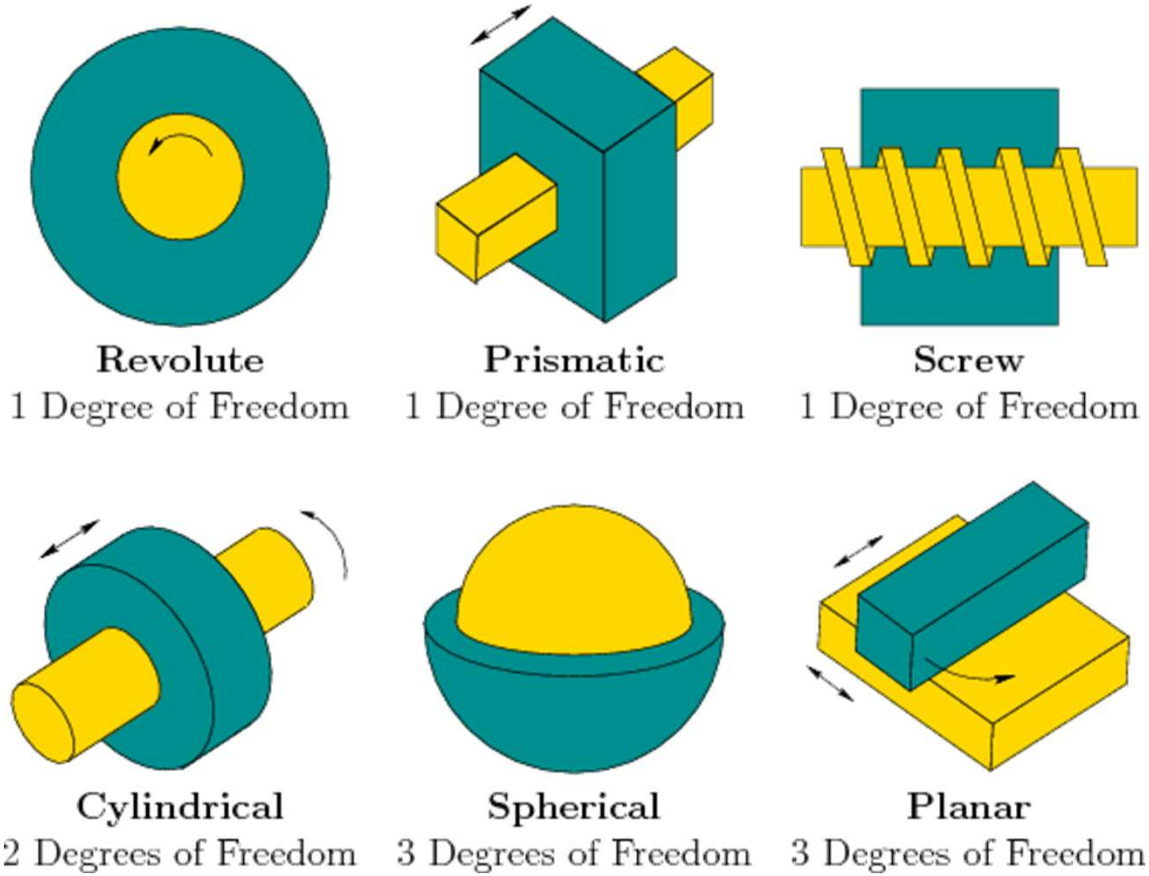
Example – Dump Truck



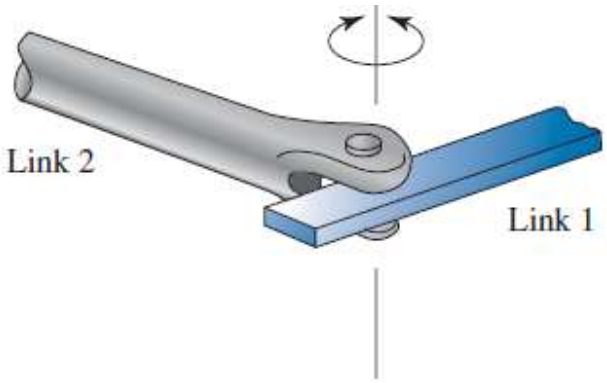
Dump truck



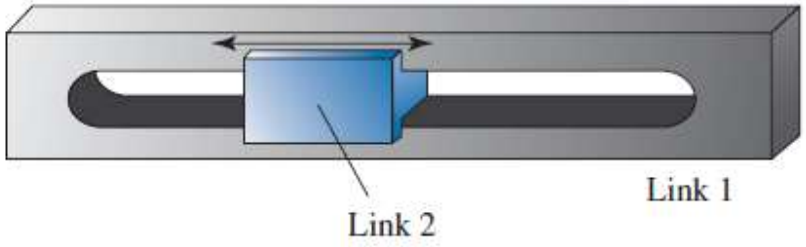
Lower Pair Joint Types



Lower Pair Joint Types

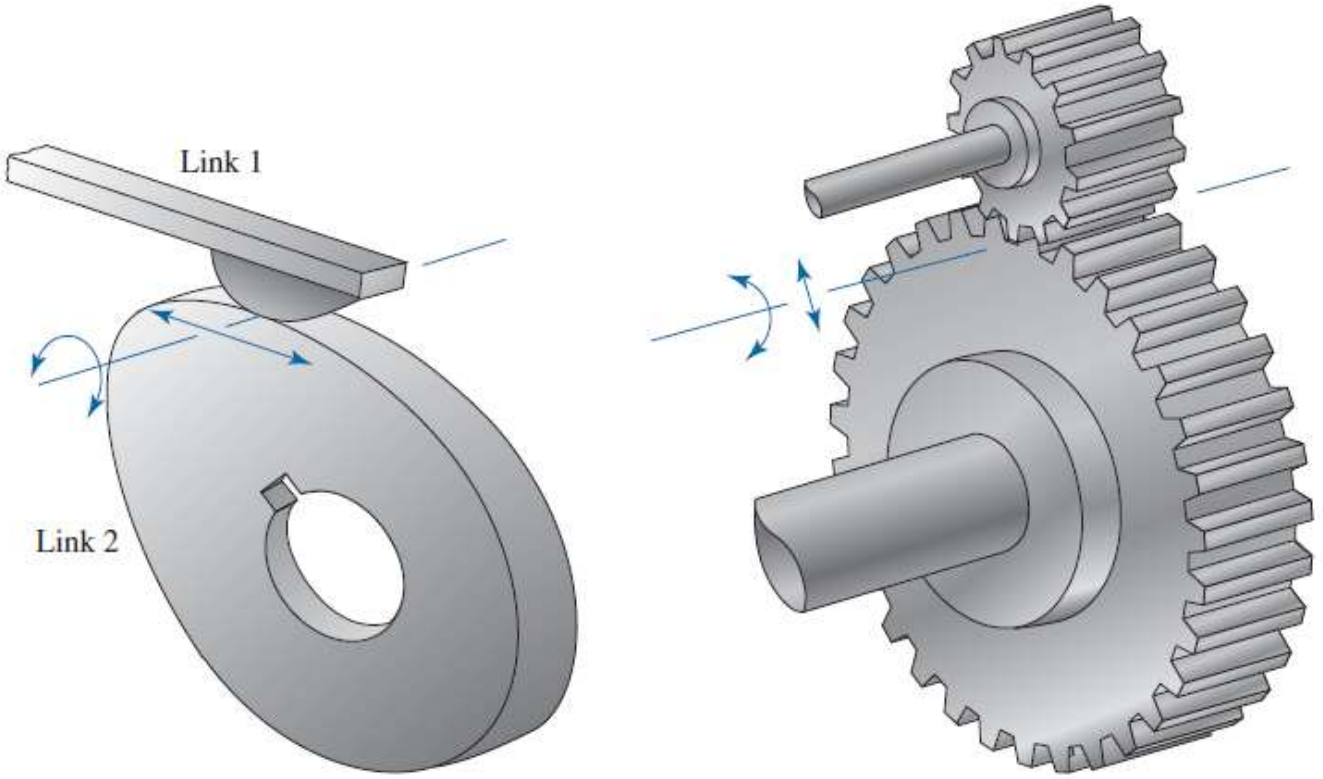


(a) Pin



(b) Sliding

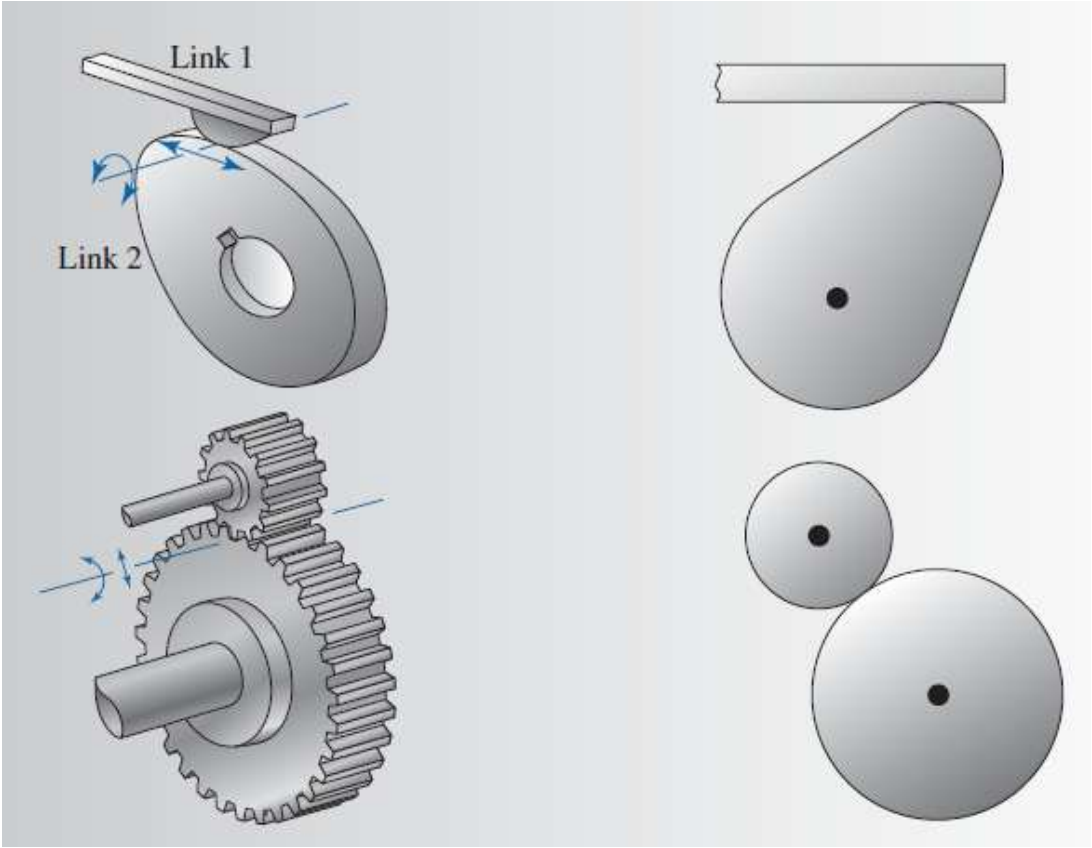
Higher Pair Joint Types



(a) Cam joint

(b) Gear joint

Higher Pair Joint Types



Compound Joint Types

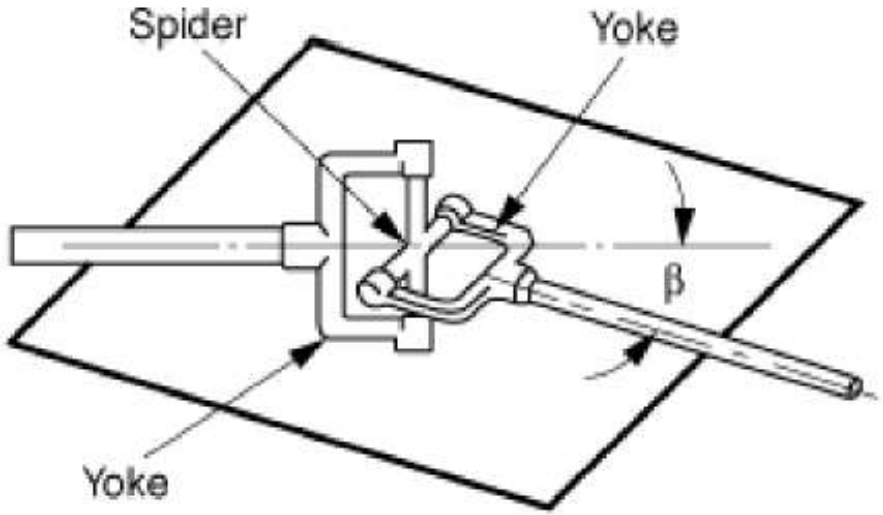
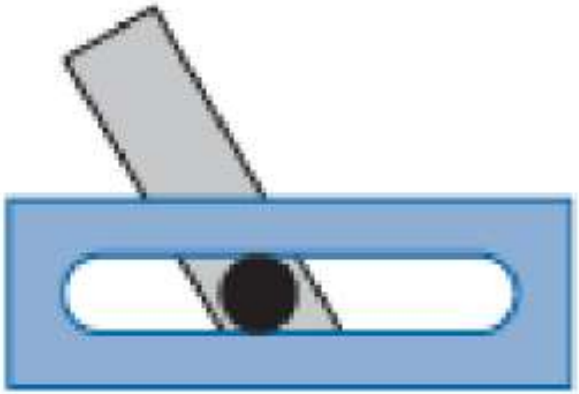
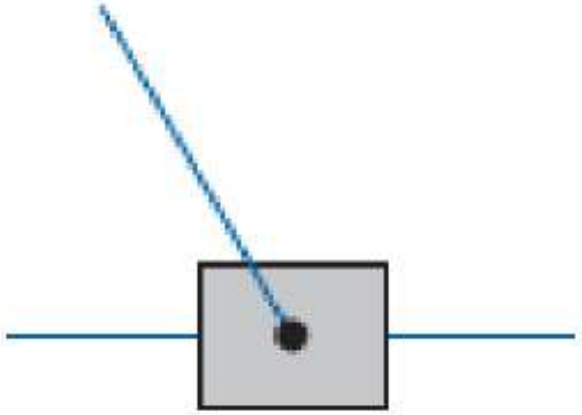


Figure 8: (a) Ball bearing (b) Universal joint

Compound Joint Types – Pin in a slot



(a) actual pin in a slot



(a) Compound model

Compound Joint Types – Screw Joint

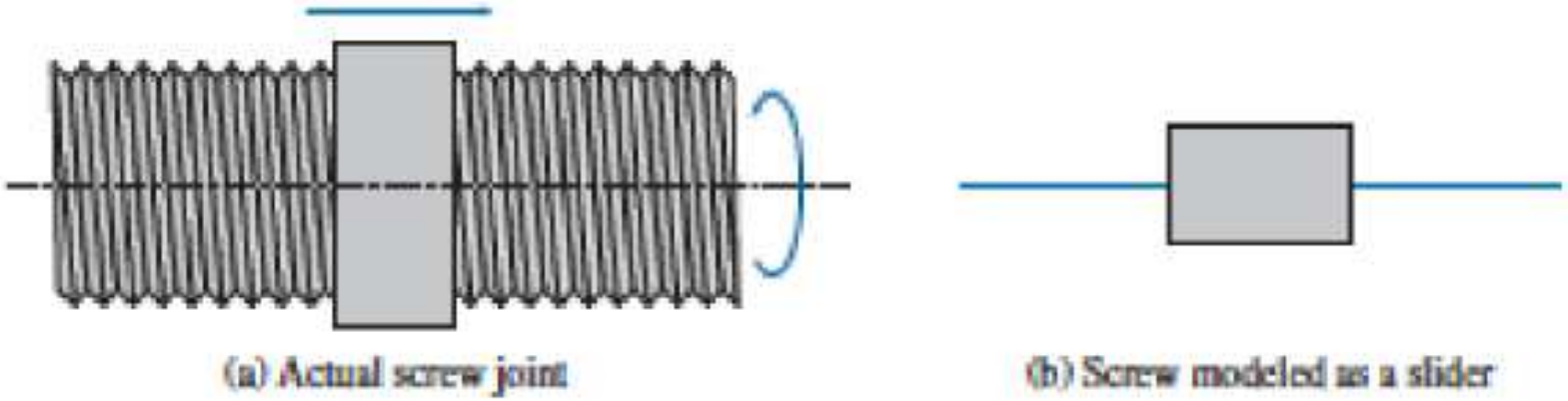
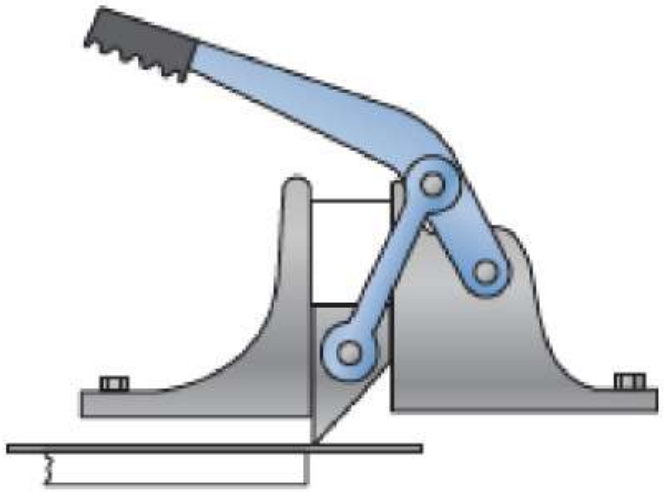
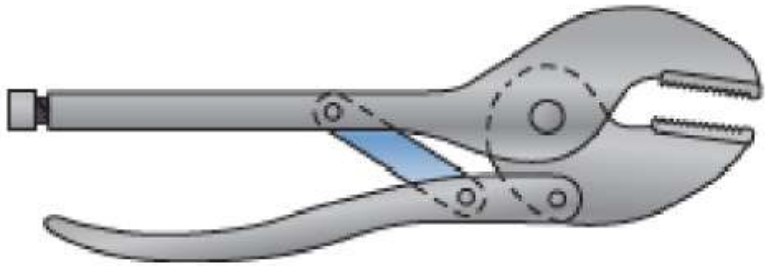


Figure 10: Screw Joint modelled as a sliding joint

Examples



(a) Sheer Press



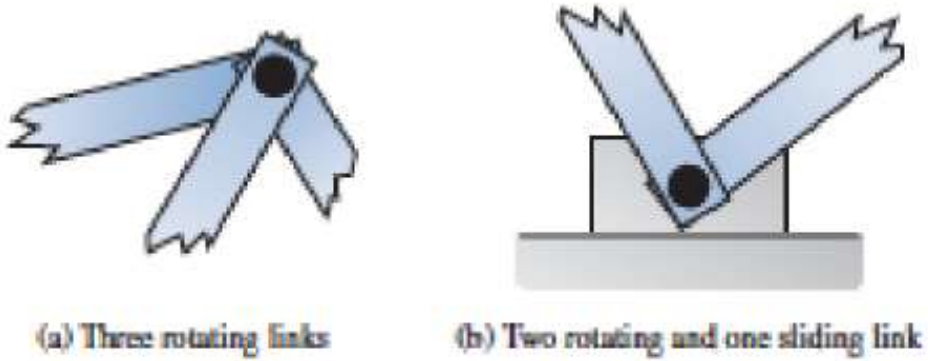
(b) Vice Grip

Gruebler's Equation

$$\boldsymbol{M = 3(n-1) - 2j_p - j_h}$$

M – Mobility of a planar mechanism
n – Total No. of links in the mechanism
j_p – Total No. of primary joints (Pivot or sliding)
j_h – Total No. of higher – order joint (cams or gears)

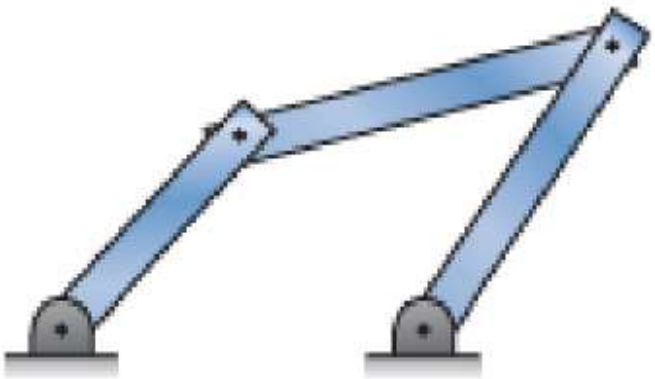
Coincide joints



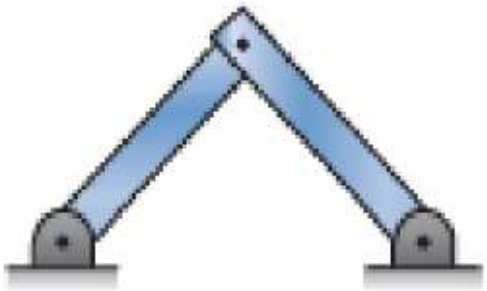
(a) Three rotating links (b) Two rotating and one sliding link

p members => $(p-1)$ identical joints

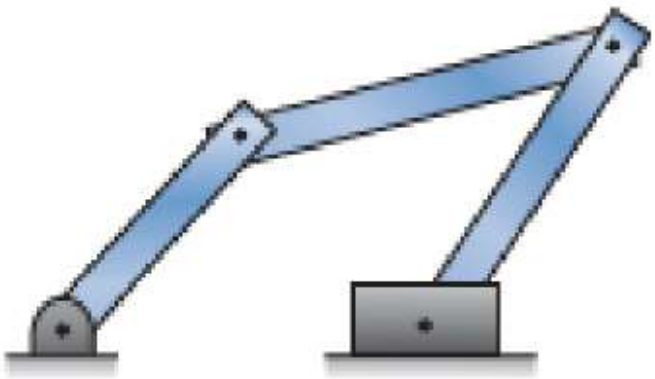
Examples



a

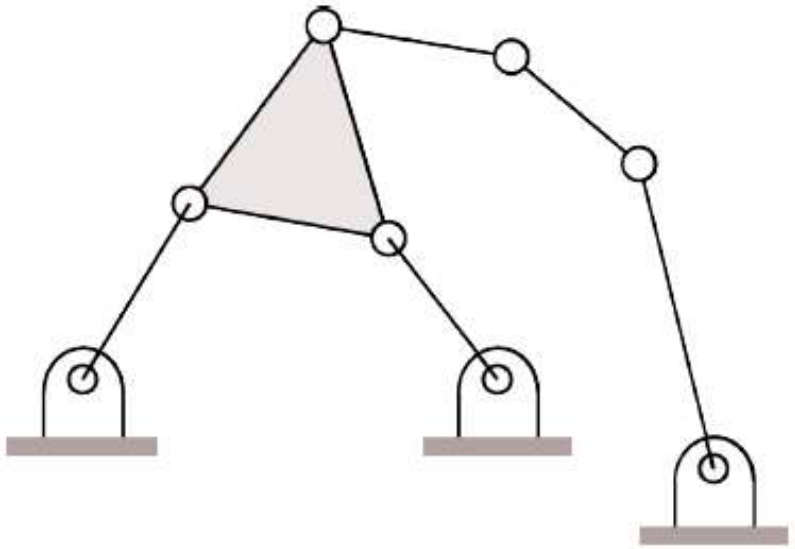


b

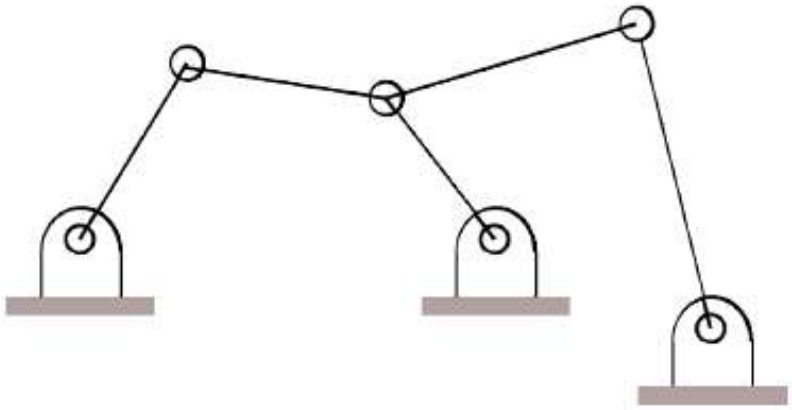


c

Examples

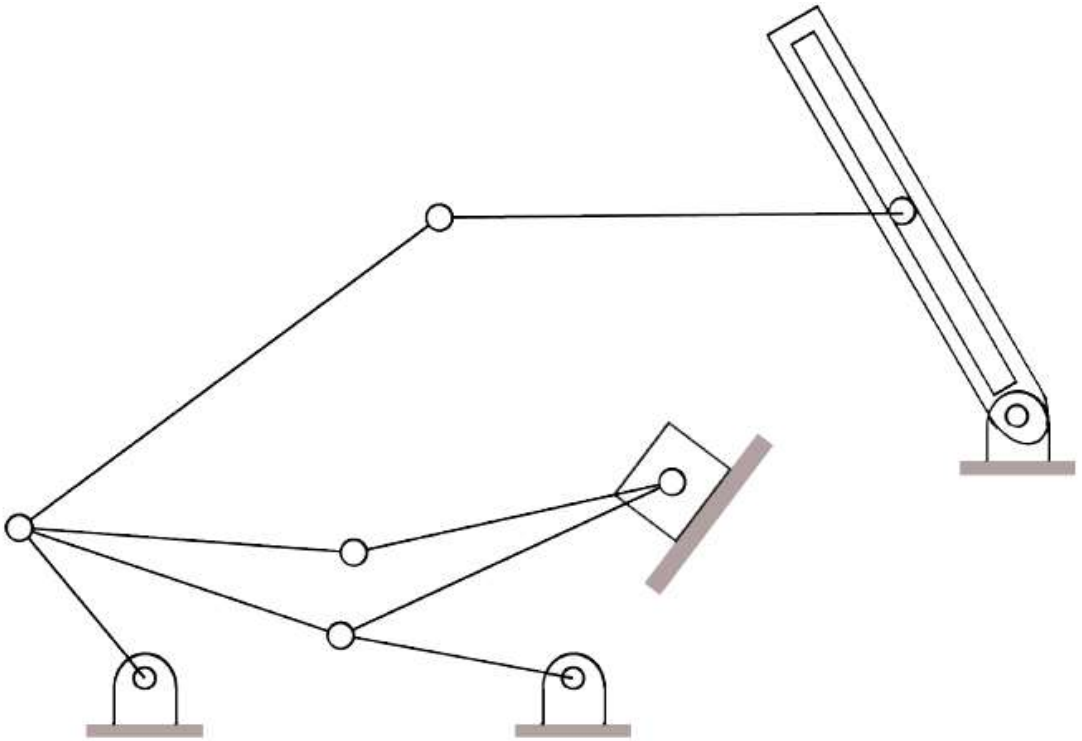


(a)



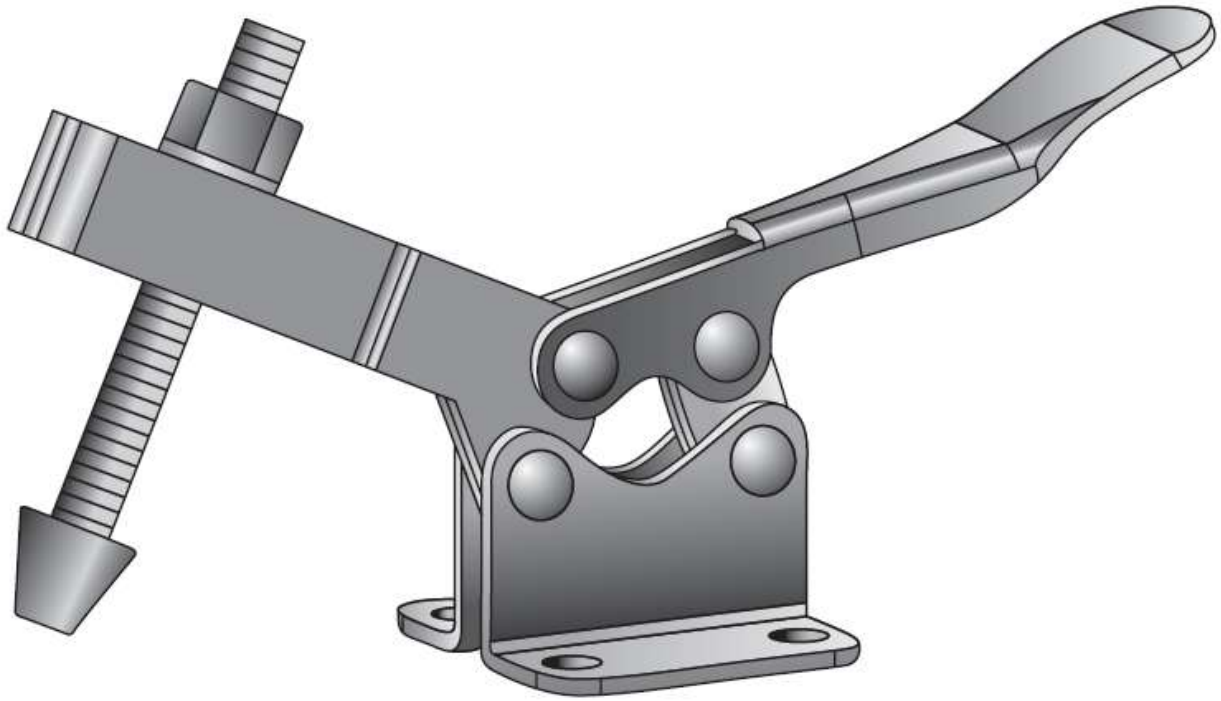
(b)

Examples

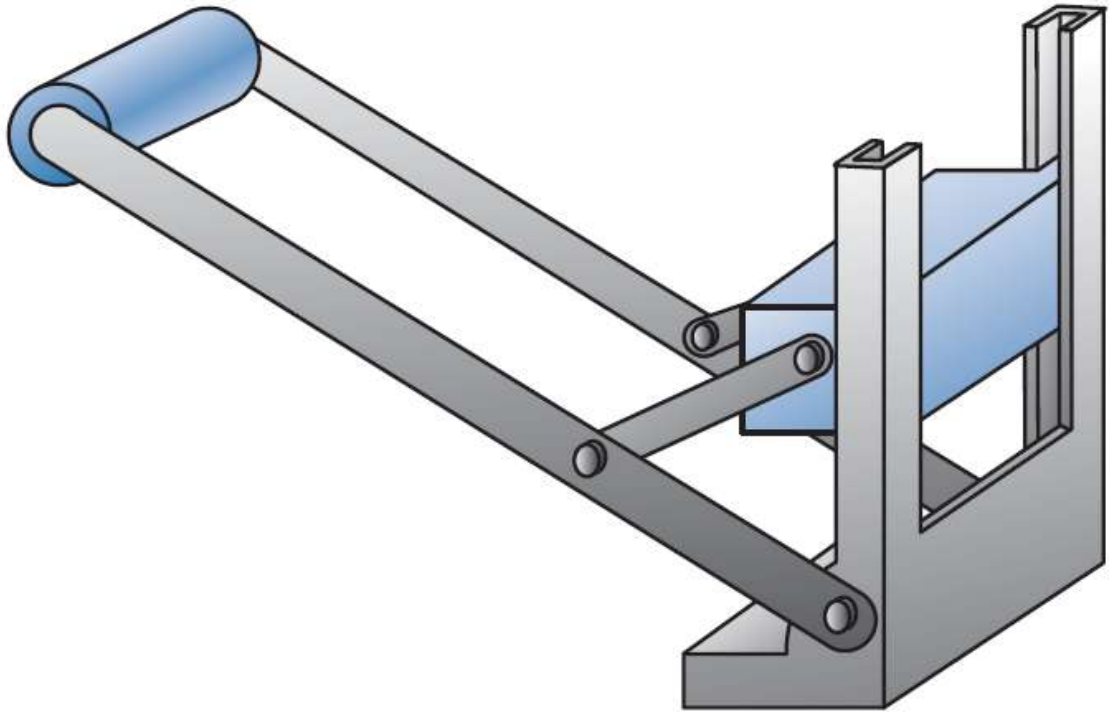


(c)

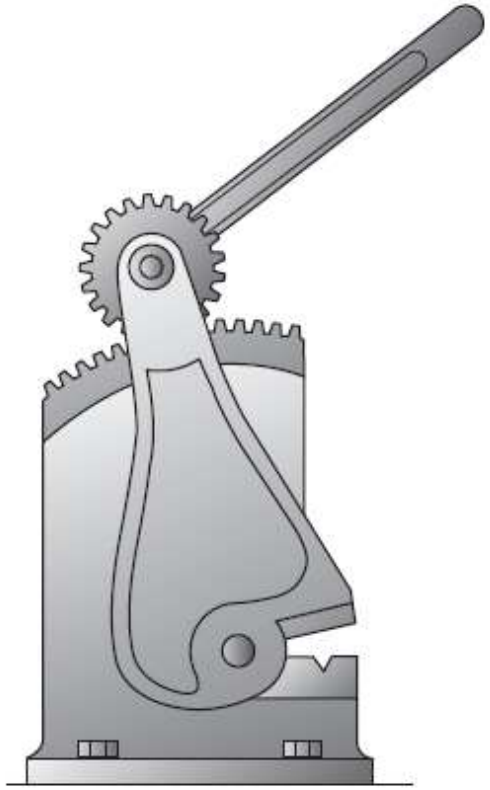
Examples – Toggle clamp



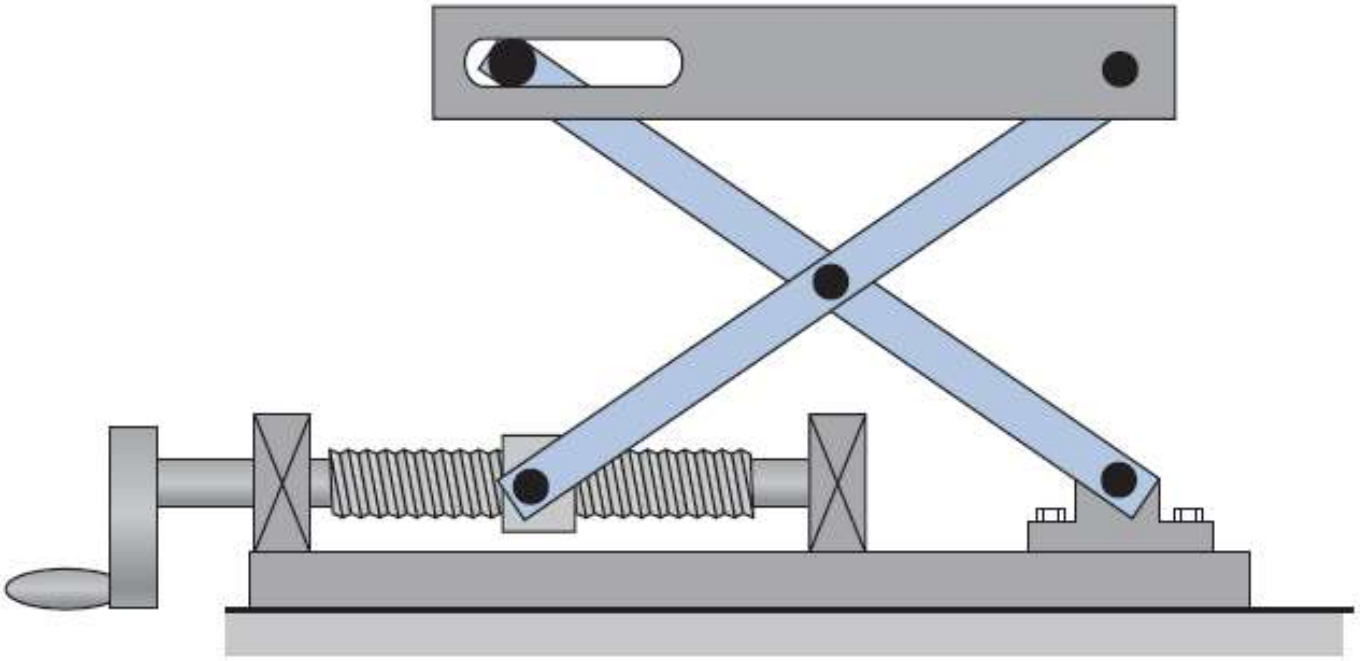
Examples – Beverage can crusher



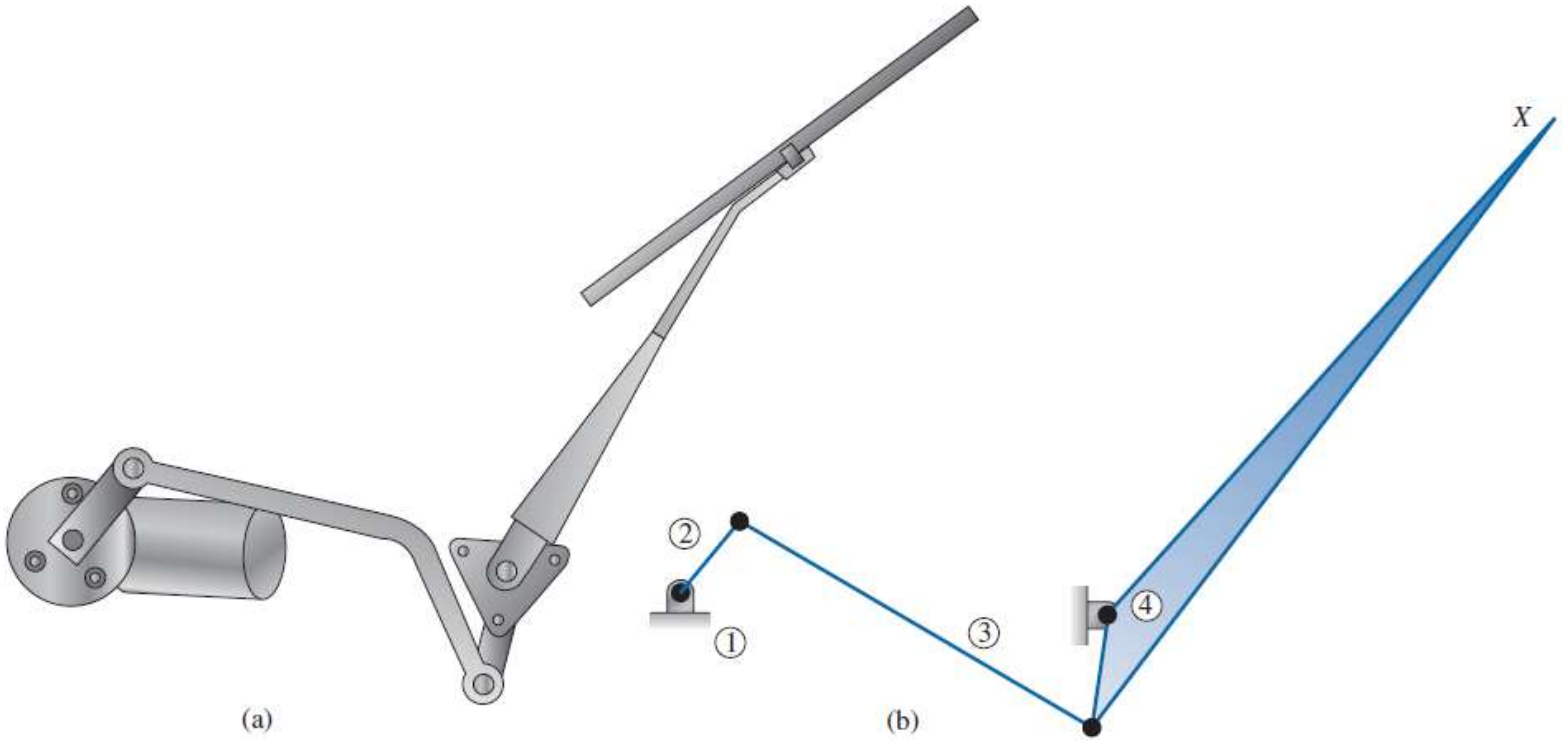
Examples – Shear Press



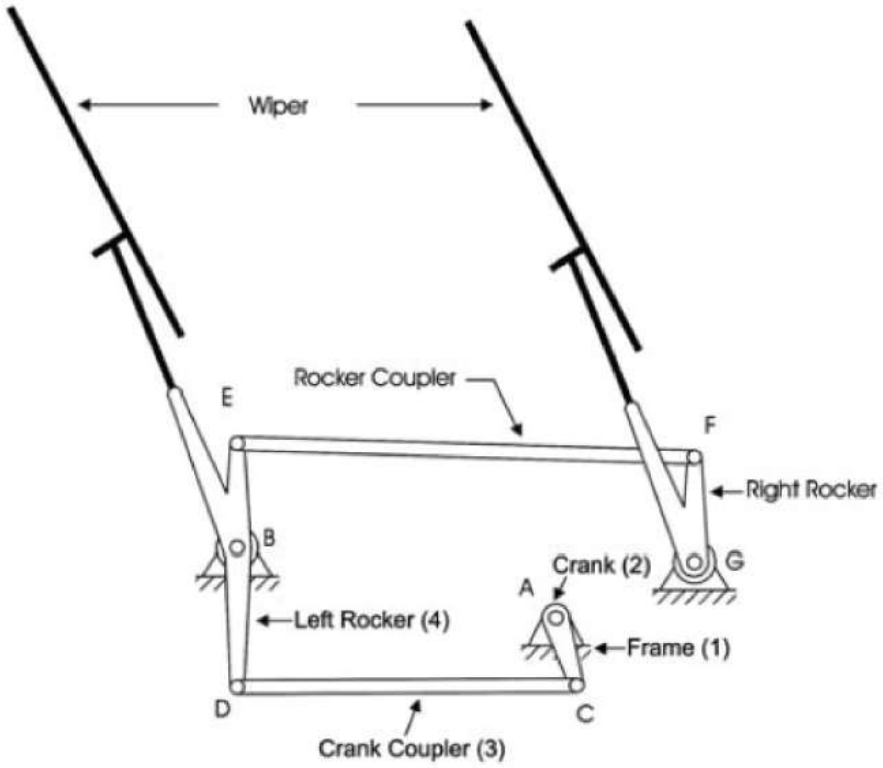
Examples – Lift Table



Examples – Rear Window wiper mechanism

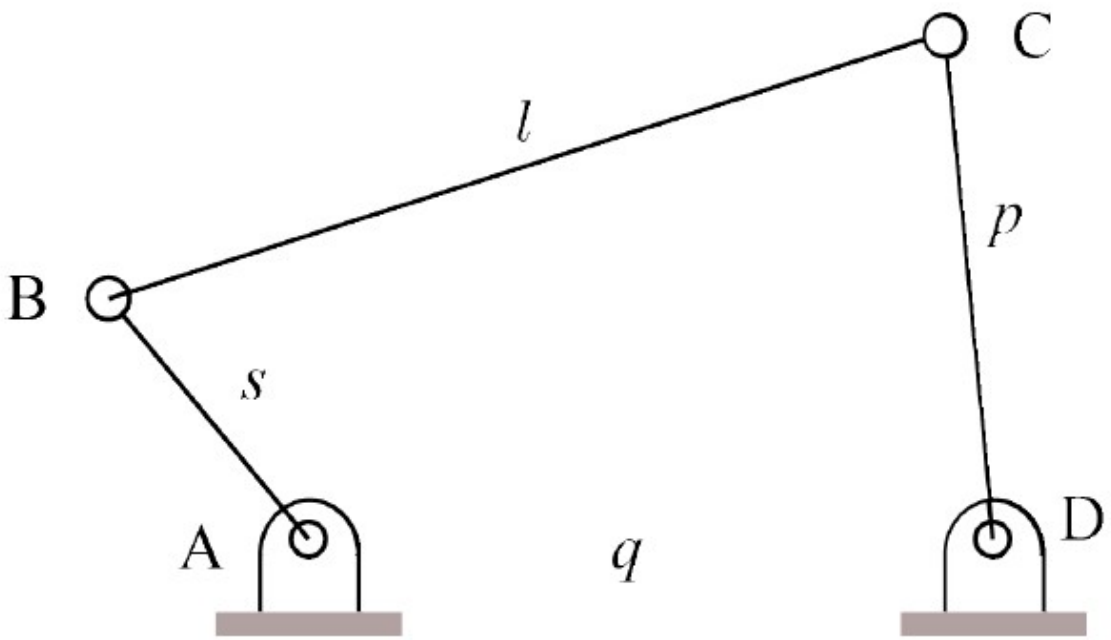


Example – Windshield wiper mechanism

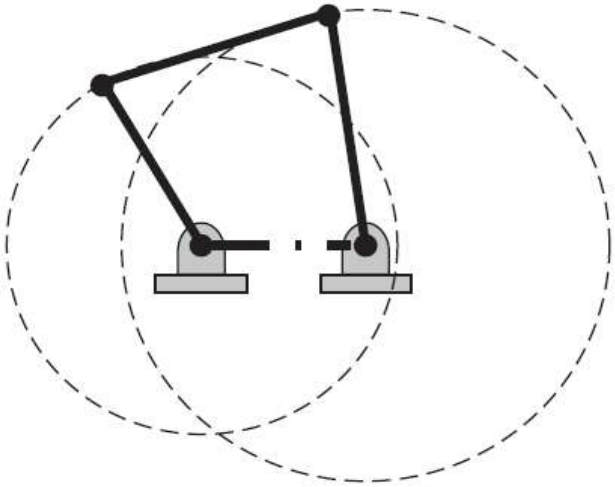


Grashof's Criteria

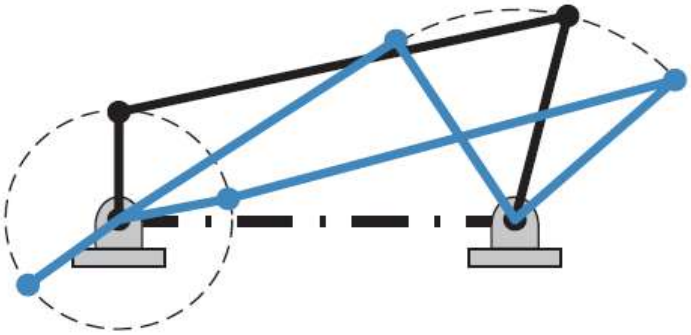
$$s + l \leq p + q$$



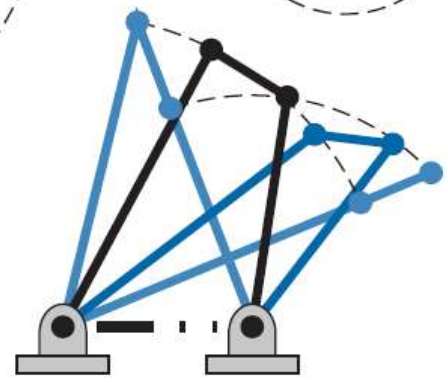
Grashof Type 1 Linkages



(a) Double crank

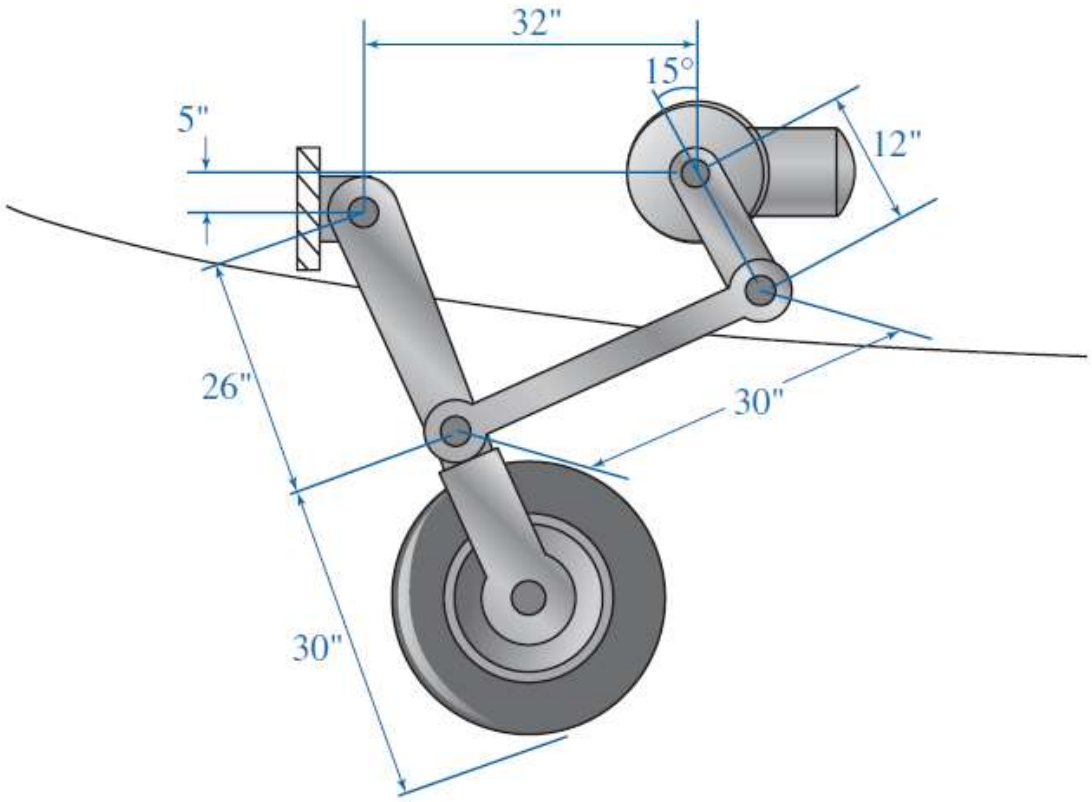


(b) Crank-rocker

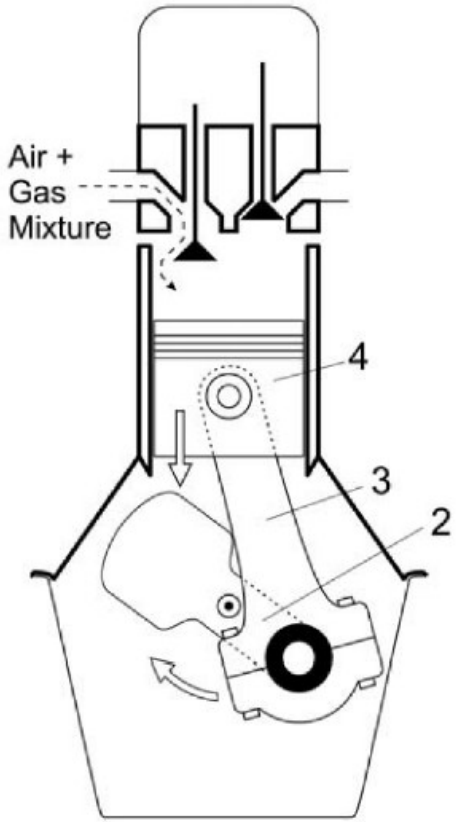


(c) Double rocker

Nose Wheel Mechanism

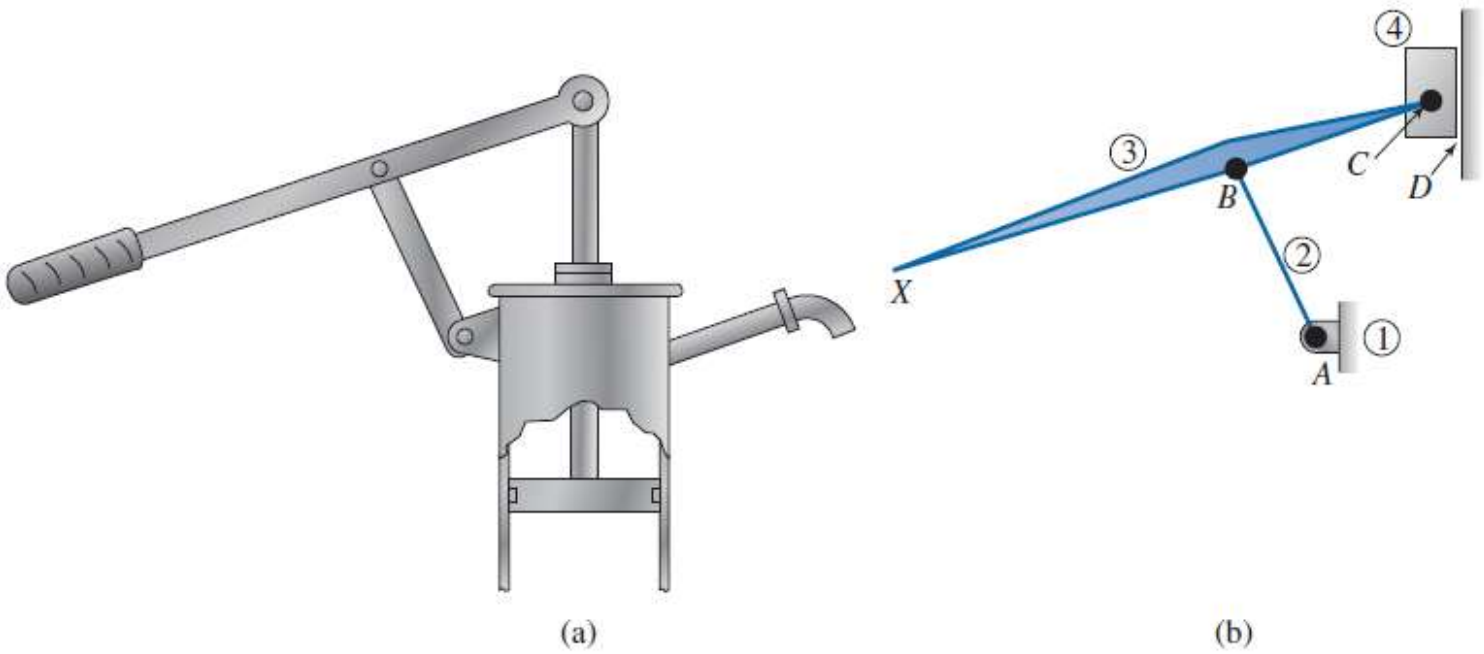


Slider Crank Mechanism



1. Frame
2. Crank
3. Connecting Rod
4. Piston

Manual water pump



Recommended Text

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- *W.L. Cleghorn,* **"Mechanisms and Machines"** *2nd edition, Oxford University Press, 2015.*
- *John J. Uicker, Gordon R. Pennock and Joseph E. Shigley,* **"Theory of Machines and Mechanisms"***, Oxford University Press*