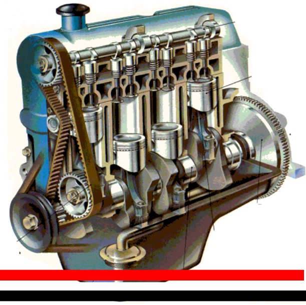

MDPG 126

Mechanics of Machines

Lecture 3

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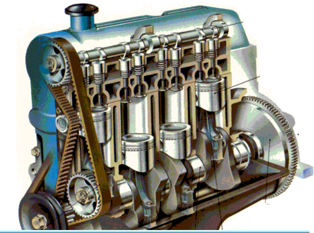
KINEMATIC DIAGRAMS



A kinematic diagram should be drawn to a scale proportional to the actual mechanism. For convenient reference, the links are numbered, starting with the frame as link number 1. To avoid confusion, the joints should be lettered.

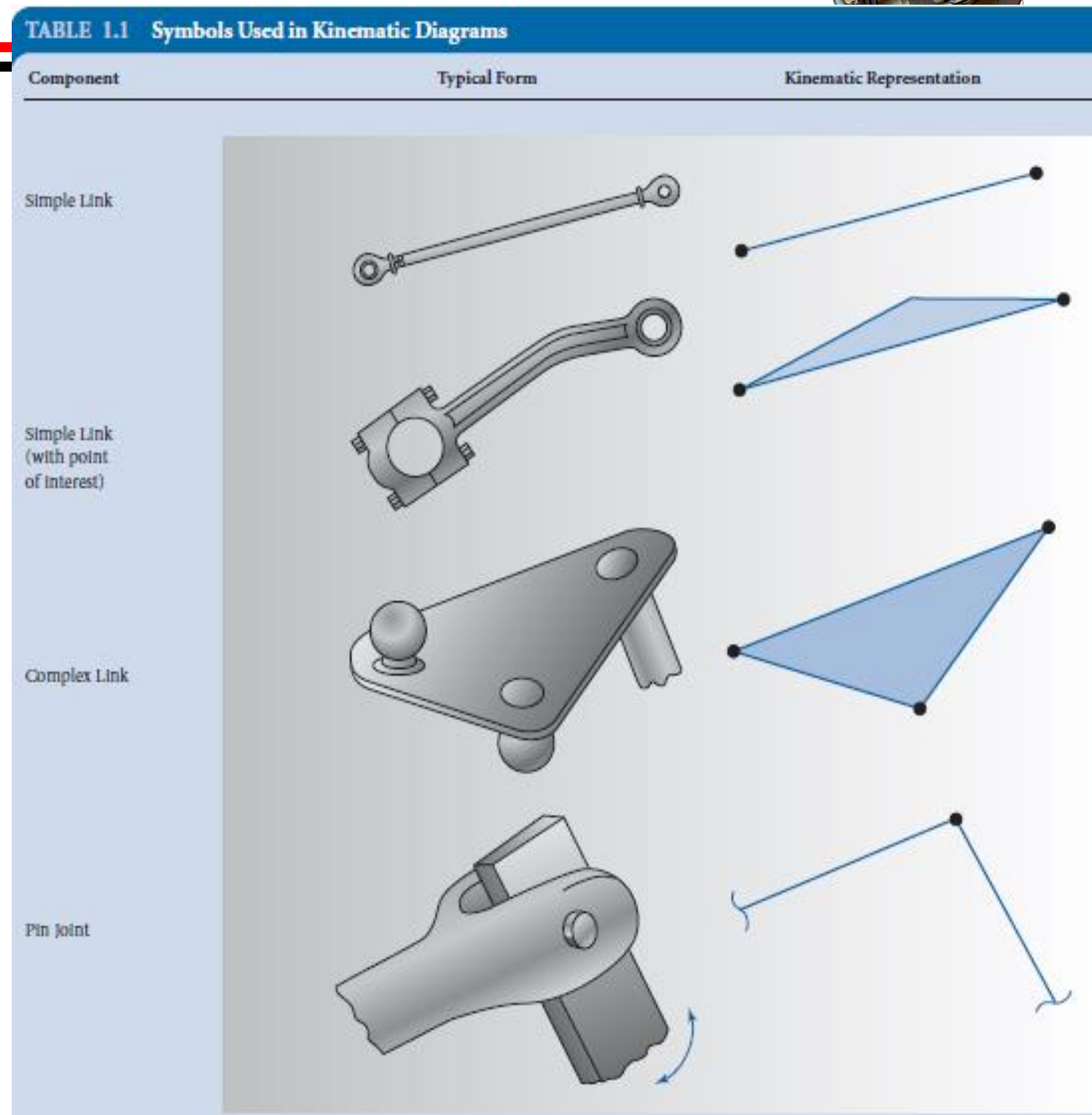


TABLE 1.1 Symbols Used in Kinematic Diagrams

Component	Typical Form	Kinematic Representation
Simple Link		
Simple Link (with point of interest)		
Complex Link		
Pin Joint		

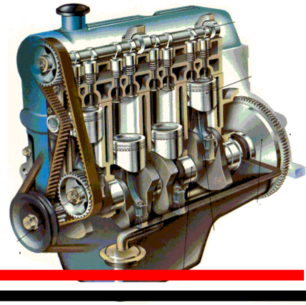
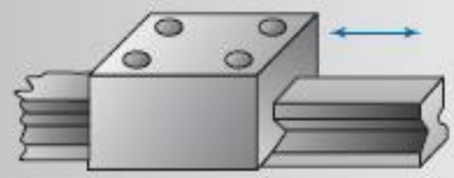
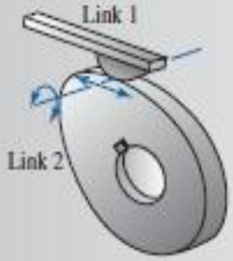
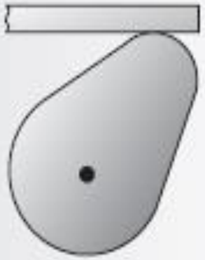
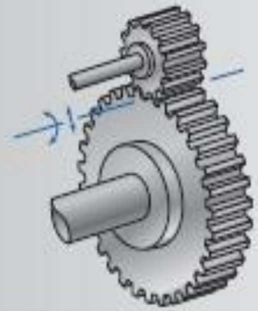
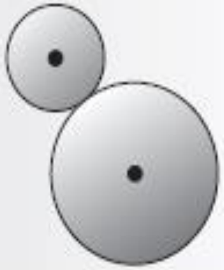
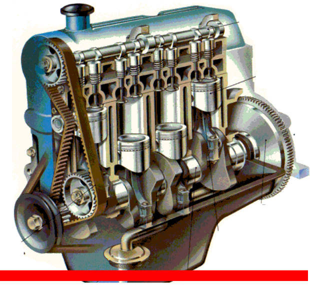


TABLE 1.1 (Continued)

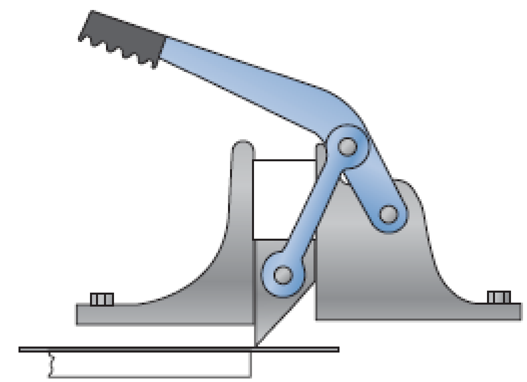
Component	Typical Form	Kinematic Representation
Slider Joint		
Cam Joint		
Gear Joint		

Draw the Kinematic Diagram



1- Identify the Frame

the large base that is bolted to the table is designated as the frame. The motion of all other links is determined relative to the base. The base is numbered as link 1.



Shear press for Example Problem 1.1.

2- Identify All Other Links

Link 2: Handle

Link 3: Cutting blade

Link 4: Bar that connects the cutter with the handle

3- Identify the Joints

Pin joints are used to connect link 1 to 2, link 2 to 3, and link 3 to 4. These joints are lettered *A* through *C*. In addition, the cutter slides up and down, along the base. This sliding joint connects link 4 to 1, and is lettered *D*.

4- Identify Any Points of Interest

Finally, the motion of the end of the handle is desired. This is designated as *point of interest X*.

5- Draw the Kinematic Diagram

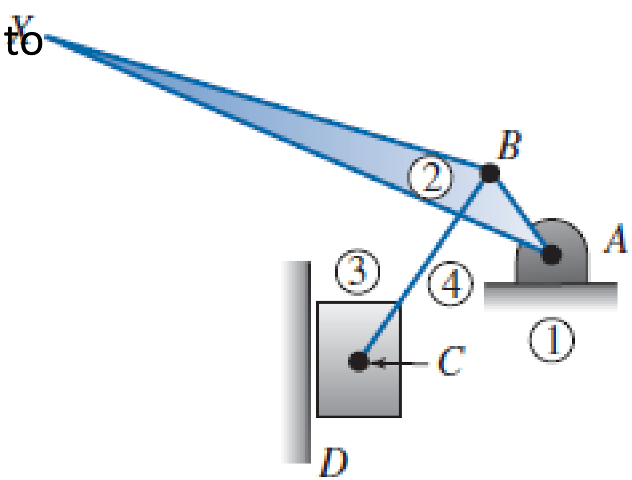
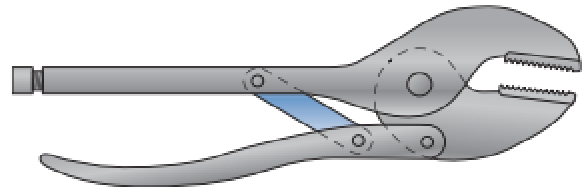
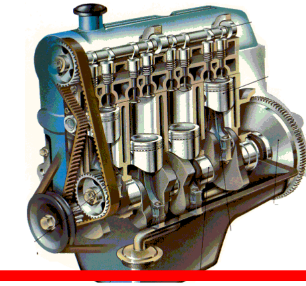


Figure 1.11 shows a pair of vise grips. Draw a kinematic diagram.





1. ***Identify the Frame***

   The first step is to decide the part that will be designated as the frame. In this problem, no parts are attached to the ground. Therefore, the selection of the frame is rather arbitrary.

   The top handle is designated as the frame. The motion of all other links is determined relative to the top handle. The top handle is numbered as link 1.

2. ***Identify All Other Links***

   Careful observation reveals three other moving parts:

   Link 2: Bottom handle
   Link 3: Bottom jaw
   Link 4: Bar that connects the top and bottom handle

3. ***Identify the Joints***

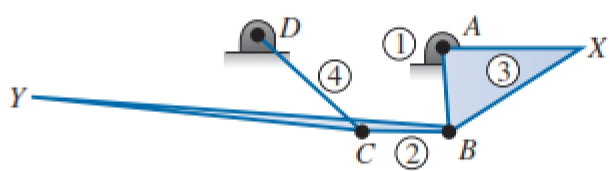
   Four pin joints are used to connect these different links (link 1 to 2, 2 to 3, 3 to 4, and 4 to 1). These joints are lettered *A* through *D*.

4. ***Identify Any Points of Interest***

   The motion of the end of the bottom jaw is desired. This is designated as point of interest *X*. Finally, the motion of the end of the lower handle is also desired. This is designated as point of interest *Y*.

5. ***Draw the Kinematic Diagram***

   The kinematic diagram is given in Figure 1.12.



Mobility

Mobility (M) or degree of freedom is the number of independent inputs required to precisely position all links of the mechanism with respect to the ground.

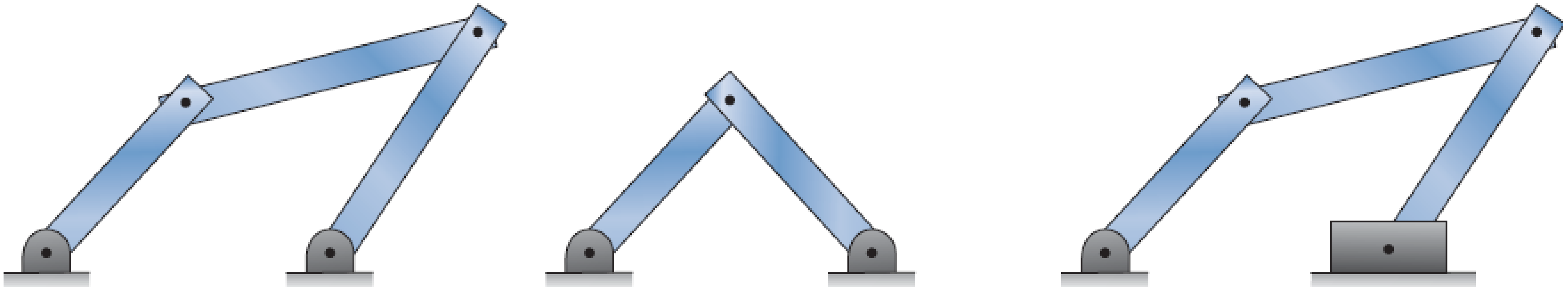
Degrees of freedom for planar linkages joined with common joints can be calculated through ***Gruebler's equation***:

$$M = \text{degrees of freedom} = 3(n - 1) - 2j_p - j_h$$

n = total number of links in the mechanism

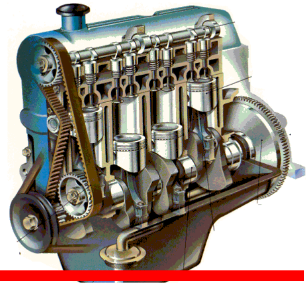
j_p = total number of primary joints (pins or sliding joints)

j_h = total number of higher-order joints (cam or gear joints)



(a) Single degree-of-freedom ($M = 1$) (b) Locked mechanism ($M = 0$) (c) Multi-degree-of-freedom ($M = 2$)

Gruebler's Equation



Degrees of freedom for planar linkages joined with common joints can be calculated through *Gruebler's equation*:

$$M = \text{degrees of freedom} = 3(n - 1) - 2j_p - j_h$$

where:

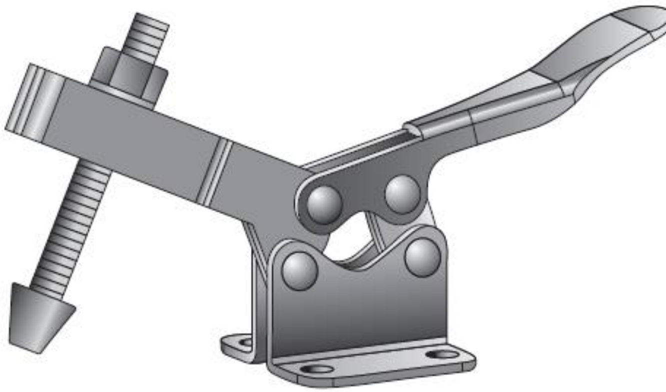
n = total number of links in the mechanism

j_p = total number of primary joints (pins or sliding joints)

j_h = total number of higher-order joints (cam or gear joints)

Figure 1.14 shows a toggle clamp. Draw a kinematic diagram, using the clamping jaw and the handle as points of interest. Also compute the degrees of freedom for the clamp.

1. ***Identify the Frame***



The component that is bolted to the table is designated as the frame. The frame is numbered as link 1.

2. ***Identify All Other Links***

Link 2: Handle

Link 3: Arm that serves as the clamping jaw

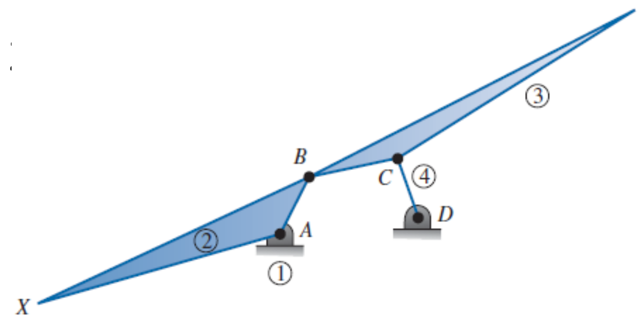
Link 4: Bar that connects the clamping arm and handle

3. ***Identify the Joints***

Four pin joints are used to connect these different links (link 1 to
2 to 3, 3 to 4, and 4 to 1). These joints are lettered *A* through *D*.

4. ***Identify Any Points of Interest***

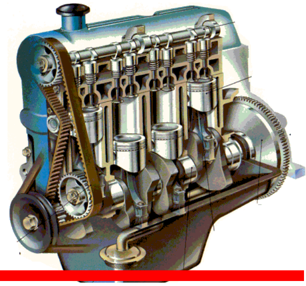
The motion of the clamping jaw is desired. This is designated as point of interest *X*. Finally, the motion of the end of the handle is also desired. This is designated as point of interest *Y*.



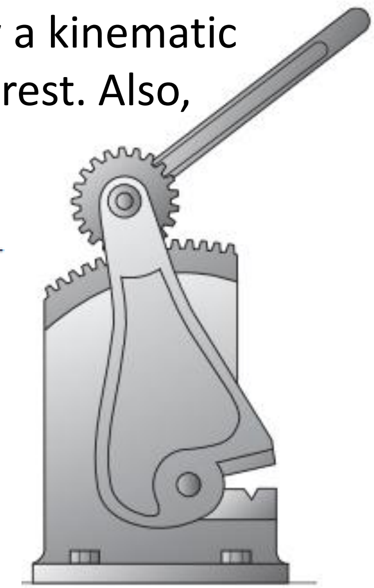
$$n = 4,\ j_p = 4 \text{ pins},\ j_h = 0$$

5. ***Draw the Kinematic Diagram***

$$M = 3(n - 1) - 2j_p - j_h = 3(4 - 1) - 2(4) - 0 = 1$$



- Figure 1.18 shows another device that can be used to shear material. Draw a kinematic diagram, using the end of the handle and the cutting edge as points of interest. Also, compute the degrees of freedom for the shear press.



1. ***Identify the Frame***

   The base is bolted to a working surface and can be designated as the frame. The motion of all other links is determined relative to this frame. The frame is numbered as link 1.

2. ***Identify All Other Links***

   Careful observation reveals two other moving parts:

   Link 2: Gear/handle

   Link 3: Cutting lever

3. ***Identify the Joints***

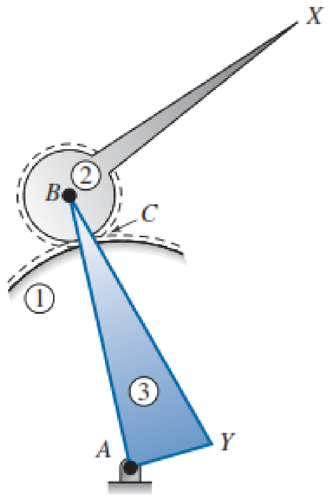
   Two pin joints are used to connect these different parts. One pin connects the cutting lever to the frame. This joint is labeled as *A*. A second pin is used to connect the gear/handle to the cutting lever. This joint is labeled *B*.

   The gear/handle is also connected to the frame with a gear joint. This higher-order joint is labeled *C*.

4. ***Identify Any Points of Interest***

   The motion of the handle end is desired and is designated as point of interest *X*. The motion of the cutting surface is also desired and is designated as point of interest *Y*.

5. ***Draw the Kinematic Diagram***



6. ***Calculate Mobility***

To calculate the mobility, it was determined that there are three links in this mechanism. There are also two pin joints and one gear joint. Therefore,

$$n = 3 \quad j_p = (2 \text{ pins}) = 2 \quad j_h = (1 \text{ gear connection}) = 1$$

and

$$M = 3(n-1) - 2j_p - j_h = 3(3-1) - 2(2) - 1 = 1$$

With one degree of freedom, the shear press mechanism is constrained. Moving only one link, the handle, precisely positions all other links and brings the cutting edge onto the work piece.

Actuators and Drivers

Electric motors (AC)

Electric motors (DC)

Engines ;

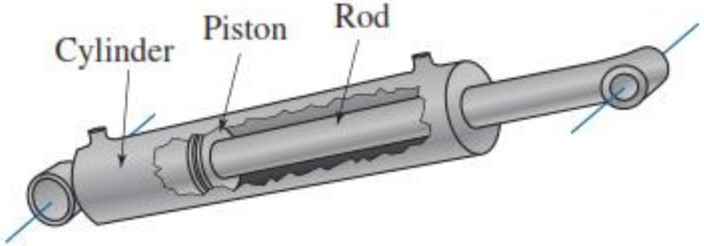
Servomotors

Air or hydraulic motors

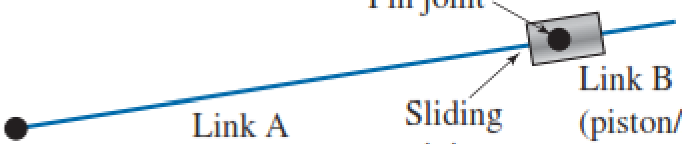
Hydraulic or pneumatic cylinders

Screw actuators

Manual

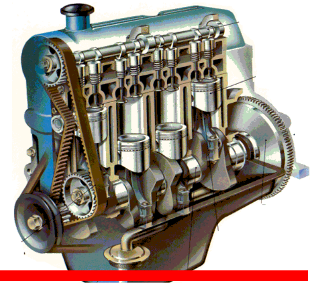


(a)

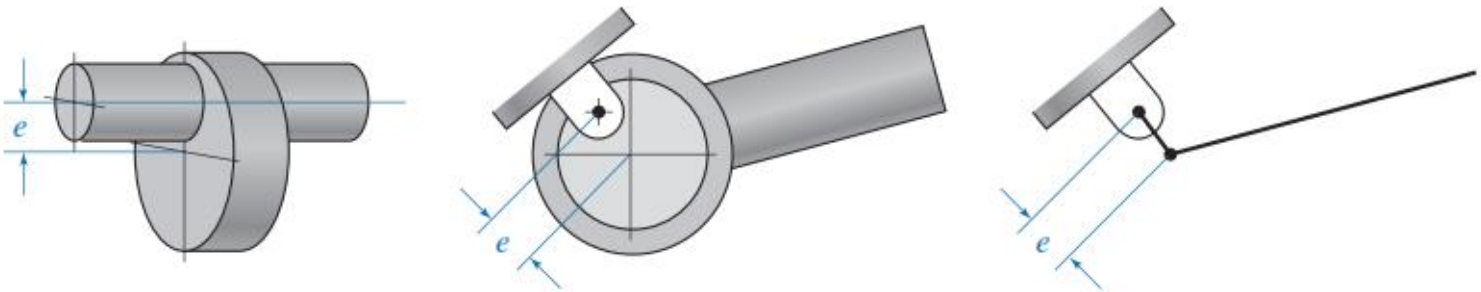


(b)

COMMONLY USED LINKS AND JOINTS

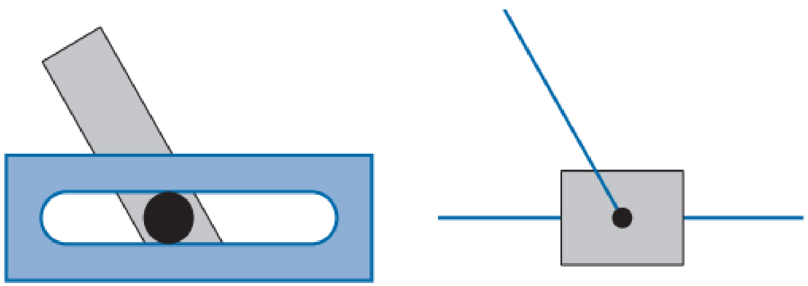


Eccentric Crank



(a) Eccentric crankshaft (b) Eccentric crank (c) Eccentric crank model

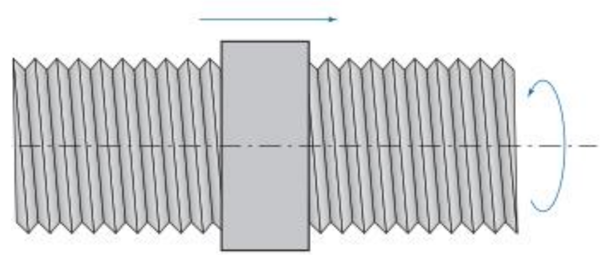
Pin-in-a-Slot Joint



(a) Actual pin-in-a-slot joint (b) Pin-in-a-slot model

FIGURE 1.24 Pin-in-a-slot joint.

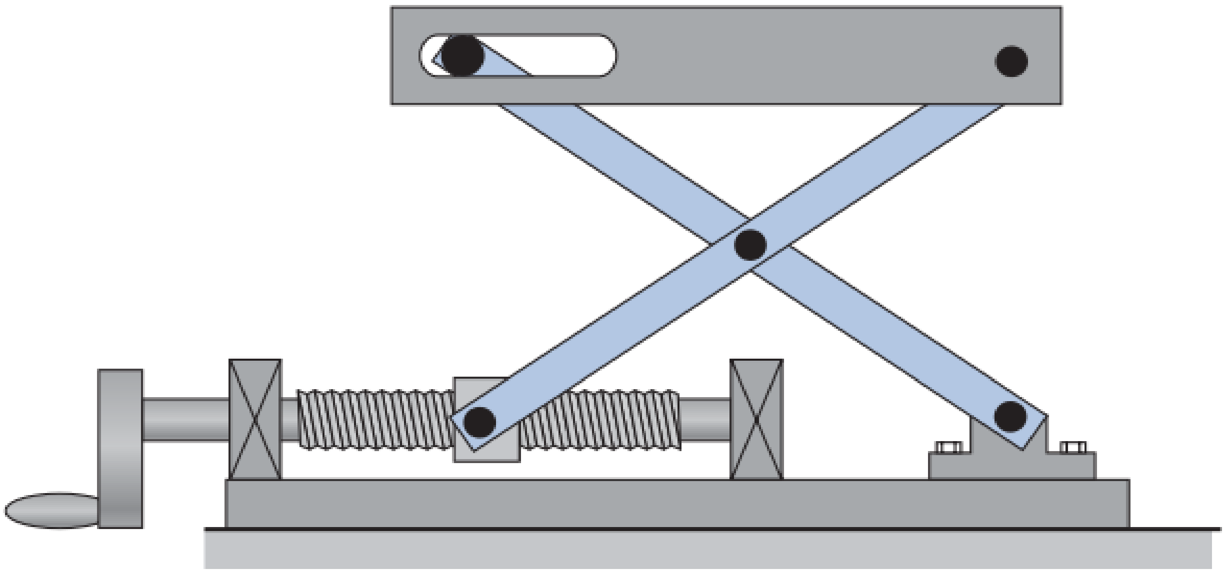
Screw Joint



(a) Actual screw joint

(b) Screw modeled as a slider

Figure 1.26 presents a lift table used to adjust the working height of different objects. Draw a kinematic diagram and compute the degrees of freedom.



1. ***Identify the Frame***

The bottom base plate rests on a fixed surface. Thus, the base plate will be designated as the frame. The bearing at the bottom right of Figure 1.26 is bolted to the base plate. Likewise, the two bearings that support the screw on the left are bolted to the base plate.

From the discussion in the previous section, the out-of-plane rotation of the screw will not be considered. Only the relative translation of the nut will be included in the kinematic model. Therefore, the screw will also be considered as part of the frame. The motion of all other links will be determined relative to this bottom base plate, which will be numbered as link 1.

2. ***Identify All Other Links***

Careful observation reveals five other moving parts:

Link 2: Nut
Link 3: Support arm that ties the nut to the table
Link 4: Support arm that ties the fixed bearing to the slot in the table
Link 5: Table
Link 6: Extra link used to model the pin in slot joint with separate pin and slider joints

3. ***Identify the Joints***

A sliding joint is used to model the motion between the screw and the nut. A pin joint, designated as point *A*, connects the nut to the support arm identified as link 3. A pin joint, designated as point *B*, connects the two support arms—link 3 and link 4. Another pin joint, designated as point *C*, connects link 3 to link 6. A sliding joint joins link 6 to the table, link 5. A pin, designated as point *D*, connects the table to the support arm, link 3. Lastly, a pin joint, designated as point *E*, is used to connect the base to the support arm, link 4.

4. ***Draw the Kinematic Diagram***

The kinematic diagram is given in Figure 1.27.

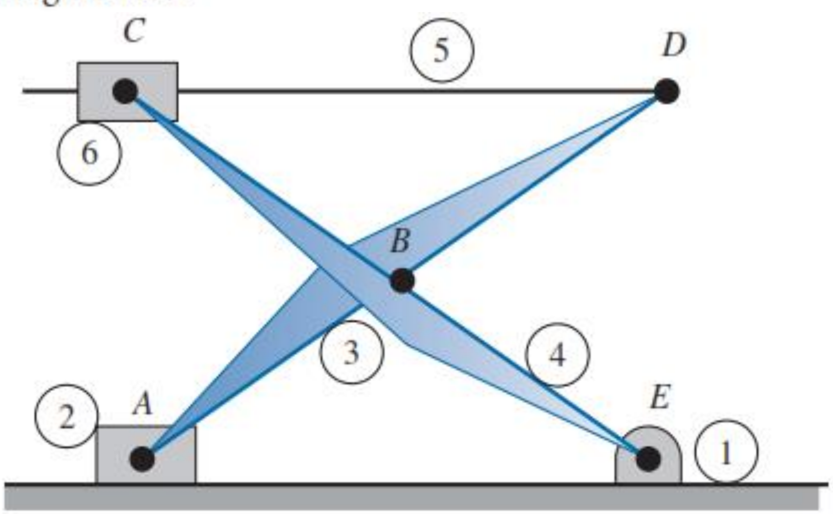
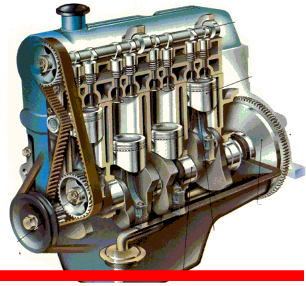


FIGURE 1.27 Kinematic diagram for Example Problem 1.7.



5. ***Calculate Mobility***

To calculate the mobility, it was determined that there are six links in this mechanism. There are also five pin joints and two slider joints. Therefore

$$n = 6 \quad j_p = (5 \text{ pins} + 2 \text{ sliders}) = 7 \quad j_h = 0$$

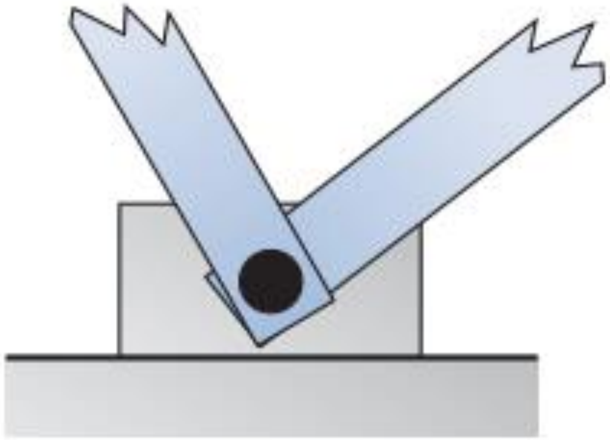
and

$$M = 3(n - 1) - 2j_p - j_h = 3(6 - 1) - 2(7) - 0 = 15 - 14 = 1$$

With one degree of freedom, the lift table has constrained motion. Moving one link, the handle that rotates the screw, will precisely position all other links in the device, raising or lowering the table.

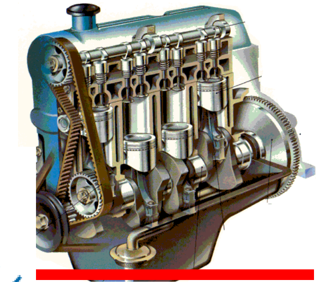
Coincident Joints

(a) Three rotating links



(b) Two rotating and one sliding link

FIGURE 1.28 Three links connected at a common pin joint.



THE FOUR-BAR MECHANISM

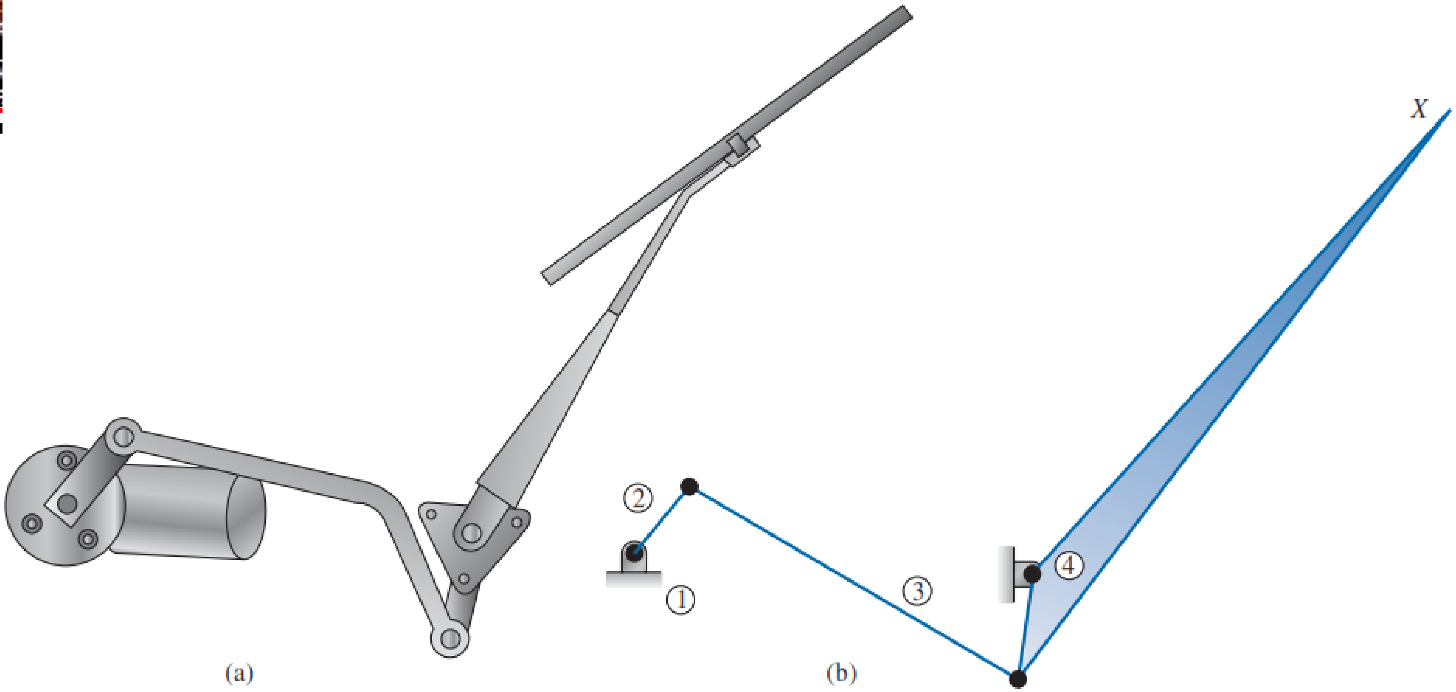


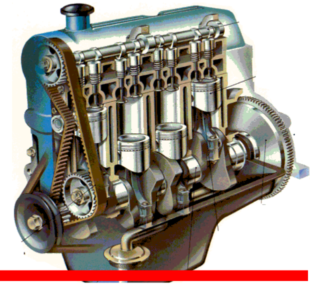
FIGURE 1.33 Rear-window wiper mechanism.

The mobility of a four-bar mechanism consists of the following:

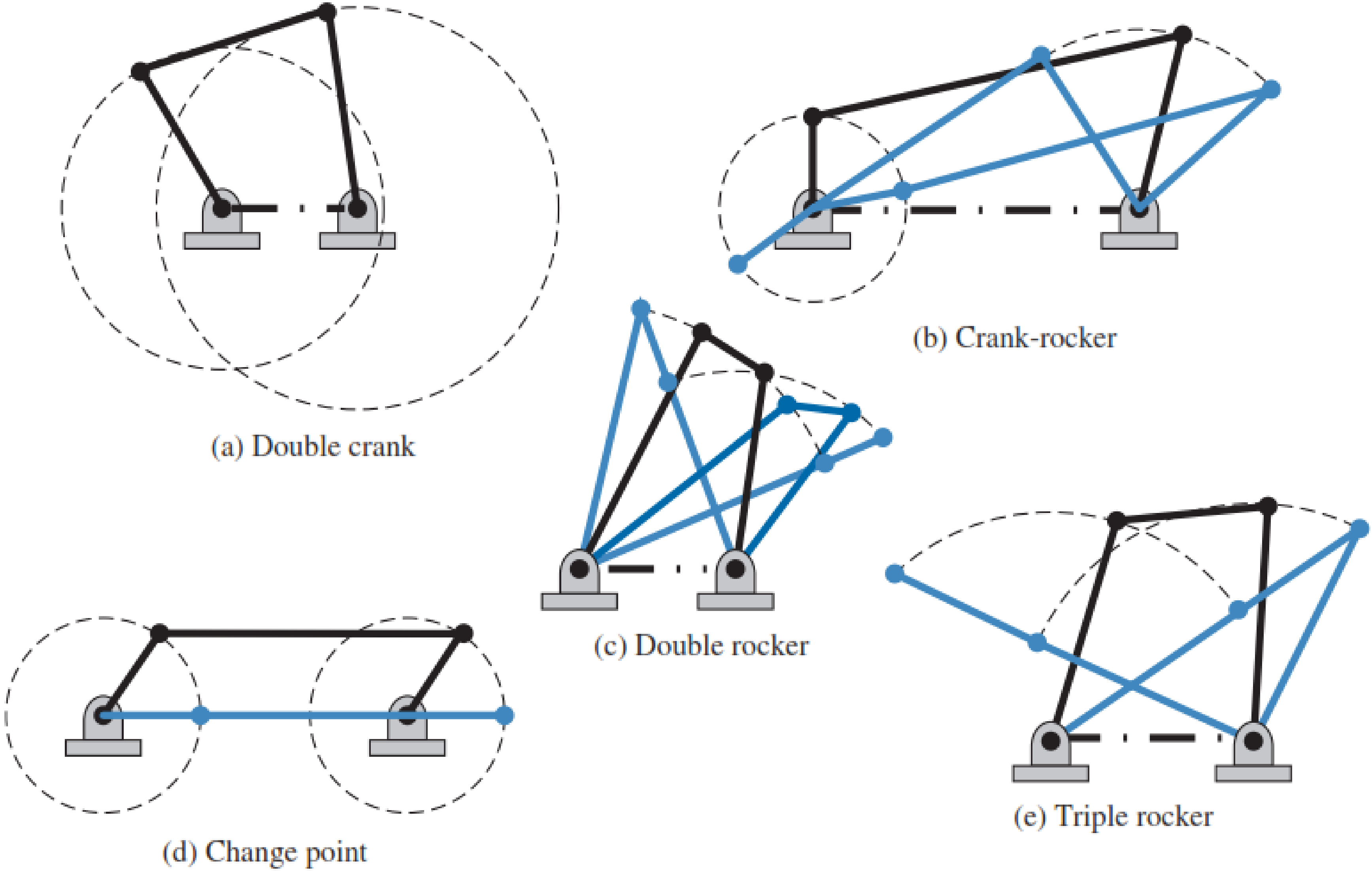
$$n = 4, j_p = 4 \text{ pins}, j_h = 0$$

and

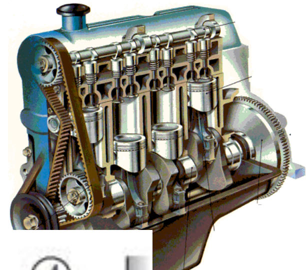
$$M = 3(n - 1) - 2j_p - j_h = 3(4 - 1) - 2(4) - 0 = 1$$

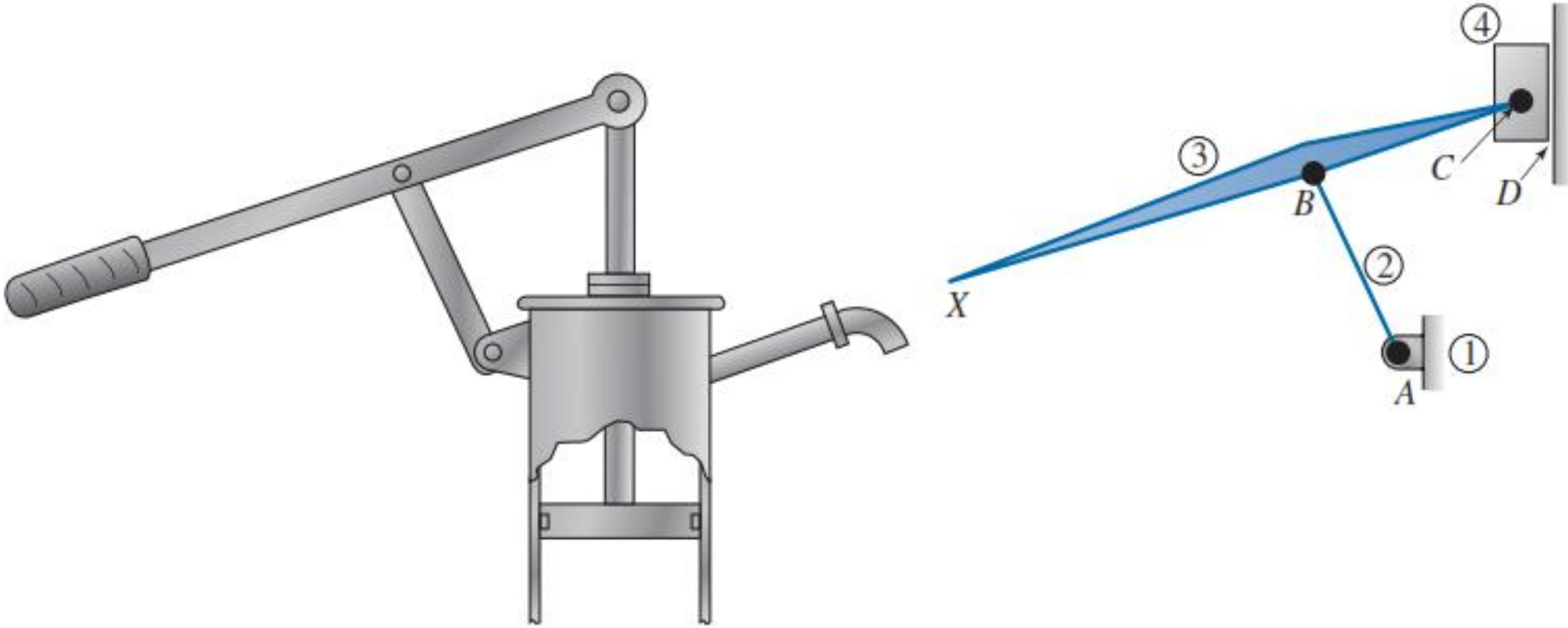


Categories of four-bar mechanisms.



SLIDER-CRANK MECHANISM





(a) (b)

FIGURE 1.37 Pump mechanism for a manual water pump: (a) Mechanism and (b) Kinematic diagram.

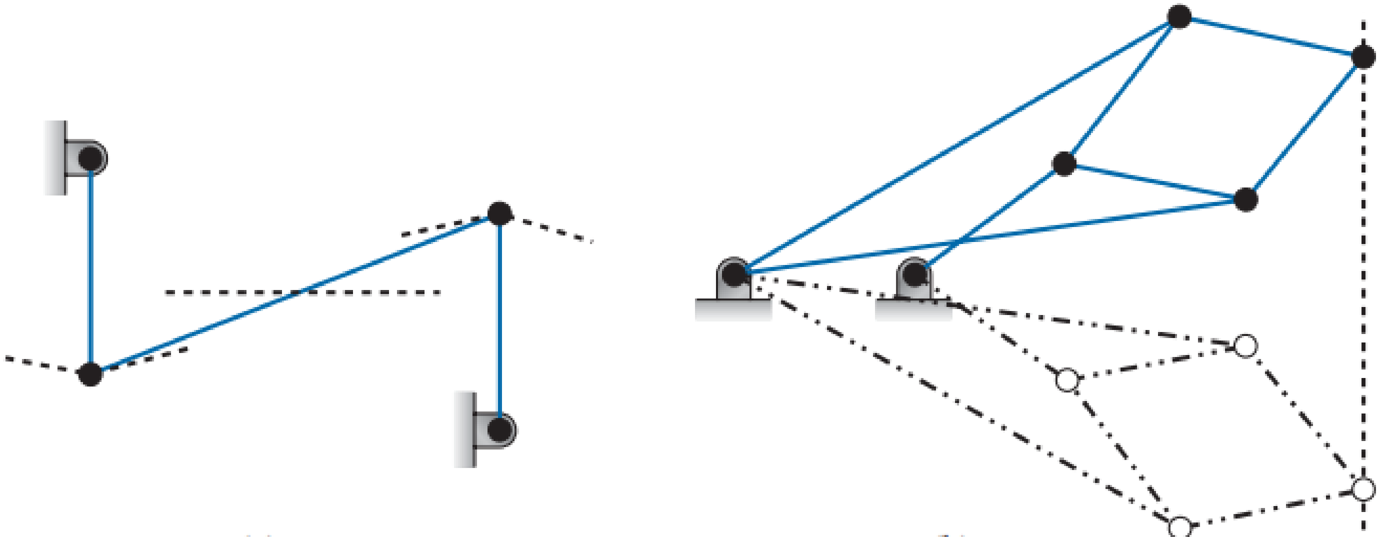
The mobility of a slider-crank mechanism is represented by the following:

$$n = 4, j_p = (3 \text{ pins} + 1 \text{ sliding}) = 4, j_h = 0$$

and

$$M = 3(n - 1) - 2j_p - j_h = 3(4 - 1) - 2(4) - 0 = 1.$$

Straight-Line Mechanisms



(a) (b)

FIGURE 1.38 Straight-line mechanisms

Quick-Return Mechanisms

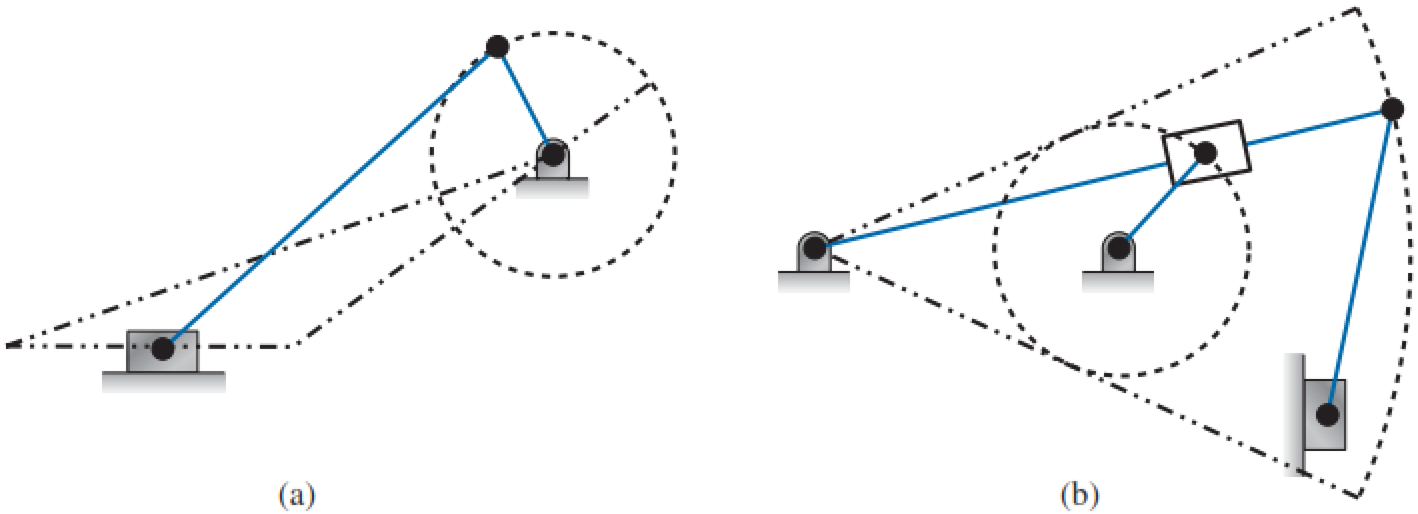
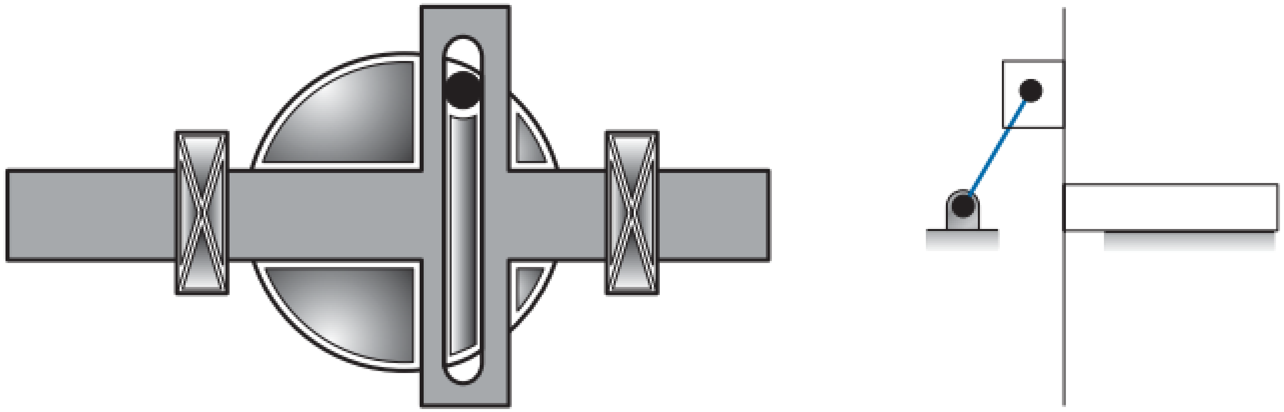


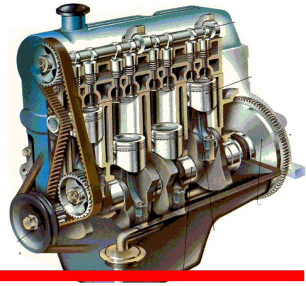
FIGURE 1.40 Quick-return mechanisms.

Scotch Yoke Mechanism



(a) Actual mechanism (b) Kinematic diagram

FIGURE 1.41 Scotch yoke mechanism.



Traditional Drafting Techniques

CAD Systems

Analytical Techniques

Computer Methods

Questions?