# 4 Slider–crank mechanisms

## 4.1 The simple slider–crank

The position diagram for SAQ 10 on sheet V2 shows a chain of links which has the end P of link BP moving horizontally towards O. If the position diagram is modified to that of Figure 40, what difference is there?

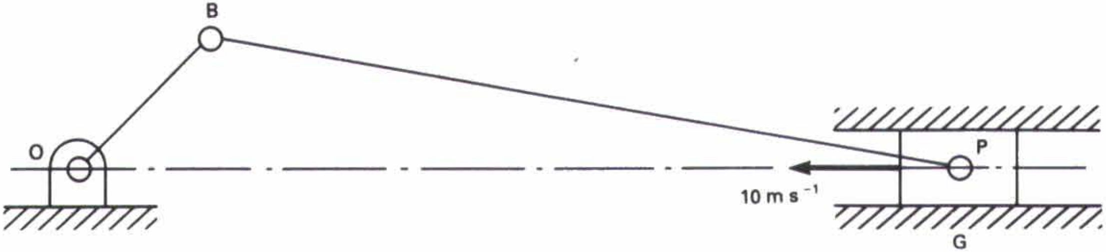


*Figure 40 Slider–crank mechanism*

**constrained slider**

**sliding velocity**

**coincident point**

There is very little difference except that at P there is now an extra link, a piston constrained to move horizontally. This is sometimes termed a *constrained slider*. In a constrained slider the motion is restricted to a specified path. As you saw in Block 1, the mechanism of Figure 40 is known as a slider–crank. The velocity of the piston at P relative to the cylinder G is termed the *sliding velocity* $(\bar{v}_P)_G$. The operation of this slider–crank system is such that the slider translates along the path PO and the motion of the connecting rod, PB, produces rotation of the crank OB. This is the basic mechanism of most reciprocating engines. The slider–crank is, of course, a four-link chain. The basic chain is OBPG, where G is a point fixed on the frame OG which at this instant is coincident with P. This is an example of an instantaneously *coincident point*, which is always required where there is a slider. The velocity diagram for the example shown in Figure 40 is the same as that in Figure 70 with $g$ added at the velocity origin.

***SAQ 14***

For each of the sketches in Figures 41–45 inclusive, identify where applicable: the link which has the input data, the basic chain, the appendages, and the first solvable point.

*Note:* The basic chain is a four-link chain, which may be a slider–crank mechanism, and must include the link with the input data.

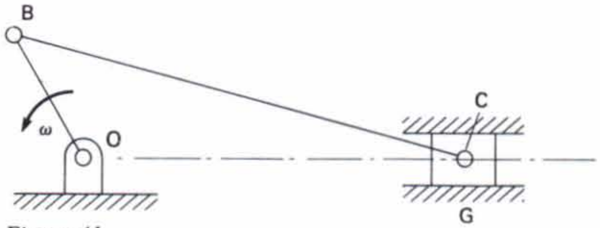


*Figure 41*

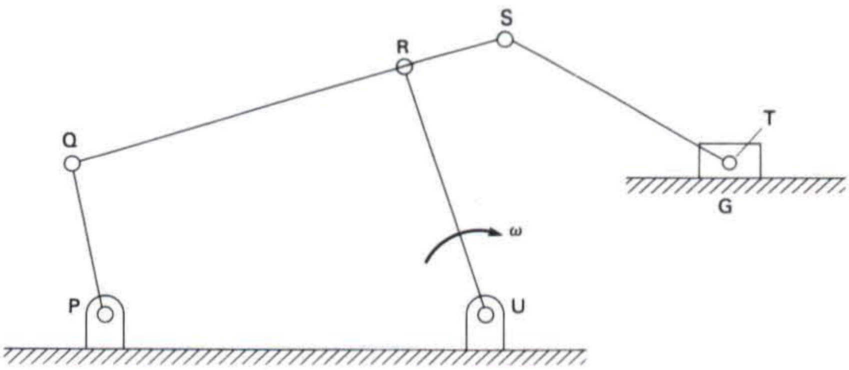


*Figure 42 (QRS rigid)*

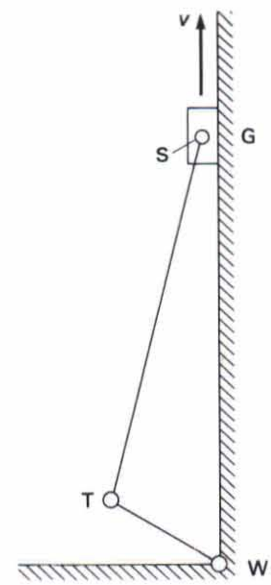


*Figure 43*

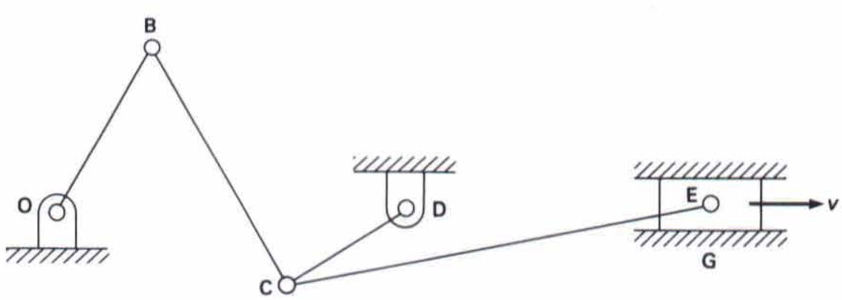


*Figure 44*

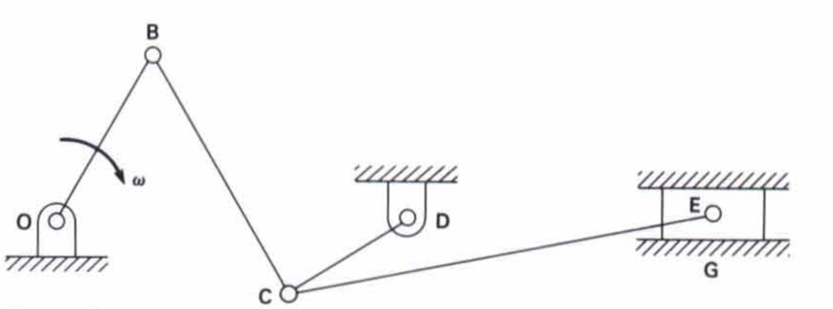


*Figure 45*

### *Example 1*

Figure 46(a) shows a piston engine and Figure 46(b) shows the line position diagram. The crank OB, 0.05 m long, rotates at 250 rad $s^{-1}$ (2387 rev $min^{-1}$) anticlockwise. The length of the connecting rod BP is 0.2 m. How do we determine the sliding velocity of the piston and the angular velocity of the line BP?

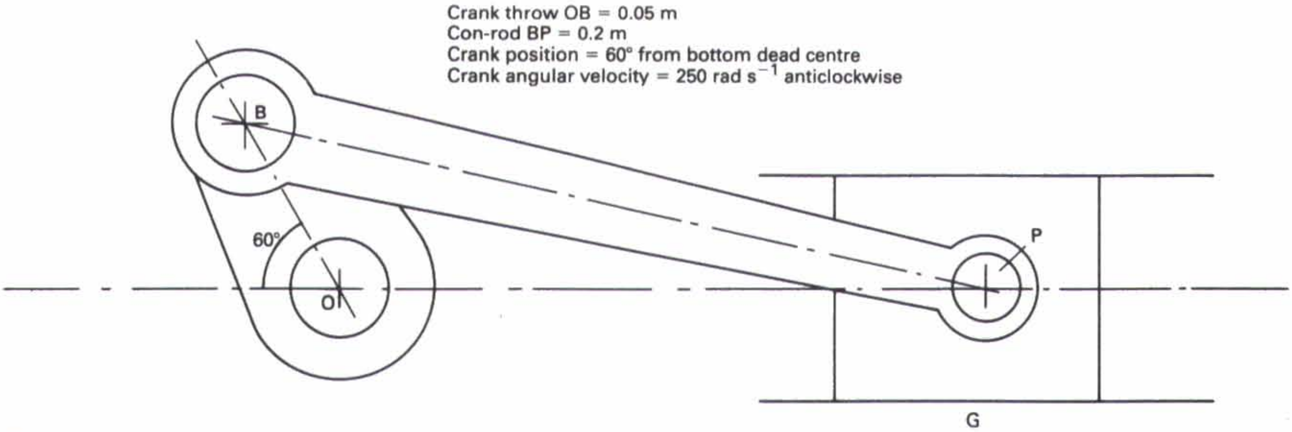


*Figure 46(a) Piston engine of Example 1*

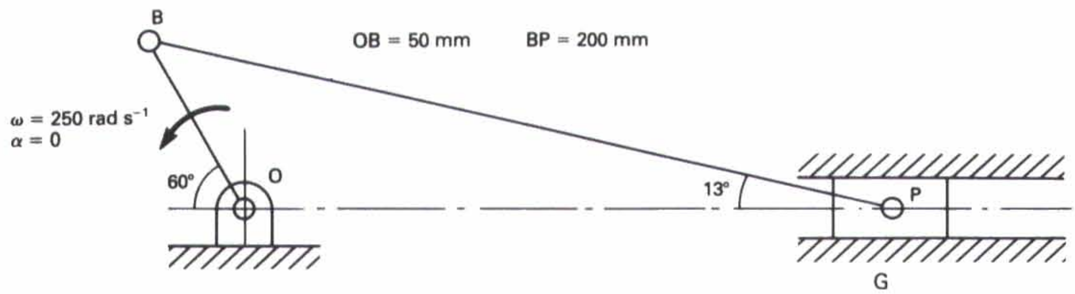


*Figure 46(b) Position diagram (half scale)*

### *Solution*

The fixed points are O and G. The input data is for link OB. First solvable point is B.

$$(\bar{v}_B)_O = \omega_{BO} \times OB \swarrow = 250 \times 0.05 \swarrow = 12.5\ \mathrm{m\,s^{-1}} \swarrow = \overline{ob}$$

$$(\bar{v}_P)_B = ?\ \mathrm{m\,s^{-1}} \swarrow\!\!\!\nearrow \quad (\perp \text{ to PB})\ p\text{-line through } b$$

$$(\bar{v}_P)_G = ?\ \mathrm{m\,s^{-1}} \leftrightarrow \quad (\text{parallel to the slider path at } G)\ p\text{-line through } g$$

The next step is to sketch the velocity diagram (Figure 47a) to determine its approximate shape and hence a suitable scale. *ob* is the longest length so this determines the scale for the velocity diagram. The velocity diagram, Figure 47(b), is drawn at a scale of 1 mm : 200 mm $s^{-1}$.

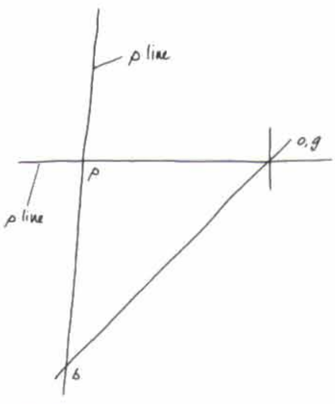


*Figure 47(a)*

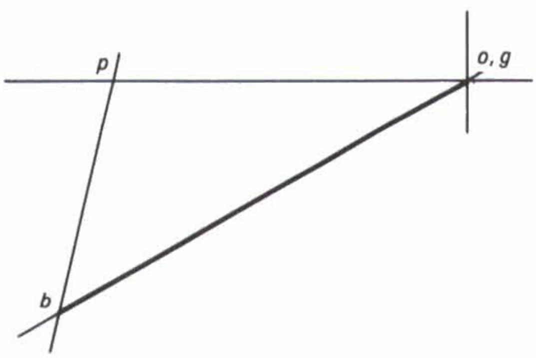


*Figure 47(b) Velocity diagram* Scale 1 mm:200 mm $s^{-1}$

Hence $(\bar{v}_P)_G = \overline{gp} = 47 \times 0.2 \leftarrow = 9.4 \text{ m s}^{-1} \leftarrow$

$$\bar{\omega}_{PB} = \frac{(v_P)_B \circlearrowleft}{BP} = \frac{bp \circlearrowleft}{BP} = \frac{(31.5 \times 0.2)\circlearrowleft}{0.2} = 31.5 \text{ rad s}^{-1} \circlearrowleft$$

***SAQ 15 (V5)***

Sheet V5 shows the position diagram of a two-cylinder engine with its pistons connected by a crankshaft with two cranks (OB, OE) at 90° to each other. The piston at C moves towards O at 5 m s$^{-1}$ with OB making 45° with CO as shown. Determine the sliding velocity of the piston at F and the angular velocities of the crankshaft (use line BO) and the connecting rod EF.

## *4.2 Mechanisms derived from the slider–crank chain*

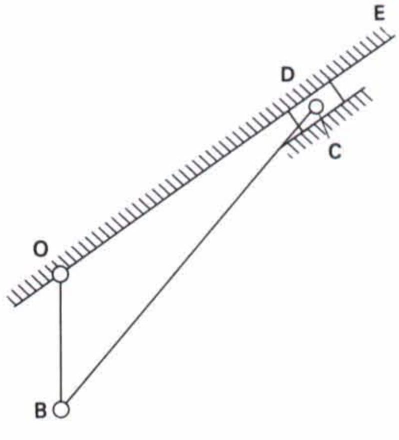


*Figure 48*

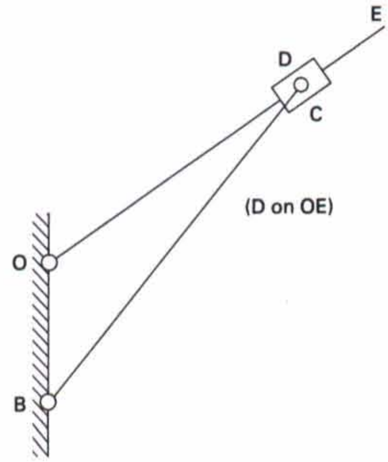


*Figure 49*

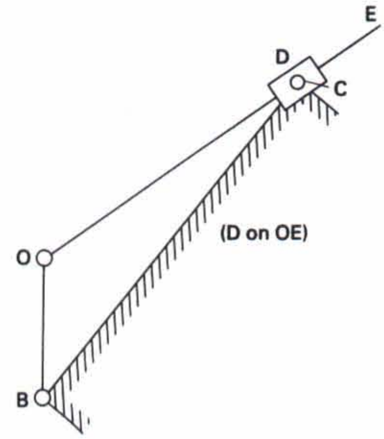


*Figure 50*

Figures 48, 49 and 50 show three mechanisms which are obtained by changing the link which is fixed. You may recognize Figure 48 as the slider–crank which was examined in Section 4.1. In Figure 49 the link OB is fixed instead of OD. This forms the basis of the Whitworth quick-return mechanism, which you studied in Unit 2. The third variant is obtained by fixing link BC (Figure 50); this mechanism is used in oscillating-cylinder steam engines. This process of obtaining different mechanisms from a given assembly of links is known as *inversion*. You will notice that in Figure 49 the slider moves along a rotating body, and in Figure 50 the slider itself can now only rotate, but ODE moves through it. Figure 51 shows the slider moving inside the link OE. Although this is physically different from Figure 49, it is kinematically identical.

inversion

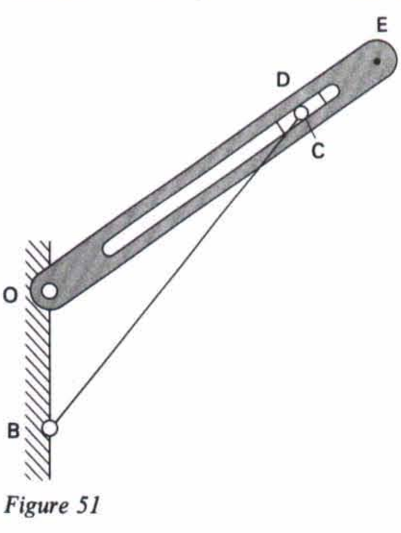


*Figure 51*

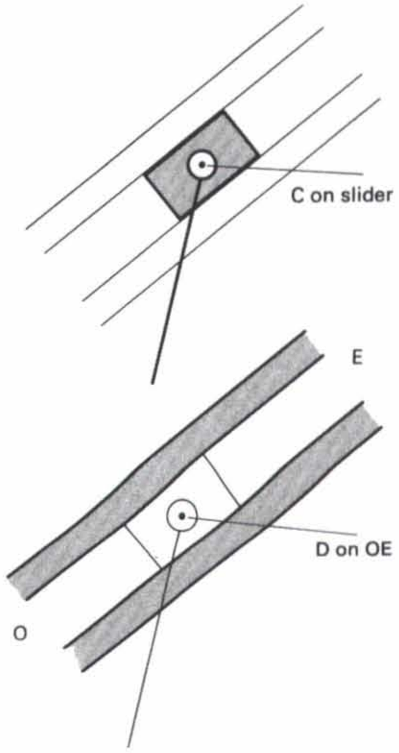


*Figure 52 Coincident points*

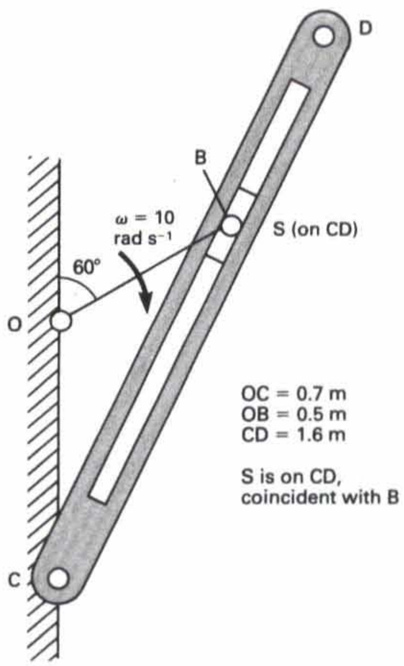


*Figure 53 Position diagram*
Scale 1 mm:20 mm

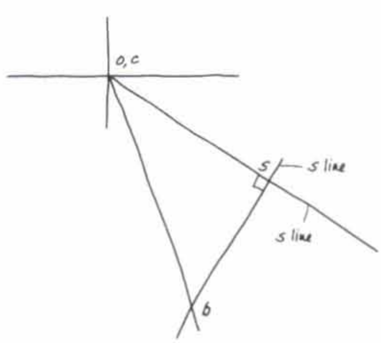


*Figure 54 Velocity diagram sketch*

We will now see how the velocity diagrams are constructed for these mechanisms.

Looking in more detail, Figure 52 shows an enlarged view of the slider of Figure 51. Notice that in this case the coincident point D is on a moving link, not on the frame. Until now you have always been able to mark *d* at the velocity origin. What are we going to do in this case? There are two important facts to remember:

- Because D is a point, on the link OE, at a fixed distance from O, the direction of the velocity of D must be *perpendicular* to the line ODE; it is a tangential velocity.
- Since the slider is constrained to move only along the slot in OE, the velocity of C relative to D must be *parallel* to the line ODE.

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***Example 2***

For the mechanism in Figure 53, find the sliding velocity of the slider at B within the slot of CD, and the angular velocity of the link CD.

What is the point S? It is the point, fixed on CD, instantaneously coincident with B.

What is the basic chain? OBSC.

In this example we are given a list of all the dimensions except CS. Measuring from the position diagram, Figure 53,

$$CS = 52.5 \times 0.02 = 1.05 \text{ m}$$

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**Velocity analysis**

O and C are fixed points. The input data is to link OB and hence B is the first solvable point.

$(\bar{v}_B)_O = 10 \times 0.5 \searrow = 5 \text{ m s}^{-1} \searrow = \overline{\boldsymbol{ob}}$

$(\bar{v}_S)_C = ? \text{ m s}^{-1} \nwarrow\!\searrow$ at right angles to CD (*s*-line through *c*, tangential)

$(\bar{v}_S)_B = ? \text{ m s}^{-1} \swarrow\!\nearrow$ along the link CD (*s*-line through *b*, sliding)

Now the velocity diagram is sketched and is shown in Figure 54.

Drawing the velocity diagram to a scale of 1 mm : 100 mm s$^{-1}$ gives Figure 55.

The basic chain is OBSC. D is an appendage to be found by proportion on *cs* extended – almost as an afterthought in this case. The sliding velocity of B is the velocity of B relative to the coincident point S, $(\bar{v}_B)_S$.

$$(\bar{v}_B)_S = \overline{\boldsymbol{sb}} = 2.85 \text{ m s}^{-1} \swarrow$$

$$\bar{\omega}_{CD} = \bar{\omega}_{SC} = \frac{(v_S)_C \circlearrowright}{CS} = \frac{cs \circlearrowright}{CS} = \frac{4.15 \circlearrowright}{1.05} = 3.95 \text{ rad s}^{-1} \circlearrowright$$

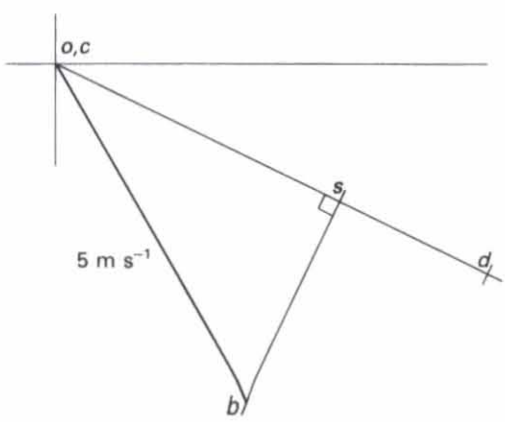


*Figure 55 Velocity diagram* Scale 1 mm : 100 mm s$^{-1}$

### SAQ 16

Use the velocity diagram (Figure 55), and the technique of proportion to obtain the velocity of D.

### SAQ 17 (V6)

Sheet V6 shows the position diagram for a slider inversion with the slider at B moving on the outside of link CD. For the position shown, obtain the sliding velocity of the slider at B, and the angular velocity of CD.

### Example 3

Another inversion of a slider–crank is shown in Figure 56.

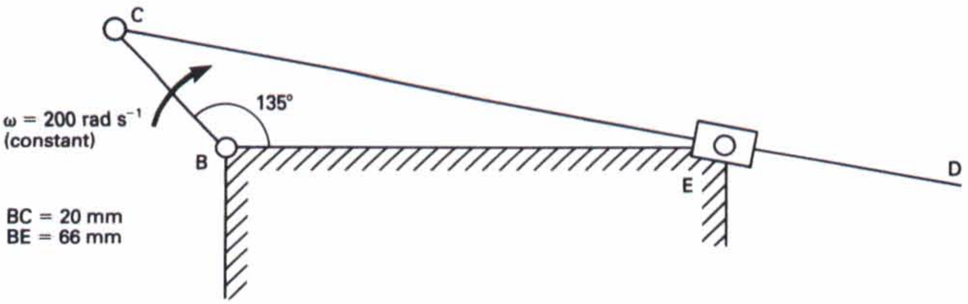


*Figure 56 Position diagram (full size)*

BC is a grounded link with an angular velocity of 200 rad $s^{-1} \circlearrowright$.

CD is a link that slides through the trunnion* at E.

Figure 57 shows the velocity diagram. What does *s* represent?

As in the previous examples involving a slider we need to use the idea of a coincident point to do the analysis. In this case we must choose the point on the link CD which is coincident with E. S is this point, represented by *s* on the velocity diagram.

What is the sliding velocity of CD through the trunnion at E in the position shown? The sliding velocity refers to the piece of CD within the trunnion, that is, the point S. The velocity of S with respect to E is

$$(\bar{v}_S)_E = \overline{es} = 2.3 \text{ m s}^{-1} \triangledown\ 10^\circ$$

What is the angular velocity of the link CD?

SC has to be measured from the position diagram (Figure 56).

$$\bar{\omega}_{CD} = \frac{sc \circlearrowright}{SC} = \frac{3.3 \circlearrowright}{0.081} = 40.7 \text{ rad s}^{-1} \circlearrowright$$

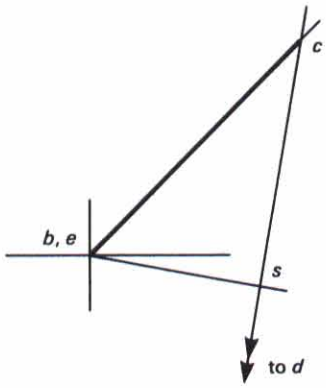


*Figure 57 Velocity diagram*
Scale 1 mm : 100 mm $s^{-1}$

### SAQ 18 (V7)

Sheet V7 shows a position diagram for a mechanism and enlarged details of the trunnion*. E is on the link BF coincident with D. Determine the velocity of the piston at C, the angular velocity of BF, and the velocity of sliding of BF in the trunnion D in the position shown.

*A *trunnion* is a grounded rotating link through which another link slides.

trunnion