



# POSTAL BOOK PACKAGE 2026

## MECHANICAL ENGINEERING

### CONVENTIONAL Practice Sets

#### CONTENTS

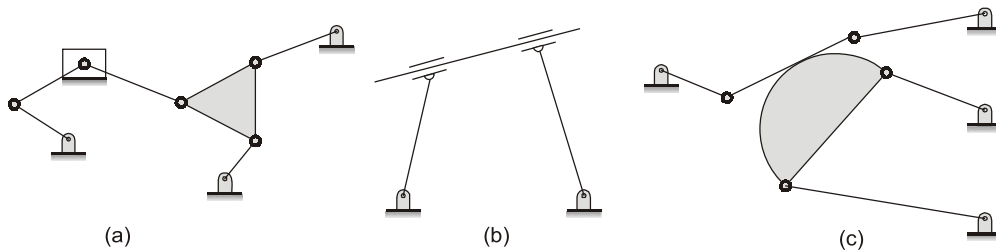
#### THEORY OF MACHINES

1. Simple Mechanisms .....	2 - 96
2. Kinematic Analysis of Plane Mechanisms .....	7 - 17
3. Mechanisms with Lower Pairs .....	18 - 22
4. Cam Design .....	23 - 27
5. Gears .....	28 - 39
6. Gear Trains .....	40 - 50
7. Dynamics of Machines, Turning Moment and Flywheel .....	51 - 68
8. Balancing .....	69 - 89
9. Governors .....	90 - 102
10. Mechanical Vibrations .....	103 - 125
11. Gyroscope and Gyroscope Effects .....	126 - 133

## Simple Mechanisms

## Practice Questions : Level-I

**Q.1** Determine the degree of freedom of the mechanisms shown in below figure.

**Solution:**

- (a) The mechanism has a sliding pair. Therefore, its degree of freedom must be found from Grubler's criterion.

Total number of links - 8 (Figure (b))

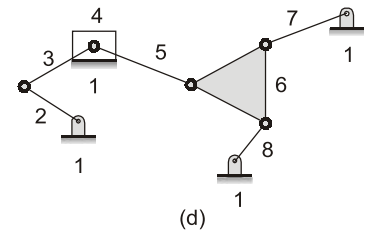
Number of pairs with 1 degree of freedom = 10

(At the slider, one sliding pair and two turning pairs)

$$F = 3(N - 1) - 2P_1 - P_2$$

$$= 3(8 - 1) - 2 \times 10 - 0 = 1$$

Thus, it is a mechanism with a single degree of freedom.



- (b) The system has a redundant degree of freedom as the rod of the mechanism can slide without causing any movement in the rest of the mechanism.

∴ Effective degree of freedom

$$= 3(N - 1) - 2P_1 - P_2 - F_r = 3(4 - 1) - 2 \times 4 - 0 - 1 = 0$$

As the effective degree of freedom is zero, it is a locked system.

- (c) The mechanism has a cam pair. Therefore, its degree of freedom must be found from Grubler's criterion.

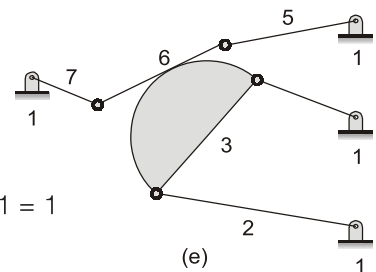
Total number of links = 7 (Fig. (e))

Number of pairs with 1 degree of freedom = 8

Number of pairs with 2 degrees of freedom = 1

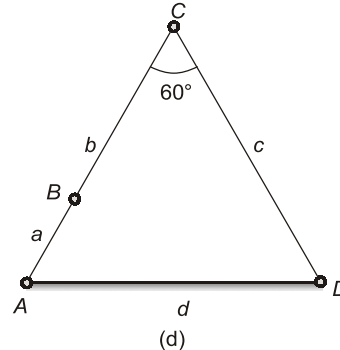
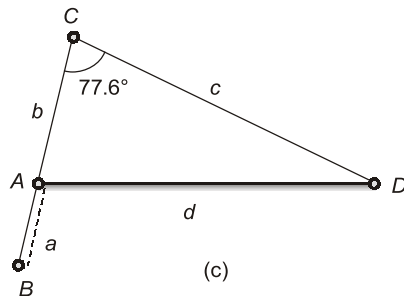
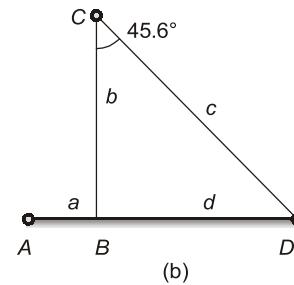
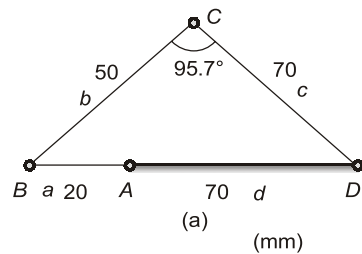
$$F = 3(N - 1) - 2P_1 - P_2 = 3(7 - 1) - 2 \times 8 - 1 = 1$$

Thus, it is a mechanism with one degree of freedom.



**Q.2** A crank-rocker mechanism has a 70 mm fixed link, a 20 mm crank, a 50 mm coupler, and a 70 mm rocker. Draw the mechanism and determine the maximum and minimum values of the transmission angle. Locate the two toggle positions and find the corresponding crank angles and the transmission angles.

**Solution:**



**Given data:** In this mechanism,

Length of the shortest link = 20 mm;

Length of the longest link = 70 mm;

Length of other links = 70 and 50 mm

Since  $70 + 20 < 70 + 50$ , it belongs to the class-I mechanism. In this case as the link adjacent to the shortest link is fixed, it is a crank-rocker mechanism.

Maximum transmission angle is when  $\theta$  is  $180^\circ$  [Fig. (a)]

Thus

$$\begin{aligned}(a + d)^2 &= b^2 + c^2 - 2bc \cos \mu \\ (20 + 70)^2 &= 50^2 + 70^2 - 2 \times 50 \times 70 \cos \mu \\ 8100 &= 2500 + 4900 - 7000 \cos \mu \\ \cos \mu &= -0.1 \\ \mu &= 95.7^\circ\end{aligned}$$

Minimum transmission angle is when  $\theta$  is  $0^\circ$ . [Fig. (b)]

Thus

$$\begin{aligned}(70 - 20)^2 &= 50^2 + 70^2 - 2 \times 50 \times 70 \cos \mu \\ 2500 &= 2500 + 4900 - 7000 \cos \mu \\ \mu &= 45.6^\circ\end{aligned}$$

The two toggle positions are shown in Fig. (c) and (d).

Transmission angle for first position,

$$\begin{aligned}d^2 &= (b - a)^2 + c^2 - 2(b - a)c \cos \mu \\ 70^2 &= 30^2 + 70^2 - 2 \times 30 \times 70 \cos \mu \\ 4900 &= 900 + 4900 - 4200 \cos \mu \\ \cos \mu &= 0.214 \\ \mu &= 77.6^\circ\end{aligned}$$

As  $c$  and  $d$  are of equal length [Fig. (c)], it is an isosceles triangle and thus input angle  $\theta = (77.6^\circ + 180^\circ) = 257.6^\circ$

Transmission angle for second position Fig. (d),

$$\begin{aligned}d^2 &= (b + a)^2 + c^2 - 2(b + a)c \cos \mu \\ 70^2 &= 70^2 + 70^2 - 2 \times 70 \times 70 \cos \mu \\ 4900 &= 4900 + 4900 - 9800 \cos \mu \\ \cos \mu &= 0.5 \\ \mu &= 60^\circ\end{aligned}$$

(or as all the sides of the triangle of Fig. (d) are of equal length, it is an equilateral triangle and thus transmission angle is equal to  $60^\circ$ )

And the input angle,  $\theta = 60^\circ$

- The above results can also be obtained graphically by drawing the figures to scale and measuring the angles.

**Q3** In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 240 mm and the length of the driving crank is 120 mm. Find the inclination of the slotted bar with the vertical in the extreme position and the time ratio of cutting stroke to the return stroke.

If the length of the slotted bar is 450 mm, find the length of the stroke if the line of stroke passes through the extreme positions of the free end of the lever.

**Solution:**

**Given data:**  $AC = 240$  mm;  $CB_1 = 120$  mm;  $AP_1 = 450$  mm

**Inclination of the slotted bar with the vertical**

Let,  $\angle CAB_1 =$  Inclination of the slotted bar with the vertical.

The extreme positions of the crank are shown in Fig. 5. We know that

$$\sin \angle CAB_1 = \sin \left( 90^\circ - \frac{\alpha}{2} \right) = \frac{B_1C}{AC} = \frac{120}{240} = 0.5$$

$$\begin{aligned} \therefore \angle CAB_1 &= 90^\circ - \frac{\alpha}{2} \\ &= \sin^{-1} 0.5 = 30^\circ \end{aligned}$$

**Time ratio of cutting stroke to the return stroke**

We know that

$$90^\circ - \alpha/2 = 30^\circ$$

$$\therefore \alpha/2 = 90^\circ - 30^\circ = 60^\circ$$

$$\text{or } \alpha = 2 \times 60^\circ = 120^\circ$$

$$\therefore \frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{360^\circ - \alpha}{\alpha} = \frac{360^\circ - 120^\circ}{120^\circ} = 2$$

**Length of the stroke**

We know that length of the stroke,

$$\begin{aligned} R_1R_2 &= P_1P_2 = 2P_1Q \\ &= 2AP_1 \sin(90^\circ - \alpha/2) \\ &= 2 \times 450 \sin(90^\circ - 60^\circ) \\ &= 900 \times 0.5 = 450 \text{ mm} \end{aligned}$$

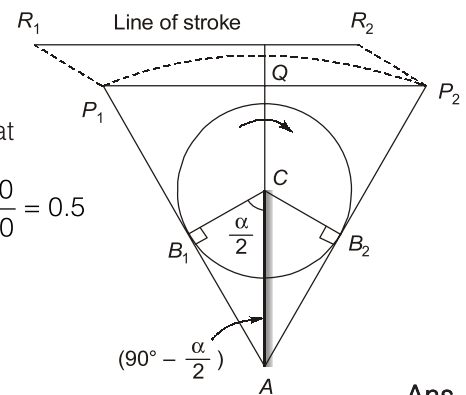


Figure 5

Ans.

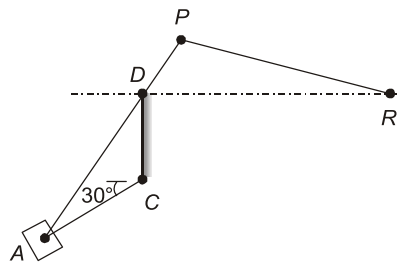
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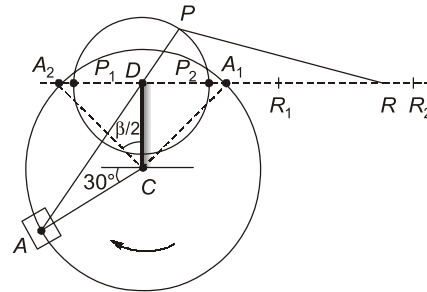
**Q4** In a Whitworth quick return motion mechanism, as shown in Fig. 6, the distance between the fixed centers is 50 mm and the length of the driving crank is 75 mm. The length of the slotted lever is 150 mm and the length of the connecting rod is 135 mm. Find the ratio of the time of cutting stroke to the time of return stroke and also the effective stroke.

**Solution:**

**Given data:**  $CD = 50$  mm;  $CA = 75$  mm;  $PA = 150$  mm;  $PR = 135$  mm



**Figure 6**



**Figure 7**

The extreme positions of the driving crank are shown in Fig. 7. From the geometry of the figure,

$$\cos \beta/2 = \frac{CD}{CA_2} = \frac{50}{75} = 0.667 \quad \dots (\because CA_2 = CA)$$

$$\beta/2 = 48.2 \quad \text{or} \quad \beta = 96.4^\circ$$

**Ratio of the time of cutting stroke to the time of return stroke**

We know that

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{360 - \beta}{\beta} = \frac{360 - 96.4}{96.4} = 2.735$$

**Ans.**

**Length of effective stroke**

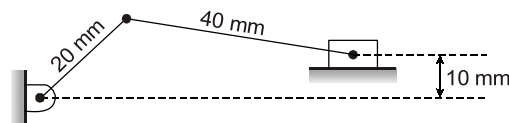
In order to find the length of effective stroke (i.e.  $R_1R_2$ ), draw the space diagram of the mechanism to some suitable scale, as shown in Fig. 7. Mark  $P_1R_2 = P_2R_2 = PR$ . Therefore by measurement we find that,

Length of effective stroke =  $R_1R_2 = 87.5$  mm.

**Ans.**

## Practice Questions : Level-II

**Q5** An offset slider-crank mechanism is shown in the figure at an instant. Conventionally, the Quick Return Ratio (QRR) is considered to be greater than one. What is the value of QRR?



**Solution:**

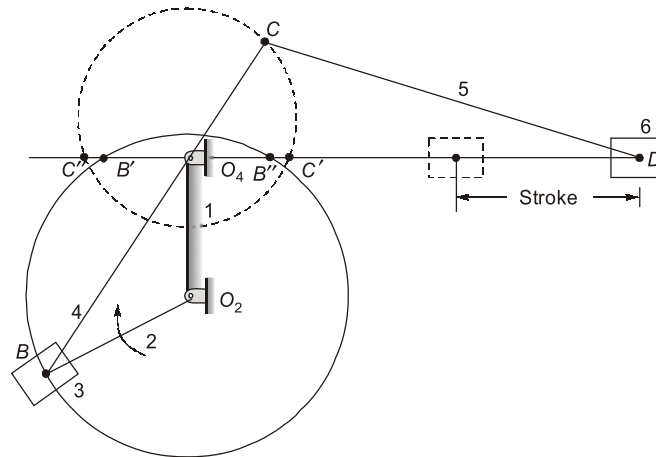
**Given data:** Length of connecting rod,  $l_r = 40$  mm; Crank radius,  $r = 20$  mm; Eccentricity,  $e = 10$  mm

$$\phi = \cos^{-1}\left(\frac{e}{l+r}\right) - \cos^{-1}\left(\frac{e}{l-r}\right) = \cos^{-1}\left(\frac{1}{6}\right) - \cos^{-1}\left(\frac{1}{2}\right) = 20.4^\circ$$

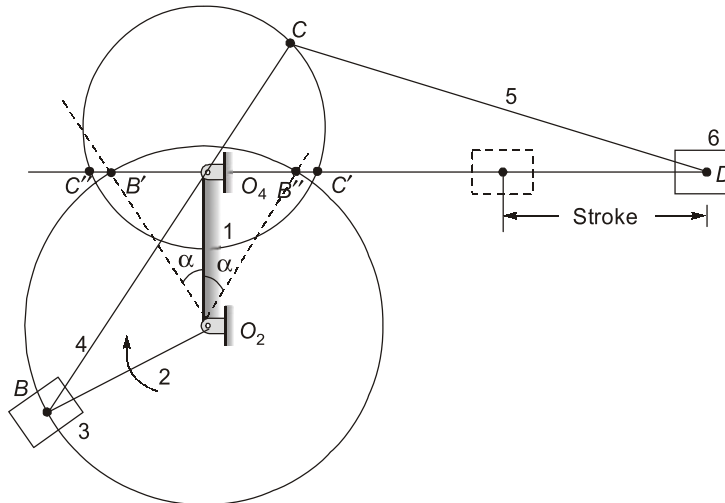
$$\text{QRR} = \frac{\text{Time of advance stroke}}{\text{Time of return stroke}} = \left(\frac{\theta_C}{2\pi N}\right) \left(\frac{2\pi N}{\theta_R}\right)$$

$$\text{QRR} = \frac{\theta_C}{\theta_R} = \frac{180^\circ + \phi}{180^\circ - \phi} = \frac{180^\circ + 20.4^\circ}{180^\circ - 20.4^\circ} = 1.25$$

**Q6** Design a Whitworth quick return mechanism as shown in the figure. Driving crank is to rotate clockwise at constant speed and the time ratio is 2 : 1. Length  $O_2O_4$  is 76.2 mm and the length of stroke is 343 mm. Further assume  $CD = 3O_4C$ . Note pivot  $O_2$  is placed below the pivot  $O_4$ . Compute the required values of  $O_2B$ ,  $O_4C$  and  $CD$ .

**Solution:**

As per given information:



$$\text{Time ratio (quick return ration)} = \frac{360 - 2\alpha}{2\alpha} = 2 \quad \Rightarrow \alpha = 60^\circ$$

$$\cos \alpha = \frac{O_2O_4}{O_2B'}$$

$$\cos 60^\circ = \frac{76.2}{O_2B'}$$

$$O_2B' = \frac{76.2}{\cos 60^\circ} = 152.4 \text{ mm} = O_2B$$

$$\text{Length of the driving crank} = 152.4 \text{ mm}$$

$$\text{Length the stroke} = 343 = 2 \times O_4C$$

$$O_4C = 171.5 \text{ mm}$$

As per given condition

$$CD = 3 \times O_4C = 3 \times 171.5 \text{ mm} = 514.5 \text{ mm}$$

