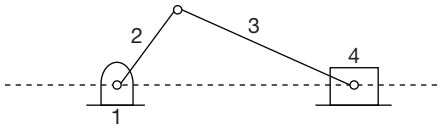
Theory of Machines Test 3

Number of Questions: 25 **Time:60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. Whitworth quick-return mechanism is obtained by fixing which link of the given slider crank chain.



(A) Link 1 (B) Link 2
(C) Link 3 (D) Link 4

2. What is the maximum transmission angle of the four bar mechanism when the link '*d*' is fixed. The lengths of the links are a = 4 cm, *b* = 7 cm, *c* = 6 cm and *d* = 8 cm.

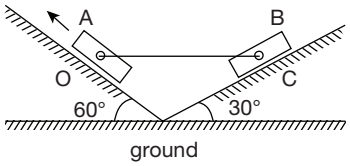
(A) 134.62° (B) 45.38°
(C) 34.77° (D) 124.77°

3. Match List I with List II

List I		List II	
(*A*)	Higher pair	(1)	Cam and follower
(*B*)	Lower pair	(2)	Piston in a cylinder
(*C*)	Turning pair	(3)	A hand of wall clock
(*D*)	Sliding pair	(4)	Tail stock of a lathe

	A	*B*	*C*	*D*
(A)	2	4	2	1
(B)	4	2	1	3
(C)	1	2	3	4
(D)	2	4	1	3

4. A double slider mechanism with the length of the link *AB* = 50 cm is shown. What is the velocity of point *B* with respect to point *A* when the link *AB* is parallel (horizontal) to the ground? The velocity of slider *A* at the instant is 3 m/s.



(A) 4 m/s (B) 5 m/s
(C) $\sqrt{3}$ m/s (D) $2\sqrt{3}$ m/s

5. A slider on a rotating link has a linear velocity '*V*' when the link is rotating with an angular velocity 'ω'. If the link length is '*r*' then the acceleration of the slider perpendicular to the link is the sum of tangential acceleration ($r\,\alpha$) and

(A) ωv (B) $2\,\omega v$
(C) $2r\,\omega^2$ (D) $r\,\omega^2$

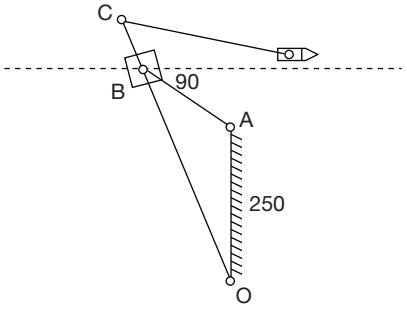
6. The faces of a gear with cycloidal profile teeth is of the form

(A) Hypocycloid
(B) Rectangular parabola
(C) Epicycloid
(D) Involute

7. In a reciprocating compressor the force exerted by the crank is 72 kN and the force exerted by the piston is 100 kN. What is the mechanical advantage of the compressor?

(A) 1.389 (B) 0.389
(C) 8.334 (D) 0.72

8. The length of the driving crank in a crank and slotted lever mechanism is 90 mm and the distance between the fixed centers is 250 mm. What is the ratio of time taken for forward stroke to the time taken for return stroke?



(A) 1.71 (B) 1.51
(C) 1.61 (D) 1.91

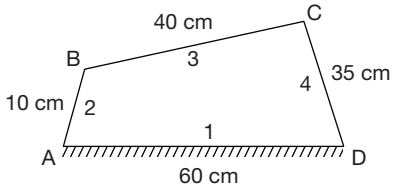
9. Mitre gears are form of

(A) Helical gears (B) Spur gears
(C) Double helical gears (D) Straight bevel gears

10. The pitch angle of a spur gear is 30° with the pitch diameter being 60 mm. What is the module of the gear?

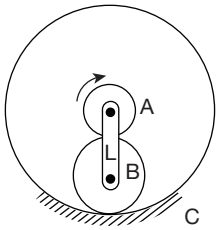
(A) 10 (B) 5
(C) 2 (D) 6

11. A four bar mechanism with the lengths as shown in figure has the input link *AB* rotating at 30 rad/s at the given instant. The instantaneous centre I_{24} is 40 cm from point *A*. What is the angular velocity of the link *CD*?



(A) 12 rad/s (B) 7.5 rad/s
(C) 15 rad/s (D) 10.5 rad/s

12. In a planetary gear train, gears A, B and C have 20, 40 and 80 teeth respectively. What is the speed and direction of rotation of gear B when the gear A rotates at 200 rpm? Internal gear C is fixed.



(A) 40 rpm, clockwise
(B) 40 rpm, counter-clockwise
(C) 80 rpm, clockwise
(D) 80 rpm, counter-clockwise

13. Two involute gears A and B mesh with one another with the centre distance between the gears as 400 mm. The ratio of speeds of gear A to gear B is 7:3. If the module of both the gears is 4 then the numbers of teeth, of gear A and B respectively, are

(A) 140, 60 (B) 100, 100
(C) 60, 140 (D) 120, 80

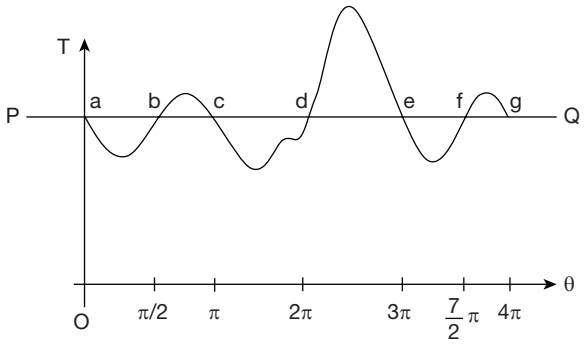
14. A flywheel has a kinetic energy of 700 kJ when the fluctuation of energy is 500 kJ. What is the ratio of maximum speed to minimum speed of the flywheel? (mean speed is the average of maximum and minimum speeds)

(A) 1.34 (B) 1.39
(C) 1.49 (D) 1.43

15. Flat strips of 200 mm wide and 30 mm thick are cut using a shearing machine. The flywheel of the machine has speeds 150 rpm and 90 rpm before and after the cut respectively. The flywheel has to regain its speed in 2 seconds. If the energy required to cut is completely supplied by the flywheel what is the torque to be applied on the flywheel? (Work required to cut 4 mm^2 of area is 30 kJ)

(A) 14323.94 kN-m (B) 7161.97 kN-m
(C) 3580.98 kN-m (D) None of these

16. The turning-moment diagram of a single-cylinder, four-stroke gas engine is given. At which points is the slope of the speed curve will be zero, if PQ is the mean torque line? (Assume that there is uniform resistance to rotation)



(A) a, c, e and g (B) b, d and f
(C) a, b, c, f and g (D) a, b, c, d, e, f and g

17. A single-cylinder, four-stroke, single-acting gas engine of fuel consumption 409.6 kg/hr has the coefficients of fluctuation of energy and speed as 2 and 1.5×10^{-2} respectively. The difference between the maximum and minimum speeds of the flywheel is 40 rad/sec and the mass moment of inertia of the flywheel is 7680 kg-m^2. What is the indicated specific fuel consumption of the engine in kg/kJ.hr?

(A) 10^{-6} (B) 10^{-3}
(C) 10^{3} (D) 10^{6}

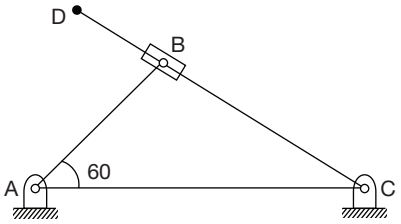
18. What is the mean kinetic energy of a flywheel with fluctuation of energy and coefficient of fluctuation of speed as 8000 kJ and 0.25 respectively?

(A) 16 kJ (B) 32 kJ
(C) 16 MJ (D) 32 MJ

19. A flywheel gives up 20 kJ of energy in reducing its speed from 150 rpm to 130 rpm. If the fluctuation of energy is 30 kJ and the mean speed is 100 rpm. What is the coefficient of fluctuation of speed?

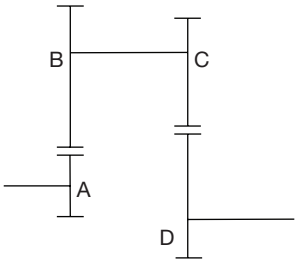
(A) 0.42 (B) 0.042
(C) 0.0042 (D) 4.2

20. An inverted slider-crank mechanism has the lengths AB = 100 mm, $BC = 100\sqrt{3}$ mm and AC = 200 mm. The crank AB rotates at 50 rpm. What is the relative velocity of the slider B with respect to the rigid link CD?



(A) 0.907 m/s (B) 0.523 m/s
(C) 0.785 m/s (D) 1.0471 m/s

21. Four gears are meshed such that the sum of the diameters of the gears A and B is equal to the sum of diameters of C and D. The numbers of teeth on gears A, B and C are 20, 60 and 50 respectively. All the gears have same module. If gear A rotates at 300 rpm clockwise, what is the speed of rotation of the gear D?



(A) 1500 rpm (B) 750 rpm
(C) 333.34 rpm (D) 166.67 rpm

22. The maximum fluctuation of energy of a four stroke engine is 30 kJ. The speed of the flywheel is to be kept between 245 rpm and 240 rpm. What is the mass of the flywheel when the radius of gyration of the flywheel is 1.25 m?
(A) 1444 kg (B) 1316.7 kg
(C) 207.75 kg (D) 722 kg

23. Which of the following is true in the case of two spur gears meshing with each other.
(A) The number of revolutions made per minute is same for both the gears.
(B) The angular velocities of both the gears are equal.
(C) The pitch line velocities of the two gears are equal.
(D) The pitch diameters are always equal.

24. Two spur gears are engaged with the angles of approach and recess as 23° and 17° respectively. What is the contact ratio if the pitch angle is 27°?
(A) 1.48 (B) 0.22
(C) 10 (D) 0.851

25. A four bar mechanism has the link lengths AB = 15 cm, BC = 5 cm, CD = 6 cm and DA = 3 cm. What type of mechanism is produced by fixing the link DA?
(A) Crank-rocker
(B) Rocker-rocker
(C) Double crank
(D) Mechanism is not possible

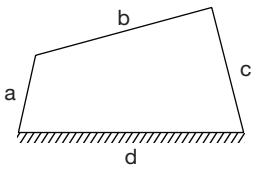
Answer Keys

1. B	**2.** A	**3.** C	**4.** D	**5.** B	**6.** C	**7.** A	**8.** C	**9.** D	**10.** B
11. A	**12.** B	**13.** C	**14.** D	**15.** C	**16.** D	**17.** B	**18.** C	**19.** A	**20.** B
21. D	**22.** A	**23.** C	**24.** A	**25.** D					

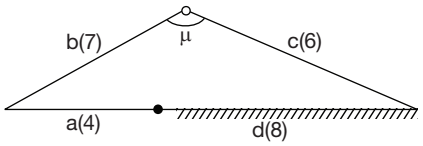
Hints and Explanations

1. Second inversion of the given slider crank chain produces a Whitworth quick return mechanism. By fixing link 2, link 3 along with the slider at its end becomes a crank. Choice (B)

2. The sum of the longest and the shortest links is less than the sum of the other two links.
$8 + 4 < 7 + 6$
$\therefore$ The mechanism belongs to Grashof's class-I mechanism.



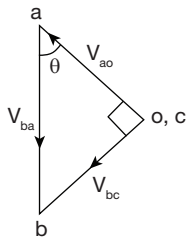
Fixing link 'd' (adjacent to the shortest link) produces a crank-rocker mechanism. Link 'a' becomes a crank.
$\therefore$ The maximum transmission angle position will be



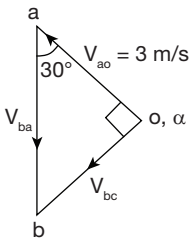
$\therefore$ $(a + d)^2 = b^2 + c^2 - 2\,bc \cos \mu$
$\therefore$ $12^2 = 7^2 + 6^2 - 2.7.6 \text{ Cos } \mu$
$\therefore$ $\text{Cos } \mu = \dfrac{-59}{84}$
$\Rightarrow$ $\mu = 134.62^\circ$ Choice (A)

3. Choice (C)

4. By drawing the velocity diagram



As, V_{ba} is perpendicular to the link AB the angle θ is 30°.
$\therefore$ The velocity diagram simplifies to



$\therefore$ $\text{Cos}30 = \dfrac{V_{ao}}{V_{ba}}$
$\Rightarrow$ $V_{ba} = \dfrac{3}{\text{Cos}\,30} = 2\sqrt{3}$ m/s Choice (D)

5. Acceleration of the slider perpendicular to the link is 2 $\omega V + r\alpha$
Where $r\alpha$ = tangential acceleration
2 ωv = Coriolis acceleration Choice (B)

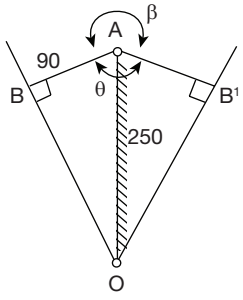
6. Cycloidal profile teeth are made with faces as epicycloids and flanks as hypocycloids. Choice (C)

7. Mechanical advantage $= \dfrac{\text{Output force}}{\text{Input force}}$

Output force = piston force = 100 kN
Input force = crank force = 72 kN

$\therefore \quad MA = \dfrac{100}{72} = 1.389$ Choice (A)

8.



$$\frac{\text{Time for forward stroke}}{\text{Time for return stroke}} = \frac{\beta}{\theta}$$

From the triangle AOB

$$\text{Cos}\left(\theta/2\right) = \frac{90}{250} \Rightarrow \theta = 137.8^{o}$$

$\beta = 360 - \theta = 222.2^{o}$

$$\therefore \frac{\beta}{\theta} = \frac{222.2}{137.8} = 1.612$$ Choice (C)

9. Straight bevel gears of same size and connecting two shafts at right angles to each other are known as mitre gears. Choice (D)

10. Pitch angle is the angle made at the centre of the pitch circle by the circular pitch.

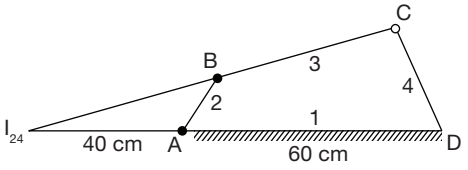
$$\therefore \theta = 30^{o} = \frac{\pi}{6}\text{ rad}$$

$$\therefore \quad \text{pitch} = p = r\,\theta = \frac{60}{2} \times \frac{\pi}{6} = 5\pi$$

$$\therefore p = 5\pi = \pi\frac{d}{T} \Rightarrow \frac{d}{T} = 5$$

$$\text{Where module} = \frac{d}{T} = 5$$ Choice (B)

11. The instantaneous center I_{24} is located as



By angular velocity ratio theorem

$\omega_2 . I_{24}A = \omega_4 . I_{24}D$

$$\therefore \quad \omega_4 = \omega_2 . \frac{I_{24}A}{I_{24}D} = 30 \times \frac{40}{100}$$

$\omega_4 = 12$ rad/s Choice (A)

12. $T_A = 20$, $T_B = 40$ and $T_C = 80$

	Operation	Revolutions			
		L(arm)	A	B	C
(1)	Fix arm, Gear A has +1 rev	0	+1	$-\frac{T_A}{T_B}$	$-\frac{T_A}{T_B} \times \frac{T_B}{T_C}$
(2)	Fix arm, Gear A has +x rev	0	x	$-x\frac{T_A}{T_B}$	$-x\frac{T_A}{T_C}$
(3)	Add y rev	Y	$x + y$	$y - x\frac{T_A}{T_B}$	$y - x\frac{T_A}{T_C}$

Gear C is fixed $\Rightarrow y - x\dfrac{T_A}{T_C} = 0$

$$\Rightarrow \quad y = x.\frac{20}{80} = \frac{x}{4}$$

Gear A rotates at 200 rpm clockwise

$\therefore \quad x + y = 200$

$$x + \frac{x}{4} = 200$$

$\Rightarrow \quad x = 160 \Rightarrow y = 40$

$\therefore$ Speed of gear B is $= y - x\dfrac{T_A}{T_B} = 40 - 160 \times \dfrac{20}{40}$

$= -40$ rpm

$\therefore$ Gear B rotates at 40 rpm counter clockwise.
($\because$ we considered clockwise as positive)
Choice (B)

13. $m = 4$, $N_A : N_B = 7:3$

$$\text{centre distance} = \frac{D_A + D_B}{2} = 400\text{ mm}$$

$\Rightarrow \quad D_A + D_B = 800$ mm

$\Rightarrow \quad m(T_A + T_B) = 800 \Rightarrow T_A + T_B = \dfrac{800}{4} = 200$

$$\frac{N_A}{N_B} = \frac{T_B}{T_A} = \frac{7}{3} \Rightarrow T_A = \frac{3}{7}T_B$$

$$\therefore \frac{3}{7}T_B + T_B = 200 \Rightarrow T_B = 140 \Rightarrow T_A = 60$$

$(T_A, T_B) = (60, 140)$ Choice (C)

14. Fluctuation of speed $= \dfrac{e}{I\omega^2} = \dfrac{e}{2E}$

Where, E = Kinetic energy $= \dfrac{1}{2} I\,\omega^2$

e = fluctuation of energy

$$\therefore \quad k = \frac{500\times10^3}{2\times700\times10^3} = \frac{5}{14}$$

But $k = 2\left(\frac{\omega_1-\omega_2}{\omega_1+\omega_2}\right)$

$$\therefore \quad 2\left(\frac{\omega_1-\omega_2}{\omega_1+\omega_2}\right) = \frac{5}{14}$$

$$\Rightarrow \quad 23\ \omega_1 = 33\ \omega_2$$

$$\frac{\text{max speed}}{\text{min speed}} = \frac{\omega_1}{\omega_2} = \frac{33}{23} = 1.435$$ Choice (D)

15. Area of = 200 × 30 = 6000 mm²

Work required per = $6000 \times \frac{30}{4} = 45000$ kJ

Mean angular speed = $\omega = \left(\frac{\omega_1+\omega_2}{2}\right)$

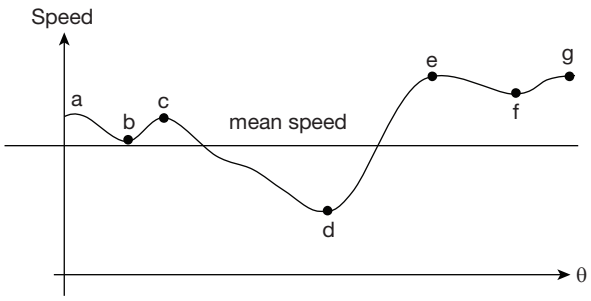
$$\therefore \quad \omega = \frac{\pi}{30}\left(\frac{N_1+N_2}{2}\right) = \frac{\pi}{30}\left(\frac{150+90}{2}\right) = 4\pi \text{ rad/sec}$$

$\therefore$ Energy required for cut = Torque × mean speed

$\therefore$ Torque × 4 π = 45000 kJ

$$\therefore \quad \text{Torque} = \frac{45000}{4\pi} = 3580.98 \text{ kN-m}$$ Choice (C)

16. The resisting moment line will coincide with the mean torque line when there is uniform resistance to rotation. The speed curve of the given turning-moment diagram will be.



At all the points of intersection the turning moment and the resisting moment are equal therefore there will not be acceleration or deceleration at these points. The slope of the speed curve at all these points will be zero.

Choice (D)

17. $k_e = 2$, $k_s = 1.5 \times 10^{-2}$

$\omega_1 - \omega_2 = 40$ rad/s, I = 7860 kg–m²

$$k_s = \frac{\omega_1-\omega_2}{\omega} \Rightarrow \omega = \frac{\omega_1-\omega_2}{k_s} = \frac{40}{1.5\times10^{-2}} = \frac{8000}{3} \text{ rad/s}$$

$\therefore$ fluctuation of energy = $E_f = k_e E = I k_s \omega^2$

Where, E = indicated work per revolution of crank shaft

$\therefore$ $ke\ E = I k_s \omega^2$

$$\Rightarrow \quad E = \frac{I k_s \omega^2}{k_e} = \frac{7680\times1.5\times10^{-2}\times8000^2}{2\times3^2} = 409600 \text{ kJ}$$

Indicated specific fuel consumption (isfc)

$$= \frac{\text{Fuel consumption/unit time}}{\text{Indicated power}}$$

fuel consumption/unit time = 409.6 kg/hr

$$\therefore isfc = \frac{409.6}{409600} = 10^{-3} \text{ kg/kJ.hr}$$ Choice (B)

18. E_f = 8000 kJ, $k_s = 0.25$

Fluctuation of energy = $E_f = I k_s \omega^2$

$$\Rightarrow \frac{E_f}{k_s} = \text{I}\ \omega^2 \qquad \Rightarrow \frac{1}{2}\text{I}\ \omega^2 = \frac{E_f}{2k_s}$$

$$\therefore \quad \text{mean kinetic energy} = \frac{1}{2}\text{I}\ \omega^2 = \frac{8000\times10^3}{2\times0.25} = 16 \text{ MJ}$$

Choice (C)

19. $\omega_1 = 150 \times \frac{\pi}{30}$ rad/s, $\omega_2 = 130 \times \frac{\pi}{30}$ rad/s

$$20 \times 10^3 = \frac{1}{2}I\left(\omega_1^2 - \omega_2^2\right) = \frac{1}{2}I\left(\frac{\pi}{30}\right)^2 (150^2 - 130^2)$$

$\Rightarrow$ I = 651.35 kg-m².

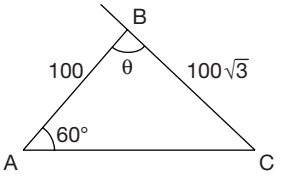
$\therefore$ fluctuation of energy = $E_f = I k_s \omega^2$

$$\omega = 100 \times \frac{\pi}{30} \text{ rad/sec}$$

$$\therefore \quad E_f = 30 \times 10^3 = 651.35 \times k_s \times \left(100\times\frac{\pi}{30}\right)^2$$

$$\therefore \quad k_s = 0.42$$ Choice (A)

20.



By sine rule, $\frac{100\sqrt{3}}{\text{Sin}\,60} = \frac{200}{\text{Sin}\,\theta} \Rightarrow \theta = 90^o$

$\therefore$ As the crank rotates the velocity of slider is along the link CD which is the linear velocity of slider B with respect to fixed link AC at the instant.

$\therefore$ $V_b = V_{ba} = r.\omega$

r = length of link AB

$$\Rightarrow \quad V_b = 0.1 \times \frac{2\pi}{60} \times 50 = \pi/6 = 0.523 \text{ m/s}$$ Choice (B)

21. Given $d_A + d_B = d_C + d_D$

$\Rightarrow$ $t_A + t_B = t_C + t_D$ ($\because$ All the gears have same module)

$\therefore$ $20 + 60 = 50 + t_D \Rightarrow t_D = 30$

From geometry, $N_B = N_C$

$$\therefore \frac{N_D}{N_A} = \frac{N_D}{N_C} \times \frac{N_B}{N_A}$$

$$= \frac{t_C}{t_D} \times \frac{t_A}{t_B} = \frac{50}{30} \times \frac{20}{60} = \frac{5}{9}$$

$$\therefore \frac{N_D}{N_A} = \frac{5}{9} \Rightarrow N_D = \frac{5}{9} \times 300$$

$\Rightarrow \quad N_D = 166.67$ rpm

Choice (D)

22. $E_f = 30 \times 10^3\ J$

$E_f = I\, k_s\, \omega^2 = mk^2.\, K_s\, .\, \omega^2$

Here, $k = 1.25\ m$, $k_s = \left(\frac{N_1 - N_2}{N}\right)$, $\omega = \frac{\pi}{30}\left(\frac{N_1 + N_2}{2}\right)$

$$\therefore N = \left(\frac{N_1 + N_2}{2}\right) = \left(\frac{245 + 240}{2}\right) = 242.5 \text{ rpm}$$

$\therefore \quad E_f = 30 \times 10^3 = m \times 1.25^2$

$$\times \left(\frac{245 - 240}{242.5}\right) \times \left(\frac{\pi}{30}\right)^2 \times \left(\frac{240 + 245}{2}\right)^2$$

$\Rightarrow \quad m = 1443.98 \simeq 1444$ kg Choice (A)

23. Choice (C)

24. angle of approach = $\alpha = 23^o$

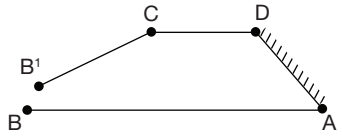
Angle of recess = $\beta = 17^o$

Pitch angle = $\delta = 27^o$

Contact ratio = $\frac{\alpha + \beta}{\delta} = \frac{23 + 17}{27} = \frac{40}{27} = 1.48$

Choice (A)

25. $AB > AD + DC + CB$ i.e., $15 > 5 + 6 + 3$



When the length of one link is greater than the sum of the other three links it is not possible to have a four bar linkage. Choice (D)