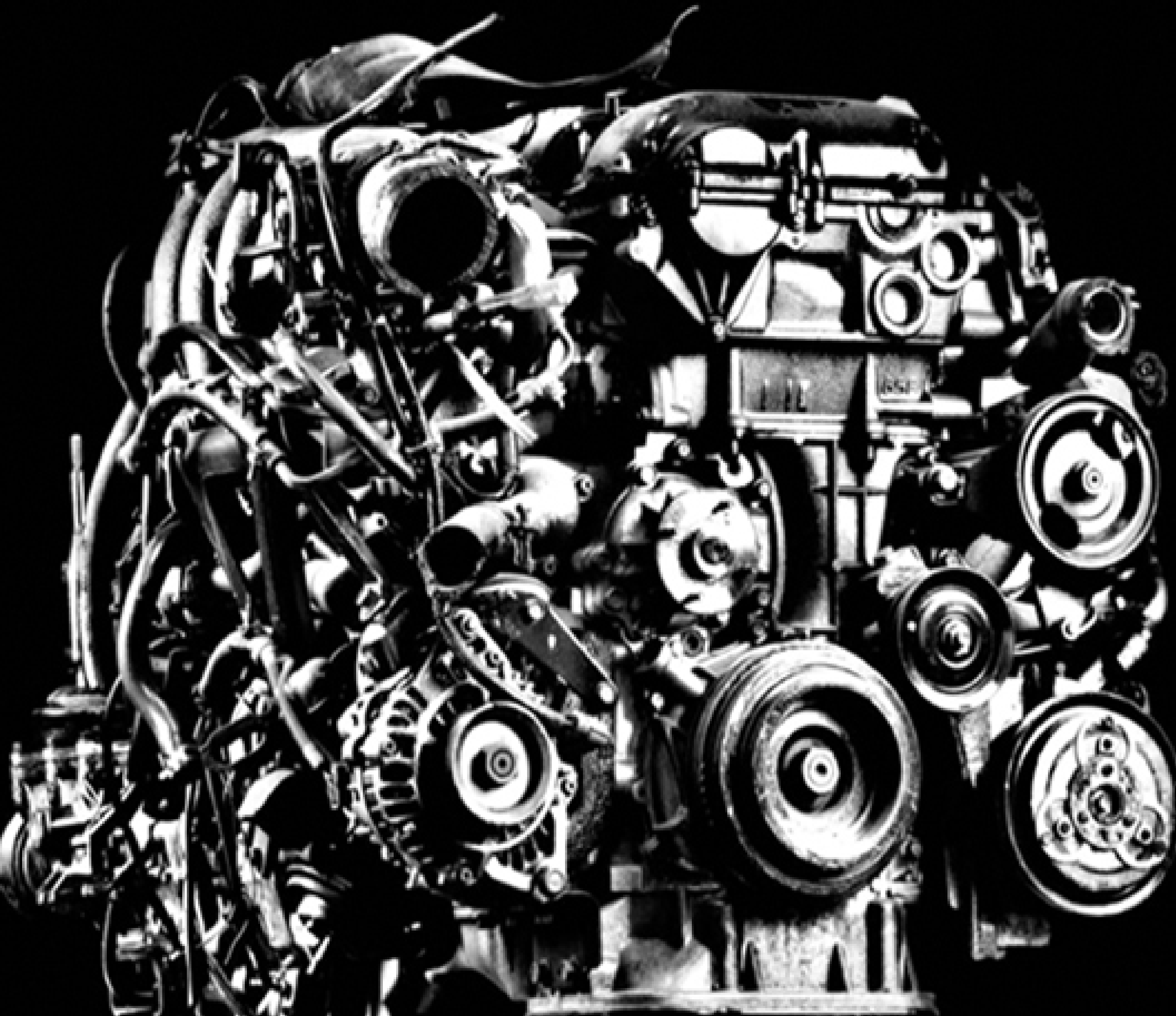
GATE
Study Material



Theory of Machines
(Mechanical Engineering)

Theory of Machines

1. Mechanism

2. Cam

3. Flywheel

4. Governor

1.

Mechanism

Objective Questions (IES, IAS, GATE)

Kinematic pair

1. Match List I with List II and select the correct answer **[IES-2002]**

List I (Kinematic pairs)	List II (Practical example)
A. Sliding pair	1. A road roller rolling over the ground
B. Revolute pair	2. Crank shaft in a journal bearing in an engine
C. Rolling pair	3. Ball and socket joint
D. Spherical pair	4. Piston and cylinder
	5. Nut and screw

	A	B	C	D		A	B	C	D
(a)	5	2	4	3	(b)	4	3	1	2
(c)	5	3	4	2	(d)	4	2	1	3

1. Ans. (d)

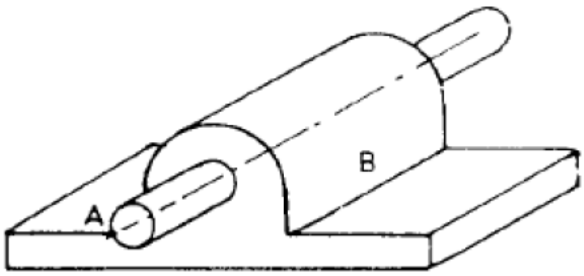
2. A round bar A passes through the cylindrical hole in B as shown in the given figure. Which one of the following statements is correct in this regard?

(a) The two links shown form a kinematic pair.

(b) The pair is completely constrained.

(c) The pair has incomplete constraint.

(d) The pair is successfully constrained.



[IES-1995]

2. Ans. (b)

3. Consider the following statements **[IAS 1994; IES-2000]**

1. A round bar in a round hole form a turning pair.
2. A square bar in a square hole forms a sliding pair.
3. A vertical shaft in a footstep bearing forms a successful constraint.

Of these statements

(a) 1 and 2 are correct (c) 1 and 3 are correct

(b) 2 and 3 are correct (d) 1, 2 and 3 are correct

3. Ans. (b)

4. Match List-I with List-II and select the correct answer using the codes given below the Lists: **[IES-1999]**

List-I	List-II
A. 4 links, 4 turning pairs	1. Complete constraint
B. 3 links, 3 turning pairs	2. Successful constraint
C. 5 links, 5 turning pairs	3. Rigid frame
D. Footstep bearing	4. Incomplete constraint

Code:	A	B	C	D		A	B	C	D
(a)	3	1	4	2	(b)	1	3	2	4
(c)	3	1	2	4	(d)	1	3	4	2

4. Ans. (d) 4 links and 4 turning pairs satisfy the equation L = $\frac{3}{2}$(j + 2); It is case of complete constraint. 3 links and 3 turning pairs form rigid frame. Foot step bearing results in successful constraint and 5 links and 5 turning pairs provide incomplete constraint.

5. The connection between the piston and cylinder in a reciprocating engine corresponding to
(a) completely constrained kinematic pair
(b) incompletely constrained kinematic pair
(c) successfully constrained kinematic pair (d) single link **[IAS 1994]**
5. Ans. (c)

6. Match the items in columns I and II **[GATE-2006]**

Column I	Column II
P. Higher kinematic pair	1. Grubler's equation
Q. Lower kinematic pair	2. Line contact
R. Quick return mechanism	3. Euler's equation
S. Mobility of a linkage	4. Planer
	5. Shaper
	6. Surface contact

(a) P-2, Q-6, R-4, S-3 (b) P-6, Q-2, R-4, S-1
(c) P-6, Q-2, R-5, S-3 (d) P-2, Q-6, R-5, S-1
6. Ans. (d)

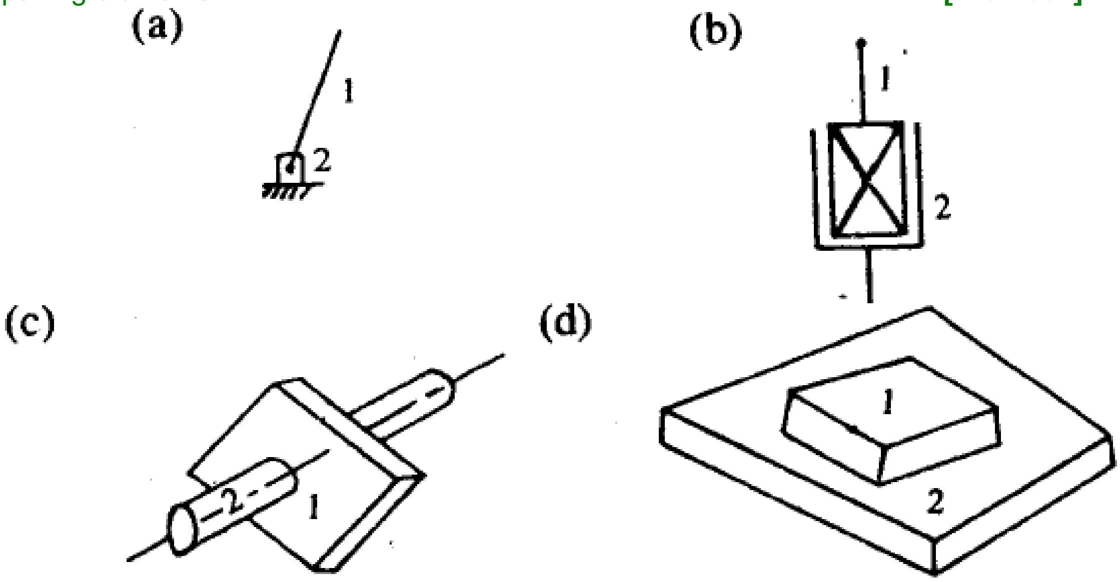
7. The minimum number of links in a single degree-of-freedom planar mechanism with both higher and lower kinematic pairs is **[GATE-2002]**
(a) 2 (b) 3 (c) 4 (d) 5
7. Ans. (c)

8. Consider the following statements: **[IES-2005]**
1. The degree of freedom for lower kinematic pairs is always equal to one.
2. A ball-and-socket joint has 3 degrees of freedom and is a higher kinematic pair
3. Oldham's coupling mechanism has two prismatic pairs and two revolute pairs.

Which of the statements given above is/are correct?
(a) 1, 2 and 3 (b) 1 only (c) 2 and 3 (d) 3 only
8. Ans. (a)

9. Which of the following are examples of forced closed kinematic pairs?
1. Cam and roller mechanism 2. Door closing mechanism **[IES-2003]**
3. Slider-crank mechanism 4. Automotive clutch operating mechanism
Select the correct answer using the codes given below:
Codes:
(a) 1, 2 and 4 (b) 1 and 3 (c) 2, 3 and 4 (d) 1, 2, 3 and 4
9. Ans. (a)

10. Which one of the following "Kinematic pairs" has 3 degrees of freedom between the pairing elements? **[IAS-2002]**



10. Ans. (d) (a) has only one DOF i.e. rotational
(b has only one DOF i.e. translational about z-axis
(c has only two DOF i.e. rotation and translation

11. Assertion (A): Hydraulic fluid is one form a link. **[IES-1996]**
Reason (R): A link need not necessarily be a rigid body but it must be a resistant body.
11. Ans. (d)

12. Assertion (A): When a link has pure translation, the resultant force must pass through the centre of gravity. **[IES-1994]**
Reason (R): The direction of the resultant force would be in the direction of acceleration of the body.
12. Ans. (d) A is false and R is true.

Lower pair

13. Consider the following statements: **[IES-2006]**
1. Lower pairs are more resistant than the higher pairs in a plane mechanism.
2. In a 4-bar mechanism (with 4 turning pairs), when the link opposite to the shortest link is fixed, a double rocker mechanism results.

Which of the statements given above is/are correct?
(a) Only 1 (b) Only 2 (c) Both 1 and 2 (d) Neither 1 nor 2
13. Ans. (c)

Higher pair

14. Consider the following pairs of parts: **[IES-2000]**
1. Pair of gear in mesh 2. Belt and pulley
3. Cylinder and piston 4. Cam and follower
Among these, the higher pairs are
(a) 1 and 4 (b) 2 and 4 (c) 1, 2 and 3 (d) 1, 2 and 4

14. Ans. (a)

15. Assertion (A): The elements of higher pairs must be force closed. **[IES-1995]**
Reason (R): This is required in order to provide completely constrained motion.
15. Ans. (a) Elements of higher pairs must be force closed to provide completely constrained motion.

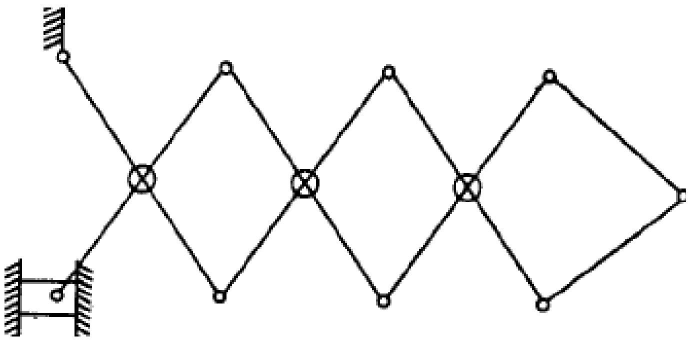
16. Which of the following is a higher pair? **[IAS-1995]**
(a) Belt and pulley (b) Turning pair (c) Screw pair (d) Sliding pair
16. Ans. (a) A higher pair have point or line contact.

17. Assertion (A): A cam and follower is an example of a higher pair. **[IAS 1994]**
Reason (R): The two elements have surface contact when the relative motion takes place.
17. Ans. (c)

Kinematic chain

18. In a Kinematic chain, a quaternary joint is equivalent to: **[IES-2005]**
(a) One binary joint (b) Two binary joints
(c) Three binary joints (d) Four binary joints
18. Ans. (c) when '*l*' number of links are joined at the same connection, the joint is equivalent to (*l* - 1) binary joints.

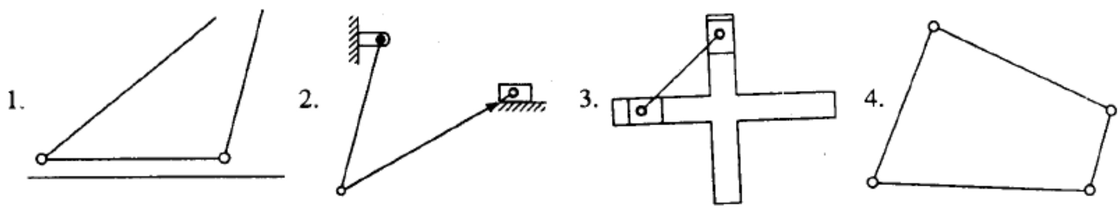
19. The kinematic chain shown in the above figure is a
(a) structure
(b) mechanism with one degree of freedom
(c) mechanism with two degree of freedom
(d) mechanism with more than two degrees of freedom



[IES-2000]

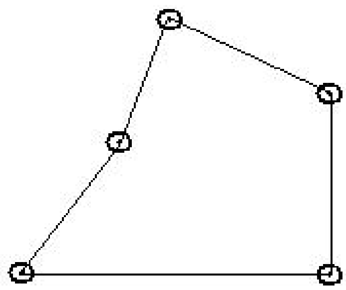
19. Ans. (d)

20. Which of the following are examples of a kinematic chain? **[IES-1998]**



Select the correct answer using the codes given below:
Codes: (a) 1, 3 and 4 (b) 2 and 4 (c) 1, 2 and 3 (d) 1, 2, 3 and 4
20. Ans. (d)

21. The given figure shows a / an
(a) locked chain
(b) constrained kinematic chain
(c) unconstrained kinematic chain
(d) mechanism



[IAS-2000]

21. Ans. (c)

Here $l = 5$, and $j = 5$

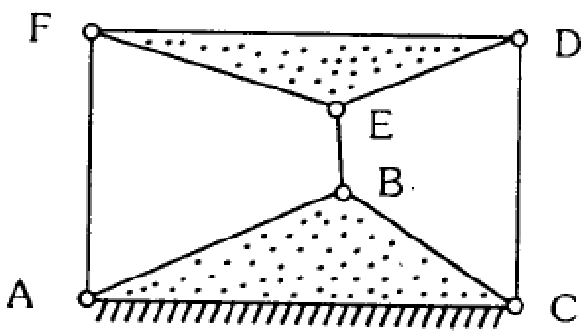
condition-1, $l = 2p - 4$ or $5 = 2 \times 5 - 4 = 6$ i.e. $L.H.S < R.H.S$

condition-2, $j = \frac{3}{2} l - 2$ or $5 = \frac{3}{2} \times 5 - 4 = 5.5$ i.e. $L.H.S < R.H.S$

It is not a kinematic chain. L.H.S < R.H.S, such a type of chain is called unconstrained chain i.e. relative motion is not completely constrained.

22. In a four-link kinematic chain, the relation between the number of links (L) and number of pairs (j) is **[IAS-2000]**
(a) L=2j+4 (b) L=2j-4 (c) L =4j+ 2 (d) L =4j-2
22. Ans. (b) Here notation of number of pairs (j) [our notation is p]

23. A linkage is shown below in the figure in which links ABC and DEF are ternary Jinks whereas AF, BE and CD are binary links.
The degrees of freedom of the linkage when link ABC is fixed are
(a) 0 (b) 1
(c) 2 (d) 3



[IES-2002]

23. Ans. (a)

24. Assertion (A): The kinematic mechanisms shown in Fig. 1 and Fig. 2 above are the kinematic inversion of the same kinematic chain. **[IAS-2002]**
Reason (R): Both the kinematic mechanisms have equal number of links and revolute joints, but different fixed links.
24. Ans. (d) *A is false*. Kinematic inversion is obtained different mechanisms by fixing different links *in a kinematic chain.* Here they change kinematic chain also.

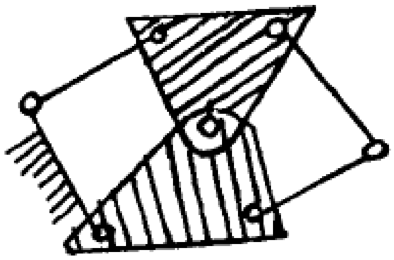


Fig. 1

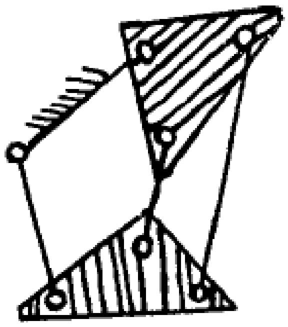


Fig. 2

Mechanism

Degrees of freedom

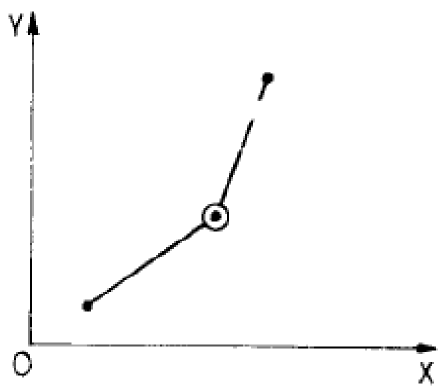
25. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II	[IES-2001]
A. 6 d.o.f. system	1. Vibrating beam	
B. 1 d.o.f. system	2. Vibration absorber	
C. 2 d.o.f. system	3. A rigid body in space	
D. Multi d.o.f. system	4. Pure rolling of a cylinder	

Codes:	A	B	C	D		A	B	C	D
(a)	1	2	4	3	(b)	1	4	2	3
(c)	3	2	4	1	(d)	3	4	2	1

25. Ans. (a)

26. The two-link system, shown in the given figure, is constrained to move with planar motion. It possesses
(a) 2-degrees of freedom
(b) 3-degrees of freedom
(c) 4-degrees of freedom
(d) 6-degrees of freedom



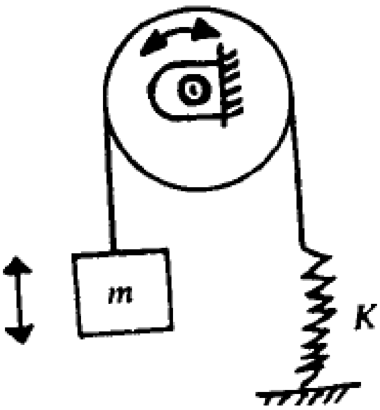
[IES-1994]

26. Ans. (a) Two link system shown in the above figure has 2 degrees of freedom.

27. When supported on three points, out of the 12 degrees of freedom the number of degrees of freedom arrested in a body is **[IES-1993]**
(a) 3 (b) 4 (c) 5 (d) 6

27. Ans. (d) When supported on three points, following six degrees of freedom are arrested (two line movements along y-axis, two rotational movements each along x-axis and z-axis.)

28. Assertion (A): The mechanical system shown in the above figure is an example of a 'two degrees of freedom' system undergoing vibrations.
Reason (R): The system consists of two distinct moving elements in the form of a pulley undergoing rotary oscillations and a mass undergoing linear



[IAS-2002]

28. Ans. (a)

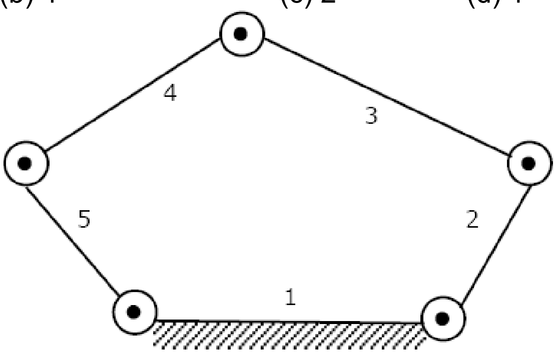
29. The number degrees of freedom of a planar linkage with Blinks and 9 simple revolute joints is
(a)1 (b) 2 (c) 3 (d) 4 **[GATE-2005]**
29. Ans. (c)

Number of degree of freedom, $n = 3(l-1) - 2J - h$

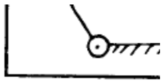
$$= (3 \times 7) - (2 \times 9) - 0 = 3$$

30. When a cylinder is located in a Vee-block, then number of degrees of freedom which are arrested is **[GATE-2003]**
(a) 2 (b) 4 (c) 7 (d) 8
30. Ans. (c)

31. The number of degrees of freedom of a five link plane mechanism with five revolute pairs as shown in the figure is **[GATE-1993]**
(a) 3 (b) 4 (c) 2 (d) 1



31. Ans. (c)



Explanation. Degrees of freedom

$$m = 3(n-1) - 2j_1 - j_2$$

where
n = nuber of links
j_1 = number of single degree of freedom, and
j_2 = number of two degree of freedom

Given, $n = 5, \quad j_1 = 5, \quad j_2 = 0$

Hence $m = 3(5-1) - 2 \times 5 - 0 = 2$

32. Match the following with respect to spatial mechanisms. **[GATE-2004]**

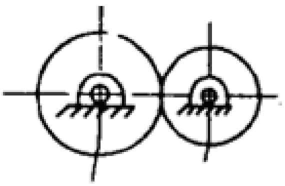
Type of Joint	Degrees of constraint
P-Revolute	1. Three
Q-Cylindrical	2. Five
R-5pherical	3. Four
	4. Two
	5. Zero

(a) P-1 Q-3 R-3 (b) P-5 Q-4 R-3 (c) P-2 Q-3 R-1 (d) P-4 Q-5 R-3

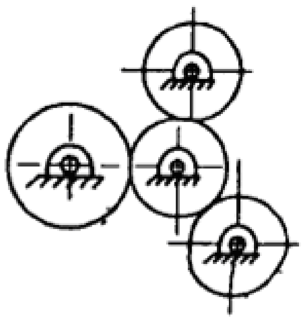
32. Ans. (c)

For revolute joint, degree of freedom = 1
For cylinderical joint, degree of freedom = 2
For spherical joint, degree of freedom = 3
Degree of constraints = 6 – Degree of freedom

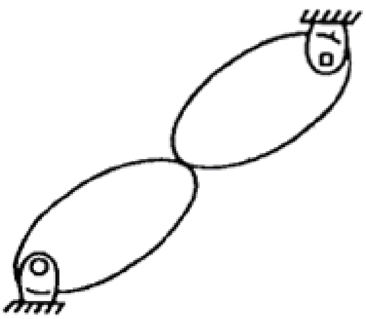
33.



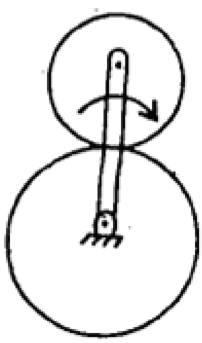
(1)



(2)



(3)



(4)

[IES-2003]

Which of the mechanisms shown above do/does not have single degree of freedom?

(a) 3 and 4 (b) 2 and 3 (c) 3 only (d) 4 only

33. Ans. (c)

Kutzbach criterion

Grubler criterion

34. f = 3 (n - 1) - 2j. In the Grubler's equation for planar mechanisms given, j is the
(a) Number of mobile links (b) Number of links **[IES-2003]**
(c) Number of lower pairs (d) Length of the longest link
34. Ans. (a)

35. Match List-I with List-II and select the correct answer using the codes given below the lists: **[IES-2001]**

List-I	List-II
A. Cam and follower	1. Grubler's rule
B. Screw pair	2. Grashof's linkage
C. 4-bar mechanism	3. Pressure angle
D. Degree of freedom of planar mechanism	4. Single degree of freedom

Codes:	A	B	C	D		A	B	C	D
(a)	3	4	2	1	(b)	1	2	4	3
(c)	1	4	2	3	(d)	3	2	4	1

35. Ans. (a)

36. For one degree of freedom planar mechanism having 6 links, which one of the following is the possible combination? **[IAS-2007]**
(a) Four binary links and two ternary links (b) Four ternary links and two binary links
(c) Three ternary links and three binary links (d) One ternary link and five binary links

36. Ans. (d) From Grubler's criteria 1=3 (*l*-1)-2j or j = $\frac{3}{2}l-2 \quad for\, six\, link$

$j=\frac{3}{2}\times 6-2=7$ 1 ternay link $\equiv$ 2 binary link

(a) j= $4+2\times 2\neq 7$ (b) j= $4\times 2+2\neq 7$
(c) j= $3\times 2+2\neq 7$ (d) j= $1\times 2+5\neq 7$ ans. is d

37. A planar mechanism has 8 links and 10 rotary joints. The number of degrees of freedom of the mechanism, using Grubler's criterion, is **[GATE-2008]**
(a) 0 (b) 1 (c) 2 (d) 3
37. Ans. (b) Whatever may be the number of links and joints Grubler's criterion applies to mechanism with only single degree freedom. Subject to the condition 3l-2j-4=0 and it satisfy this condition.

Grashof's law

38. In a four-bar linkage, S denotes the shortest link length, L is the longest link length, P and Q are the lengths of other two links. At least one of the three moving links will rotate by 360^o if **[GATE-2006]**

(a) $S + L \leq P + Q$ (b) $S + L > P + Q$ (c) $S + P \leq L + Q$ (d) $S + P > L + Q$

38. Ans. (a)

According to Grashoff's Criteria.

$$S + L \leq P + Q$$

39. Consider the following statements in respect of four bar mechanism: **[IAS-2003]**

1. It is possible to have the length of one link greater than the sum of lengths of the other three links.
2. If the sum of the lengths of the shortest and the longest links is less than the sum of lengths of the other two, it is known as Grashof linkage.
3. It is possible to have the sum of the lengths of the shortest and the longest links greater than that of the remaining two links.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 2 and 3 (c) 2 only (d) 3 only

39. Ans. (c)

40. The lengths of the links of a 4-bar linkage with revolute pairs only are p, q, r, and s units. Given that $p < q < r < s$. Which of these links should be the fixed one, for obtaining a "double crank" mechanism? **[GATE-2003]**

(a) link of length p (b) link of length q (c) link of length r (d) link of length s

40. Ans. (d) To obtain a "DOUBLE CRANK MECHANISM", shortest link is always fixed. While obtaining a "DOUBLE LEVER MECHANISM", the link opposite to the "SHORTEST LINK" is fixed.

Inversion of Mechanism

41. Assertion (A): Inversion of a kinematic chain has no effect on the relative motion of its links.

Reason(R): The motion of links in a kinematic chain relative to some other links is a property of the chain and is not that of the mechanism. **[IAS-2000]**

41. Ans. (a) Ina kinematic inversion relative motion does not change but absolute motion change drastically.

42. Assertion (A): An inversion is obtained by fixing in turn different links in a kinematic chain.

Reason (R): Quick return mechanism is derived from single slider crank chain by fixing the ram of a shaper with the slotted lever through a link. **[IAS-1997]**

42. Ans. (c)

43. Inversion of a mechanism is **[IES-1992]**

(a) changing of a higher pair to lower pair
(b) obtained by fixing different links in a kinematic chain
(b) turning it upside down
(d) obtained by reversing the input and output motion

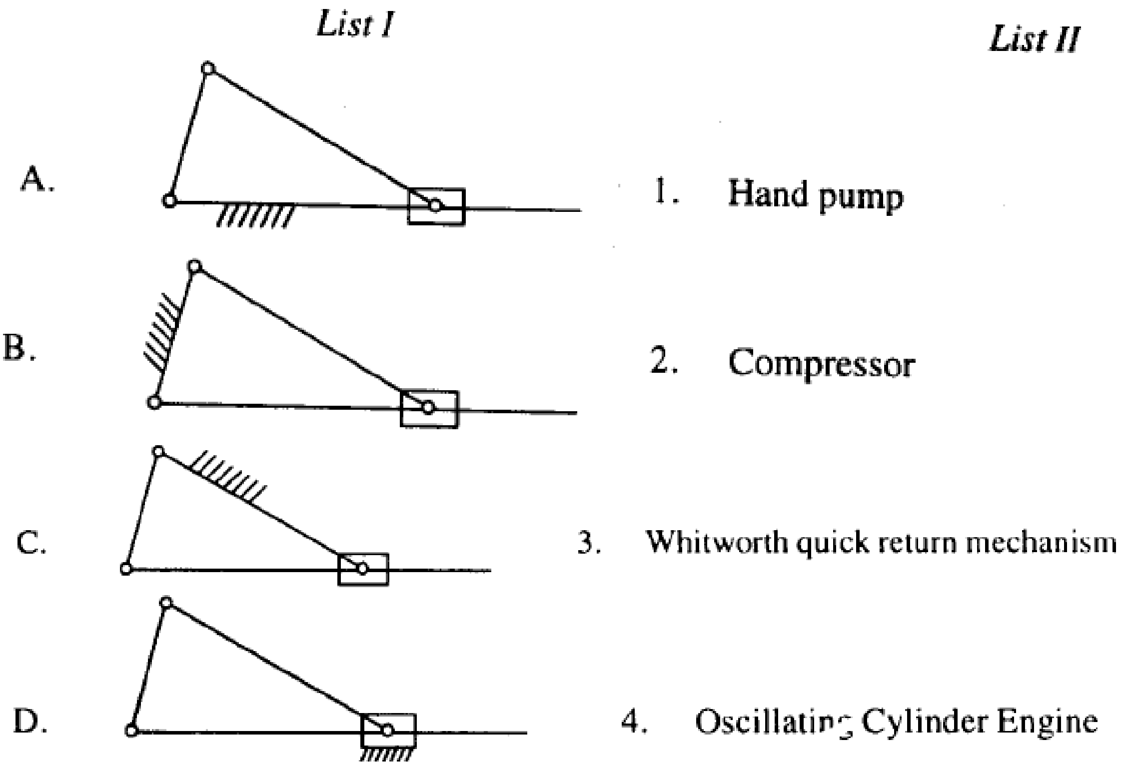
43. Ans. (b)

44. For L number of links in a mechanism, the number of possible inversions is equal to
(a) L - 2 (b) L – 1 (c) L (d) L + 1 **[IAS-1996]**
44. Ans. (b)

45. The number of inversions for a slider crank mechanism is **[GATE-2006]**
(a) 6 (b) 5 (c) 4 (d) 3
45. Ans. (c)

There are four number of inversions for a slider crank mechanism.

46. Match List I (Kinematic inversions) with List II (Applications) and select the correct answer using the codes given below the Lists: **[IES-2000]**



Code:	A	B	C	D		A	B	C	D
(a)	1	3	4	2	(b)	2	4	3	1
(c)	2	3	4	1	(d)	1	4	3	2

46. Ans. (c)

Inversion of four bar chain

47. Which of the following pairs are correctly matched? Select the correct answer using the codes given below the pairs. **[IES-1998]**

Mechanism Chain from which derived
1. Whitworth quick return motion….. Single slider crank chain
2. Oldham's coupling………………. Four bar chain
3. Scotch Yoke……………………….Double slider crank chain

Codes: (a) 1 and 2 (b) 1, 2 and 3 (c) 1 and 3 (d) 2 and 3

47. Ans. (c)

48. Which one of the following conversions is used by a lawn-sprinkler which is a four bar mechanisms? **[IES-2004]**

(a) Reciprocating motion to rotary motion

(b) Reciprocating motion to oscillatory motion

(c) Rotary motion to oscillatory motion

(d) Oscillatory motion to rotary motion

48. Ans. (*)

49. The four bar mechanism shown in the figure

(Given: OA = 3 cm, AB = 5 cm

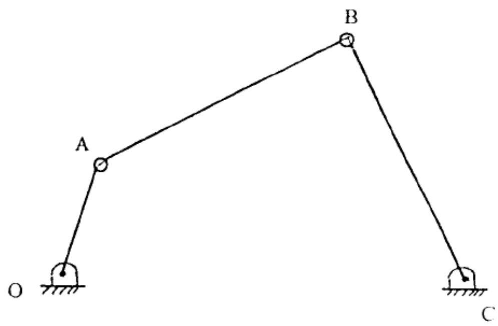
BC = 6 cm, OC = 7 cm) is a

(a) Double crank mechanism

(b) Double rocker mechanism

(c) Crank rocker mechanism

(d) Single slider mechanism



[IAS-2004]

49. Ans. (c)

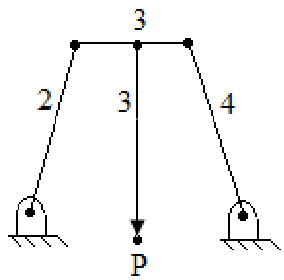
50. In the four bar mechanism shown in the given figure, linhs2 and 4 have equal length. The point P on the coupler 3 will generate a/an

(a) ellipse

(b) parabola

(c) approximately straight line

(d) circle



[IAS-1995]

50. Ans. (a) Point P being rigidly connected to point 3, will trace same path as point 3, *i.e.* ellipse.

51. A four-bar chain has **[IES-2000]**

(a) all turning pairs (b) one turning pair and the others are sliding pairs

(c) one sliding pair and the others are turning pairs (d) all sliding pairs

51. Ans. (a)

GATE Study Material Theory of Machines (Mechanical Engineering)