Theory of Machines

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1.

Mechanism

Objective Questions (IES, IAS, GATE)

Kinematic pair

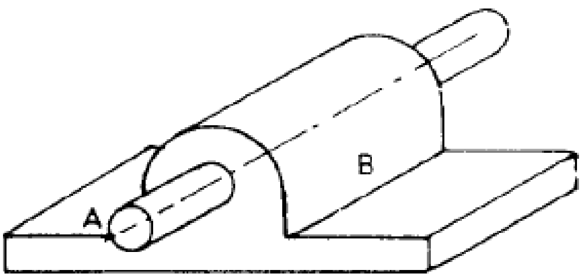
1. Match List I with List II and select the correct answer [IES-2002]

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)

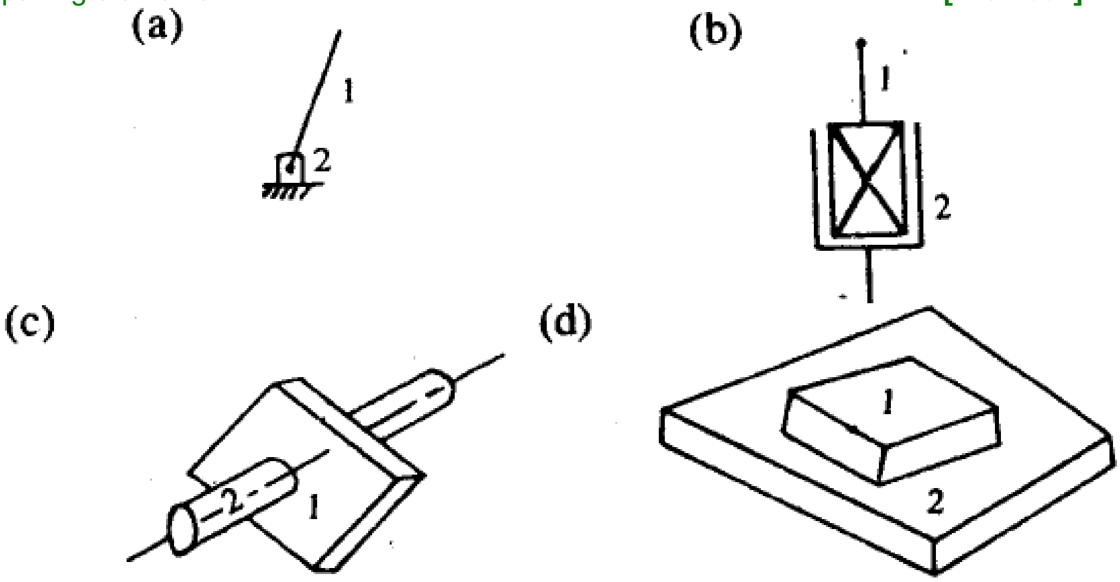
7. The minimum number of links in a single degree-of-freedom planar mechanism with both higher and lower kinematic pairs is **[GATE-2002]**
(a) 2 (b) 3 (c) 4 (d) 5
7. Ans. (c)

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.

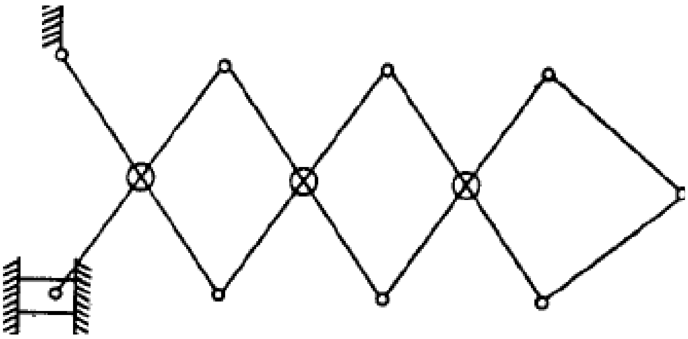
16. Which of the following is a higher pair? **[IAS-1995]**
(a) Belt and pulley (b) Turning pair (c) Screw pair (d) Sliding pair
16. Ans. (a) A higher pair have point or line contact.

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.

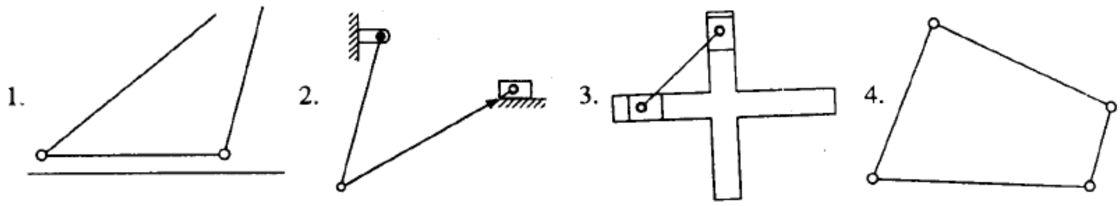
19. The kinematic chain shown in the above figure is a
(a) structure
(b) mechanism with one degree of freedom
(c) mechanism with two degree of freedom
(d) mechanism with more than two degrees of freedom



[IES-2000]

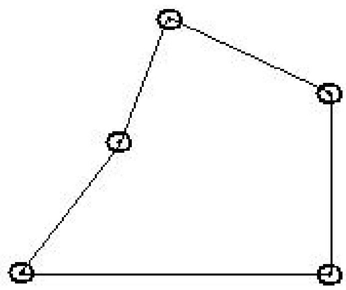
19. Ans. (d)

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 $j = 5$

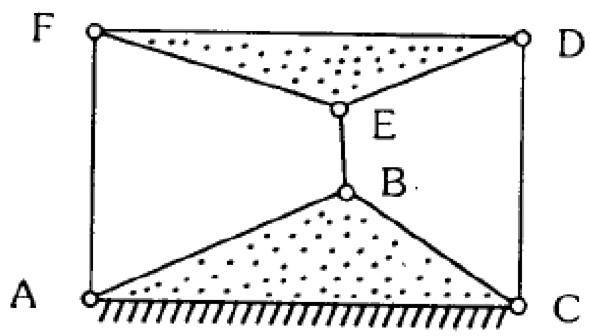
condition-1, $l = 2p - 4$ or $5 = 2 \times 5 - 4 = 6$ i.e. $L.H.S < R.H.S$

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.

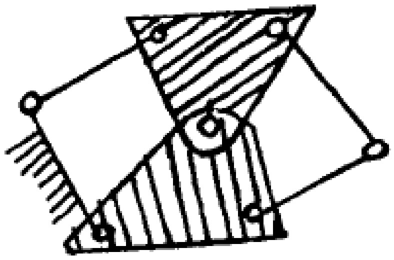


Fig. 1

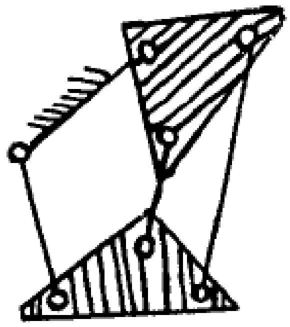


Fig. 2

Mechanism

Degrees of freedom

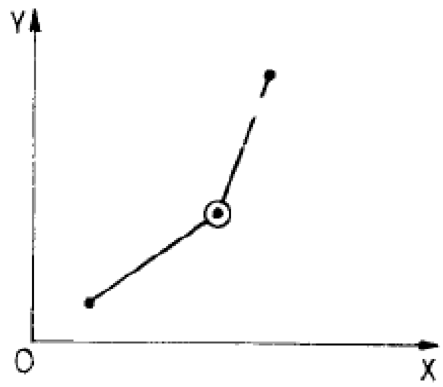
25. Match List-I with List-II and select the correct answer using the codes given below the lists:

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



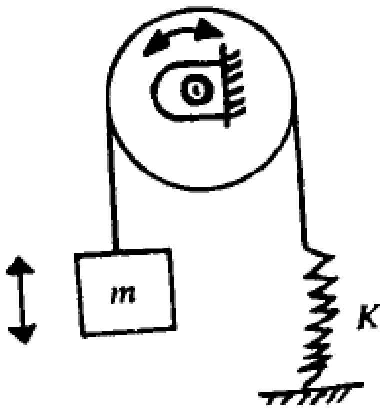
[IES-1994]

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)

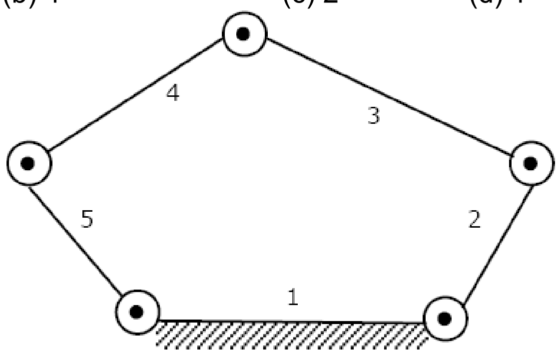
29. The number degrees of freedom of a planar linkage with Blinks and 9 simple revolute joints is
(a)1 (b) 2 (c) 3 (d) 4 **[GATE-2005]**
29. Ans. (c)

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

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

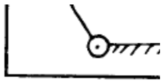
30. When a cylinder is located in a Vee-block, then number of degrees of freedom which are arrested is **[GATE-2003]**
(a) 2 (b) 4 (c) 7 (d) 8
30. Ans. (c)

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]**

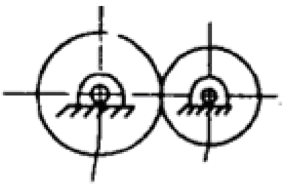
Type of Joint	Degrees of constraint
P-Revolute	1. Three
Q-Cylindrical	2. Five
R-5pherical	3. Four
	4. Two
	5. Zero

(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

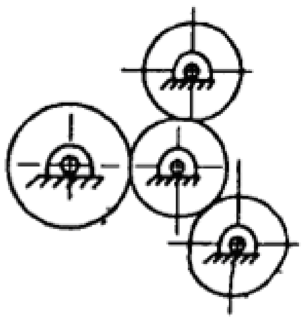
32. Ans. (c)

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

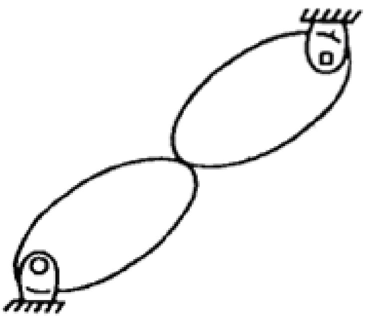
33.



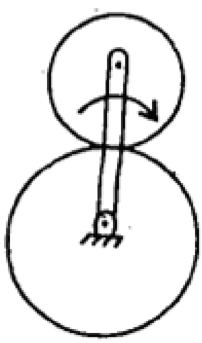
(1)



(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° 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

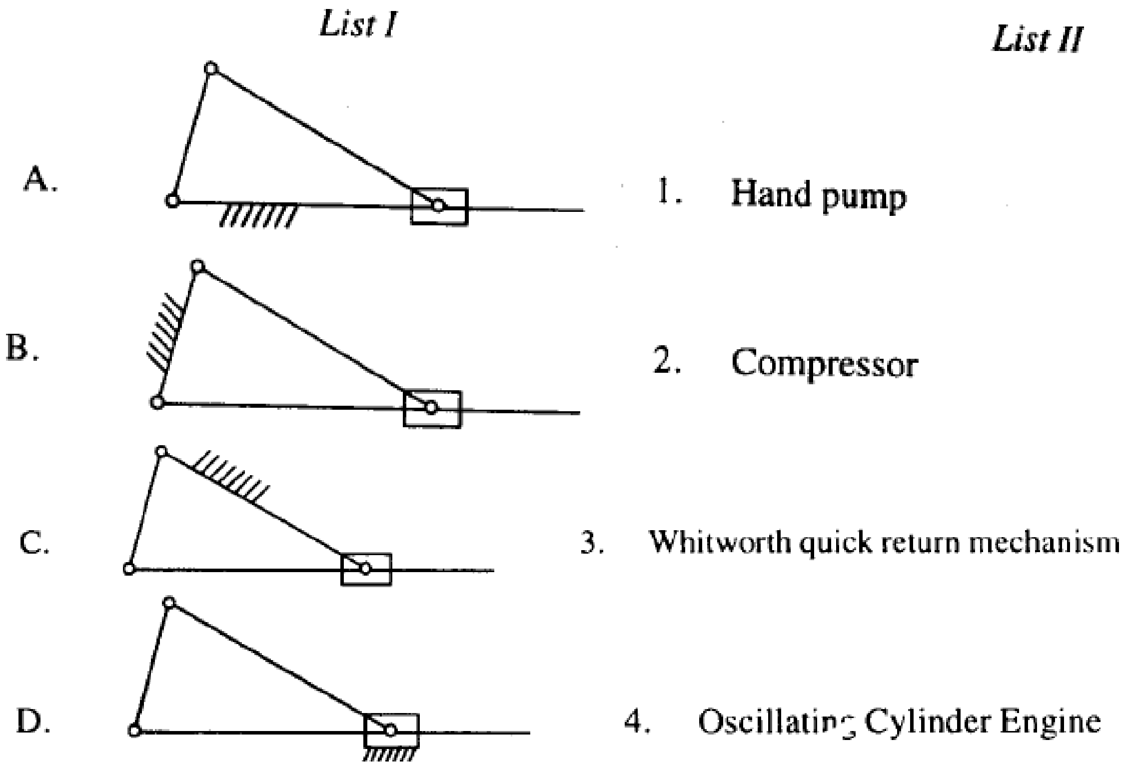
43. Ans. (b)

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

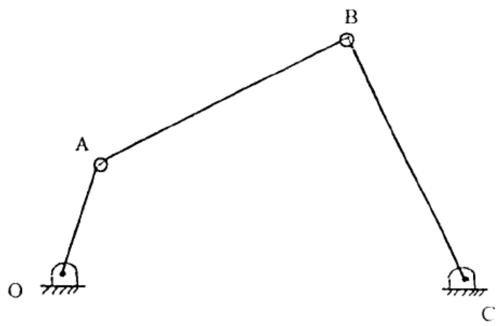
47. Which of the following pairs are correctly matched? Select the correct answer using the codes given below the pairs. **[IES-1998]**

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)

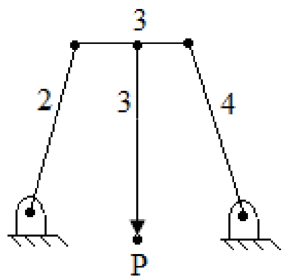
48. Which one of the following conversions is used by a lawn-sprinkler which is a four bar mechanisms? **[IES-2004]**
(a) Reciprocating motion to rotary motion
(b) Reciprocating motion to oscillatory motion
(c) Rotary motion to oscillatory motion
(d) Oscillatory motion to rotary motion
48. Ans. (*)

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)

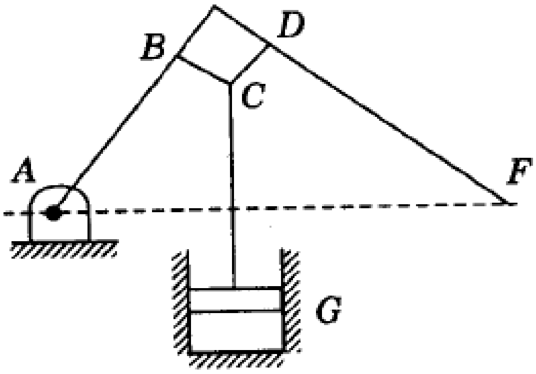
50. In the four bar mechanism shown in the given figure, linhs2 and 4 have equal length. The point P on the coupler 3 will generate a/an
(a) ellipse
(b) parabola
(c) approximately straight line
(d) circle



[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)

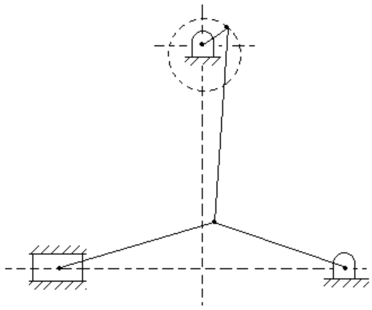
52. Assertion (A): The given line diagram of Watt's indicator mechanism is a type of crank and lever mechanism.
Reason (R): BCD acts as a lever.



[IES-1997]

52. Ans. (a)

53. The mechanism shown in the given figure represents
(a) Hart's mechanism
(b) Toggle mechanism
(c) Watts's mechanism
(d) Beam Engine mechanism

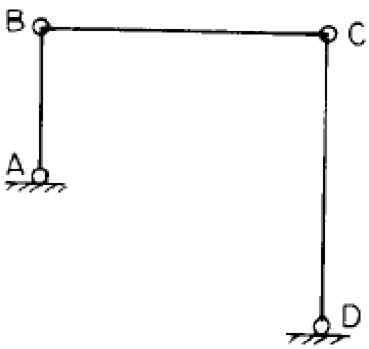


[IAS-1995]

53. Ans. (d)

54. The centre of gravity of the coupler link in a 4-bar mechanism would experience
(a) no acceleration (b) only linear acceleration **[IES-1996]**
(c) only angular acceleration (d) both linear and angular accelerations.
54. Ans. (d)

55. In the given figure, ABCD is a four-bar mechanism. At the instant shown, AB and CD are vertical and BC is horizontal AB is shorter than CD by 30 cm. AB is rotating at 5 radius and CD is rotating at 2 rad/s. The length of AB is
(a) 10cm
(b) 20 cm
(c) 30 cm
(d) 50 cm.



[IES-1994]

55. Ans. (b) $5l = 2(l+30),\ 3l = 60 \text{ and } l = 20\,\text{cm}$

Inversion of Single Slider crank chain

56. In a single slider four-bar linkage, when the slider is fixed, it forms a mechanism of
(a) hand pump (b) reciprocating engine (c) quick return (d) oscil1ating cylinder

[IES-1999]

56. Ans. (a)

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

List-I	List-II [IES-1997]
A. Quadric cycle chain	1. Rapson's slide
B. Single slider crank chain	2. Oscillating cylinder engine mechanism
C. Double slider crank chain	3. Ackermann steering mechanism
D. Crossed slider crank chain	4. Oldham coupling

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

57. Ans. (d)

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

List - I	List-II [IAS-1997]
A. Pantograph	1. Scotch yoke mechanism
B. Single slider crank chain	2. Double lever mechanism
C. Double slider crank chain	3. Tchebicheff mechanism
D. Straight line motion	4. Double crank mechanism
	5. Hand pump

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

58. Ans. (b)

59. The mechanism used in a shaping machine is [GATE-2003]

(a) a closed 4-bar chain having 4 revolute pairs

(b) a closed 6-bar chain having 6 revolute pairs

(c) a closed 4-bar chain having 2 revolute and 2 sliding pairs

(d) an inversion of the single slider-crank chain

59. Ans. (*)

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

List I	List II [IES-1993]
A. Quadric cycle chain	1. Elliptic trammel
B. Single slider crank chain	2. Rapsons slide
C. Double slider crank chain	3. Ackerman steering
D. Crossed slider crank chain	4. Eccentric mechanism
	5. Pendulum pump

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

60. Ans. (d)

Quick return motion mechanism

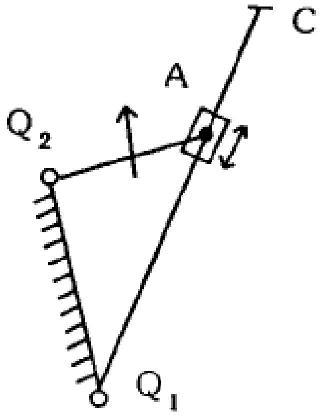
61. Match List I with List II and select the correct answer: **[IES-2002]**

List I (Mechanism)	List II (Motion)
A. Hart mechanism	1. Quick return motion
B. Pantograph	2. Copying mechanism
C. Whitworth mechanism	3. Exact straight line motion
D. Scotch yoke	4. Simple harmonic motion
	5. Approximate straight line motion

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

61. Ans. (b)

62. The crank and slotted lever quick-return motion mechanism is shown in figure. The length of links O_1O_2, O_1C and O_2A are 10 cm, 20 cm and 5 cm respectively.
The quick return ratio of the mechanism is
(a) 3.0 (b) 2.75
(c) 2.5 (d) 2.0



[IES-2002]

62. Ans. (d)

63. Match List I with List II and select the correct answer using the codes given below the Lists: **[IES-2000]**

List I	List II
(a) Quick return mechanism	1. Lathe
(b) Apron mechanism	2. Milling machine
(c) Indexing mechanism	3. Shaper
(d) Regulating wheel	4. Centreless grinding

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

63. Ans. (d)

64. Match List I with List II and select the correct answer using the codes given below the Lists: **[IES-2000]**

List I	List II
A. Compound train	1. Hart mechanism
B. Quick return mechanism	2. Corioli's force
C. Exact straight line motion	3. Transmission of motion around bends and corners
D. Approximate straight line motion	4. Watt mechanism

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

(c)	3	4	1	2	(d)	1	4	3	2

64. Ans. (b)

65. The type of quick return mechanism employed mostly in shaping machines is:
(a) DC reversible motor (b) Fast and loose pulleys
(c) Whitworth motion (d) Slotted link mechanism **[IES-1997]**
65. Ans. (d)

66. In order to draw the acceleration diagram, it is necessary to determine the Corioli's component of acceleration in the case of **[IES-1997]**
(a) crank and slotted lever quick return mechanism
(b) slider-crank mechanism (c) four bar mechanism (d) pantograph
66. Ans. (a)

67. Consider the following mechanisms: **[IAS-2002]**
1. Oscillating cylinder engine mechanism
2. Toggle mechanism
3. Radial cylinder engine mechanism
4. Quick Return Mechanism

Which of the above are inversions of Slider-crank mechanism?
(a) 1, 2 and 4 (b) 2, 3 and 4 (c) 1, 2 and 3 (d) 1, 3 and 4
67. Ans. (d)

68. In a shaping operation, the average cutting speed is (Stroke length S, Number of strokes per minute N, Quick return ratio R) **[IAS-2000]**
(a) NSR (b) NSR/2 (c) NS (1+ R) (d) NS (1 +R)/2
68. Ans. (c) Time for forward stroke = T_f, Time for return stroke = T_r, R = $\frac{T_r}{T_f}$

$$\therefore Time\ for\ only\ one\ cutting\ stroke\,(T) = \frac{1}{N} \times \frac{T_f}{\left(T_f + T_r\right)}$$

$$\therefore Average\ cutting\ speed = \frac{S}{T} = SN\frac{\left(T_f + T_r\right)}{T_f} = SN(1+R)$$

69. Match List-I (Mechanism) with List-II (Associated function) and select the correct answer using the codes given below the List: **[IAS-1997]**

List-I	List-II
A. Geneva gearing	1. Feed motion in shaper
B. Rachet and Pawl	2. Feed motion in drilling machine
C. Whitworth	3. Indexing of turret
D. Rack and pinion	4. Quick return motion in shaper

Codes:

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

69. Ans. (d)

70. A standard gear has outside diameter of 96mm and module 3 mm. The number of teeth on the gear is
(a) 32 (b) 30 (c) 16 (d) 15 **[IAS-1997]**

70. Ans. (a) $T = \frac{96}{3} = 32$

71. Which of the following are the inversions of double slider crank mechanism?
1. Oldham coupling 2. Whitworth quick return mechanism
3. Beam engine mechanism 4. Elliptic trammel mechanism **[IAS-1995]**
Select the correct answer from the codes given below.-
Codes: (a) 1 and 2 (b) 1 and 4 (c) 1, 2 and 3 (d) 2, 3 and 4
71. Ans. (b) The inversions of double slider crank mechanism are
(i) First inversion-Elliptic Trammel,
(ii) Second inversion-Scotch Yoke
(iii) Third inversion-Oldham's coupling
Thus out of choices given, only 1 and 4 are correct.

72. The Whitworth quick return mechanism is formed in a slider-crank chain when the
(a) coupler link is fixed (b) longest link is a fixed link
(c) slider is a fixed link (d) smallest link is a fixed link
72. Ans. (d)

73. Match the following

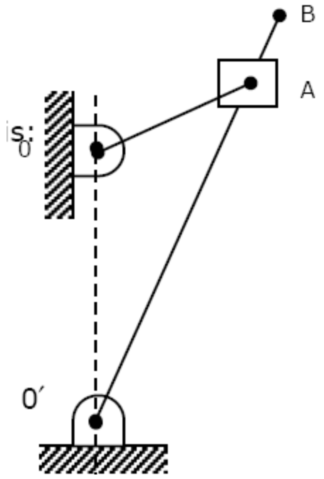
Type of Mechanism	Motion achieved
P. Scott - Russel mechanism	1. Intermittent motion
Q. Geneva mechanism	2. Quick return motion
R. Off-set slider-crank mechanism	3. Simple harmonic motion
S. Scotch Yoke mechanism	4. Straight line motion

[GATE-2004]

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

74. Geneva mechanism is used to transfer components from one station to the other in
(a) an inline transfer machine (b) a rotary transfer machine **[IAS-1996]**
(c) a linked line (d) an unlinked flow line
74. Ans. (b)

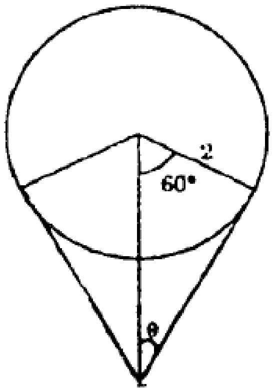
75. Figure shows a quick return mechanism. The crank OA rotates clockwise uniformly.
OA =2 cm.
OO=4 cm.
(a) 0.5 (b) 2.0
(c) $\sqrt{2}$ (d) 1



[GATE-1995]

75. Ans. (b)

$$\frac{\text{Forward stroke}}{\text{Return stroke}} = \frac{240}{120} = 2.$$



Inversion of Double slider crank chain

76. ABCD is a mechanism with link lengths AB = 200, BC = 300, CD = 400 and DA = 350. Which one of the following links should be fixed for the resulting mechanism to be a double crank mechanism? (All lengths are in mm) **[IES-2004]**
(a) A B (b) BC (c) CD (d) DA
76. Ans. (c)

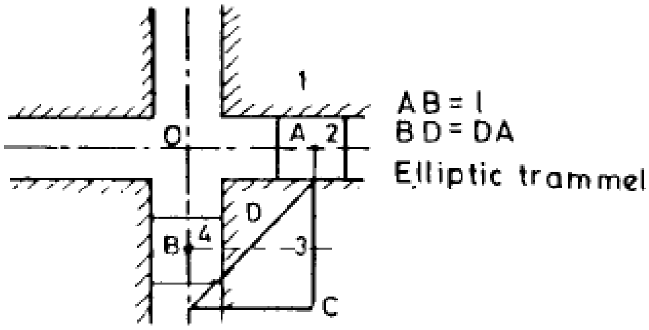
Elliptical trammels

77. Consider the following statements: **[IAS-2007]**
1. In a kinematic inversion, the relative motions between links of the mechanism change as different links are made the frame by turns.
2. An elliptical trammel is a mechanism with three prismatic pairs and one revolute pair.
Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2
77. Ans. (d) Through the process of inversion the relative motions between the various links is not changed in any manner but their absolute motions may be changed drastically.
Elliptical trammels have two sliding pairs and two turning pairs. It is an instruments used for drawing ellipse.

78. Oldham's coupling is an inversion of the kinematic chain used in **[IAS-2003]**
(a) Whitworth quick-return mechanism (b) Elliptical trammel
(c) Rotary engine (d) Universal joint
78. Ans. (b)

79. A point on a link connecting a double slider crank chain will trace a **[IES-2000]**
(a) straight line (b) circle (c) parabola (d) ellipse
79. Ans. (d)

80. An elliptic trammel is shown in the given figure. Associated with the motion of the mechanism are fixed and moving centrodes. It can be established analytically or graphically that the moving centrode is a circle with the radius and centre respectively of
(a) l and 0 (b) l/2 and B
(c) l/2 and C (d) l/2 and D



[IES-1994]

80. Ans. (a) For given elliptic trammel, the moving centrode is a circle with radius and centre as l and O.

81. A point on a connecting line (excluding end points) of a double 'slider crank mechanism traces a **[IAS-1995]**
(a) straight line path (b) hyperbolic path (c) parabolic path (d) elliptical path
81. Ans. (d)

Scotch yoke mechanism

82. Scotch yoke mechanism is used to generate **[IES-1992]**
(a) sine functions (b) square roots (c) logarithms (d) inversions
82. Ans. (a)

83. Which of the following are inversions of a double slider crank chain? **[IES-1993]**
1. Whitworth return motion 2. Scotch Yoke 3. Oldham's Coupling 4. Rotary engine.
Select correct answer using the codes given below:
Codes:
(a) 1 and 2 (b) 1, 3 and 4 (c) 2 and 3 (d) 2, 3 and 4.
83. Ans. (c) Scoth Yoke and Oldman's coupling are the inversions of double slider crank chain.

Oldham's coupling

84. When two shafts are neither parallel nor intersecting, power can be transmitted by using
(a) a pair of spur gears (b) a pair of helical gears
(c) an Oldham's coupling (d) a pair of spiral gears **[IES-1998]**
84. Ans. (c)

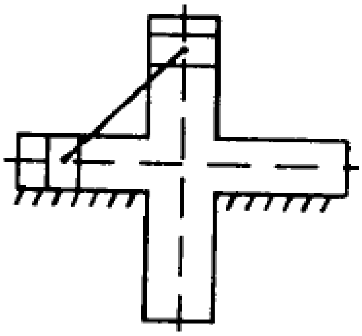
85. Match List I (Coupling) with List II (Purpose) and select the correct answer using the codes given below the lists: **[IES-2004]**

List I	List II
A. Muff coupling	1. To transmit power between two parallel shafts
B. Flange coupling	2. To transmit power between two intersecting shafts with flexibility
C. Oldham's coupling	3. For rigid connection between two aligned shafts for power transmission
D. Hook's joint	4. For flexible connection between two shafts with some misalignment for transmitting power

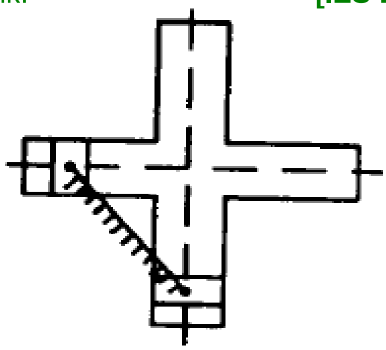
	A	B	C	D		A	B	C	D
(a)	1	4	3	2	(b)	3	4	2	1
(c)	3	2	1	4	(d)	1	2	3	4

85. Ans. (c)

86. The double slider-crank chain is shown below in the diagram in its three possible inversions. The link shown hatched is the fixed link: **[IES-2004]**



1.



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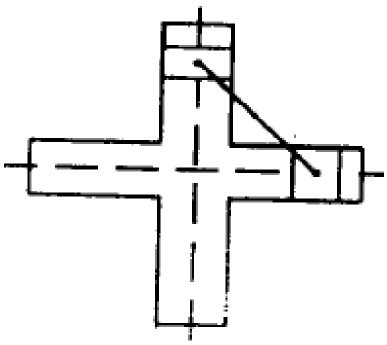


3.

Which one of the following statements is correct?

(a) Inversion (1) is for ellipse trammel and inversion (2) is for Oldham coupling
(b) Inversion (1) is for ellipse trammel and inversion (3) is for Oldham coupling
(c) Inversion (2) is for ellipse trammel and inversion (3) is for Oldham coupling
(d) Inversion (3) is for ellipse trammel and inversion (2) is for Oldham coupling

86. Ans. (a)

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

List I (Connecting shaft)	List II (Couplings)
A. in perfect alignment	1. Oldham coupling
B. With angular misalignment of 10°	2. Rigid coupling
C. Shafts with parallel misalignment	3. Universal joint
D. Where one of the shafts may undergo more deflection with respect to the other	4. Pin type flexible coupling·

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

87. Ans. (c)

88. Match List-I (Positioning of two shafts) with List-II (Possible connection) and select the correct answer using the codes given below the Lists: **[IES-1997]**

List-I	List-II
A. Parallel shafts with slight offset	1. Hooks joint
B. Parallel shafts at a reasonable distance	2. Worm and wheel
C. Perpendicular shafts	3. Oldham coupling
D. Intersecting shafts	4. Belt and pulley

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

88. Ans. (d)

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

List I (Name)	List II (Type)
A. Oldham coupling	1. Joins collinear shafts and is of rigid type.
B. Flange coupling	2. Joins non-collinear shafts and is adjustable.
C. Universal coupling	3. Joins collinear shafts and engages and disengages them during motion.
D. Friction coupling	4. Compensates peripheral shafts, longitudinal and angular shifts of shafts

[IES-1995]

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

89. Ans. (a)

90. Assertion (A): Oldham coupling is used to transmit power between two parallel shafts which are slightly offset. **[IES-1994]**
Reason (R): There is no sliding member to reduce power in Oldham coupling.
90. Ans. (c) A is true and R is false.

91. In Oldham's coupling' the condition for maximum speed ratio is **[IES-1992]**

(a) $\frac{w_1}{W}\cos\alpha$ (b) $\frac{w_1}{W}\sin\alpha$ (c) $\frac{w_1}{W}=\frac{1}{\cos\alpha}$ (d) $\frac{w_1}{W}=\frac{1}{\sin\alpha}$

91. Ans. (c)

$$\frac{\omega_1}{\omega}=\frac{\cos\alpha}{1-\cos^2\theta\sin^2\alpha}$$

For maximum speed ratio $\cos^2\theta = 1$

$$\therefore \quad \frac{\omega_1}{\omega}=\frac{1}{\cos\alpha}$$

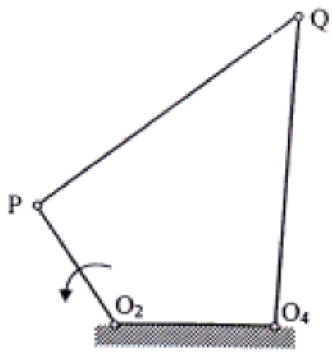
92. It two parallel shafts are to be connected and the distance between the axes of shafts is small and variable, then one would need to use **[IAS-1998]**
(a) a clutch (b) a universal joint (c) an Oldham's coupling (d) a knuckle joint
92. Ans. (c)

93. Oldham's coupling is the inversion of **[IAS-1996]**
(a) four bar mechanism (b) crank and lever mechanism
(c) single slider crank mechanism (d) double slider crank mechanism
93. Ans. (d)

Velocity of a point on a link

94. Which one of the following statements is correct? **[IES-2004]**
In a petrol engine mechanism the velocity of the piston is maximum when the crank is
(a) at the dead centers (b) at right angles to the line of stroke
(c) slightly less than 90° to line of stroke (d) slightly above 90° to line of stroke
94. Ans. (a)

95. The input link O_2P of a four bar linkage is rotated at 2 rad/s in counter clockwise direction as shown below. The angular velocity of the coupler PQ in rad/s, at an instant when $\angle O_4O_2P$ = 180°, is
PQ = $O_4Q = \sqrt{2}$ a and $O_2P = O_2O_4$ = a.
(a) 4 (b) $2\sqrt{2}$ (c) 1 (d) $1/\sqrt{2}$

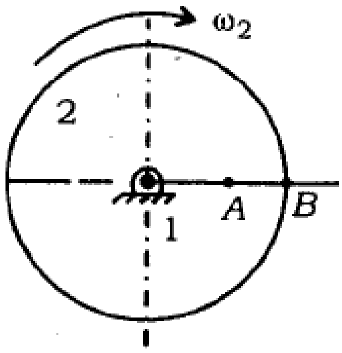


(Fig.)
[GATE-2007]

95. Ans. (c)

96. A wheel is rolling on a straight level track with a uniform velocity 'v'. The instantaneous velocity of a point on the wheel lying at the mid-point of a radius
(a) varies between 3 v/2 and - v/2 (b) varies between v/2 and - v/2 **[IES-2000]**
(c) varies between 3 v/2 and - v/2 (d) does not vary and is equal to v
96. Ans. (b)

97. Two points, A and B located along the radius of a wheel, as shown in the figure above, have velocities of 80 and 140 m/s, respectively. The distance between points A and B is 300 mm. The radius of wheel is
(a) 400 mm (b) 500 mm
(c) 600 mm (d) 700 mm

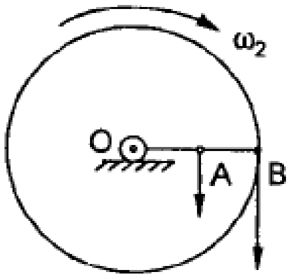


[IES-2003]

97. Ans. (d)

Angular velocity of both points A and B are same.

$V_A = 800$ m/s; $V_B = 800$ m/s; AB = 300 mm; OA + AB =OB

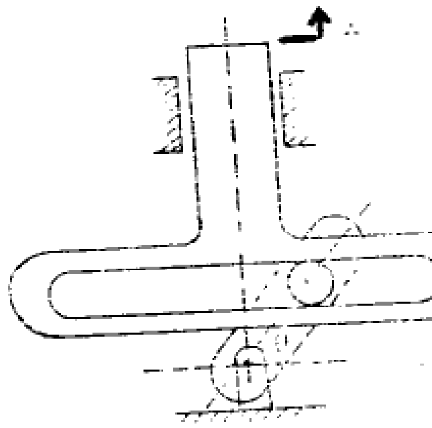


or $\frac{V_A}{OA} = \frac{V_B}{OB}$

or 80 x OB = 140 x OA = $140 \times$(OB-AB)

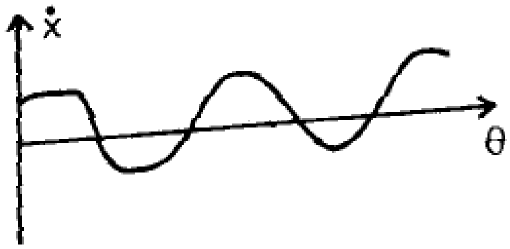
or OB = $\frac{140}{60}$ =700mm

98. The crank of the mechanism shown in the side the diagram rotates at a uniform angular velocity θ:

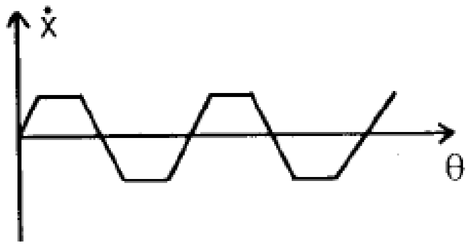


Which one of the following diagrams shows the velocity of slider $\dot{x}$ with respect to the crank angle?

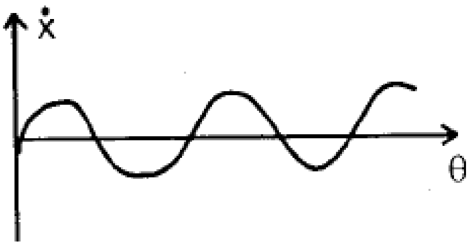
(a)



(b) **[IES-2004]**



(c)



(d)

98. Ans. (d)

99. In a slider-crank mechanism, the velocity of piston becomes maximum when

(a) Crank and connecting rod are in line with each other **[IES-2003]**

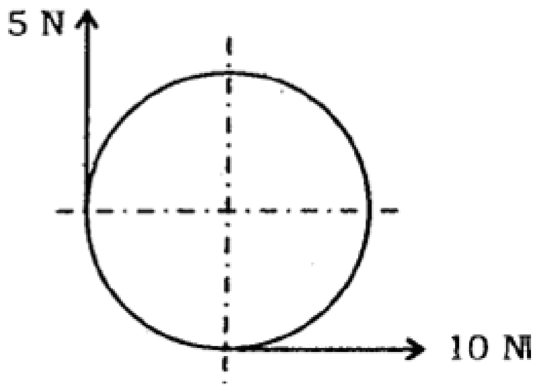
(b) Crank is perpendicular to the line of stroke of the piston

(c) Crank and connecting rod are mutually perpendicular

(d) Crank is 120^o with the line of stroke

99. Ans. (b) When the piston will be in the middle of the spoke length

100



The above figure shows a circular disc of 1kg mass and 0.2 m radius undergoing unconstrained planar motion under the action of two forces as shown. The magnitude of angular acceleration a of the disc is **[IES-2003]**

(a) 50 rad/s^2 (b) 100 rad/s^2 (c) 25 rad/s^2 (d) 20 rad/s^2

100. Ans. (a)

$$T = I\alpha \quad \text{Where, } I = \frac{1}{2}mr^2 = \frac{1}{2}\times 1\times(0.2)^2 = 0.2 \text{ kgm}^2$$

$$\therefore \alpha = \frac{T}{I} = \frac{(10\text{-}5)\times 0.2}{0.02} = \frac{5\times 0.2}{0.02} = 50 \text{ rad/sec}^2$$

101. Consider the following statements regarding motions in machines: **[IES-2001]**

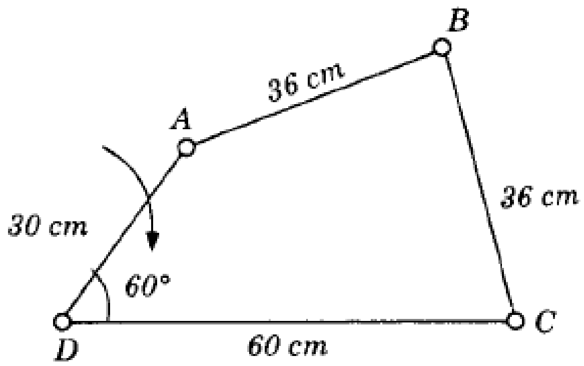
1. Tangential acceleration is a function of angular velocity and the radial acceleration is a function of angular acceleration.
2. The resultant acceleration of a point A with respect to a point B on a rotating link is perpendicular to AB.
3. The direction of the relative velocity of a point A with respect to a point B on a rotating link is perpendicular to AB.

Which of these statements is/are correct?

(a) 1 alone (b) 2 and 3 (c) 1 and 2 (d) 3 alone

101. Ans. (d)

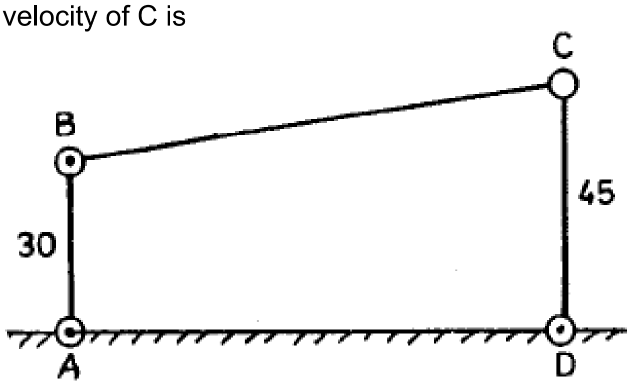
102. Consider a four-bar mechanism shown in the given figure.
The driving link DA is rotating uniformly at a speed of 100 r.p.m. clockwise.
The velocity of A will be
(a) 300 cm/s
(b) 314 cm/s
(c) 325 cm/s
(d) 400 cm/s



[IES-1999]

102. Ans. (b) Velocity of A = $\omega r = \frac{2\pi\times 100}{60}\times 30$ = 314 cm/s

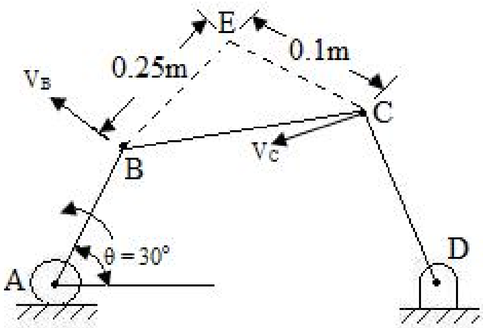
103. ABCD is a four-bar mechanism in which AD = 30 cm and CD = 45 cm. AD and CD are both perpendicular to fixed link AD, as shown in the figure. If velocity of B at this condition is V, then velocity of C is **[IES-1993]**



$(a) V$ $(b)\frac{3}{2}V$ $(c)\frac{9}{4}V$ $(d)\frac{2}{3}V$

103. Ans. (a) Velocity of C = $\frac{45}{30}V = \frac{3}{2}V$

104. A four-bar mechani8m ABCD is shown in the given figure. If the linear velocity 'V$_B$' of the point 'B' is 0.5 m/s, then the linear velocity 'V$_c$' of point 'c' will be
(a) 1.25 m/s
(b) 0.5 m/s
(c) 0.4 m/s
(d) 0.2 m/s



[IAS-1999]

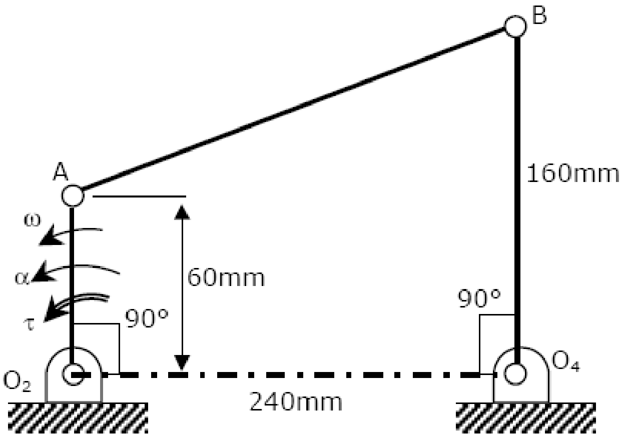
104. Ans. (d) Instantaneous centre method gives

$$\frac{V_B}{EB} = \frac{V_C}{EC} \text{ or } V_C = \frac{V_B}{EB} \times EC = \frac{0.5}{0.25} \times 0.1 = 0.2 \text{ m/s}$$

Common Data Questions

Common Data for Questions 105, 106, 107:

An instantaneous configuration of a four-bar mechanism, whose plane is horizontal, is shown in the figure below. At this instant, the angular velocity and angular acceleration of link O_2 A are (ω = 8 rad/s and α = 0, respectively, and the driving torque (τ) is zero. The link O_2 A is balanced so that its centre of mass falls at O_2



105. Which kind of 4-bar mechanism is O_2ABO_4? **[GATE-2005]**

(a) Double-crank mechanism (b) Crank-rocker mechanism
(c) Double-rocker mechanism (d) Parallelogram mechanism

105. Ans. (b)

106. At the instant considered, what is the magnitude of the angular velocity of Q4B?

(a) 1 rad/s (b) 3 rad/s (c) 8 rad/s (d) $\frac{64}{3}$ rad/s **[GATE-2005]**

106. Ans. (b)

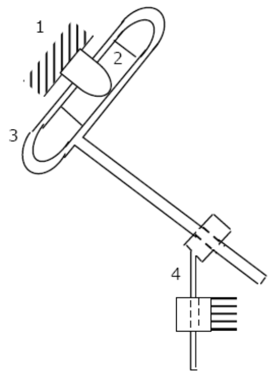
107. At the same instant, if the component of the force at joint A along AB is 30 N, then the magnitude of the joint raction at O_2 **[GATE-2005]**

(a) is zero (b) is 30 N (c) is 78 N (d) cannot be determined from the given data

107. Ans. (d)

108. For the planar mechanism shown in figure select the most appropriate choice for the motion of link 2 when link 4 is moved upwards.

(a) Link 2 rotates clockwise
(b) Link 2 rotates counter – clockwise
(c) Link 2 does not move
(d) Link 2 motion cannot be determined



[GATE-1999]

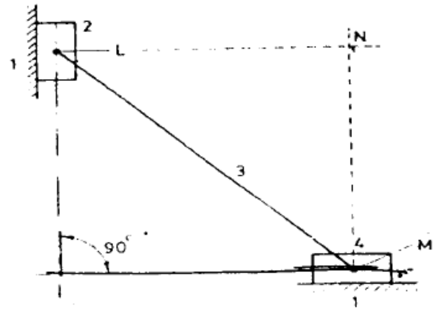
108. Ans. (b)

Location of Instantaneous centres

109. The figure below shows a planar mechanism with single degree of freedom. The instant centre 24 for the given configuration is located at a position

(a) L (b) M

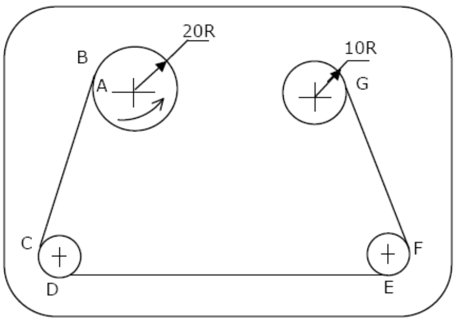
(c) N (d) ∞



[GATE-2004]

109. Ans. (c)

110. For the audio cassette mechanism shown in Figure given below where is the instantaneous centre of rotation (point) of the two spools? **[GATE-1999]**



(a) Point P lies to the left of both the spools but at infinity along the line joining A and H

(b) Point P lies in between the two spools on the line joining A and H, such that PH = 2 AP

(c) Point P lies to the right of both the spools on the line joining A and H, such that AH = HP

(d) Point P lies at the intersection of the line joining B and C and the line joining G and F

110. Ans. (d)

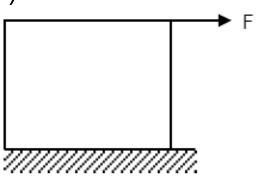
111. Instantaneous centre of a body rolling with sliding on a stationary curved surface lies

(a) at the point of contact **[GATE-1992]**

(b) on the common normal at the point of contact

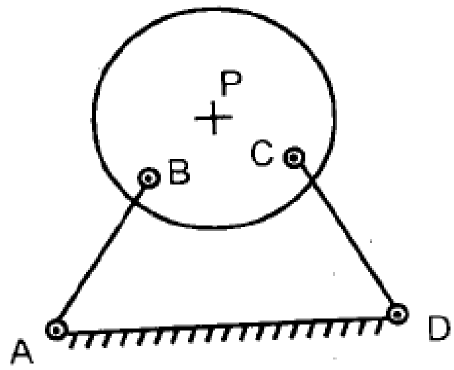
(c) on the common tangent at the point of contact

(d) at the centre of curvature of the stationary surface



111. Ans. (b, d)

112. ABCD is a bar mechanism, in which AD is the fixed link, and link BC, is in the form of a circular disc with centre P. In which one of the following cases P will be the instantaneous centre of the disc?
(a) If it lies on the perpendicular bisector of line BC
(b) If it lies on the intersection of the perpendicular bisectors of BC & AD
(c) If it lies on the intersection of the perpendicular bisectors of AB & CD

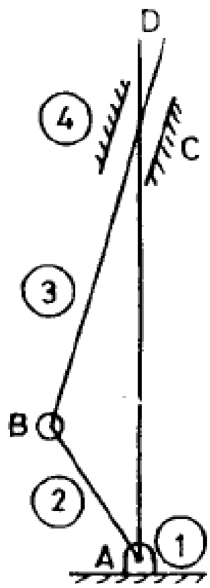


(d) If it lies on the intersection of the extensions of AB and CD **[IES-2004]**
112. Ans. (d)

113. The instantaneous centre of rotation of a rigid thin disc rolling without slip on a plane rigid surface is located at **[IES-2002]**
(a) the centre of the disc (b) an infinite distance perpendicular to the plane surface
(c) the point of contact
(d) the point on the circumference situated vertically opposite to the contact point
113. Ans. (c)

114. The relative acceleration of two points which are at variable distance apart on a moving link can be determined by using the
(a) three centers in line theorem (b) instantaneous centre of rotation method
(c) Corioli's component of acceleration method (d) Klein's construction
114. Ans. (b) The relative acceleration of two variable points on a moving link can be determined by using the instantaneous centre of rotation method.

115. In the mechanism ABCD shown in the given figure, the fixed link is denoted as (1), Crank AB as (2), rocker BD as (3), Swivel trunnion at C as (4). The instantaneous centre I_{41} is at
(a) the centre of swivel trunnion.
(b) the intersection of line AB and a perpendicular to BD to
(c) infinity along AC
(d) infinity perpendicular to BD.

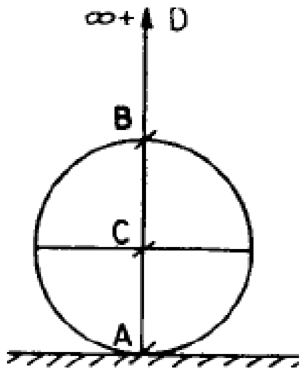


[IES-1996]

115. Ans. (d)

116. The instantaneous centre of motion of a rigid-thin-disc-wheel rolling on plane rigid surface shown in the figure is located at the point.

(a) A (b) B (c) C (d) D.



[IES-1996]

116. Ans. (a)

117. The instantaneous centre of rotation of a rigid thin disc rolling on a plane rigid surface is located at **[IES-1995]**

(a) the centre of the disc (b) an infinite distance on the plane surface.

(c) the point of contact

(d) the point on the circumference situated vertically opposite to the contact point.

117. Ans. (a) The instantaneous centre of rotation of a rigid thin disc rolling on a plane rigid surface is located at the point of contact.

Number of Instantaneous centres in Mechanism and Kennedy Theorem

118. What is the number of instantaneous centres of rotation for a 6-link mechanism?

(a) 4 (b) 6 (c) 12 (d) 15 **[IES-2006]**

118. Ans. (d) $N = \frac{n(n-1)}{2} = \frac{6\times(6-1)}{2} = 15$

119. The total number of instantaneous centers for a mechanism consisting of 'n' links is

(a) n/2 (b) n (c) $\frac{n-1}{2}$ (d) $\frac{n(n-1)}{2}$ **[IES-1998]**

119. Ans. (d)

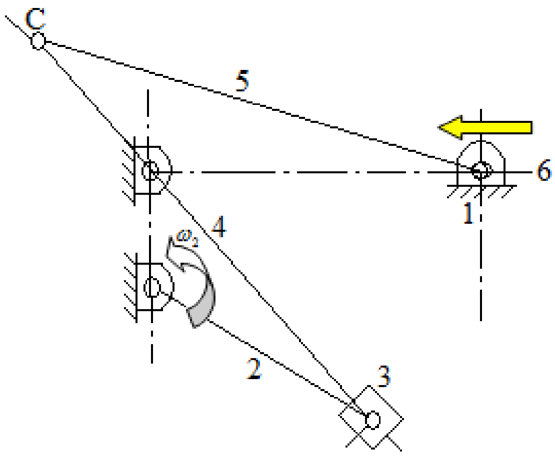
120. How many instantaneous centers of rotation are there for the mechanism shown in the figure given above?

(a) 6

(b) 10

(c) 15

(d) 21



[IAS-2007]

120. Ans. (c) Kennedy theorem says number of instantaneous centre (N) = $\frac{n(n-1)}{2}$

or $\frac{6\times(6-1)}{2}=15$

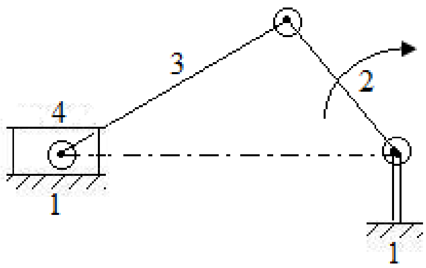
121. What is the number of instantaneous centers for an eight link mechanism?

(a) 15 (b) 28 (c) 30 (d) 8 **[IAS-2004]**

121. Ans. (b) $\frac{n(n-1)}{2}=\frac{8\times 7}{2}=28$

122. The given figure shows a slider crank mechanism in which link 1is fixed. The number of instantaneous centers would be

(a) 4 (b) 5 (c) 6 (d)12



[IAS-1998]

122. Ans. (c) $N=\frac{4(4-1)}{2}=6$

Force acting in a mechanism

123. A link AB is subjected to a force F ($\rightarrow$) at a point P perpendicular to the link at a distance a from the CG as shown in the figure.

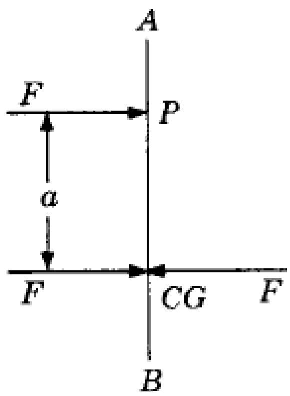
This will result in

(a) an inertia force F ($\rightarrow$) through the CG and no inertia torque

(b) all inertia force F.a (clockwise) and no inertia force

(c) both inertia force F ($\rightarrow$) through the CG and inertia torque Fa (clockwise)

(d) both inertia force F ($\rightarrow$) through the CG and inertia torque Fa (anti-clockwise)

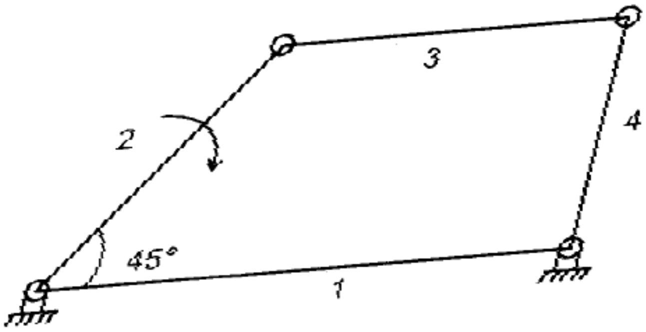


[IES-1999]

123. Ans. (c) Apply two equal and opposite forces Fat CG. Thus inertia force F ($\rightarrow$) acts at CG and inertia torque Fa (clockwise)

Acceleration of a link in a mechanism

124. In the diagram given below, the magnitude of absolute angular velocity of link 2 is 10 radians per second while that of link 3 is 6 radians per second. What is the angular velocity of link 3 relative to 2?



(a) 6 radians per second
(b) 16 radians per second
(c) 4 radians per second
(d) 14 radians per second **[IES-2004]**

124. Ans. (c) $\vec{\omega}_{32} = \vec{\omega}_3 - \vec{\omega}_2 = 6 - 10 = -4\,\text{rad/s}$

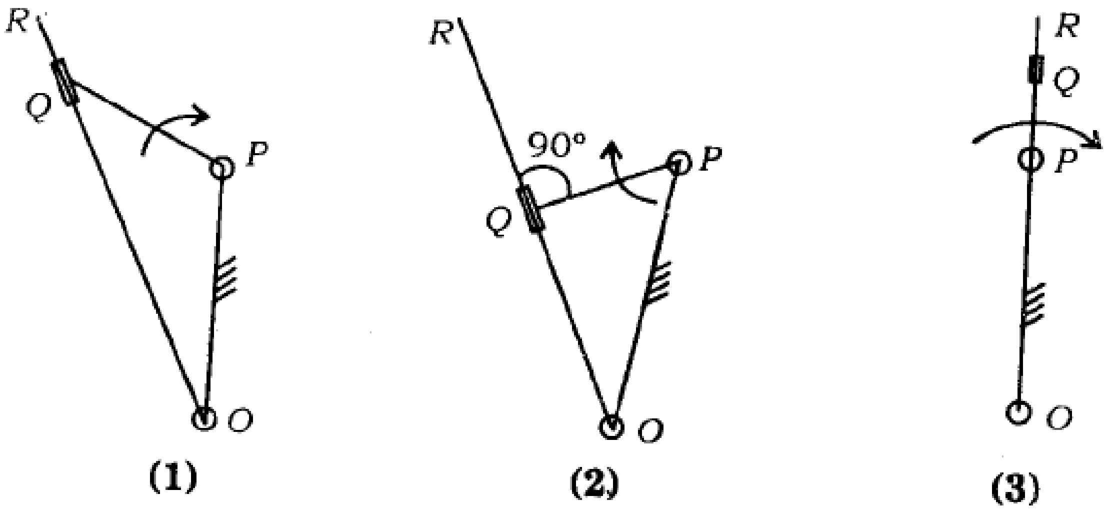
Coriolis component of Acceleration

125. When a slider moves with a velocity 'V' on a link rotating at an angular speed of ω, the Corioli's component of acceleration is given by **[IES-1998]**

(a) $\sqrt{2}V\omega$ (b) Vω (c) $\dfrac{V\omega}{2}$ (d) 2 Vω

125. Ans. (d)

126.



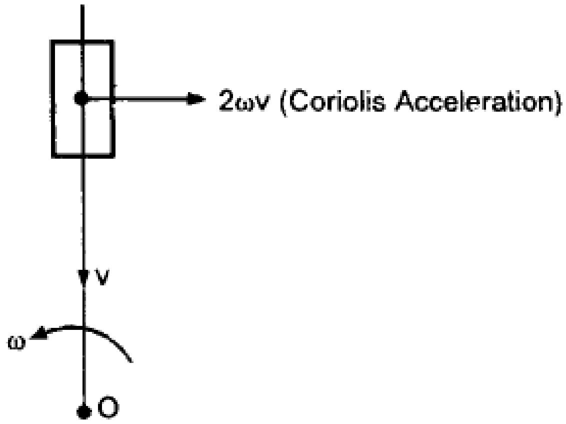
Three positions of the quick-return mechanism are shown above. In which of the cases does the Corioli's component of acceleration exist? **[IES-2003]**

Select the correct answer using the codes given below:

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

126. Ans. (c)

127. Assertion (A): The direction of Corioli's acceleration shown in the given figure is correct.
Reason (R): The direction of Corioli's acceleration is such that it will rotate at a velocity v about its origin in the direction opposite to ω.



[IES-2000]

127. Ans. (a)

128. The directions of Coriolis component of acceleration, 2ωV, of the slider A with respect to the coincident point B is shown in figures 1, 2, 3 and 4.
Directions shown by figures
(a) 2 and 4 are wrong
(b) 1 and 2 are wrong
(c) 1 and 3 are wrong
(d) 2 and 3 are wrong.

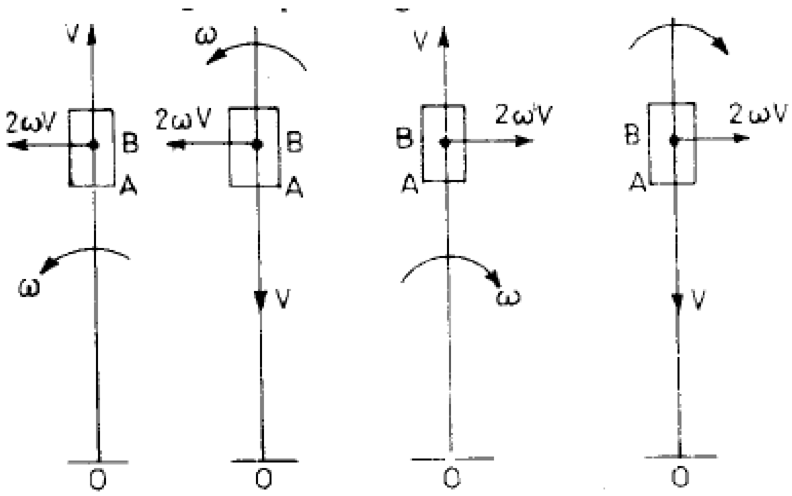


Fig.1 Fig.2 Fig.3 Fig.4

[IES-1995]

128. Ans. (a)

129. Consider the following statements: **[IES-1993]**
Coriolis component of acceleration depends on
1. velocity of slider 2. angular velocity of the link
3. acceleration of slider 4. angular acceleration of link
Of these statements
(a) 1 and 2 are correct (b) 1 and 3 are correct (c) 2 and 4 are correct (d) 1 and 4 are correct
129. Ans. (a)

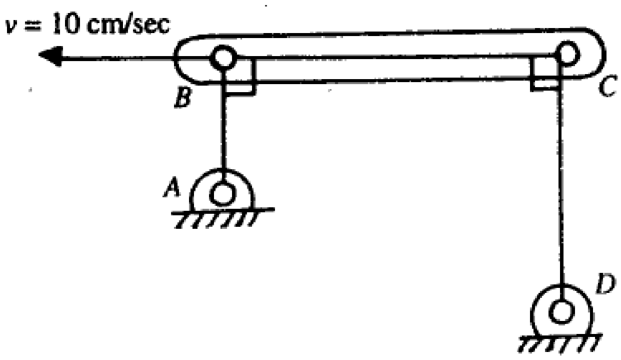
130. The sense of Coriolis component $2\omega V$ is the same as that of the relative velocity vector V rotated.
(a) 45° in the direction of rotation of the link containing the path **[IES-1992]**
(b) 45° in the direction opposite to the rotation of the link containing the path
(c) 90° in the direction of rotation of the link containing the path
(d) 180° in the direction opposite to the rotation of the link containing the path
130. Ans. (c)

131. Consider the following statements: **[IAS-2007]**
1. Corioli's component of acceleration is a component of translatory acceleration.
2. If the relative motion between two links of a mechanism is pure sliding, then the relative instantaneous centre for these- two links does not exist.
Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2
131. Ans. (a) Its unit is m/s^2. Therefore translatory acceleration (a^t = 2ωV). It does exist at infinity distance. Kennedy theorem says number of instantaneous centre (N)
$=\frac{n(n-1)}{2}$. Count it.

132. Consider the following statements:
Corioli's acceleration component appears in the acceleration analysis of the following planar mechanisms:
1. Whitworth quick-return mechanism. **[IAS-2003]**
2. Slider-crank mechanism.
3. Scotch-Yoke mechanism.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1and 2 (c) 2 and 3 (d) 1 only
132. Ans. (d)

133. The above figure shows a four bar mechanism. If the radial acceleration of the point C is 5 cm/s^2, the length of the link CD is
(a) 2 cm
(b) 10 cm
(c) 20 cm
(d) 100 cm



[IAS-2002]

133. Ans. (c)

Radial component of acceleration $(\alpha^r)=\frac{V^2}{CD} \quad or\ 5=\frac{10^2}{CD} \quad or\ CD=20\,\text{cm}$

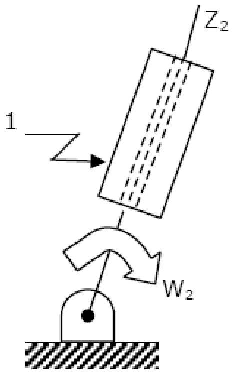
134. A slider sliding at 10 cm/s on a link which is rotating at 60 r.p.m. is subjected to Corioli's acceleration of magnitude **[IAS-2002]**
(a) $40\pi^2\ cm/s^2$ (b) $0.4\pi\ cm/s^2$ (c) $40\pi\ cm/s^2$ (d) $4\pi\ cm/s^2$

134. Ans. (c) Coriolis acceleration = $2\omega V=2\times\frac{2\pi N}{60}\times V=2\times\frac{2\pi\times 60}{60}\times 10=40\pi\ \text{cm/s}^2$

135. A body in motion will be subjected to Corioli's acceleration when that body is
(a) in plane rotation with variable velocity
(b) in plane translation with variable velocity **[IAS 1994]**
(c) in plane motion which is a resultant of plane translation and rotation
(d) restrained to rotate while sliding over another body
135. Ans. (d)

136. In the figure shown, the relative velocity of link 1 with respect to link 2 is 12 m/sec. Link 2 rotates at a constant speed of 120 rpm. The magnitude of Coriolis component of acceleration of link 1 is

(a) 302m/s^2 (b) 604 m/s^2
(c) 906m/s^2 (d) 1208 m/s^2



[GATE-2004]

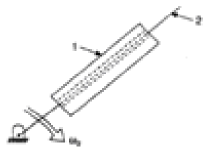
136. Ans. (a)

Velocity of link 1 with respect to link 2, $V_{1/2} = 12$ m/s

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 120}{60} = 4\pi$$

$\therefore$ Corioli's component of acceleration

$$= 2V_{1/2}\omega = 2 \times 12 \times 4\pi$$
$$= 301.59 \approx 302 \text{ m/s}^2.$$



137. The Coriolis component of acceleration is present in **[GATE-2002]**

(a) 4-bar mechanisms with 4 turning pairs (b) shaper mechanism
(c) slider-crank mechanism (d) Scotch Yoke mechanism

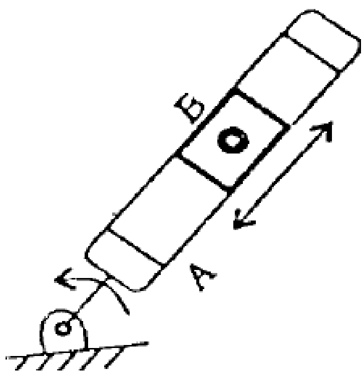
137. Ans. (b)

138. What is the direction of the Coriolis component of acceleration in a slotted lever-crank mechanism? **[IES 2007]**

(a) Along the sliding velocity vector
(b) Along the direction of the crank
(c) Along a line rotated 90^0 from the sliding velocity vector in a direction opposite to the angular velocity of the slotted lever
(d) Along a line rotated 90^0 from the sliding velocity vector in a direction same as that of the angular velocity of the slotted lever

138. Ans. (d)

139. Assertion (A): Link A experiences Corioli's acceleration relative to the fixed link.
Reason (R): Slotted link A is rotating with angular velocity ω and the Block B slides in the slot of A.



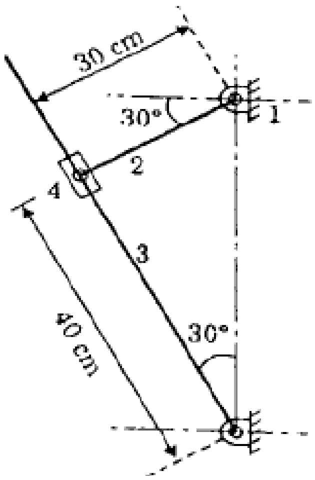
[IES-2006]

139. Ans. (d) Link B experiences Coriolis acceleration relative to the fixed link.

140. Consider the following statements: **[IES-2005]**

1. Corioli's acceleration component in a slotted bar mechanism is always perpendicular to the direction of the slotted bar.
2. In a 4-link mechanism, the instantaneous centre of rotation of the input link and output link always lies on a straight line along the coupler.
Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2
140. Ans. (a)

141. In the figure given above, the link 2 rotates at an angular velocity of 2 rad/s. What is the magnitude of Corioli's, acceleration experienced by the link 4?
(a) 0 (b) 0.8 m/s^2
(c) 0.24 m/s^2 (d) 0.32 m/s^2



[IES-2005]

141. Ans. (a)

142. Which one of the following sets of accelerations is involved in the motion of the piston inside the cylinder of a uniformly rotating cylinder mechanism? **[IES-2000]**
(a) Corioli's and radial acceleration (b) Radial and tangential acceleration
(c) Corioli's and gyroscopic acceleration (d) Gyroscopic and tangential acceleration
142. Ans. (b)

Pantograph

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

List I	List II
A. Governor	1. Pantograph device
B. Automobile differential	2. Feed-back control
C. Dynamic Absorber	3. Epicyclic train
D. Engine Indicator	4. Two-mass oscillator

[IES-1993]

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

143. Ans. (c)

144. Match List I (Mechanism) with List II **[IAS-2002]**
(Name) and select the correct answer using the codes given below the Lists:

List I (Mechanism)	List II (Name)
A. Mechanism used to reproduce a diagram to an	1. Hart's mechanism

enlarged or reduced scale

B. A straight line mechanism made up of turning pairs — 2. Pantograph

C. Approximate straight line motion consisting of one sliding pair — 3. Grasshopper mechanism

D. Exact straight line motion mechanism — 4. Peaucellier's mechanism

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

144. Ans. (b & d) Exact straight line motion mechanisms made up of turning pairs are Peaucellier's mechanism and Hart's mechanism. Hart's mechanism consists of six links and Peaucellier's mechanism consists of eight links.

Exact straight line motion mechanism

145. Which one of the following is an exact straight line mechanism using lower pairs? **[IAS-2003]**

(a) Watt's mechanism
(b) Grasshopper mechanism
(c) Robert's mechanism
(d) Paucellier's mechanism

145. Ans. (d)

Approximate straight line motion mechanism

Steering gear mechanism

146. Assertion (A): The Ackermann steering gear is commonly used in all automobiles.
Reason (R): It has the correct inner turning angle for all positions. **[IES-1996]**

146. Ans. (c)

147. Assertion (A): Davis steering gear is preferred to Ackermann type in automobile applications. **[IAS-2001]**
Reason (R): Davis steering gear consists of sliding pairs as well as turning pairs.

147. Ans. (d) Ackermann steerig gear is preferred to Devis as it consists of turning pairs.

148. Match List-I with List-II and select the correct answer using the codes given below the Lists.(Notations have their usual meanings) : **[IES-2001]**

List I	List II
A. Law of correct steering	1. $f = 3(n-1) - 2j$
B. Displacement relation of Hook's joint	2. $x = R\left[(1-\cos\theta) + \dfrac{\sin^2\theta}{2n}\right]$
C. Relation between kinematic pairs and links	3. $\cot\phi - \cot\theta = c/b$
D. Displacement equation of reciprocating engine piston	4. $\tan\theta = \tan\phi\cos\alpha$

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

148. Ans. (c)

149. A motor car has wheel base of 280 cm and the pivot distance of front stub axles is 140 cm. When the outer wheel has turned through 30°, the angle of turn of the inner front wheel for correct steering will be **[IES-2001]**

(a) 60° (b) $\cot^{-1} 2.23$ (c) $\cot^{-1} 1.23$ (d) 30°

149. Ans. (c)

150. Given θ = angle through which the axis of the outer forward wheel turns

ϕ = angle through which the axis of the inner forward wheel turns

a = distance between the pivots of front axle and **[IES-1997]**

b = wheel base.

For correct steering, centre lines of the axes of four wheels of an automobile should meet at a common point. This condition will be satisfied if

$(a)\cos\theta - \cos\phi = a/b$ $(b)\cot\theta - \cot\phi = a/b$ $(c)\cos\theta + \cos\phi = a/b$ $(d)\tan\theta - \tan\phi = b/a$

150. Ans. (b)

Hooke's Joint (Universal Joint)

151. Which one of the following statements is **not** correct? **[IES-2006]**

(a) Hooke's joint is used to connect two rotating co-planar, non-intersecting shafts

(b) Hooke's joint is used to connect two rotating co-planar, intersecting shafts

(c) Oldham's coupling is used to connect two parallel rotating shafts

(d) Hooke's joint is used in the steering mechanism for automobiles

151. Ans. (a)

152. A Hook's Joint is used to connect two: **[IES-2005]**

(a) Coplanar and non-parallel shafts (b) Non-coplanar and non-parallel shafts

(c) Coplanar and parallel shafts (d) Non-coplanar and parallel shafts

152. Ans. (b)

153. The speed of driving shaft of a Hooke's joint of angle 19.5° (given sin 19.5° =0.33. cos 19.5° = 0.94) is 500 r.p.m. The maximum speed of the driven shaft is nearly

(a) 168 r.p.m. (b) 444 r.p.m. (c) 471 r.p.m. (d) 531 r.p.m. **[IES-2001]**

153. Ans. (d)

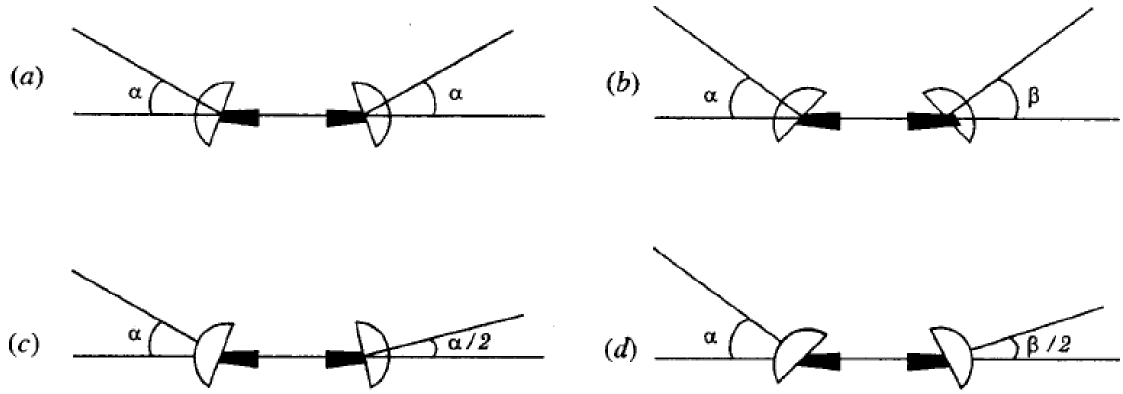
154. Match List I (Applications) with List II (Joints) and select the correct answer using the codes given below the Lists: **[IES-2000]**

List I	List II
A. Roof girder	1. Hook's joint
B. Cylinder head of an IC engine	2. Screwed joint
C. Piston rod and cross head	3. Cotter joint
D. Solid shaft and a plate	4. Welded joint
	5. Riveted joint

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

154. Ans. (c)

155. Which one of the following figures representing Hooke's jointed inclined shaft system will result in a velocity ratio of unity? **[IES-1998]**



155. Ans. (a)

156. The coupling used to connect two shafts with large angular misalignment is
(a) a Flange coupling (b) an Oldham's coupling **[GATE-2002]**
(c) a Flexible bush coupling (d) a Hooke's joint
156. Ans. (d)

Answers with Explanation (Objective)

2.

Cam

Objective Questions (IES, IAS, GATE)

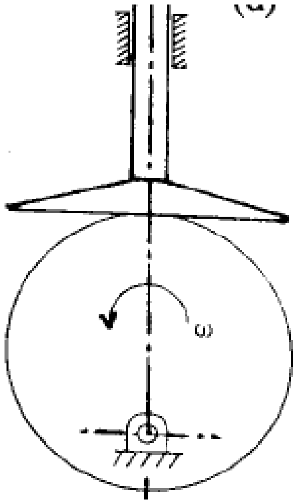
Classification of follower

1. In a circular arc cam with roller follower, the acceleration in any position of the lift would depend only upon **[IES-1994]**
(a) total lift, total angle of lift, minimum radius of earn and earn speed.
(b) radius of circular are, earn speed, location of centre of circular arc and roller diameter.
(c) weight of earn follower linkage, spring stiffness and earn speed.
(d) total lift, centre of gravity of the earn and earn speed.
1. Ans. (b)

2. In a single spindle automatic lathe two tools are mounted on the turret, one form tool on the front slide and the other, a parting tool on the rear slide. The parting tool operation is much longer than form tool operation and they operate simultaneously (overlap). The number of cams required for this job is **[IES-1994]**
(a) one (b) two (c) three (d) four
2. Ans. (a) One cam is required.

3. Consider the following statements: **[IES-2006]**
Cam followers are generally classified according to
1. the nature of its motion 2. the nature of its surface in contact with the cam
3. the speed of the cam
Which of the statements given above are correct?
(a) 1, 2 and 3 (b) Only 1 and 2 (c) Only 2 and 3 (d) Only 1 and 3
3. Ans. (b)

4. The above figure shows a cam with a circular profile, rotating with a uniform angular velocity of ω rad/s.
What is the nature of displacement of the follower?
(a) Uniform (b) Parabolic
(c) Simple harmonic (d) Cycloidal



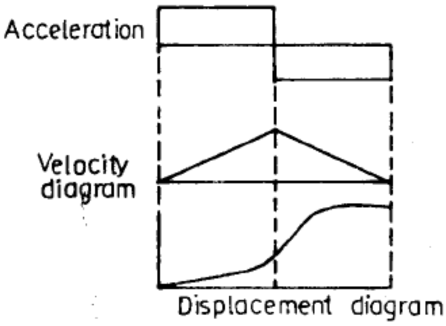
[IES-2005]

4. Ans. (c)

5. 1ft a plate cam mechanism with reciprocating roller follower, in which one of the following cases the follower has constant acceleration? **[IES-2004]**
(a) Cycloidal motion (b) Simple harmonic motion
(c) Parabolic motion (d) 3 - 4 - 5 polynomial motion
5. Ans. ()

6. The choice of displacement diagram during rise or return of a follower of a cam-follower mechanism is based on dynamic considerations. For high speed cam follower mechanism, the most suitable displacement for the follower is **[IES-2002]**
(a) Cycloidal motion (b) simple harmonic motion
(c) parabolic or uniform acceleration motion
(d) uniform motion or constant velocity motion
6. Ans. (a)

7. In a plate cam mechanism with reciprocating roller follower, the follower has a constant acceleration in the case of **[GATE-1993]**
(a) cycloidal motion (b) simple harmonic motion
(c) parabolic motion (d) 3-4-5 polynomial motion
7. Ans. (c)
For uniform acceleration and retardation, the velocity of the follower must change at a constant rate and hence the velocity diagram of the follower consists of sloping straight lines. The velocity diagram represents everywhere the slope of the displacement diagram, the later must be a curve whose slope changes at a constant rate. Hence the displacement diagram consists of double parabola.



8. Which one of the following sets of elements are quick acting clamping elements for fixtures? **[IES-2001]**
(a) Wedge and Cam (b) Cam and Toggle
(c) Toggle and Wedge (d) Wedge, Cam and Toggle
8. Ans. (a)

9. Assertion (A): Cam of a specified contour is preferred to a cam with a specified follower motion.
Reason (R): Cam of a specified contour has superior performance. **[IES-2000]**
9. Ans. (d)

10. In a cam drive, it is essential to off-set the axis of a follower to **[IES-1998]**
(a) decrease the side thrust between the follower and guide
(b) decrease the wear between follower and cam surface
(c) take care of space limitation (d) reduce the cost
10. Ans. (b)

11. Which one of the following is an Open Pair? **[IES-1996]**
(a) Ball and socket joint (b) Journal bearing
(c) Lead screw and nut (d) Cam and follower.
11. Ans. (d) Cam and follower is open pair.

Pressure angle

Pitch point

12 Consider the following statements:
1. For a radial-translating roller follower, parabolic motion of the follower is very suitable for high speed cams.
2. Pitch point on pitch circle of a cam corresponds to the point of maximum pressure angle. **[IAS-2007]**

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2
12.Ans. (d) For high speed use cycloidal motion.
Pitch point on pitch circle of a cam corresponds to the point of maximum pressure angle.

13. The profile of a cam in a particular zone is given by x = $\sqrt{3}\cos\theta$ and y =sinθ. The normal to the cam profile at $\theta = \pi/4$ is at an angle (with respect to x axis)

$(a)\frac{\pi}{4}$ $(b)\frac{\pi}{2}$ $(c)\frac{\pi}{3}$ $(d)0$ **[GATE-1998]**

13. Ans. (c)

Explanation. $\sin^2\theta + \cos^2\theta = 1$

Equation of curve is

$$y^2 + \frac{x^2}{3} = 1$$

or $$x^2 + 3y^2 = 3$$

To find Slope at required point $\left(\frac{\sqrt{3}}{2}, \frac{1}{\sqrt{2}}\right)$, differentiating we get

$$2x + 6y\frac{dy}{dx} = 0$$

or $$\frac{dy}{dx} = -\frac{x}{3y} = -\frac{1}{\sqrt{3}}$$

–ve sign indicates that slope is – ve.

$\therefore$ $$\frac{dy}{dx} = 2x + 6y\tan\theta = \frac{1}{\sqrt{3}}$$

or $$\theta = 30°$$

$\therefore$ Angle made by normal $= 60° = \pi/3$ **radians.**

Displacement, Velocity, Acceleration and Jerk (Follower moves in uniform velocity)

14. In a cam drive with uniform velocity follower, the slope of the displacement must be as shown in Fig. I. But in actual practice it is as shown in Fig. II (i.e. rounded at the corners). This is because of

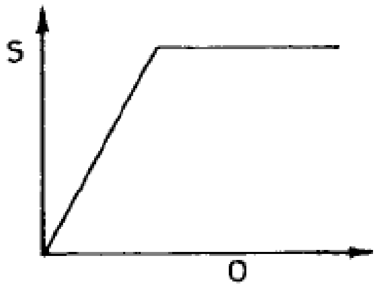


Fig. I

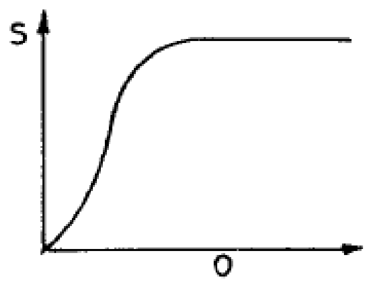


Fig. II

(a) the difficulty in manufacturing cam profile **[IES-1996]**
(b) loose contact of follower with cam surface
(c) the acceleration in the beginning and retardation at the end of stroke would require to be infinitely high
(d) uniform velocity motion is a partial parabolic motion.
14. Ans. (c)

15. In a cam-follower mechanism, the follower needs to rise through 20 mm during 60° of cam rotation, the first 30° with a constant acceleration and then with a deceleration of the same magnitude. The initial and final speeds of the follower are zero. The cam rotates at a uniform speed of 300 rpm. The maximum speed of the follower is **[GATE-2005]**
(a) 0.60m/s (b) 1.20m/s (c) 1.68m/s (d) 2.40m/s
15. Ans. (d)

$$\omega = \frac{2\pi N}{60}$$

Time taken to move 30° = $\dfrac{\frac{\pi}{180} \times 30}{\omega} = \dfrac{\pi}{6} \times \dfrac{60}{2\pi N} = \dfrac{5}{N}$ sec

During this period follower move 20 mm = .02 m and u = 0

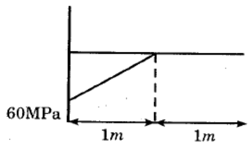
From $\qquad s = ut + \frac{1}{2}at^2$

$$0.02 = 0 + \frac{1}{2} a \times \left(\frac{5}{N}\right)^2$$

$\Rightarrow \qquad a = 144 \text{ m/sec}^2$

$\therefore \qquad v = u + at$

$$v = 0 + \left(144 \times \frac{5}{300}\right) = 2.4 \text{ m/sec}$$



16. For a given lift of the follower in a given angular motion of the cam, the acceleration/retardation of the follower will be the least when the profile of the cam during the rise portion is
(a) such that the follower motion is simple harmonic **[IES-1999]**
(b) such that the follower motion has a constant velocity from start to end
(c) a straight line, it being a tangent cam
(d) such that the follower velocity increases linearly for half the rise portion and then decreases linearly for the remaining half of the rise portion.
16. Ans. (b)

Displacement, Velocity, Acceleration and Jerk (Follower moves in SHM)

17. What is the maximum acceleration of a cam follower undergoing simple harmonic motion? **[IES-2006]**

(a) $\dfrac{h}{2}\left(\dfrac{\pi\omega}{\phi}\right)^2$ (b) $4h\left(\dfrac{\omega}{\phi}\right)^2$ (c) $4h\left(\dfrac{\omega^2}{\phi}\right)$ (d) $\dfrac{2h\pi\omega^2}{\phi^2}$

Where, h = Stroke of the follower; (ω) = Angular velocity of the cam; ϕ = Cam rotation angle for the maximum follower displacement.
17. Ans. (a)

18. In a cam design, the rise motion is given by a simple harmonic motion (SHM) s = $\dfrac{h}{2}\left(1-\cos\dfrac{\pi\theta}{\beta}\right)$ where h is total rise, θ is camshaft angle, β is the total angle of the rise interval. The jerk is given by **[GATE-2008]**

(A) $\dfrac{h}{2}\left(1-\cos\dfrac{\pi\theta}{\beta}\right)$ (B) $\dfrac{\pi}{\beta}\dfrac{h}{2}\sin\left(\dfrac{\pi\theta}{\beta}\right)$ (C) $\dfrac{\pi^2}{\beta^2}\dfrac{h}{2}\cos\left(\dfrac{\pi\theta}{\beta}\right)$ (D) $-\dfrac{\pi^3}{\beta^3}\dfrac{h}{2}\sin\left(\dfrac{\pi\theta}{\beta}\right)$

18. Ans. (D)

S= $\dfrac{h}{2}\left(1-\cos\dfrac{\pi\theta}{\beta}\right)$

or $\dot{S} = \frac{h}{2}.Sin\left(\frac{\pi\theta}{\beta}\right).\left(\frac{\pi}{\beta}\right)$

or $\ddot{S} = \frac{h}{2}.\cos\left(\frac{\pi\theta}{\beta}\right).\frac{\pi^2}{\beta^2}$

or Jerk= $\left(\dddot{S}\right) = \frac{h}{2}.-\sin\left(\frac{\pi\theta}{\beta}\right).\frac{\pi^3}{\beta^3} = -\frac{\pi^3}{\beta^3}.\frac{h}{2}\sin\left(\frac{\pi\theta}{\beta}\right)$

Displacement, Velocity, Acceleration and Jerk (Follower moves in uniform acceleration or retardation)

Displacement, Velocity, Acceleration and jerk (Follower moves in cycloidal motion)

19. Consider the following follower motions in respect of a given lift, speed of rotation and angle of stroke of a cam:

1. Cycloidal motion.
2. Simple harmonic motion.
3. Uniform velocity motion.

Which one of the following is the correct sequence of the above in the descending order of maximum velocity?

(a) 3-2-1 (b) 1-2-3

(c) 2-3-1 (d) 3-1-2 **[IES 2007]**

19. Ans. (d) $1 \rightarrow 2h\left(\frac{\omega}{\phi}\right)$, $2 \rightarrow \frac{h}{2}\pi\left(\frac{\omega}{\phi}\right)$, $3 \rightarrow 2h\left(\frac{\omega}{\phi}\right)$

20. In an experiment to find the velocity and acceleration of a particular cam rotating at 10 rad/s, the values of displacements and velocities are recorded. The slope of displacement curve at an angle of 'θ' is 1.5 m/s and the slope of velocity curve at the same angle is -0.5 m/s^2. The velocity and acceleration of the cam at the instant are respectively **[GATE-2000]**

(a) 15 m/s and – 5 m/s^2 (b) 15 m/s and 5 m/s^2

(c) 1.2 m/s and - 0.5 m/s^2 (d) 1.2 m/s and 0.5 m/s^2

20. Ans. (*)

Cam profile

Answers with Explanation (Objective)

3.

Flywheel

Objective Questions (IES, IAS, GATE)

1. Consider the following statements: **[IES-2003]**
   1. Flywheel and governor of an engine are the examples of an open loop control system
   2. Governor is the example of closed loop control system
   3. The thermostat of a refrigerator and relief valve of a boiler are the examples of closed loop control system

Which of these statements is/are correct?
(a) 1 only (b) 2 and 3 (c) 3 only (d) 2 only
1. Ans. (c)

2. Which of the following statement is correct? **[GATE-2001]**
(a) Flywheel reduces speed fluctuations during a cycle for a constant load, but flywheel does not control the mean speed of the engine if the load changes
(b) Flywheel does not educe speed fluctuations during a cycle for a constant load, but flywheel does control the mean speed of the engine if the load changes
(c) Governor control a speed fluctuations during a cycle for a constant load, but governor does not control the mean speed of the engine if the load change
(d) Governor controls speed fluctuations during a cycle for a constant load, and governor also controls the mean speed of the engine if the load changes
2. Ans. (a)

3. Which of the following pairs of devices and their functions are correctly matched?
1. Flywheel ……………. For storing kinetic energy **[IES-2001]**
2. Governors ……………..For controlling speeds
3. Lead screw in lathe ……………..For providing feed to the slides
4. Fixtures ……………..For locating workpiece and guiding tools
Select the correct answer using the codes given below:
Codes: (a) 1, 3 and 4 (b) 2 and 3 (c) 1 and 2 (d) 2 and 4
3. Ans. (c)

4. Assertion (A): In designing the size of the flywheel, the weight of the arms and the boss are neglected.
Reason (R): The flywheel absorbs energy during those periods when the turning moment is greater than the resisting moment. **[IES-2000]**
4. Ans. (b)

5. A rotating shaft carries a flywheel which overhangs on the bearing as a cantilever. If this flywheel weight is reduced to half of its original weight, the whirling speed will
(a) be double (b) increase by $\sqrt{2}$ times **[IES-1999]**

(c) decrease by $\sqrt{2}$ times (d) be half

5. Ans. (b) Whirling speed $\infty\sqrt{\frac{1}{I}}$

6. The speed of an engine varies from 210 rad/s to 190 rad/s. During a cycle the change in kinetic energy is found to be 400 Nm. The inertia of the flywheel in kgm^2 is
(a) 0.10 (b) 0.20 (c) 0.30 (d) 0.40 **[GATE-2007]**
6. Ans. (a)

7. Which one of the following engines will have heavier flywheel than the remaining ones?
(a) 40 H.P. four-stroke petrol engine running at 1500 rpm.
(b) 40 H.P. two-stroke petrol engine running at 1500 rpm. **[IES-1996]**
(c) 40 H.P. two-stroke diesel engine running at 750 rpm.
(d) 40 H.P. four-stroke diesel engine running at 750 rpm.
7. Ans. (d) The four stroke engine running at lower speed needs heavier fly wheel.

Coefficient of Fluctuation of speed

8. If C_f is the coefficient of speed fluctuation of a flywheel then the ratio of $\omega_{max}/\omega_{min}$ will be

(a) $\frac{1-2C_f}{1+2C_f}$ (b) $\frac{2-C_f}{1+2C_f}$

(c) $\frac{1+2C_f}{1-2C_f}$ (d) $\frac{2+C_f}{2-C_f}$ **[GATE-2006]**

8. Ans. (d)

$$C_f = \frac{\omega_{max}-\omega_{min}}{\frac{\omega_{max}+\omega_{min}}{2}}$$

$$\Rightarrow \quad \frac{\omega_{max}}{\omega_{min}} = \frac{2+C_f}{2-C_f}$$

9. The maximum fluctuation of energy E_f, during a cycle for a flywheel is

(a) $I\left(\omega_{max}^2-\omega_{min}^2\right)$ (b) $\frac{1}{2}.I.\omega_{av}.\left(\omega_{max}-\omega_{min}\right)$ **[IES-2003]**

(c) $\frac{1}{2}.I.K_{es}.\omega_{av}^2$ (d) $I.K_{es}.\omega_{av}^2$

(Where, I = Mass moment of inertia of the flywheel
ω_{av} = Average rotational speed
K_{es} = Coefficient of fluctuation of speed)
9. Ans. (d)

$$\text{Maximum fluctuation of energy} = \frac{1}{2} I \left(\omega_{\max}^2 - \omega_{\min}^2 \right)$$
$$= \frac{1}{2} I \left(\omega_{\max} + \omega_{\min} \right) \left(\omega_{\max} - \omega_{\min} \right)$$
$$= I \omega_{avg} \left(\omega_{\max} - \omega_{\min} \right) = I \left(\omega_{avg} \right)^2 K_{es}$$

10. Consider the following parameters: **[IES-1999]**
1. Limit of peripheral speed 2. Limit of centrifugal stress
3. Coefficient of fluctuation of speed 4. Weight of the rim
Which of these parameters are used in the calculation of the diameter of fly wheel rim?
(a) 1, 3 and 4 (b) 2, 3 and 4 (c) 1, 2 and 3 (d) 1, 2 and 4
10. Ans. (a) Limit of centrifugal stress is not considered.

11. Consider the following statements: **[IAS-2001]**
If the fluctuation of speed during a cycle is ± 5% of mean speed of a flywheel, the coefficient of fluctuation of speed will
1. increase with increase of mean speed of prime mover
2. decrease with increase of mean speed of prime mover
3. remain same with increase of mean speed of prime mover
Which of these statement(s) is/are correct?
(a) 1 and 3 (b) 1 and 2 (c) 3 alone (d) 2 alone
11. Ans. (c)

12. For minimizing speed fluctuations of an engine as a prime mover, it must have
(a) Only a flywheel fitted to the crankshaft **[IES-2003]**
(b) A governor provided in the system
(c) Both a flywheel and a governor provided in the system
(d) Neither a flywheel nor a governor
12. Ans. (c)

13. In the case of a flywheel, the maximum fluctuation of energy is the **[IES-1998]**
(a) sum of maximum and minimum energies
(b) difference between the maximum and minimum energies
(c) ratio of the maximum and minimum energy (d) ratio of the minimum and maximum energy
13. Ans. (b)

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

List-I	List-II
A. Flywheel	1. Dunkerley Method
B. Governor	2. Turning Moment
C. Critical speed	3. D' Alembert's Principle
D. Inertia Force	4. Speed control on par with load

[IES-1997]

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

14. Ans. (d)

Energy stored in a flywheel

15. What is the value of the radius of gyration of disc type flywheel as compared to rim type flywheel for the same diameter? **[IES-2004]**

(a) $\sqrt{2}$ times (b) $1/\sqrt{2}$ times (c) 2 times (d) 1/2 times

15. Ans. (b) moment of gyration of a disc $= \frac{d}{\sqrt{8}}$

moment of gyration of a rim $= \frac{d}{2}$

16. If the rotating mass of a rim type fly wheel is distributed on another rim type flywheel whose mean radius is half mean radius of the former, then energy stored in the latter at the same speed will be **[IES-1993]**

(a) four times the first one (b) same as the first one
(c) one-fourth of the first one (d) one and a half times the first one

16. Ans. (c) Energy stored $\propto I\omega^2$, also $I \propto k^2$ (k = radius of gyration which is function of radius of wheel)

:. If radius is reduced to half, then energy stored will be reduced to one-fourth.

17. A flywheel is fitted to the crankshaft of an engine having 'E' amount of indicated work per revolution and permissible limits of co-efficient of fluctuation of energy and speed as K_e and K_s respectively. **[IES-1993]**

The kinetic energy of the flywheel is then given by

$(a)\frac{2K_eE}{K_s}$ $(b)\frac{K_eE}{2K_s}$ $(c)\frac{K_eE}{K_s}$ $(d)\frac{K_sE}{2K_e}$

17. Ans. (b)

18. With usual notations for different parameters involved, the maximum fluctuation of energy for a flywheel is given by **[IAS-2002]**

(a) $2EC_s$ (b) $\frac{EC_s}{2}$ (c) $2EC_s^2$ (d) $2E^2C_s$

18. Ans. (a)

19. The amount of energy absorbed by a flywheel is determined from the **[IAS-2000]**

(a) torque-crank angle diagram (b) acceleration-crank angle diagram
(c) speed-space diagram (d) speed-energy diagram

19. Ans. (a)

20. In the case of a flywheel of mass moment of inertia 'I' rotating at an angular velocity 'ω', the expression $\frac{1}{2}I\omega^2$ represents the **[IAS-1999]**

(a) centrifugal force (b) angular momentum (c) torque (d) kinetic energy

20. Ans. (d)

21. The moment of inertia of a flywheel is 2000 kg m^2.Starting from rest, it is moving with a uniform acceleration of 0.5 rad/s^2.After 10 seconds from the start, its kinetic energy will be

(a) 250 Nm (b) 500 Nm (c) 5,000 Nm (d) 25,000 Nm **[IAS-1997]**

21. Ans. (c) $\omega = \omega_o + \alpha t = 0 + 0.5 \times 10 = 5 \text{rad/s}$

$$K.E = \frac{1}{2} I\omega^2 = \frac{1}{2} \times 2000 \times 5 = 5000 \text{Nm}$$

22. Consider the following statements: **[IAS-1997]**

The flywheel in an IC engine

1. acts as a reservoir of energy 2. minimizes cyclic fluctuations in the engine speed.
3. takes care of load fluctuations in the engine and controls speed variation.

Of these statements:

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

22. Ans. (a) Flywheel has no effect on load fluctuations

23. The radius of gyration of a solid disc type flywheel of diameter 'D' is **[IAS-1996]**

(a) D (b) D/2 (c) $D/2\sqrt{2}$ (d) $\left[\frac{\sqrt{3}}{2}\right] D$

23. Ans. (c) Moment of inertia = $\frac{mr^2}{2} = mk^2$ or $k = \frac{r}{\sqrt{2}} = \frac{D}{2\sqrt{2}}$

24. A fly wheel of moment of inertia 9.8 kgm^2 fluctuates by 30 rpm for a fluctuation in energy of 1936 Joules. Tire mean speed of the flywheel is (in rpm) **[GATE-1998]**

(a) 600 (b) 900 (c) 968 (d) 2940

24. Ans. (a)

Explanation.

$$\Delta E = mR^2\omega^2\Delta S = mR^2\omega(\omega_1 - \omega_2)$$

$$\therefore \quad 1936 = 9.8 \times \omega\left(\frac{2\pi}{60} \times 30\right)$$

or Mean speed of flywheel, ω = **600 rpm**

25. For the same indicated work per cycle, mean speed and permissible fluctuation of speed, what is the size of flywheel required for a multi-cylinder engine in comparison to a single cylinder engine? **[IES-2006]**

(a) Bigger (b) Smaller (c) Same (d) depends on thermal efficiency of the engine

25. Ans. (b)

Flywheel rim (Dimension)

26. Consider the following methods: **[IES-2004]**

1. Trifiler suspension 2. Torsional oscillation 3. Fluctuation of energy of engine
4. Weight measurement & measurement of radius of flywheel

Which of the above methods are used to determine the polar mass moment of inertia of an engine flywheel with arms?

(a) 1 and 4 (b) 2 and 3 (c) 1, 2 and 3 (d) 1, 2 and 4

26. Ans. (c)

27. For a certain engine having an average speed of 1200 rpm, a flywheel approximated as a solid disc, is required for keeping the fluctuation of speed within 2% about the average speed. The fluctuation of kinetic energy per cycle is found to be 2 kJ. What is the least possible mass of the flywheel if its diameter is not to exceed 1m? **[GATE-2003]**

(a) 40 kg (b) 51 kg (c) 62 kg (d) 73 kg

27. Ans. (b)

Average speed, N = 1200 rpm

Co-efficient of fluctuation of speed $= c_s = \dfrac{\omega_1 - \omega_2}{\omega} = 2\% = 0.02$

Fluctuation of kinetic energy $= \Delta E = 2 \times 10^3$ J

Now
$$\Delta E = \frac{1}{2} I\omega_1^2 - \frac{1}{2} I\omega_2^2$$
$$= \frac{1}{2} I(\omega_1^2 - \omega_2^2)$$

Since $\dfrac{\omega_1 + \omega_2}{2} = \omega$

$$= I\left(\frac{\omega_1 + \omega_2}{\omega}\right)(\omega_1 - \omega_2)$$
$$= I\omega \frac{(\omega_1 - \omega_2)}{\omega} . \omega$$
$$= I\omega^2 cs.$$

$\Rightarrow$
$$2 \times 10^2 = \frac{1}{2} MR^2 . \omega^2 .c_s^2, \text{ where R = Radius of disc}$$
$$= \frac{1}{2} M \times \left(\frac{1}{2}\right)^2 \times \left(\frac{2176200}{60}\right) \times 0.02$$

$\therefore$
$$M = \frac{2 \times 10^3 \times 60 \times 60 \times 8}{0.02 \times (2 \times \pi \times 1200)^2}$$
$$= 50.65 \approx 51 \text{ kg}.$$

28. The safe rim velocity of a flywheel is influenced by the

(a) centrifugal stresses (b) fluctuation of energy **[IAS-1998]**

(c) fluctuation of speed (d) mass of the flywheel

28. Ans. (a) centrifugal stresses $(\sigma) = \rho v^2$

29. If the rotating mass of a rim type fly wheel is distributed on another rim type fly wheel whose mean radius is half the mean radius of the former, then energy stored in the latter at the same speed will be **[IES-2002]**

(a) four times the first one (b) same as the first one

(c) one-fourth of the first one (d) two times the first one

29. Ans. (c)

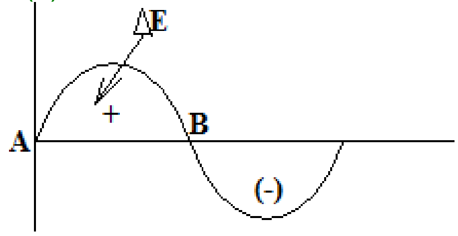
Turning moment diagram

30. The turning moment diagram for a single cylinder double acting steam engine consists of +ve and –ve loops above and bellow the average torque line. For the +ve loop, the ratio of the speeds of the flywheel at the beginning and the end is which one of the following?

(a) less than unity (b) Equal to unity **[IES 2007]**

(c) Greater than unity (d) Zero

30. Ans. (a)

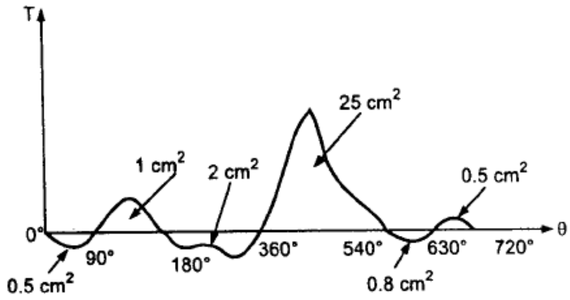


Energy at B = Energy at A + ΔE

or $\frac{1}{2}I\omega_B{}^2 = \frac{1}{2}I\omega_A{}^2 + \Delta E$

$\therefore\ \omega_A > \omega_A$ or $\frac{\omega_A}{\omega_B} < 1$

31. Consider the following statements regarding the turning moment diagram of a reciprocating engine shown in the above figure: (Scale 1 cm^2 = 100 N· m)



[IES-2000]

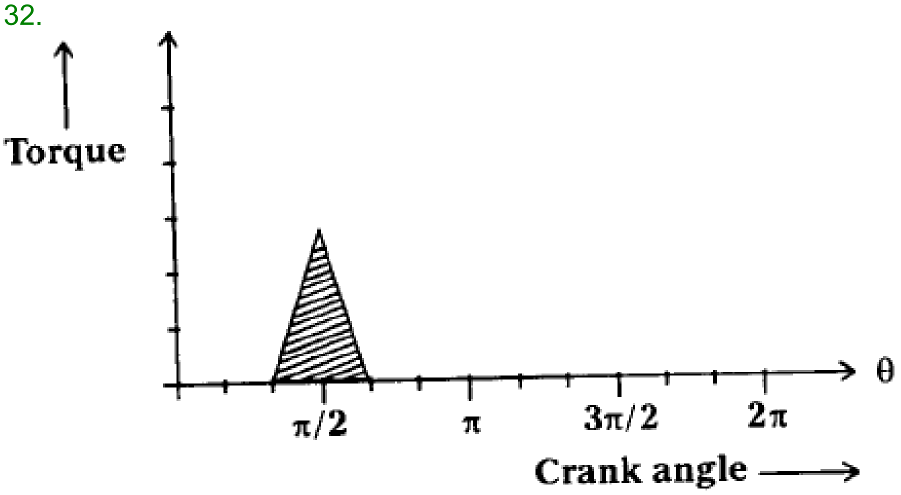
1. It is four stroke IC engine
2. The compression stroke is 0° to 180°
3. Mean turning moment $T_m = \frac{580}{\pi}$ N. m
4. It is a multi-cylinder engine.

Which of these statements are correct?

(a)1, 2 and 3 (b) 1, 2 and 4 (c) 2, 3 and 4 (d) 1, 3 and 4

31. Ans. (a)

32.



The crank of a slider-crank punching press has a mass moment of inertia of 1 kgm^2. The above figure shows the torque demand per revolution for a punching operation. If the speed of the crank is found to drop from 30 rad/s to 20 rad/s during punching, what is the
maximum torque demand during the punching operation? **[IES-2005]**

(a) 95.4 Nm (b) 104.7 Nm (c) 477.2 Nm (d) 523.8 Nm

32. Ans. (c) Energy needed for punching = $\frac{1}{2}I\left(\omega_1^2-\omega_2^2\right)=\frac{1}{2}\times1\times\left(30^2-20^2\right)J=250J$

From graph $\frac{1}{2}\times T_{max}\times\Delta\theta=250$ or $T_{max}=\frac{250\times2}{\Delta Q}=\frac{500\times2}{\Delta\theta}=\frac{500}{\left(\frac{2\pi}{3}-\pi/3\right)}=\frac{1500}{\pi}=477.2Nm$

33. A certain machine requires a torque of (500 + 50Sinθ) KNm to derive it, θ where is the angle of rotation of shaft measured from certain datum. The machine is directly coupled to an engine which produces a toques (500 +50sin θ) KNm in a cycle how many times the value of torque of machine and engine will be identical **[IES-1992]**

(a) 1 (b) 2 (c) 4 (d) 8

33. Ans. (c)

$$50 \sin 2\theta = 50 \sin \theta$$

$\Rightarrow$ $$\sin 2\theta - \sin \theta = 0$$

$\Rightarrow$ $$\sin 2\theta [2 \cos \theta - 1] = 0$$

or $$\sin \theta = 0$$

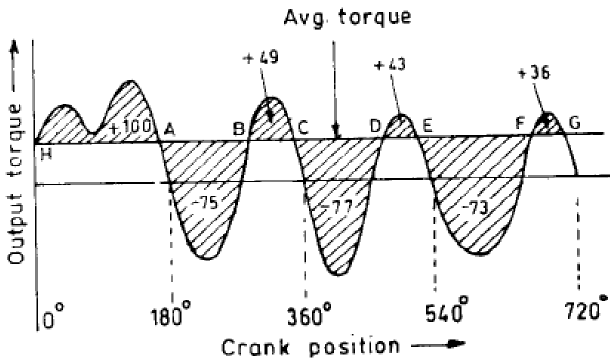
$\Rightarrow$ $$\theta = 0°, 180°, 360°$$

and $$2 \cos \theta = 1$$

$\Rightarrow$ $$\cos \theta = \frac{1}{2}$$

$$\theta = 60°, 300°$$

34. The given figure shows the output torque plotted against crank positions for a single cylinder four-stroke-cycle engine. The areas lying above the zero-torque line represent positive work and the areas below represent negative work. The engine drives a machine which offers a resisting torque equal to the average torque. The relative magnitudes of the hatched areas are given by the numbers (in the areas) as shown:



During the cycle, the minimum speed occurs in the engine at **[IES-1995]**

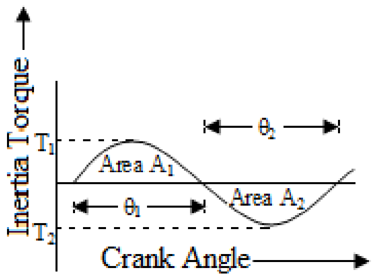
(a) B (b) D (c) H (d) F

34. Ans. (d) Minimum speed occurs at point where cumulative torque is least, i.e. -23 at F.

35. Consider the following statements relating to the curve for the inertia torque v/s crank angle for a horizontal, single cylinder petrol engine shown in the given figure:

1. $\theta_1 + \theta_2 = 180°$ 2. $T_1 = T_2$

3. $\theta_1 \neq \theta_2$ 4. $A_1 = A_2$



Of these statements:

(a) 1 and 3 are correct (b) 2 and 3 are correc

(c) 1, 2 and 4 are correct (d) 1, 3 and 4 are correct **[IAS-1998]**

35. Ans. (d)

36. In which of the following case, the turning moment diagram will have least variations:

(a) Double acting steam engine (b) Four stroke single cylinder patrol engine

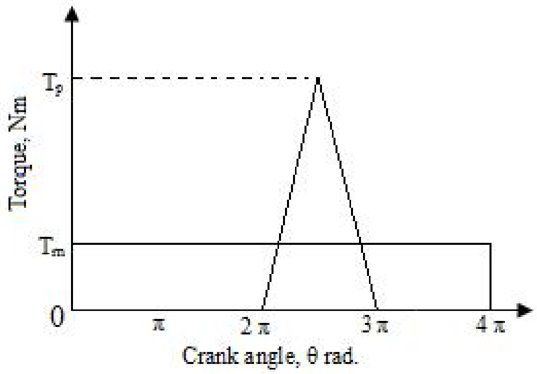
(c) 8 cylinder, 4 stroke diesel engine (d) Pelton wheel **[IES-1992]**

36. Ans. (d)

37. A simplified turning moment diagram of a four-stroke engine is shown in the given figure. If the mean torque 'T_m ' is 10 Nm, the estimated peak torque 'T_p 'will be (assuming negative torque demand is negligible)

(a) 80 Nm (b) 120 Nm

(c) 60 Nm (d) 40 Nm



[IAS-1999]

37. Ans. (a) $\text{Area } T_m \times (4\pi - 0) = \text{Area } T_p \times \left(\frac{3\pi - 2\pi}{2}\right)$ or $T_p = 8T_m = 8 \times 10 = 80\text{Nm}$

38. In a 4-stroke I.C. engine, the turning moment during the compression stroke is

(a) positive throughout (b) negative throughout

(c) positive during major portion of the stroke **[IES-1996]**

(d) negative during major portion of the stroke.

38. Ans. (a)

Answers with Explanation (Objective)

4.

Governor

Objective Questions (IES, IAS, GATE)

1. For a governor running at constant speed, what is the value of the force acting on the sleeve?
(a) Zero (b) Variable depending upon the load
(c) Maximum (d) Minimum **[IES 2007]**
1. Ans. (a)

Watt Governor

2. The height of a simple Watt governor running at a speed 'N' is proportional to
(a)N (b) 1/N (c) N^2 (d) $1/N^2$ **[IAS-1999]**
2. Ans. (d) For Watt governor, height (h) = $\frac{895}{N^2}$ metre

3. Consider the following speed governors: **[IES-1999]**
1. Porter governor 2. Hartnell governor 3. Watt governor 4. Proell Governor
The correct sequence of development of these governors is
(a) 1, 3, 2, 4 (b) 3, 1, 4, 2 (c) 3, 1, 2, 4 (d) 1, 3, 4, 2
3. Ans. (b) Watt, Porter, Proell, Hartnell.

4. Match List I (Feature or application) with List-II (Governor) and select the correct answer using the codes given below the lists: **[IAS-1999]**

List 1	List II
A. Gas engines	1. Quantity governing
B. Rate of change of engine speed	2. Isochronous governor
C. Low speeds	3. Pickering governor
D. Gramophone mechanism	4. Watt governor
	5. Inertia governor

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

4. Ans. (a)

5. Given that m = mass of the ball of the governor, **[IES-1998]**
ω = angular velocity of the governor and
g = acceleration due to gravity,
the height of Watt's governor is given by
(a) $\frac{g}{2\omega^2}$ (b) $\frac{g}{\omega^2}$ (c) $\frac{\sqrt{2}g}{\omega^2}$ (d) $\frac{2g}{\omega^2}$
5. Ans. (b)

6. The height of Watt's governor is **[IAS-2003]**
(a) directly proportional to the speed
(b) directly proportional to the $(\text{speed})^2$
(c) inversely proportional to the speed
(d) inversely proportional to the $(\text{speed})^2$

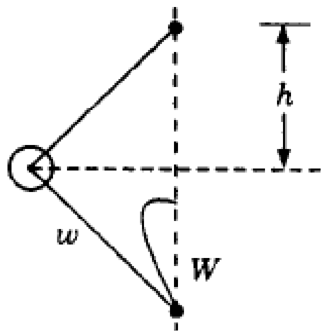
6. Ans. (d)

Porter Governor

7. Consider the given figure:

Assertion (A): In order to have the same equilibrium speed for the given values of w, W and h, the masses of balls used in the Proell governor are less than those of balls used in the Porter governor.

Reason (R): The ball is fixed to an extension link in Proell governor.



[IES-1999]

7. Ans. (a)

8. The height h of Porter governor with equal arms pivoted at equal distance from axis of rotation is expressed as (where m = mass of balls of the governor, M =mass of sleeve of the governor and N = rpm) **[IAS-1998]**

(a) $h = 91.2\left[\dfrac{m+M}{m}\right]\dfrac{g}{N^2}$ (b) $h = 91.2\left[\dfrac{mg-Mg}{mg}\right]\dfrac{g}{N^2}$

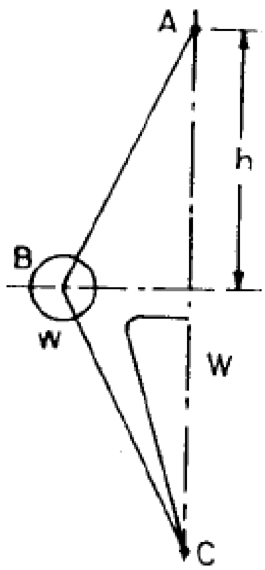
(c) $h = 91.2\left[\dfrac{m}{mM}\right]\dfrac{g}{N^2}$ (d) $h = 91.2\left[\dfrac{M}{m}\right]\dfrac{g}{N^2}$

8. Ans. (a)

9. Which one of the following equation is valid with reference to the given figure?

(a) $\omega^2 = \left(\dfrac{W}{w}\right)\left(\dfrac{g}{h}\right)$ (b) $\omega^2 = \left(\dfrac{W+w}{w}\right)\left(\dfrac{g}{h}\right)^{1/2}$

(c) $\omega^2 = \left(\dfrac{w}{W+w}\right)\left(\dfrac{h}{g}\right)^{1/2}$ (d) $\omega^2 = \left(\dfrac{W+w}{w}\right)\left(\dfrac{g}{h}\right)$



[IES-1996]

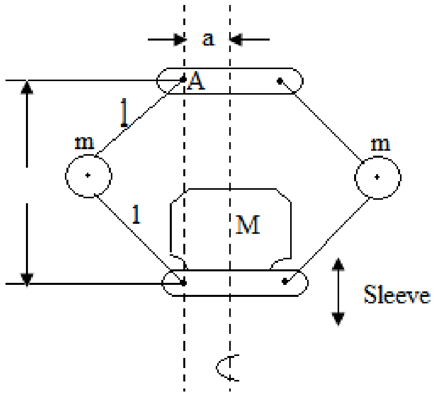
9. Ans. (d)

10. The sensitivity dh/dN of a given Porter Governor. Where 'h' is the height of the pin point A from the sleeve and N is the ripe. m., is proportional to

(a) N^2 (b) N^3

(c) $\frac{1}{N^2}$ (d) $\frac{1}{N^3}$

[IAS-1995]



10. Ans. (d)

For porter governer, $h \propto \frac{1}{N^3}$.

$\therefore \quad \frac{dh}{dN} \propto \frac{1}{N^3}$

Proell Governor

Hartnell Governor

11. A Hartnell governor is a governor of the **[IAS-1996]**

(a) inertia type (b) pedulum type (c) centrifugal type (d) dead weight type

11. Ans. (c) It is a spring loaded centrifugal governor.

12. In a Hartnell governor, the mass of each ball is 2.5 kg. Maximum and minimum speeds of rotation are 10 rad/s and 8 rad/s respectively. Maximum and minimum radii of rotation are 20 cm and 14 cm respectively. The lengths of horizontal and vertical arms of bell crank levers are 10 cm and 20 cm respectively. Neglecting obliquity and gravitational effects, the lift of the sleeve is

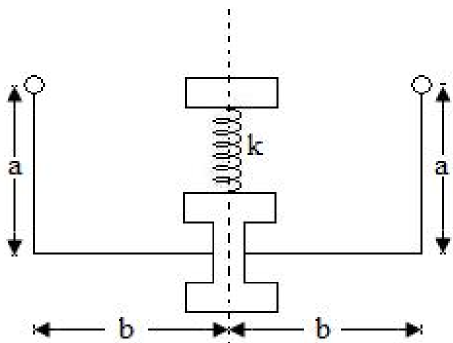
(a) 1.5 cm (b) 3.0 cm (c) 6.0 cm (d) 12.0 cm **[IES-2002]**

12. Ans. (b)

13.. The stiffness of spring k used in the Hartnell governor as shown in the given figure (F_1 and F_2 are centrifugal forces at maximum and minimum radii of rotation r_1 and r_2 respectively) is

(a) $2\left(\frac{b}{a}\right)^2\left(\frac{F_1-F_2}{r_1-r_2}\right)$ (b) $2\left(\frac{a}{b}\right)^2\left(\frac{F_1-F_2}{r_1-r_2}\right)$

(c) $\left(\frac{b}{a}\right)^2\left(\frac{F_1-F_2}{r_1-r_2}\right)$ (d) $\left(\frac{a}{b}\right)^2\left(\frac{F_1-F_2}{r_1-r_2}\right)$



[IAS-2001]

13. Ans. (b)

Hartung Governor

Pickering Governor

14. Which one of the following governors is used to drive a gramophone? **[IES-2005]**

(a) Watt governor (b) Porter governor

(c) Pickering governor (d) Hartnell governor

14. Ans. (c)

Sensitiveness of Governor

15. Sensitiveness of a governor is defined as **[IES-2000]**

(a) $\frac{\text{Range of speed}}{\text{2x Mean speed}}$ (b) $\frac{\text{2x Mean speed}}{\text{Range of speed}}$

(c) $\text{Mean speed} \times \text{Range of speed}$ (d) $\frac{\text{Range of speed}}{\text{Mean speed}}$

15. Ans. (d)

16. Which one of the following expresses the sensitiveness of a governor? **[IES-2005]**

(a) $\frac{N_1 + N_2}{2N_1 N_2}$ (b) $\frac{N_1 - N_2}{2N_1 N_2}$ (c) $\frac{2(N_1 + N_2)}{N_1 - N_2}$ (d) $\frac{2(N_1 - N_2)}{N_1 + N_2}$

(Where N_1 = Maximum equilibrium speed, N_2 = Minimum equilibrium speed)

16. Ans. (d)

17. If a centrifugal governor operates between speed limits ω_1 and ω_2 then what is its sensitivity equal to? **[IAS-2007]**

(a) $\frac{\omega_1 + \omega_2}{\omega_2 - \omega_1}$ (b) $\frac{\omega_1 + \omega_2}{2(\omega_2 - \omega_1)}$ (c) $\frac{\omega_2 - \omega_1}{2(\omega_2 + \omega_1)}$ (d) $\frac{\omega_2 - \omega_1}{\omega_2 + \omega_1}$

17. Ans. (c) [no one is correct] because correct expression is $\frac{2(\omega_2 - \omega_1)}{(\omega_2 + \omega_1)}$

18. Sensitiveness of a governor is defined as the ratio of the

(a) maximum equilibrium speed to the minimum equilibrium speed **[IAS-2000]**

(b) difference between maximum and minimum equilibrium speeds to the mean equilibrium speed

(c) difference between maximum and minimum equilibrium speeds to the maximum equilibrium speed

(d) minimum difference in speeds to the minimum equilibrium speed

18. Ans. (b) Sensitiveness of a governor = $\frac{N_2 - N_1}{N} = \frac{2(N_2 - N_1)}{(N_2 + N_1)}$

19. For a given fractional change of speed, if the displacement of the sleeve is high, then the governor is said to be **[IES-1998]**
(a) hunting (b) isochronous (c) sensitive (d) stable
19. Ans. (c)

20. Effect of friction, at the sleeve of a centrifugal governor is to make it **[IES-2003]**
(a) More sensitive (b) More stable
(c) Insensitive over a small range of speed (d) Unstable
20. Ans. (c)

21. Which one .of the following statement is correct? **[IES-2004]**
A governor will be stable if the radius of rotation of the balls
(a) increases as the equilibrium speed decreases
(b) decreases as the equilibrium speed increases
(c) increases as the equilibrium speed increases
(d) remains unaltered with the change in equilibrium speed
21. Ans. (c)

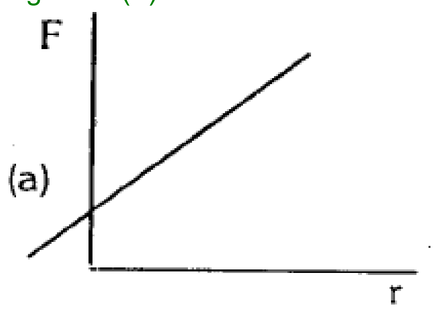
22. The sensitivity of an isochronous governor is **[IES-1997]**
(a) zero (b) one (c) two (d) infinity
22. Ans. (d) Sensitivity = $\frac{N_1+N_2}{2\left(N_1-N_2\right)}$, since $N_1 \simeq N_2$ for isochronous governor, sensitivity = α.

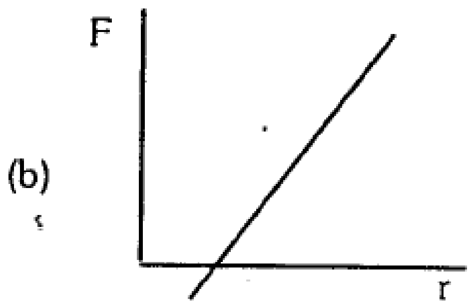
23. A spring controlled governor is found unstable. It can be made stable by **[IES-1994]**
(a) increasing the spring stiffness (b) decreasing the spring stiffness
(c) increasing the ball weight (d) decreasing the ball weight.
23. Ans. (b) A spring controlled governor can be made stable by decreasing the spring stiffness.

Isochronous Governor

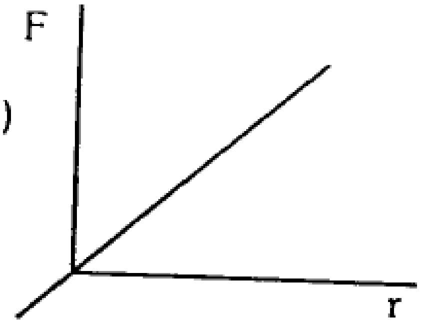
24. A governor is said to be isochronous when the equilibrium speed for all radii or rotation the balls within the working range **[IAS-1996]**
(a) is not constant (b) is constant (c) varies uniformly (d) has uniform acceleration
24. Ans. (b)

25. The nature of the governors is shown by the graph between radius (r) of rotation and controlling force (F). Which of the following is an isochronous governor? **[IES-2002]**

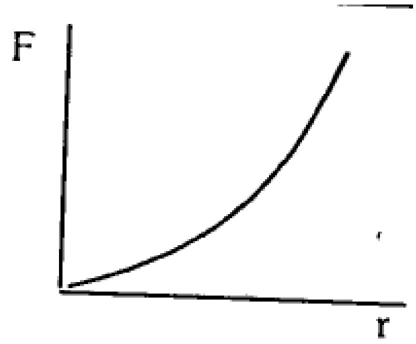




(c)



(d)



25. Ans. (c)

26. Assertion (A): The degree of hunting with an unstable governor will be less than with an isochronous governor. **[IES-1997]**
Reason (R): With an unstable governor, once the sleeve has moved from one extreme position to the other, a finite change of speed is required to cause it to move back again.
26. Ans. (a)

27. A Hartnell governor has its controlling force F given by **[IES-1993]**
F = p + qr
Where, is the radius of the balls and p and q are constants.
The governor becomes isochronous when
(a) P = 0 and q is positive (b) p is positive and q = 0
(c) p is negative and q is positive (d) P is positive and q is also positive
27. Ans. (a) For isochronous governor F = qr
So P should be zero and q be + ve.

28. Match List - I (Type of Governor) with List-II (Characteristics) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Isochronous governor	1. Continuously fluctuates above and below mean speed
B. Sensitive governor	2. For each given speed there is only one radius of rotation
C. Hunting governor	3. Higher displacement of sleeve for fractional change of speed
D. Stable governor	4. Equilibrium speed is constant for all radii of rotation

[IAS-1998]

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

28. Ans. (d)

29. In a spring -controlled governor, the controlling force curve is straight line. The balls are 400mm apart when the controlling force is 1600 N, and they are 240mm apart when the force is 800 N. To make the governor isochronous, the initial tension must be increased by **[IAS-1997]**
(a) 100 N (b) 200 N (c) 400 N (d) 800 N
29. Ans. (c) It is a stable governor so F = ar – b

Or 1600 = a x 0.4 – b and 800 = a x 0.24 – b
Solving we get a = 5000   and 400
For isochronous governor, F = a.r i.e. b must be zero. i.e. initial tension must increase by 400 N.

Hunting

30. Match List I with List II and select the correct answer

List I	List II [IES-1996]
A. Hunting	1. One radius rotation for each speed
B. Isochronism	2. Too sensitive
C. Stability	3. Mean force exerted at the sleeve during change of speed.
D. Effort	4. Constant equilibrium speed for all radii of rotation

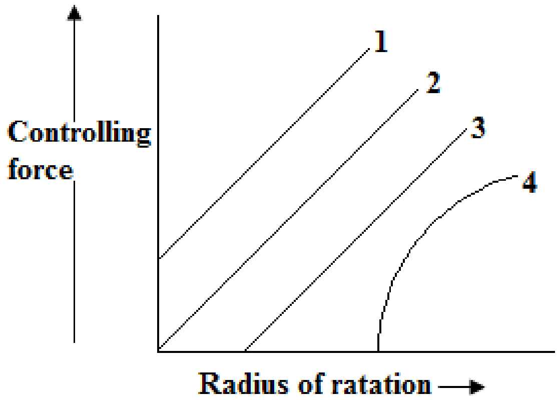
Codes:	A	B	C	D		A	B	C	D
(a)	2	4	1	3	(b)	3	1	4	2
(c)	2	1	4	3	(d)	1	2	3	4

30. Ans. (a)

Controlling force

31. The controlling force curve of spring-loaded governor is given by the equation F = ar - c, (where r is the radius of rotation of the governor balls and a, c are constants). The governor is **[IAS-1999]**
(a) stable (b) unstable (c) isochronous (d) insensitive
31. Ans. (a)

32.



The controlling force curves for a spring-controlled governor are shown in the above figure. Which curve represents a stable governor? **[IES 2007]**
(a) 1 (b) 2
(c) 3 (d) 4
32. Ans. (c)

33. Consider the following statements: **[IES-2006]**
1. The condition of stability of a governor requires that the slope of the controlling force curve should be less than that of the line representing the centripetal force at the equilibrium speed under consideration.

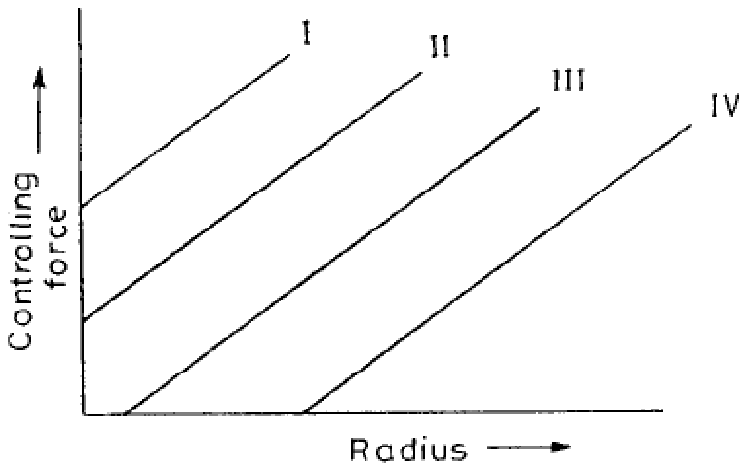
2. For a centrifugal governor when the load on the prime mover drops suddenly, the sleeve should at once reach the lower-most position.
Which of the statements given above is/are correct?
(a) Only 1 (b) Only 2 (c) Both 1 and 2 (d) Neither 1 nor 2
33. Ans. (b)

34. Consider the following statements concerning centrifugal governors: **[IES-2005]**
1. The slope of the controlling force curve should be less than that of the straight line representing the centripetal force at the speed considered for the stability of a centrifugal governor.
2. Isochronism for a centrifugal governor can be achieved only at the expense of stability.
3. When sleeve of a centrifugal governor reaches its topmost position, the engine should develop maximum power.

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

35. For a spring controlled governor to be stable, the controlling force (F) is related to the radius (r) by the equation. **[IES-1995]**
(a) F = ar - b (b) F = ar + b (c) F = ar (d) F = a/r + b
35. Ans. (a)

36. The plots of controlling force versus radii of rotation of the balls of spring controlled governors are shown in the given diagram. A stable governor is characterised by the curve labelled
(a) I
(b) II
(c) III
(d) IV



[IES-1993]
36. Ans. (d) For stable governor, F = qr - p which is possible with curve IV.

Answers with Explanation (Objective)

5.

Balancing of rigid rotors and field balancing

Objective Questions (IES, IAS, GATE)

1. What is the condition for dynamic balancing of a shaft-rotor system? **[IES 2007]**

(a) $\sum M = 0$ and $\sum F = 0$ (b) $\sum M = 0$

(c) $\sum F = 0$ (d) $\sum M + \sum F = 0$

1. Ans. (a)

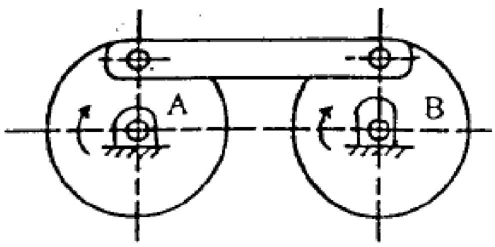
2. Assertion (A): A dynamically balanced system of multiple rotors on a shaft can rotate smoothly at the critical speeds of the system. **[IES-2002]**
Reason (R): Dynamic balancing eliminates all the unbalanced forces and couples from the system.
2. Ans. (b)

3. A system in dynamic balance implies that **[IES-1993]**
(a) the system is critically damped (b) there is no critical speed in the system
(c) the system is also statically balanced (d) there will be absolutely no wear of bearings.
3. Ans. (c) A system in dynamic balance implies that the system is also statically balanced.

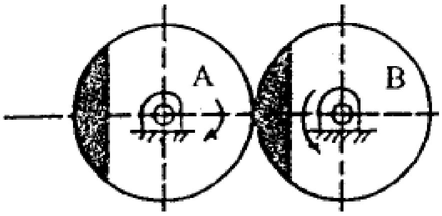
4. Which of the following statement is correct? **[IES-1992]**
1. If a rotor is statically balanced it is always dynamically balanced also.
2. If a rotor is dynamically balanced, it may not be statically balanced.
3. If a rotor is dynamically balanced, it mayor may not be dynamically balanced
4. If a rotor is statically balanced, it mayor may not be dynamically balanced.
(a) 1 and 2 only (b) 2 and 4 only (c) 2 and 3 only (d) 1 and 4 only
4. Ans. (d)

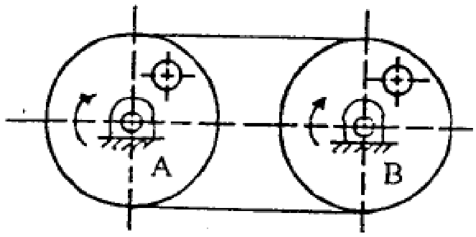
5. The figures given on right show different schemes suggested to transmit continuous rotary motion from axis A to axis B. Which of these schemes are not dynamically balanced?
(a) 1 and 3 (b) 2and3
(c) 1 and 2 (d) 1, 2 and 3

(1)



[IAS-2004]

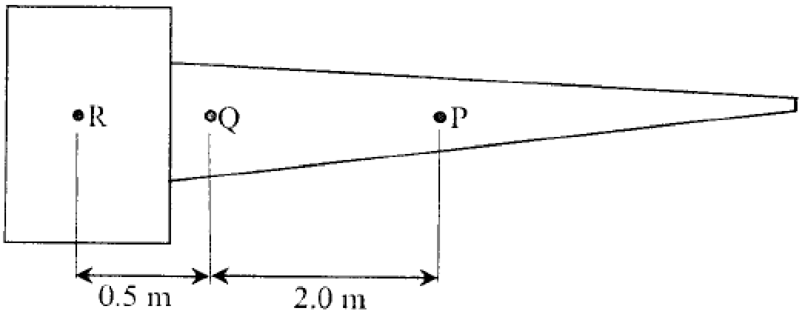
(2) 

(3) 

5. Ans. (a)

6. Static balancing is satisfactory for low speed rotors but with increasing speeds, dynamic balancing becomes necessary. This is because, the **[IAS 1994]**
(a) unbalanced couples are caused only at higher speeds
(b) unbalanced forces are not dangerous at higher speeds
(c) effects of unbalances are proportional to the square of the speed
(d) effects of unbalances are directly proportional to the speed
6. Ans. (c)

7. A cantilever type gate hinged at Q is shown in the figure. P and R are the centers of gravity of the cantilever part and the counterweight respectively. The mass of the cantilever part is 75 kg. The mass of the counterweight, for static balance, is



[GATE-2008]

7. Ans. (d) Taking Moment about 'Q' $75 \times 2.0 = R \times 0.5$ or $R = 300\,kg$

Balancing of a single rotating mass by a single mass rotating in a same plane

8. Consider the following statements for completely balancing a single rotating mass:
   1. Another rotating mass placed diametrically opposite in the same plane balances the unbalanced mass. **[IES-2002]**
   2. Another rotating mass placed diametrically opposite in a parallel plane balances the unbalanced mass.
   3. Two masses placed in two different parallel planes balance the unbalanced mass.

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

Balancing of a single rotating mass by two masses rotating in different planes

9. Which of the following conditions are to be satisfied by a two-mass system which is dynamically equivalent to a rigid body? **[IAS-1997]**
1. The total mass should be equal to that of the rigid body.
2. The centre of gravity should coincide with that of the rigid body.
3. The total moment of inertia about an axis through the centre of gravity must be equal to that of the rigid body.

Select the correct answer using the codes given below:
Codes: (a) 1 and 2 (b) 2 and 3 (c) 1 and 3 (d) 1 and 3
9. Ans. (d) A is false. The centre of gravity of the two masses should coincide with that of the rigid body.

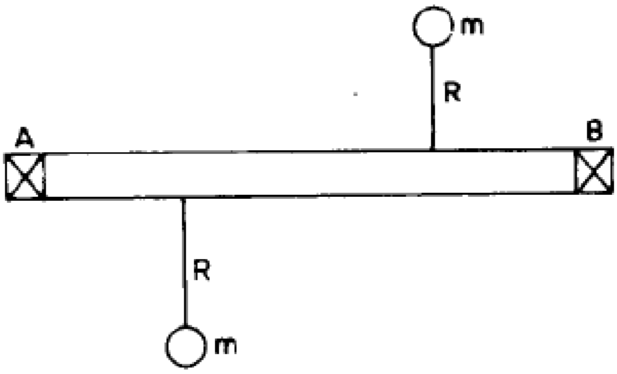
10. Consider the following necessary and sufficient conditions for replacing a rigid body by a dynamical equivalent system of two masses: **[IAS-2002]**
1. Total mass must be equal to that of the rigid body.
2. Sum of the squares of radii of gyration of two masses about the c.g. of the rigid body must be equal to square of its radius of gyration about the same point.
3. The c.g. of two masses must coincide with that of the rigid body.
4. The total moment of inertia of two masses about an axis through the c.g. must be equal to that of the rigid body.

Which of the above conditions are correct?
(a) 1, 2 and 3 (b) 1, 3 and 4 (c) 2, 3 and 4 (d) 1, 2 and 4
10. Ans. (b)

11. If a two-mass system is dynamically equivalent to a rigid body, then the system will not satisfy the condition that the **[IES-1999]**
(a) sum of the two masses must be equal to that of the rigid body
(b) polar moment of inertia of the system should be equal to that of the rigid body
(c) centre of gravity (e.g.) of the system should coincide with that of the rigid body
(d) total moment of inertia about the axis through e.g. must be equal to that of the rigid body
11. Ans. (d) First three conditions are essential.

12. A system of masses rotating in different parallel planes is in dynamic balance if the resultant. **[IES-1996]**
(a) force is equal to zero (b) couple is equal to zero
(c) force and the resultant couple are both equal to zero
(d) force is numerically equal to the resultant couple, but neither of them need necessarily be zero.
12. Ans. (c)

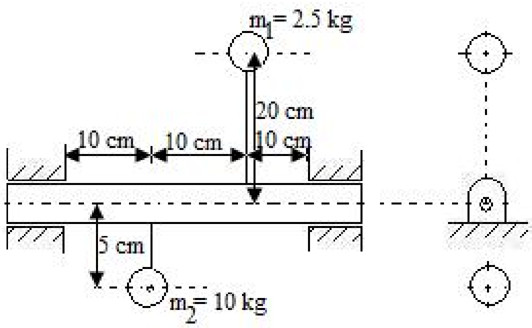
13. A rotor supported at A and B, carries two masses as shown in the given figure. The rotor is
(a) dynamically balanced
(b) statically balanced
(c) statically and dynamically balanced
(d) not balanced.



[IES-1995]

13. Ans. (a) The rotor in given figure is not balanced because couple formed is not taken care of.

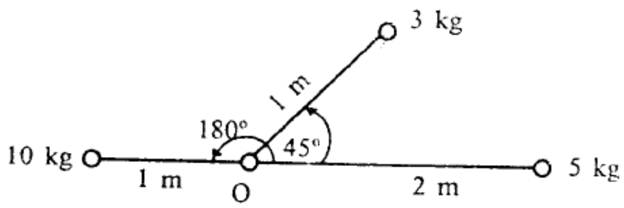
14. A rigid rotor consists of a system of two masses located as shown in the given figure. The system is
(a) statically balanced
(b) dynamically balanced
(c) statically unbalanced
(d) both statically and dynamically unbalanced



[IAS-2000]

14. Ans. (a) As centre of masses lie on the axis of rotation.

15. For the rotor system shown in figure, the mass required for its complete balancing is
(a) 1.5 kg at 2 m radius and at 2250 from reference
(b) 3 kg at 1m radius and at 450 from reference
(c) 8 kg at 1 m radius and at 2250 from reference
(d) 4 kg at 2 m radius and at 450 from reference



[IAS-2004]

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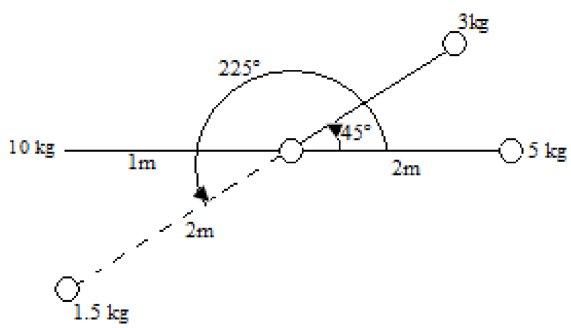
15. Ans. (a) 10×1 *and* 2×5 are balanced each other
Unbalance mass is 3 kg at 45^0
∴ Balanced system given in figure



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16. Balancing of a rigid rotor can be achieved by appropriately placing balancing weights in
(a) a single plane (b) two planes (c) three planes (d) four planes **[IAS-1995]**
16. Ans. (b)
An unbalance rigid rotor behaves as if several masses are there in different planes. Such a situation can be handled by fixing balancing weights in two planes.

17. A rotating disc of 1 m diameter has two eccentric masses of 0.5 kg each at radii of 50 mm and 60 mm at angular positions of 0°and 150°, respectively. a balancing mass of 0.1 kg is to be used to balance the rotor. What is the radial position of the balancing mass? **[GATE-2005]**
(a) 50 mm (b) 120 mm (c) 150 mm (d) 280mm
17. Ans. (c)

Along x-axis, $0.5\,(-60 \times 10^{-3} \cos 30° + 50 \times 10^{-3})\,\omega^2 = 0.1\omega^2 \times x \times 10^{-3}$

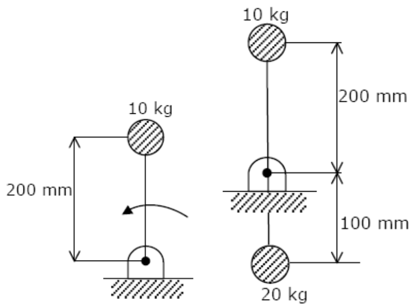
$\therefore \quad x = -9.8076 \text{ mm}$

Along y-axis, $0.5\,(60 \times 10^{-3} \sin 30°)\,\omega^2 = 0.1\omega^2\,y$

$\therefore \quad y = 150 \text{ mm}$

$\therefore \quad r = \sqrt{x^2 + y^2} = 150.32 \text{ mm}$

18. A rigid body shown in the Fig. (a) has a mass of 10 kg. It rotates with a uniform angular velocity 'ω'. A balancing mass of 20 kg is attached as shown in Fig. (b). The percentage increase in mass moment of inertia as a result of this addition is
(a) 25% (b) 50%
(c) 100% (d) 200%



(a) (b)

[GATE-2004]

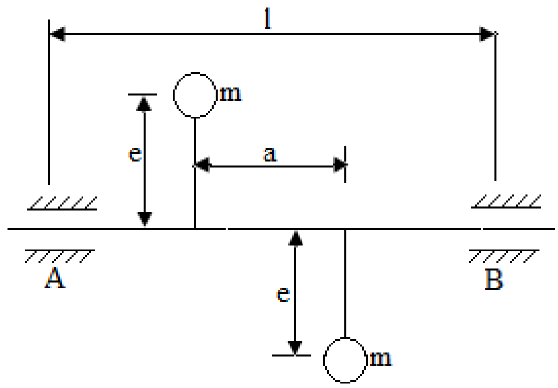
18. Ans. (b)

$$I_1 = 10 \times (0.2)^2 = 0.4 \text{kgm}^2$$

$$I_2 = 10 \times (0.2)^2 + 20 \times 0.1^2 = 0.6 \text{kg} - \text{m}^2$$

$$\%\text{Increase} = \frac{I_2 - I_1}{I_1} \times 100 = 50\%$$

19. The shaft-rotor system given above is
(a) Statically balanced only
(b) Dynamically balanced only
(c) Both statically and dynamically balanced
(d) Neither statically nor dynamically balanced



[IAS-2007]

19. Ans. (a)

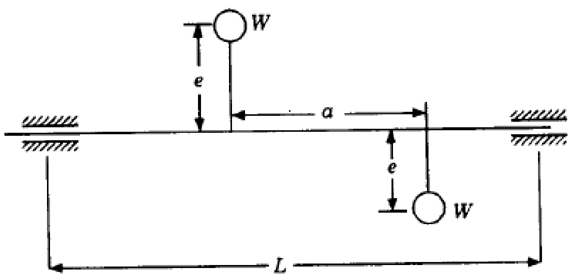
20. Consider the following statements:
Two rotors mounted on a single shaft can be considered to be equivalent to a geared-shaft system having two rotors provided. **[IAS-2003]**

1. the kinetic energy of the equivalent system is equal to that of the original system.
2. the strain energy of the equivalent system is equal to that of the original system.
3. the shaft diameters of the two systems are equal

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1and 2 (c) 2 and 3 (d) 1 and 3
20. Ans. (b)

21. Two rotors are mounted on a shaft. If the unbalanced force due to one rotor is equal in magnitude to the unbalanced force due to the other rotor, but positioned exactly 180^0 apart, then the system will be balanced **[IAS-1999]**
(a) statically (b) dynamically
(c) statically as well as dynamically (d) neither statically nor dynamically
21. Ans. (a)

22. A statically-balanced system is shown in the given Figure. Two equal weights W, each with an eccentricity e, are placed on opposite sides of the axis in the same axial plane. The axial distance between them is 'a'. The total dynamic reactions at the supports will be



[IES-1997]

(a)zero (b) $\frac{W}{g}\omega^2 e\frac{a}{L}$ (c) $\frac{W}{g}\omega^2 e\frac{a}{L}$ (d) $\frac{W}{g}\omega^2 e\frac{L}{a}$

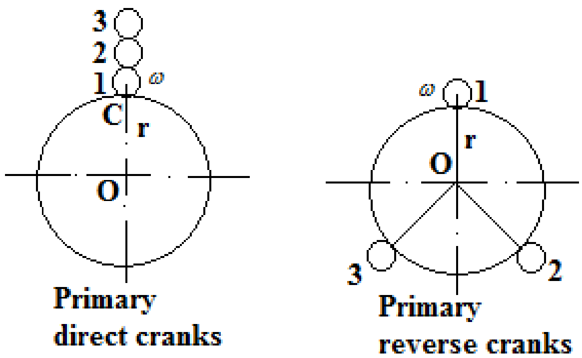
22. Ans. (c)

23. A rotor which is balanced statically but not dynamically is supported on two bearings L apart, and at high speed of the rotor, dynamic reaction on the left bearing is R. The right side of the bearing is shifted to a new position 2L apart from the left bearing. At the same rotor speed, dynamic reaction on the left bearing in the new arrangement will
(a) remain same as before (b) become equal to 2R **[IES-1994]**

(c) become equal to R/2 (d) become equal to R/4.
23. Ans. (b)

Balancing of several masses rotating in a same plane

24.



(W = Weight of reciprocating parts per cylinder) **[IES 2007]**
For a three-cylinder radial engine, the primary and direct reverse cranks are as shown in the above figures.
Which one of the following pairs is **not** correctly matched in this regard?

(a) Primary direct force… $\frac{3W}{2g}\omega^2.r$ (b) Primary reverse force… Zero

(c) Primary direct crank speed… ω (d) Primary reverse crank speed…2ω

24. Ans. (d)

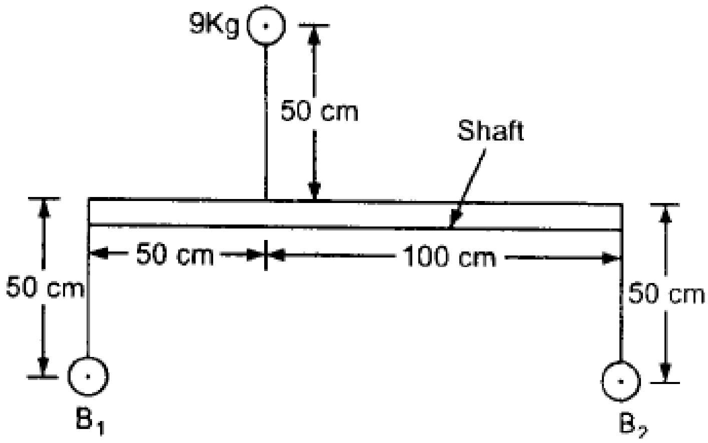
Balancing of several masses rotating in different planes

25. The balancing weights are introduced in planes parallel to the plane of rotation of the disturbing mass. To obtain complete dynamic balance, the minimum number of balancing weights to be introduced in different planes is **[IAS-2001]**
(a) 1 (b) 2 (c) 3 (d) 4
25. Ans. (b)

26. What is the number of nodes in a shaft carrying three rotors? **[IES-2006]**
(a) Zero (b) 2 (c) 3 (d) 4
26. Ans. (b)

27. Which one of the following can completely balance several masses revolving in different planes on a shaft? **[IES-2005]**
(a) A single mass in one of the planes of the revolving masses
(b) A single mass in anyone plane
(c) Two masses in any two planes
(d) Two equal masses in any two planes.
27. Ans. (c)

28. Masses B_1, B_2 and 9 kg are attached to a shaft in parallel planes as shown in the figure. If the shaft is rotating at 100 rpm, the mass B_2 is
(a) 3 kg
(b) 6 kg
(c) 9 kg
(d) 27 kg



[IES-2000]

28. Ans. (a)

29. Which one of the following can completely balance several masses revolving in different planes on a shaft? **[IES-1993]**
(a) A single mass in one of the planes of the revolving masses
(b) A single mass in a different plane
(c) Two masses in any two planes (d) Two equal masses in any two planes
29. Ans. (c)

Answers with Explanation (Objective)

6.

Balancing of single and multi-cylinder engines

Objective Questions (IES, IAS, GATE)

D-Alembert's Principle

1. Assertion (A): The supply of fuel is automatically regulated by governor according to the engine speed. **[IES-2001]**
Reason (R): The automatic function is the application of d' Alembert's principle.
1. Ans. (c)

2. If s, v, t, .F, m and a represent displacement, velocity, time, force, mass and acceleration respectively, match List I (Expression) with List II (Feature / Principle) and select the correct answer using the codes given below the lists: **[IAS-2003]**

List-I (Expression)	List-II (Feature/Principle)
(A) $v = 6t^2 - 9t$	1. Constant acceleration
(B) $v = 9t + 12$	2. Variable acceleration
(C) $s = 4t$	3. D' Alembert's principle
(D) $F - ma = 0$	4. Uniform motion

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

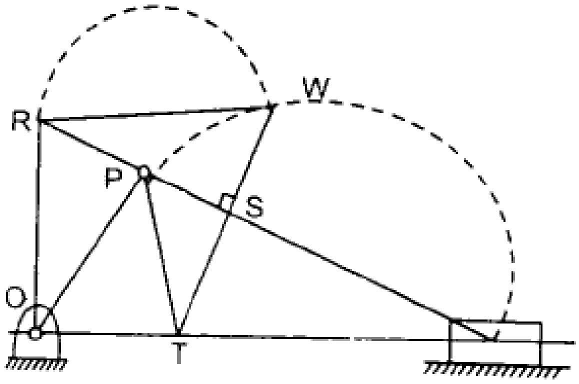
2. Ans. (a)

3. Assertion (A): d' Alembert's principle is known as the principle of dynamic equilibrium.
Reason(R): d' Alembert's principle converts a dynamic problem into a static problem. **[IAS-2000]**

3. Ans. (a)

Klein's Construction

4. The given figure shows the Klein's construction for acceleration of the slider-crank mechanism
Which one of the following quadrilaterals represents the required acceleration diagram?
(a) ORST
(b) OPST
(c) ORWT
(d) ORPT



[IES-2001]

4. Ans. (b)

5. The Klein's method of construction for reciprocating engine mechanism.
(a) is a simplified version of instantaneous centre method **[IES-1994]**
(b) utilizes a quadrilateral similar to the diagram of mechanism for reciprocating engine
(c) enables determination of Corioli' s component.
(d) is based on the acceleration diagram.
5. Ans. (d) Klein's method of construction for reciprocating engine mechanism is based on the acceleration diagram.

6.

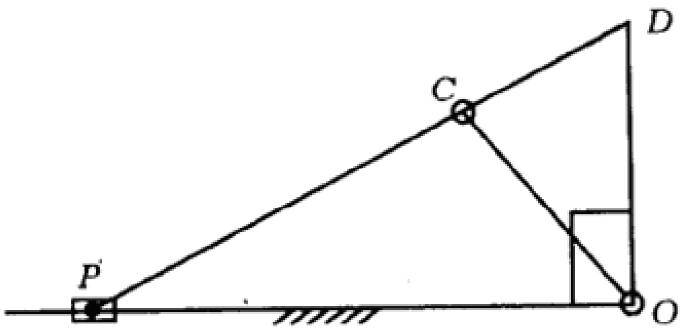
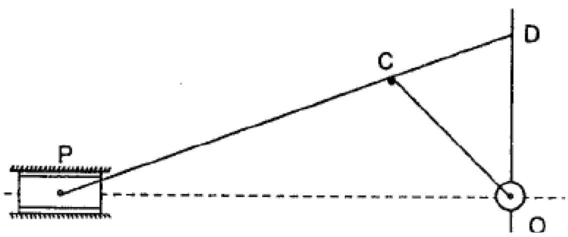


Figure shows Klein's construction for slider-crank mechanism OCP drawn to full scale. What velocity does CD represent?
(a) Velocity of the crank pin (b) Velocity of the piston
(c) Velocity of the piston with respect to crank pin **[IES-2003]**
(d) Angular velocity of the connecting rod
6. Ans. (c)

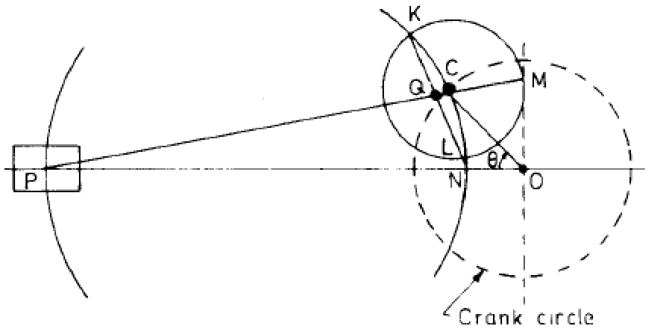
Velocity of crank pin $(V_c) = OC$

Velocity of piston $(V_p) = OD$

Velocity of piston with respect to crank pin $(V_{pc}) = CD$



7. Klein's construction for determining the acceleration of piston P is shown in the given figure. When N coincides with K
(a) acceleration of piston is zero and its velocity is zero.
(b) acceleration is maximum and velocity is maximum.
(c) acceleration is maximum and velocity is zero
(d) acceleration is zero and velocity is maximum. **[IES-1995]**



7. Ans. (d)

8. Consider the following statements:
The Klein's construction for slider crank mechanism with crank rotating at constant angular velocity provides values of **[IAS-1998]**

1. piston velocity.
2. piston acceleration.
3. normal acceleration of crank pin
4. angular acceleration of the connecting rod.

Of these statements:
(a) 1 and 2 are correct
(b) 1, 2, 3 and 4 are correct
(c) 1, 2 and 4 are correct
(d) 3 and 3 are correct

8. Ans. (b)

Velocity and Acceleration of the Piston---page 505

9. For a slider-crank mechanism with radius of crank r, length of connecting rod l, obliquity ratio n, crank rotating at an angular velocity ω; for any angle θ of the crank, match List-I (Kinematic Variable) with List-II (Equation) and select the correct answer using the codes given below-the Lists: **[IES-2003]**

List-I (Kinematic Variable)	List II (Equation)
A Velocity of piston	1. $\frac{\omega}{n}.\cos\theta$
B. Acceleration of piston	2. $\omega^2 r.\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$
C. Angular velocity of connecting rod	3. $-\frac{\omega^2}{n}.\sin\theta$
D. Angular acceleration of connecting rod	4. $\omega r.\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)$

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

9. Ans. (c)

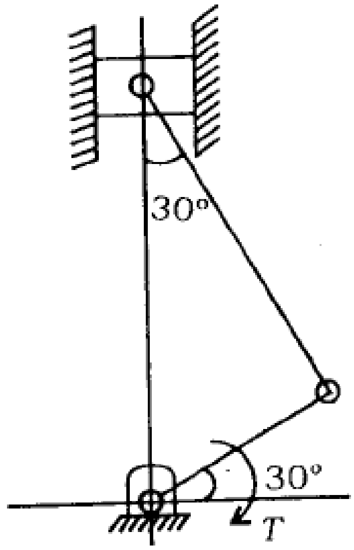
10. Consider the following statements: **[IES-2001]**
In petrol engine mechanism, the piston is at its dead centre position when piston

1. acceleration is zero
2. acceleration is maximum
3. velocity is zero
4. velocity is infinity

Which of these statements are correct?
(a) 1 and 4 (b) 1 and 3 (c) 2 and 3(d) 2 and 4
10. Ans. (c)

11. The above figure shows the schematic diagram of an IC engine producing a torque T = 40 N-m at the given instant. The Coulomb friction coefficient between the cylinder and the piston is 0.08. If the mass of the piston is 0.5 kg and the crank radius is 0.1 m, the Coulomb friction force occurring at the piston cylinder interface is

(a) 16 N (b) 0.4 N
(c) 4 N (d) 16.4 N

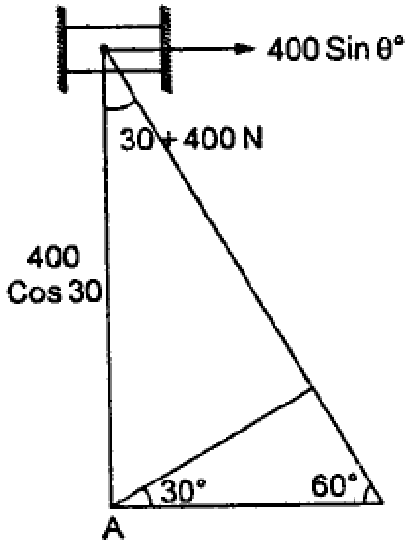


[IES-2003]

11. Ans. (a)

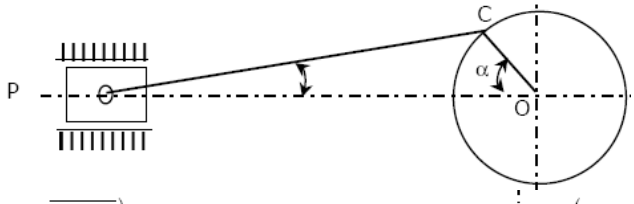
$$T=40 \text{ N-m} \ \therefore \ F_T = \frac{40}{0.1} = 400 \text{ N}$$

Friction force = 400 sin 30 x 0.08 = 16 N



12. In a slider-crank mechanism the maximum acceleration of slider is obtained when the crank is
(a) at the inner dead centre position **[IES-2001]**
(b) at the outer dead centre position
(c) exactly midway position between the two dead centers
(d) slightly in advance of the midway position between the two dead centers
12. Ans. (b)

13. The cross head velocity in the slider crank mechanism, for the polarization shown in figure is, **[GATE-1997]**



(a) $V_C \cos\left(90 - \overline{\alpha + \beta}\right)\cos\beta$ (b) $V_C \cos\left(90 - \overline{\alpha + \beta}\right)\sec\beta$

(c) $V_C \cos\left(90 - \overline{\alpha - \beta}\right)\cos\beta$ (d) $V_C \cos\left(90 - \overline{\alpha - \beta}\right)\sec\beta$

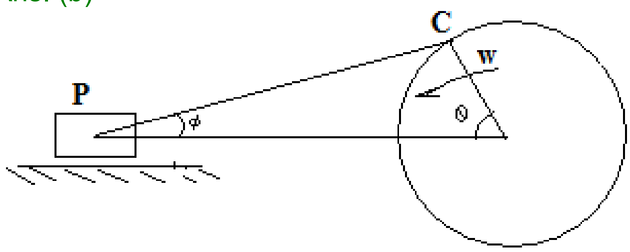
13. Ans. (b)

Angular velocity and acceleration of connecting rod

14. In a slider-bar mechanism, when does the connecting rod have zero angular velocity?

(a) When crank angle = 0^o (b) When crank angle = 90^0
(c) When crank angle = 45^0 (d) Never **[IES 2007]**

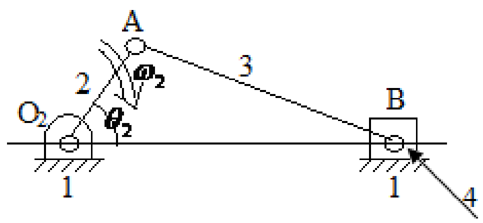
14. Ans. (b)



At $\theta = 90^0$, $\omega_{PC} = 0 \because \omega_{PC} = \dfrac{\omega\cos\theta}{\sqrt{(n^2 - \sin^2\theta)}}$

15. In the figure given above, when is the absolute velocity of end B of the coupler equal to the absolute velocity of the end A of the coupler?

(a) $\theta_2 = 90^o$ (b) $\theta_2 = 45^o$
(c) $\theta_2 = 0^0$ (d) Never



[IAS-2007]

15. Ans. (a) When relative velocity V_{AB} will be zero. Or V_{AB} = AB. ω_{AB} = AB.

$\dfrac{\omega\cos\theta_2}{\sqrt{\left(n^2 - \sin^2\theta_2\right)}} = 0$ Or θ2 = 90°

16. In a reciprocating engine mechanism, the crank and connecting rod of same length r meters are at right angles to each other at a given instant, when the crank makes an angle of 45^0 with IDC. If the crank rotates with a uniform velocity of ω rad/s, the angular acceleration of the connecting rod will be **[IAS-1999]**

(a) $2\omega^2 r$ (b) $\omega^2 r$ (c) $\dfrac{\omega^2}{r}$ (d) zero

16. Ans. (d) Angular acceleration of connecting rod $n = \frac{l}{r} = 1$ and $\theta = 45^0$

$$\alpha_c = \frac{-\omega^2 \sin\theta\left(n^2 - 1\right)}{\left(n^2 - \sin^2\theta\right)^{3/2}} = 0 \quad [\text{as} \quad n = 1]$$

Forces on the reciprocating parts of an engine ---page 510

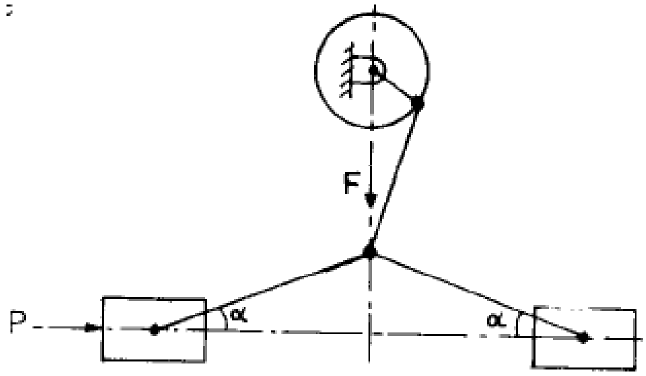
17. With reference to the mechanism shown in the figure, the relation between F and P is

(a) F = $\frac{1}{2}$ P . tanα

(b) F = P . tanα

(c) P = 2F tanα

(d) F = 2P tanα

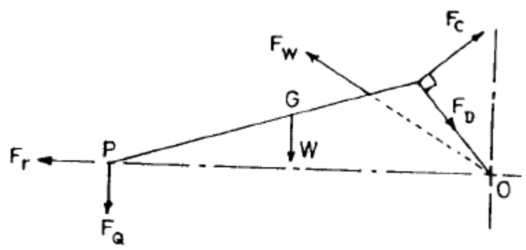


[IES-1994]

17. Ans. (b)

18. With reference to the engine mechanism shown in the given figure, match List I with List II and select the correct answer

List I	List II
A. F_Q	1. Inertia force of reciprocating mass
B. F_R	2. Inertia force of connecting rod
C. F_w	3. Crank effort
D. F_C	4. Piston side thrust



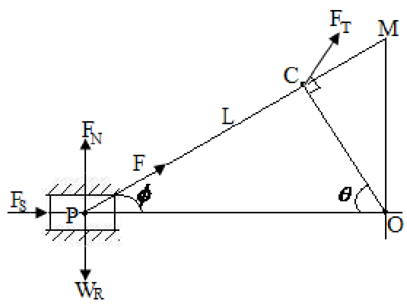
[IES-1996]

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

18. Ans. (c)

19. A. slider crank mechanism is shown in the given figure.

1. $F_Q.\sin(\theta+\phi)$ 2. $F_S.\sin\theta + \left(\frac{\sin 2\theta}{n}\right)$ 3. $F_S.OM$ 4. $F_T.r$



[IAS-1996]

Which of the following expressions stand for crank effort?
Select the correct answer using the codes given below:
Codes:

(a) 1 and 3 (b) 1, 2 and 4 (c) 1, 2 and 3 (d) 2, 3 and 4

19. Ans. (d)

20. Assertion (A): The resultant unbalanced force at any instant would be the minimum when half of the reciprocating parts is balanced by a rotating weight fixed opposite the crank, but the common practice is to balance two-thirds of the reciprocating parts.
Reason (R): Unbalanced force along the line of stroke is more harmful than that in a direction perpendicular to it. **[IES-1993]**
20. Ans. (c) Assertion A is true but reason R is false. In fact the introduction of balance masses causes unbalanced forces perpendicular to the line of the stroke. At high speed, these may, be large enough to cause lifting of the wheel from the rails.

21. The piston rod of diameter 20 mm and length 700 mm in a hydraulic cylinder is subjected to a compressive force of 10 KN due to the internal pressure. The end conditions for the rod may be assumed as guided at the piston end and hinged at the other end. The Young's modulus is 200 GPa. The factor of safety for the piston rod is
(a) 0.68 (b) 2.75 (c) 5.62 (d) 11.0 **[GATE-2007]**
21. Ans. (c)

22. Consider the triangle formed by the connecting rod and the crank of an IC engine as the two sides of the triangle. If the maximum area of this triangle occurs when the crank angle is 75°, the ratio of connecting rod length to crank radius is **[GATE-1998]**
(a) 5 (b)4 (c) 3.73 (d) 3
22. Ans. (c)

Explanation. $\Delta = \frac{1}{2}(PQ)(PR)\sin A$

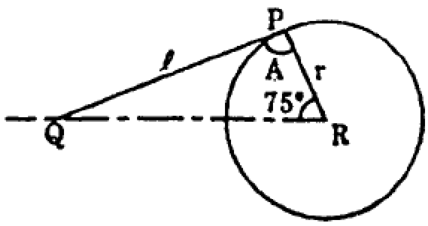
Area will be maximum when $A = 90°$

i.e. PQR is a right angled triangle.

$\therefore$ Ratio of connecting rot length to crank radius,

$$\frac{\ell}{r} = \tan 75° = 3.732;$$

$$\ell = 3.732\, r$$



Primary unbalanced forces

23. In reciprocating engines primary forces **[IAS-1996]**
(a) are completely balanced (b) are partially balanced
(c) are balanced by secondary forces (d) cannot be balanced
23. ans. (b)

24. Consider the following statements for a 4-cylinder inline engine whose cranks are arranged at regular intervals of 90°: **[IES-2005]**
1. There are 8 possible firing orders for the engine.
2. Primary force will remain unbalanced for some firing orders.

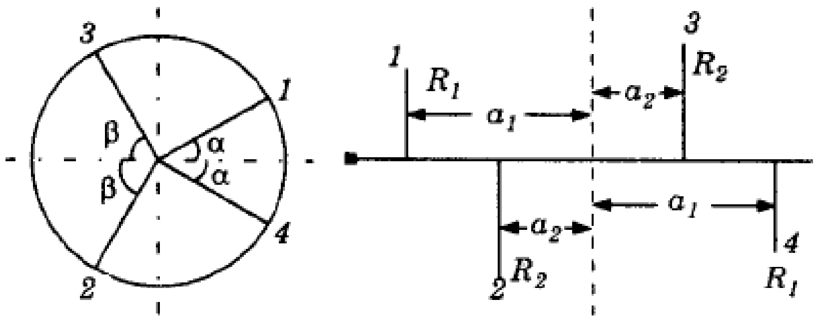
Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2
24. Ans. (d)

25. Which one of the following statements in the context of balancing in engines is correct? **[IES-2004]**
(a) Magnitude of the primary unbalancing force is less than the secondary unbalancing force
(b) The primary unbalancing force attains its maximum value twice in one revolution of the crank
(c) The hammer blow in the locomotive engines occurs due to unbalanced force along the line of stroke of the piston
(d) The unbalanced force due to reciprocating masses varies in magnitude and direction
25. Ans. (b)

26. In case of partial balancing of single-cylinder reciprocating engine, what is the primary disturbing force along the line of stroke? **[IES-2006]**
(a) $cmr\omega^2 \cos\theta$ (b) $\left(1-c^2\right)mr\omega^2 \cos\theta$
(c) $\left(1-c\right)mr\omega^2 \cos\theta$ (d) $\left(1-c\right)mr\omega^2 \cos 2\theta$
Where, c = Fraction of reciprocating mass to be balanced; ω = Angular velocity of crankshaft; θ = Crank angle.
26. Ans. (c)

27. The primary disturbing force due to inertia of reciprocating parts of mass m at radius r moving with an angular velocity ω is given by **[IES-1999]**
$(a) m\omega^2 r\sin\theta$ $(b) m\omega^2 r\cos\theta$ $(c) m\omega^2 r\sin\left(\frac{2\theta}{n}\right)$ $(d) m\omega^2 r\left(\frac{2\theta}{n}\right)$ Ans. (b)
27. Ans. (b)

28. A four-cylinder symmetrical in-line engine is shown in the given figure. Reciprocating weights per cylinder are R_1 and R_2, and the corresponding angular disposition of the crank are α and β.



Which one of the following equations should be satisfied for its primary force balance?
(a) $a_1 \tan\alpha = a_2 \tan\beta$ (b) $\cos\alpha = \frac{1}{2}\sec\beta$ **[IES-1998]**
(c) $R_1 a_1 \sin 2\alpha = -R_2 a_2 \sin 2\beta$ (d) $a_1\cos\alpha = R_2\cos\beta$
28. Ans. (d)

29. For a twin cylinder V-engine, the crank positions for Primary reverse cranks and Secondary direct cranks are given in the following diagrams: **[IES-1993]**

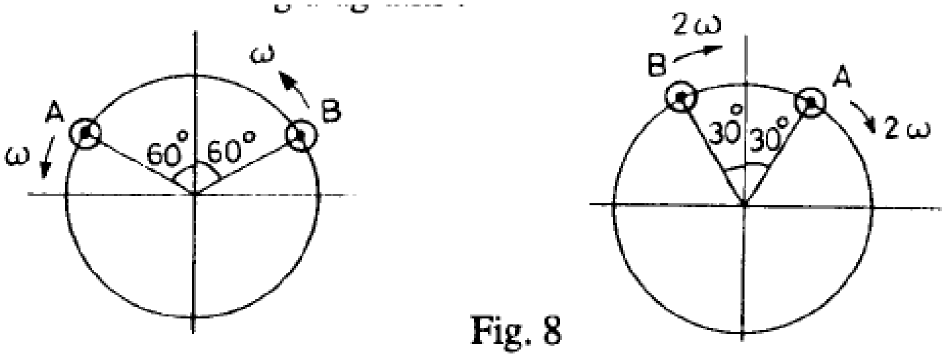


Fig. 8

The engine is a

(a) 60° V-engine (b) 120° V-engine (c) 30° V-engine (d) 150° V-engine

29. Ans. (a) The engine is 60° V-engine.

30. The primary direct crank of a reciprocating engine is located at an angle θ clockwise. The secondary direct crank will be located at an angle **[IAS-1999]**

(a) 2θ clockwise (b) 2θ anticlockwise (c) θ clockwise (d) θ anticlockwise

30. Ans. (a)

Secondary unbalanced forces

31. If the ratio of the length of connecting rod to the crank radius increases, then

(a) primary unbalanced forces will increase (b) primary unbalanced forces will decrease

(c) secondary unbalanced forces will increase

(d) secondary unbalanced forces will decrease **[IES-1999]**

31. Ans. (d) Secondary force only involves ratio of length of connecting rod and crank radius and is equal to $m\omega^2 r\dfrac{\cos 2\theta}{n}$.If n increases, value of secondary force will decrease.

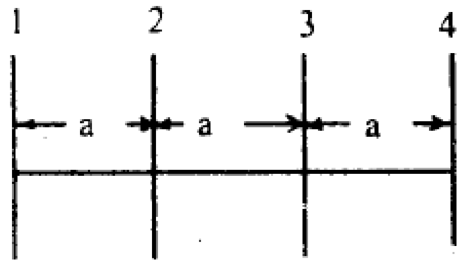
32. A single cylinder, four-stroke I.C. engine rotating at 900 rpm has a crank length of 50 mm and a connecting rod length of 200 mm. If the effective reciprocating mass of the engine is 1.2 kg, what is the approximate magnitude of the maximum 'secondary force' created by the engine? **[IES-2005]**

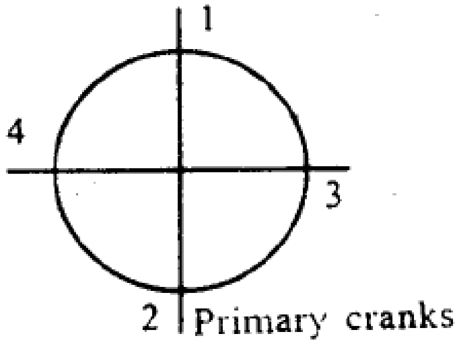
(a) 533 N (b) 666 N (c) 133 N (d) None of the above

32. Ans. (c) Maximum Secondary force

$$= \frac{mw^2r}{n} = 1.2\times\left(\frac{2\pi N}{60}\right)^2\times\frac{r}{\left(\frac{l}{r}\right)} = 1.2\times\left(\frac{2\pi\times 900}{60}\right)^2\times\frac{0.050^2}{0.2} = 133\text{N}$$

33. A four-cylinder in-line reciprocating engine is shown in the diagram given below. The cylinders are numbered 1 to 4 and the firing order is 1-4-2-3: **[IES-2004]**





Which one of the following statements is correct?
(a) Both primary and secondary forces are balanced
(b) Only primary force is balanced
(c) Only secondary force is balanced
(d) Both primary and secondary forces are unbalanced
33. Ans. (a)

34. Assertion (A): For a radial engine containing four or more cylinders, the secondary forces are in complete balance, **[IES-2000]**
Reason (R): The secondary direct and reverse cranks form a balanced system in the radial engines.
34. Ans. (a)

35. In a multi-cylinder in-line internal combustion engine, even number of cylinders is chosen so that **[IES-1998]**
(a) uniform firing order is obtained (b) the couples are balanced
(c) primary forces are balanced (d) secondary forces are balanced
35. Ans. (a)

36. When the primary direct crank of a reciprocating engine is positioned at 30° clockwise, the secondary reverse crank for balancing will be at **[IES-1997]**
(a) 30 ° anticlockwise (b) 60° anticlockwise (c) 30° clockwise (d) 60° clockwise
36. Ans. (d)

37. In balancing of 4-stroke in line engines, firing order helps to control the magnitude of
(a) Primary forces only (b) Secondary forces only **[IAS-2003]**
(c) Primary forces and primary couples only (d) Primary and secondary couples only.
37. Ans. (c)

38. Consider the following statements:
An in-line four-cylinder four-stroke engine is completely balanced for
1. primary forces. 2. secondary forces.3. primary couples. 4. secondary couples.
Of these statements: **[IAS-1998]**
(a) 1, 3 and 4 are correct (b) 1, 2 and 4 are correct
(c) 1 and 3 are correct (d) 2 and 4 are correct
38. Ans. (a)

39. An in-line four-cylinder four-stroke engine is balanced in which of the following?
1. Primary forces. 2. Primary couples **[IAS-1997]**
3. Secondary forces. 4. Secondary couples

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

40. In a four-stroke engine, the secondary imbalance has a frequency equal to four times engine speed. **[GATE-1995]**
40. Ans. False
Frequency of secondary imbalance will be two times the engine speed.

Partial balancing Primary unbalanced forces

41. The method of direct and reverse cranks is used in engines for **[IAS-2003]**
(a) the control of speed fluctuations (b) balancing of forces and couples
(c) kinematic analysis (d) vibration analysis
41. Ans. (b)

42. Consider the following statements:
The unbalanced force in a single-cylinder reciprocating engine is
1. equal to inertia force of the reciprocating masses
2. equal to gas force
3. always fully balanced **[IAS-2001]**
Which of the statement(s) is/are correct?
(a) 1 alone (b) 2 alone (c) 1 and 3 (d) 2 and 3
42. Ans. (a)

Tractive force

43. What causes a variation in the tractive effort of an engine?
(a) Unbalanced portion of the primary force, along the line of stroke
(b) Unbalanced portion of the primary force, perpendicular to the line of stroke
(c) The secondary force
(d) Both primary and secondary unbalanced forces **[IAS-2007]**
43. Ans. (a)

Swaying couple

Hammer Blow

44. Which of the following pair(s) is/are correctly matched? **[IES-1998]**
I. Four bar chain Oscillating…………….oscillating converter
II. Inertia governor……………………... Rate of change of engine speed
III. Hammer blow ………………………Reciprocating unbalance.
Select the correct answer using the codes given below:
Codes: (a) I alone (b) I, II and III (c) II and III (d) I and III
44. Ans. (c)

45. Hammer blow

(a) is the maximum horizontal unbalanced force caused by the mass provided to balance the reciprocating masses **[IAS-2002]**
(b) is the maximum vertical unbalanced force caused by the mass added to balance the reciprocating masses
(c) varies as the square root of the speed
(d) varies inversely with the square of the speed
45. Ans. (b)

46. Match 4 correct pairs between list I and List II for the questions **[GATE-1994]**

List I	List II
(a) Collision of bodies	1. Kinetics
(b) Minimum potential energy	2. Reciprocating unbalance
(c) Degree of freedom	3. Dynamics
(d) Prony brake	4. Coefficient of restitution
(e) Hammer blow	5. Stability
(f) Ellipse trammels	6. Gravity idler

46. Ans. (a) – 4, (b) – 5, (e) – 2, (f) – 3

Balancing of multi-cylinder engine

47. Assertion (A): In locomotive engines, the reciprocating masses are only partially balanced. **[IES-1999]**
Reason (R): Full balancing might lead to lifting the locomotive engine off the rails.
47. Ans. (a)

48. Consider the following statements regarding a high speed in-line engine with identical reciprocating parts with cranks spaced to give equal firing intervals:
1. All harmonic forces, except those which are multiples of half the number of cylinders, are balanced. **[IES-1994]**
2. Couples are balanced if the engine is symmetrical about a place normal to the axis of the crank shaft
3. In a four cylinder in-line engine, second and fourth harmonic forces are unbalanced whereas in a six cylinder in-line engine, second, fourth and sixth harmonic forces are unbalanced.
Of these statements
(a) 1, 2 and 3 are correct (b) 1 and 3 are correct
(c) 1 and 2 are correct (d) 2 and 3 are correct
48. Ans. (a)

49. In the statement, "an eccentric mass rotating at 3000 rpm will create X times more unbalanced force than 50% of the same mass rotating at 300 rpm, 'X' stands for
(a) 10 (b) 50 (c) 100 (d) 200 **[IES-1994]**
49. Ans. (d) m x 3000^2 = X x m x 300^2 or X = 200

Answers with Explanation (Objective)

7.

Vibration Analysis

Objective Questions (IES, IAS, GATE)

Natural frequency of free longitudinal vibration

1. Consider the following statements:

    1. SHM is characteristic of all oscillating motions, where restoring force exists.
    2. In SHM, the motion is of uniform velocity. **[IAS-2002]**
    3. Frequency in SHM is equal to number of oscillations.
    4. Frequency is number of complete cycles per unit time.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1 and 4 (c) 1, 2 and 4 (d) 2, 3 and 4

1. Ans. (b)

2. Assertion (A): In a simple harmonic motion, the potential energy reaches its maximum value twice during each cycle. **[IAS-2000]**
Reason(R): Velocity becomes zero twice during each cycle.

2. Ans. (a) As total energy is constant when V = 0, P.E is maximum. And V = 0 becomes at both extreme ends.

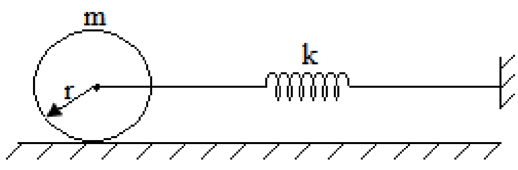
3. A disc of mass 'm' and radius 'r' is attached to a spring of stiffness 'k' During its motion, the disc rolls on the ground. When released from some stretched position, the centre of the disc will execute harmonic motion with a time period of **[IAS 1994]**

(a) $2\pi\frac{\sqrt{m}}{ak}$

(b) $2\pi\frac{\sqrt{m}}{k}$

(c) $2\pi\frac{\sqrt{3m}}{2k}$

(d) $2\pi\frac{\sqrt{2m}}{k}$



3. Ans. (c)

4. A simple pendulum of length 5 m, with a bob of mass 1 kg, is in simple harmonic motion as it passes through its mean position, the bob has a speed of 5 m/s. The net force on the bob at the mean position is **[GATE-2005]**

(a) zero (b) 2.5 N (c) 5 N (d) 25N

4. Ans. (a) Force at mean position is zero.

5. Consider the following statements: **[IAS-1996]**

The period of oscillation of the fluid column in a U-tube depends upon the

1. diameter of U-tube
2. length of the fluid column
3. acceleration due to gravity

Of these statements:

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

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

5. Ans. (d)

6. A mass m attached to a light spring oscillates with a period of 2 sec. If the mass is increased by 2 kg, the period increases by 1sec. The value of m is **[GATE-1994]**

(a) 1 kg (b) 1.6 kg (c) 2 kg (d) 2.4 kg

6. Ans. (b)

$$\text{Period of oscillation } = \frac{\sqrt{\delta}}{4.99}\cdot\frac{\text{seconds}}{\text{cycle}}$$

$$\therefore \qquad \frac{\sqrt{\delta_1}}{4.99} = 2 \quad \text{and} \quad \frac{\sqrt{\delta_2}}{4.99} = 3$$

$$\text{Hence} \qquad \frac{\delta_1}{\delta_2} = \frac{4}{9}$$

$$\text{Now} \qquad mgk = \delta_1 \quad \text{and} \quad (m+2)\,gk = \delta_2$$

where k is the stiffness of the spring.

$$\therefore \qquad 9\delta_1 = 4\delta_2$$

$$\text{or} \qquad 9\,mgk = 4\,(m+2)\,gk$$

$$\therefore \qquad m = \mathbf{1.6\ kg}$$

7. Consider the following statements: **[IAS-1999]**

1. Periodic time is the time for one complete revolution.
2. The acceleration is directed towards the centre of suspension.
3. The acceleration in proportional to distance from mean position.

Of these statements:

(a) 1, 2 and 3 are correct. (b) 2, 3 and 4 are correct

(c) 1, 3 and 4 correct (d) 1, 2 and 4 are correct

7. Ans. (c)

8. Match List-I (Property) with List-II (System) and select the correct answer using the code given below the Lists: **[IES-2006]**

List-I	List - II
A. Resonance	1. Closed-loop control system
B. On-off control	2. Free vibrations
C. Natural frequency	3. Excessively large amplitude
D. Feedback signal	4. Mechanical brake

A B C D A B C D

(a)	1	2	4	3	(b)	3	4	2	1
(c)	1	4	2	3	(d)	3	2	4	1

8. Ans. (b)

9. A rod of uniform diameter is suspended from one of its ends in vertical plane. The mass of the rod is 'm' and length' l', the natural frequency of this rod in Hz for small amplitude is **[IES-2002]**

(a) $\frac{1}{2\pi}\sqrt{\frac{g}{l}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{g}{3l}}$ (c) $\frac{1}{2\pi}\sqrt{\frac{2g}{3l}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{3g}{2l}}$

9. Ans. (c)

10. The equation of free vibrations of a system is $\ddot{x}+36\pi^2x=0$. Its natural frequency is

(a) 6 Hz (b) 3π Hz (c) 3 Hz (d) 6π Hz. **[IES-1995]**

10. Ans. (c) $\omega=\sqrt{36\pi^2}$ and $f=\frac{\omega}{2\pi}$

11. If air resistance is neglected, while it is executing small oscillations the acceleration of the bob of a simple pendulum at the mid-point of its swing will be

(a) zero (b) a minimum but not equal to zero (c) a maximum

(d) not determinable unless the length of the pendulum and the mass of the bob are known **[IES-1997]**

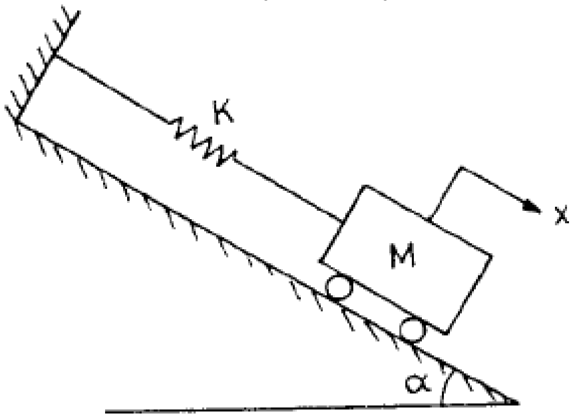
11. ans. (a)

12. A simple spring mass vibrating system has a natural frequency of N. If the spring stiffness is halved and the mass is doubled, then the natural frequency will become

(a) N/2 (b) 2N (c) 4N (d) 8N **[IES-1993]**

12. Ans. (a) Natural frequency of vibration $f_n \infty \sqrt{\frac{k}{m}}$ In new system $f_n \infty \sqrt{\frac{k/2}{2m}}=\frac{1}{2}\sqrt{\frac{k}{m}}=\frac{N}{2}$

13. For the single degree of freedom system shown in the figure, the mass M rolls along an incline of α. The natural frequency of the system will **[IES-1993]**

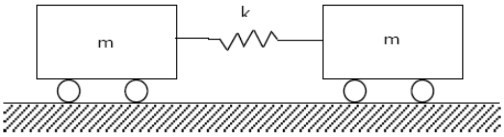


(a) increase as α increases (b) decrease as α increases (c) be independent of α

(d) increase initially as α increases and then decrease with further increase in α

13. Ans. (a) As the angle of indication increases, the mass m will be more and more predominant and the natural frequency of vibration will increase.

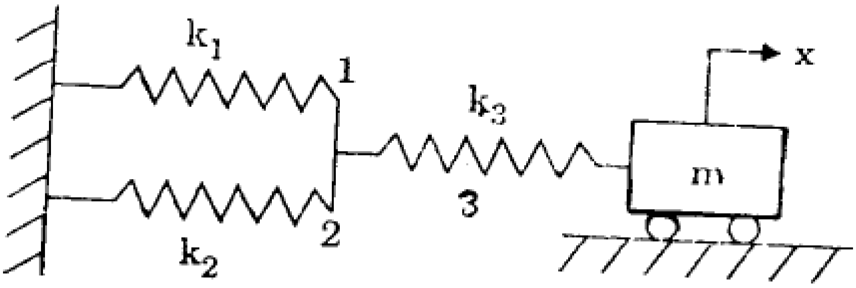
14. Consider the system of two wagons shown in Figure. The natural frequencies of this system are **[GATE-1999]**



(a) $0, \frac{\sqrt{2k}}{m}$ (b) $\frac{\sqrt{k}}{m}, \frac{\sqrt{2k}}{m}$ (c) $\frac{\sqrt{k}}{m}, \frac{\sqrt{k}}{2m}$ (d) $0, \frac{\sqrt{k}}{2m}$

14. Ans. (c)

15.



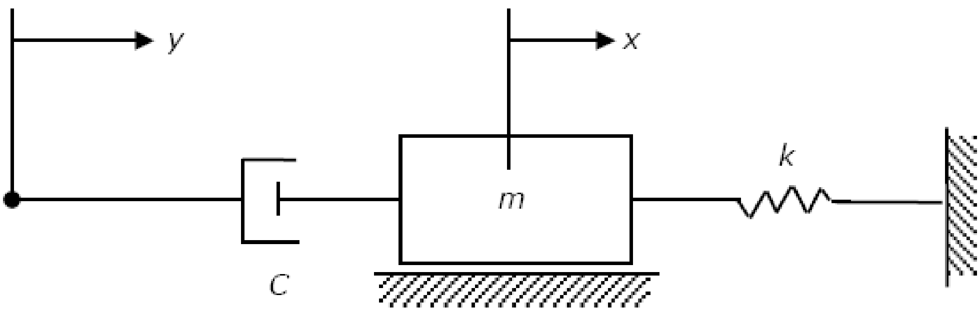
Which one of the following is the correct value of the natural frequency (ω_n) of the system given above? **[IES-2005]**

(a) $\left[\frac{1}{\left\{\frac{1}{(k_1+k_2)}+\frac{1}{k_3}\right\}m}\right]^{1/2}$ (b) $\left(\frac{3k}{m}\right)^{1/2}$ (c) $\left(\frac{k}{3m}\right)^{1/2}$ (d) $\left[\frac{k_3+\left(\frac{1}{\frac{1}{k_1}+\frac{1}{k_2}}\right)}{m}\right]^{1/2}$

15. Ans. (a)

$\omega_n = \sqrt{\frac{K_e}{m}}$; Equivalent stiffness $\frac{1}{(K_e)} = \frac{1}{K_3} + \frac{1}{k_1+k_2}$; $\omega_n = \left[\frac{1}{\left\{\frac{1}{k_1+k_2}+\frac{1}{k_3}\right\}m}\right]^{1/2}$

16. The differential equation governing the vibrating system is **[GATE-2006]**



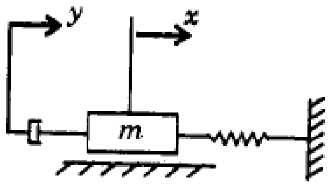
(a) $m\ddot{x}+c\dot{x}+k(x-y)=0$

(b) $m(\ddot{x}-\ddot{y})+c(\dot{x}-\dot{y})+kx=0$

(c) $m\ddot{x}+c(\dot{x}-\dot{y})+kx=0$

(d) $m(\ddot{x}-\ddot{y})+c(\dot{x}-\dot{y})+k(x-y)=0$

16. Ans. (c)



$$\therefore \quad m\frac{d^2x}{dt^2}+c\left(\frac{dx}{dt}-\frac{dy}{dt}\right)+kx=0$$

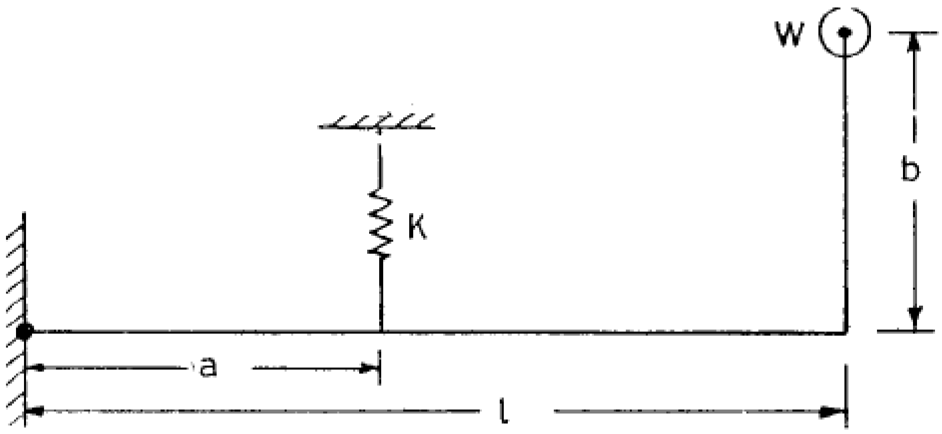
This is the differential equation governing the above vibrating system.

17. For the system shown in the given figure the moment of inertia of the weight W and the ball about the pivot point is I_o, The natural frequency of the system is given by **[IES-1993]**

$$f_n=\frac{1}{2\pi}\sqrt{\frac{Ka^2-Wb}{I_o}}$$

The system will vibrate when

(a) $b<\frac{Ka^2}{W}$ (b) $b=\frac{Ka^2}{W}$ (c) $b>\frac{Ka^2}{W}$ (d) $a=0$



17. For system to vibrate, f_n should be positive, which is possible when $b<\frac{Ka^2}{W}$

18. Two vibratory systems are shown in the given figures. The ratio of the natural frequency of longitudinal vibration of the second system to that of the first is

(a) 4 (b) 2 (c) 0.5 (d) 0.25

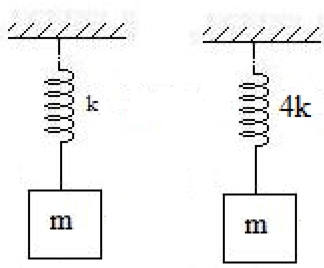
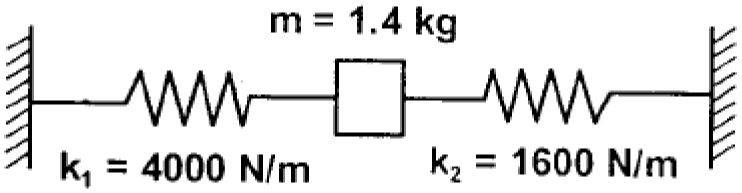


Fig. 1 Fig. 2

[IAS-1998]

18. Ans. (b) $n = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$ $\quad \frac{n_2}{n_1} = \sqrt{\frac{4k}{k}} = 2$

19. The natural frequency of the spring mass system shown in the figure is closest to



[GATE-2008]

(A) 8 Hz (B) 10 Hz (C) 12 Hz (D) 14 Hz

19. Ans. (B)

$m\frac{d^2y}{dx^2} + (K_1 + K_2)y = 0$ Therefore $\omega_n = 2\pi N = \sqrt{\frac{K_1 + K_2}{m}}$ or

N= $\frac{1}{2\pi}\sqrt{\frac{4000+1600}{1.4}} = 10.06\,Hz$

20. A machine mounted on a single coil spring has a period of free vibration of T. If the spring is cut into four equal parts and placed in parallel and the machine is mounted on them, then the period of free vibration of the new system will become.

(a) 16T (b) 4T (c) $\frac{T}{4}$ (d) $\frac{T}{16}$ **[IAS-1995]**

20. Ans. (c)

Period of free vibration of a spring $T \alpha \sqrt{\frac{1}{k}}$ (k = spring stiffness). When a spring is cut into 4 equal pieces, spring stiffness of each cut spring will be $4k$.

When four such springs are placed in parallel, spring stiffness of combination will be $4 \times (4k) = 16\,k$.

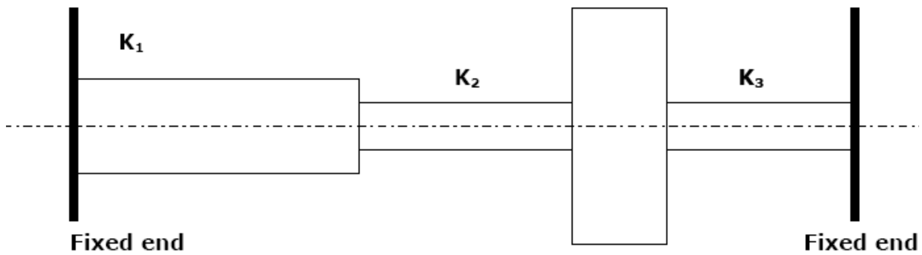
$\therefore$ new $T \alpha \sqrt{\frac{1}{16k}}$ or $\frac{T}{4}$

21. A uniform rigid rod of mass *In* = I kg and length *L* = 1 m is hinged at its centre and laterally supported at one end by a spring of constant *k* = 300 N/m. The natural frequency (ω_n in rad/s is **[GATE-2008]**

(A) 10 (B) 20 (C) 30 (D) 40

21. Ans. (A)

22. Consider the arrangement shown in the figure below where J is the combined polar mass moment of inertia of the disc and the shafts. K_1, K_2, K_3 are the torsional stiffness of the respective shafts. The natural frequency of torsional oscillation of the disc is given by **[GATE-2003]**



(a) $\sqrt{\dfrac{K_1+K_2+K_3}{J}}$ (b) $\sqrt{\dfrac{K_1K_2+K_2K_3+K_3K_1}{J(K_1+K_2)}}$

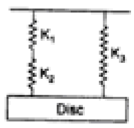
(c) $\sqrt{\dfrac{K_1K_2K_3}{J(K_1K_2+K_2K_3+K_3K_1)}}$ (d) $\sqrt{\dfrac{K_1K_2+K_2K_3+K_3K_1}{J(K_2+K_3)}}$

22. Ans. (b)

$$K_{eq} = \frac{1}{\frac{1}{K_1}+\frac{1}{K_2}} + \frac{1}{K_3}$$

$$= \frac{K_1K_2}{K_1K_2} + K_3$$

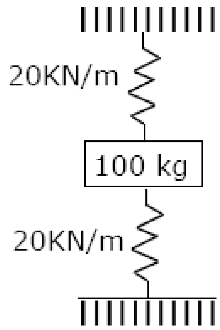
$$= \frac{K_1K_2+K_1K_3+K_2K_3}{K_1+K_2}$$



$\therefore$ Natural frequency $= \sqrt{\dfrac{K_1K_2+K_1K_3+K_2K_3}{J(K_1+K_2)}}$

23. As shown in Figure, a mass of 100 kg is held between two springs. The natural frequency of vibration of the system, in cycles/s, is

$(a)\dfrac{1}{2\pi}$ $(b)\dfrac{5}{\pi}$ $(c)\dfrac{10}{\pi}$ $(d)\dfrac{20}{\pi}$



[GATE-2000]

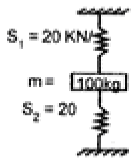
23. Ans. (c)

$$S = S_1 + S_2 = 20 + 20$$

$$= 40\ \text{kN/m} = 40{,}000\ \text{N/m}$$

$\therefore$ Natural frequency of vibration of the system,

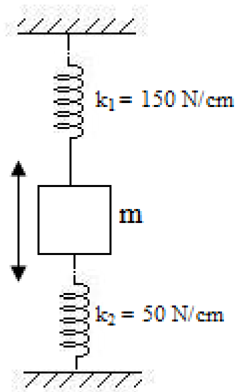
$$f_n = \frac{1}{2\lambda}\sqrt{\frac{S}{m}} = \frac{1}{2\lambda}\sqrt{\frac{40\times 1000}{100}} = \frac{20}{2\lambda} = \frac{10}{\lambda}$$



24. For the vibratory system shown in the given figure, the natural frequency of vibration in rad. /sec is

(a) 43.3 (b) 86.6

(c) 100 (d)200



[IAS-1997]

24. Ans. (c) Equivalent (K) = $K_1 + K_2$ = 200 N/cm = 20000 N/m

Mass = 2 kg. Natural frequency $(\omega) = \sqrt{\dfrac{K}{m}} = \sqrt{\dfrac{20000}{2}} = 100\,\text{rad/s}$

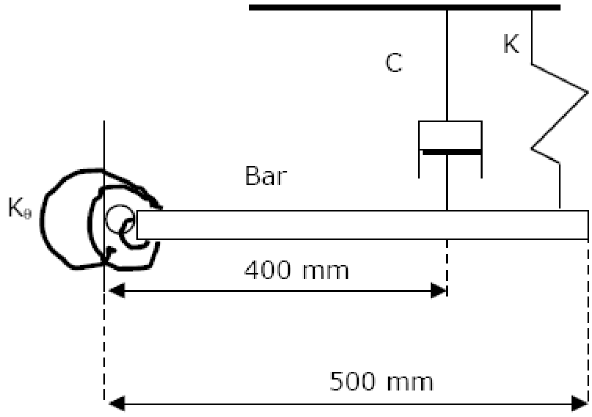
25. In a single degree of freedom vibration system, the undamped natural frequency is…….. to/than the damped natural frequency. (greater than/equal/less)

[GATE-1995]

25. Ans. greater than

Data for Q. 26 - 27 are given below. Solve the problems and choose correct answers.

A uniform rigid slender bar of mass 10 kg, hinged at the left end is suspended with the help of spring and damper arrangement as shown in the figure where K = 2 kN/m, C = 500 Ns/m and the stiffness of the torsional spring k_θ is 1 kN/m/rad. Ignore the hinge dimensions.



26. The un-damped natural frequency of oscillations of the bar about the hinge point is **[GATE-2003]**

(a) 42.43 rad/s (b) 30 rad/s (c) 17.32 rad/s (d) 14.14 rad/s

26. Ans. (a)

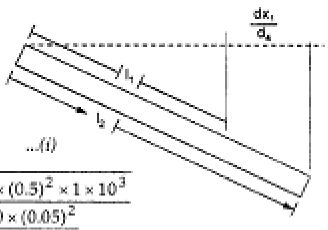
$x_1 = l_1 Q$

$x_2 = Q.l_2$

For small deflection, after equilibrium.

Taking momentum about O

$$C\frac{dx_1}{dt}.l_1 + kx_2 l_2 + I\alpha + k_0.Q = 0 \quad ...(i)$$



$$w_n = \sqrt{\frac{kl_2^2 + kw}{\frac{ml^2}{3}}} = \sqrt{\frac{2\times10^3\times(0.5)^2\times1\times10^3}{\frac{10\times(0.05)^2}{3}}}$$

$$= \sqrt{\frac{1.5\times10^3\times3}{10\times(.5)^2}}$$

$= 42.43$ rad/sec.

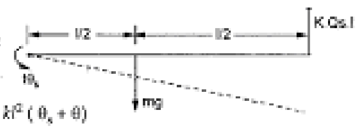
27. The damping coefficient in the vibration equation is given by **[GATE-2003]**

(a) 500 Nms/rad (b) 500 N/(m/s) (c) 80 Nms/rad (d) 80 N/(m/s)

27. Ans. (c)

For staic equilibrium

$$k_t.\theta_s + k_t.\theta_s L^2 = mgl^2$$



For additional deflection θ, equation will be.

$$I.\ddot{\theta} = \frac{mgl}{2} - k_t(\theta_s + \theta) - C.l_1^2\dot{\theta} - kl^2(\theta_s + \theta)$$

$$\Rightarrow \quad I.\ddot{\theta} + C.l_1^2\dot{\theta} + (k_t + kl^2)\theta = 0$$

where, $I = ml^2/3$

$\therefore$ Un-damped frequency, $\omega = \sqrt{\frac{(k_t + kl^2)\times3}{ml^2}}$

$$= \sqrt{\frac{(1000 + 2000\times0.5)^2\times3}{10\times0.5^2}}$$

$= 42.426$

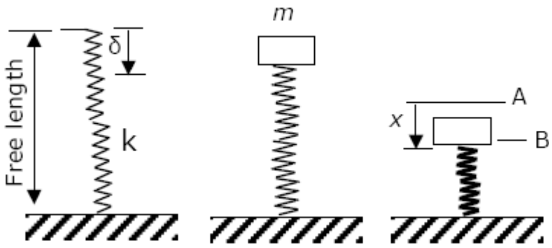
$= 42.43$ rad/sec.

and, Equivalent damping coefficient $= Cl_1^2$ Nm/rad

$= 500 \times (0.04)^2$

$= 80$ Nms/rad

28. In the figure shown, the spring deflects by δ to position A (the equilibrium position) when a mass m is kept on it. During free vibration, the mass is at position B at some instant. The change in potential energy of the spring-mass system from position A to position B is **[GATE-2001]**



(a) $\frac{1}{2}kx^2$ (b) $\frac{1}{2}kx^2 - mgx$ (c) $\frac{1}{2}k(x+\delta)^2$ (d) $\frac{1}{2}kx^2 + mgx$

28. Ans. (b)

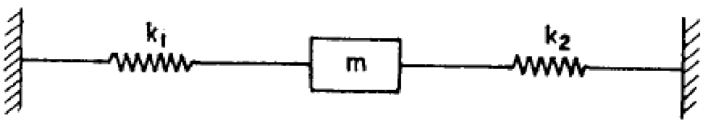
Explanation : Potential energy at A $= mg(l - \delta)$

Total energy at B $= mg[l - (\delta + x)] + \frac{1}{2}kx^2$

$\therefore$ Change in energy $= mgl - mg(\delta + x) + \frac{1}{2}kx^2 - mgl + mg\delta$.

$= \frac{1}{2}kx^2 - mgx.\delta$

29. For the spring-mass system shown in the given figure, the frequency of oscillations of the block along the axis of the springs is



[IES-1996]

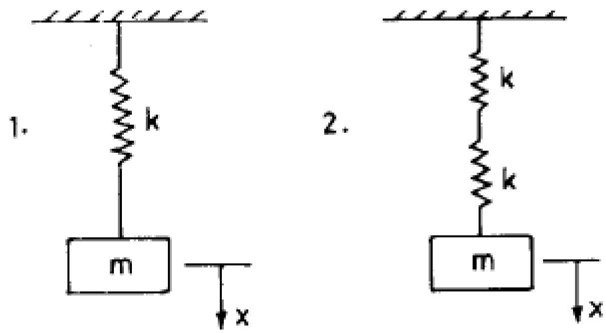
(a) $\frac{1}{2\pi}\sqrt{\frac{k_1 - k_2}{m}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{k_1 k_2}{(k_1 + k_2)m}}$ (c) $\frac{1}{2\pi}\sqrt{\frac{k_1 + k_2}{m}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{m}{(k_1 + k_2)}}$

29. Ans. (c)

30. For the spring-mass system shown in the figure 1, the frequency of vibration is N. What will be the frequency when one more similar spring is added in series, as shown in figure 2?

(a) N/2 (b) N/$\sqrt{2}$

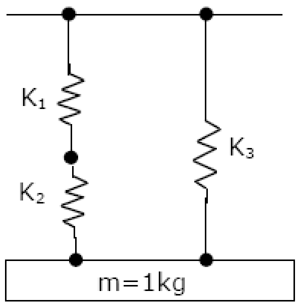
(c) $\sqrt{2}$ /N (d) 2N.



[IES-1995]

30. Ans. (b)

31. A mass of 1 kg is suspended by means of 3 springs as shown in figure. The spring constants K_1, K_2 and K_3 are respectively 1 kN/m, 3kN/m and 2 kN/m. The natural frequency of the system is approximately



[GATE-1996]

(a) 46.90 Hz (b) 52.44 Hz (c) 60.55 Hz (d) 77.46 Hz

31. Ans. (b)

Explanation. We know,

$$\frac{1}{K_s} = \frac{1}{K_1} + \frac{1}{K_2}$$

$$= \frac{1}{1} + \frac{1}{3} = \frac{4}{3} \text{ kN/m}$$

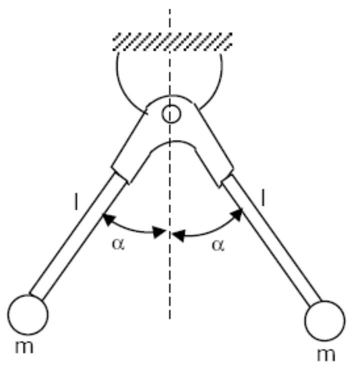
$$\text{Combined stiffness} = K_s + K_3$$

$$= \frac{3}{4} + 2$$

$$= \frac{11}{4} \text{kN / m}$$

$$\therefore \quad f = \frac{1}{2\pi}\sqrt{\frac{11 \times 10^3}{4 \times 1}} = \mathbf{52.44\ Hz}$$

32. The assembly shown in the figure is composed of two mass less rods of length 'l' with two particles, each of mass m. The natural frequency of this assembly for small oscillations is



(a) $\sqrt{g/l}$

(b) $\sqrt{2g/(l\cos\alpha)}$

(c) $\sqrt{g/(l\cos\alpha)}$

(d) $\sqrt{(g\cos\alpha)/l}$

[GATE-2001]

32. Ans. (d)

Explanation : Net restoring torque when displaced by a small angle θ,

$$\tau = mg\cos(\alpha - \theta)\, l - mg(\alpha + \theta)\, l = 2\, mgl\cos\alpha\sin\theta$$

For very small θ, $\sin\theta \approx \theta$

$$\therefore \quad \tau = 2mgl\cos\alpha\,\theta \text{ (restorative)}$$

Now, $$I\frac{d^2\theta}{dt^2} + 2mgl\cos\alpha\,\theta = 0$$

But $I = 2ml^2$

$$\therefore \quad 2ml^2\frac{d^2\theta}{dt^2} + 2mgl\cos\alpha\,\theta = 0$$

or $$\frac{d^2\theta}{dt^2} + \frac{g\cos\alpha}{l}\theta = 0$$

$$\therefore \quad \omega_n = \sqrt{\frac{g\cos\alpha}{l}}$$

33. Match List I (Applications) with List II (Features of vibration) and select the correct answer using the codes given below the Lists: **[IES-2000]**

List I	List II
A. Vibration damper	1. Frequency of free vibration
B. Shock absorber	2. Forced vibration
C. Frahm tachometer	3. Damping of vibration
D. Oscillator	4. Transverse vibration
	5. Absorption of vibration

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

33. Ans. (a)

Energy method

Rayleigh's method

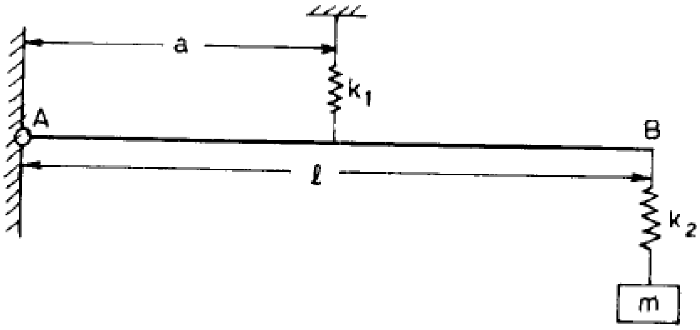
Natural frequency of free transverse vibration

34. The natural frequency of transverse vibration of a massless beam of length L having a mass m attached at its midspan is given by (EI is the flexural rigidity of the beam) **[IES-2001]**

(a) $\left(\frac{mL^3}{48EI}\right)^{\frac{1}{2}}$ rad/s (b) $\left(\frac{48mL^3}{EI}\right)^{\frac{1}{2}}$ rad/s (c) $\left(\frac{48EI}{mL^3}\right)^{\frac{1}{2}}$ rad/s (d) $\left(\frac{3EI}{mL^3}\right)^{\frac{1}{2}}$ rad/s

34. Ans. (c)

35. A system is shown in the following figure. The bar AB is assumed to be rigid and weightless.
The natural frequency of vibration of the system is given by



[IES-1994]

(a) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1k_2(a/l)^2}{m[k_2+(a/l)^2k_1]}}$

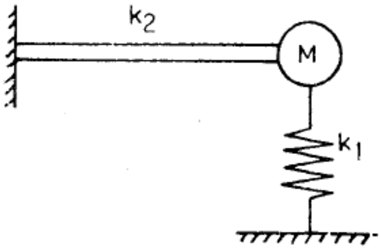
(b) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1k_2}{m(k_1+k_2]}}$

(c) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1}{mk_2}}$

(d) $f_n = \frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{mk_1k_2}}$

35. Ans. (a)

36. A cantilever beam of negligible weight is carrying a mass M at its free end, and is also resting on an elastic support of stiffness k_1 as shown in the figure below.
If k_2 represents the bending stiffness of the beam, the natural frequency (rad/s) of the system is **[GATE-1993]**



(a) $\sqrt{\dfrac{k_1k_2}{M(k_1+k_2)}}$ (b) $\sqrt{\dfrac{2(k_1+k_2)}{M}}$ (c) $\sqrt{\dfrac{k_1+k_2}{M}}$ (d) $\sqrt{\dfrac{k_1-k_2}{M}}$

36. Ans. (c)

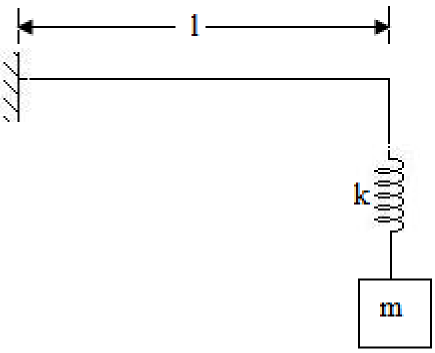
$$\text{Natural frequency, } F = \frac{1}{2\pi}\sqrt{\frac{k}{M}}$$

$$\text{where } \quad k = k_1 + k_2$$

$$f = \frac{1}{2\pi}\sqrt{\frac{(k_1+k_2)}{M}}$$

37. A vibratory system is shown in the given figure. The flexural rigidity of the light cantilever beam is EI. The frequency of small vertical vibrations of mass m is

(a) $\dfrac{\sqrt{3EIk}}{\left(3EI+K\iota^3\right)m}$ (b) $\dfrac{k}{m}$ (c) $\dfrac{\sqrt{k\iota^3+3EI}}{m\iota^3}$ (d) $\dfrac{\sqrt{k\iota^3-3EI}}{m\iota^3}$ **[IAS-1997]**



37. Ans. (a)

38. A uniform cantilever beam undergoes transverse vibrations. The number of natural frequencies associated with the beam is **[IAS-1998]**

(a) 1 (b) 10 (c) 100 (d) infinite

38. Ans. (d)

39. A reed type tachometer uses the principle of

(a) torsional vibration (b) longitudinal vibration
(c) transverse vibration (d) damped free vibration

39. Ans. (c)

Effect of Inertia on the longitudinal and transverse vibration

40. A uniform bar, fixed at one end carries a heavy concentrated mass at the other end. The system is executing longitudinal vibrations. The inertia of the bar may be taken into account by which one of the following portions of the mass of the bar at the free end?

(a) $\frac{5}{384}$ (b) $\frac{1}{48}$ (b) $\frac{33}{140}$ (d) $\frac{1}{3}$ **[IES 2007]**

40. Ans. (d)

41. If a mass 'm' oscillates on a spring having a mass m_s and stiffness 'k', then the natural frequency of the system is given by **[IES-1998]**

(a) $\sqrt{\frac{k}{m+\frac{m_s}{3}}}$ (b) $\sqrt{\frac{k}{\frac{m}{3}+m_s}}$ (c) $\sqrt{\frac{3k}{m+m_s}}$ (d) $\sqrt{\frac{k}{m+m_s}}$

41. Ans. (a) 3

42. In a simple spring mass vibrating system, the natural frequency ω_n of the system is (k is spring stiffness, m is mass and m_s, is spring mass) **[IAS-2000]**

(a) $\sqrt{\frac{K}{m-\frac{m_s}{3}}}$ (b) $\sqrt{\frac{K}{m+\frac{m_s}{3}}}$ (c) $\sqrt{\frac{K}{m+3m_s}}$ (d) $\sqrt{\frac{K}{m-3m_s}}$

42. Ans. (b)

43. If the length of the cantilever beam is halved, then natural frequency of the mass M at the end of this cantilever beam of negligible mass is increased by a factor of

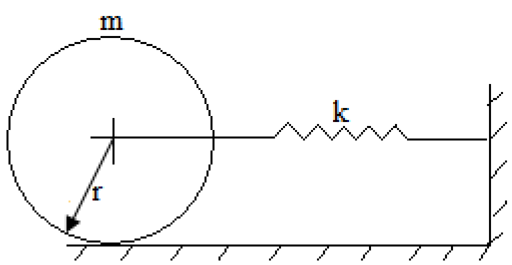
(a) 2 (b) 4 (c) $\sqrt{8}$ (d) 8 **[GATE-2002]**

43. Ans. (c)

Natural frequency of free transverse vibrations of a shaft subjected to a number of point load

Rayleigh's method (accurate result)

44.



A rolling disc of radius 'r' and mass 'm' is connected to one end of a linear spring of stiffness 'k', as shown in the above figure. The natural frequency of oscillation is given by which one of the following? **[IES 2007]**

(a) $\omega = \sqrt{\frac{2}{3}\frac{k}{m}}$ (b) $\omega = \sqrt{\frac{k}{m}}$ (c) $\omega = \sqrt{\frac{k}{2m}}$ (d) $\omega = \sqrt{\frac{2k}{m}}$

44. Ans. (a) Energy method $\frac{d}{dt}\left[\frac{1}{2}m\left(\frac{dx}{dt}\right)^2+\frac{1}{2}I\left\{\frac{1}{r}\left(\frac{dx}{dt}\right)\right\}^2+\frac{1}{2}kx^2\right]=0$

where I = mk^2

or $\frac{d}{dt}\left[\frac{3m}{2}\left(\frac{dx}{dt}\right)^2 + kx^2\right] = 0$ or $\frac{3m}{2}.\frac{d^2x}{dt^2} + kx = 0$

or $\frac{d^2x}{dt^2} + \left(\frac{2k}{3m}\right)x = 0$ or $\omega^2 = \frac{2k}{3m}$

45. The value of the natural frequency obtained by Rayleigh's method **[IES-1999]**
(a) is always greater than the actual fundamental frequency
(b) is always less than the actual fundamental frequency
(c) depends upon the initial deflection curve chose and may be greater than or less than the actual fundamental frequency
(d) is independent of the initial deflection curve chosen
45. Ans. (d)

46. Which of the following methods can be used to determine the damping of machine element?
1. Logarithmic method 2. Band-width method 3. Rayleigh method 4. Holzer method
Select the correct answer using the codes given below: **[IES-1995]**
Codes: (a) 1 and 3 (b) 1 and 2 (c) 3 and 4 (d) 1, 3 and 4.
46. Ans. (b)

47. Consider the following methods: **[IAS-2001]**
1. Energy method 2. Equilibrium method 3. Rayleigh's method
Which of these methods can be used for determining the natural frequency of the free vibrations?
(a) 1 and 2 (b) 1, 2 and 3 (c) 1 and 3 (d) 2 and 3
47. Ans. (b)

48. Which one of the following pairs is correctly matched? **[IAS-1995]**
(a) Coulomb---------- Energy Principle
(b) Rayleigh------------ Dynamic Equilibrium
(c) D' Alembert-------- Damping Force
(d) Fourier------------- Frequency domain analysis
48. Ans. (d) Coulomb is concerned with damping force, Rayleigh with energy principle, *D'* Alembert with dynamic equilibrium, and Fourier with frequency domain analysis. Thus the correctly matched pair is *(d).*

Dunkerley's method (Approximate result)

49. Consider the following statements:
1. Critical or whirling speed of the shaft is the speed at which it tends to vibrate violently in the transverse direction. **[IAS-2003]**
2. To find the natural frequency of a shaft carrying several loads, the energy method gives accurate result.
3. Dunkerley's method gives approximate results of the natural frequency of a shaft carrying several loads.

Which of these statements is/are correct?
(a) 1 only (b) 2 and 3 (c) 1 and 3 (d) 1, 2 and 3
49. Ans. (a)

Frequency of free damped vibration

50. A system has viscous damped output. There is no steady-state lag if input is
(a) unit step displacement (b) step velocity **[IES-2001]**
(c) harmonic (d) step velocity with error-rate damping
50. Ans. (c)

51. There are four samples P, Q, Rand S, with natural frequencies 64, 96, 128 and 256 Hz, respectively. They are mounted on test setups for conducting vibration experiments. If a loud pure note of frequency 144 Hz is produced by some instrument, which of the samples will show the most perceptible induced vibration?
(a) P (b) Q (c) R (d) S **[GATE-2005]**
51. Ans. (a)

Damping factor

52. A motion is aperiodic at what value of the damping factor? **[IES 2007]**
(a) 1.0 or above (b) 0.5 (c) 0.3 (d) 0.866
52. Ans. (a)

53. The equation of motion for a damped viscous vibration is $3\ddot{x} + 9\dot{x} + 27x = 0$
The damping factor is **[IES-2000]**
(a) 0.25 (b) 0.50 (c) 0.75 (d) 1.00
53. Ans. (b)

54. A viscous damping system with free vibrations will be critically damped if the damping factor is **[IAS-2000]**
(a) zero (b) less than one (c) equal to one (d) greater than one
54. Ans. (c)

55. The transmitted force through a mass-spring damper system will be greater than the transmitted through rigid supports for all values of damping factors, if the frequency ratio $\left(\frac{\omega}{\omega_n}\right)$ is **[IAS-1999]**
(a) more than $\sqrt{2}$ (b) less than $\sqrt{2}$ (c) equal to one (d) less than one
55. Ans. (b)

56. If a damping factor in a vibrating system is unity, then the system will **[IAS-1996]**
(a) have no vibrations (b) be highly damped (c) be under damped (d) be critically damped
56. Ans. (d)

57. A machine of 250 kg mass is supported on springs of total stiffness 100 kN/m. Machine has an unbalanced rotating force of 350 N at speed of 3600 rpm. Assuming a damping factor of 0.15, the value of transmissibility ratio is **[GATE-2006]**
(a) 0.0531 (b) 0.9922 (c) 0.0162 (d) 0.0028
57. Ans. (d)

$$\omega_n = \sqrt{\frac{S}{M}} = 20$$

$$\omega = \frac{2\pi \times N}{60} = 377$$

$$\therefore \text{ Transmissibility ratio } = \frac{\omega_n^2}{\omega^2 - \omega_n^2} = 0.0028$$

58. The natural frequency of an undamped vibrating system is 100 rad/s A damper with a damping factor of 0.8 is introduced into the system, The frequency of vibration of the damped system, m rad/s, is **[GATE-2000]**

(a) 60 (b) 75 (c)80 (d) 100

58. Ans. (a)

$\xi < 1$, hence it is underdamped vibration case.

$\therefore$ Frequency of the system, $\omega_d = \sqrt{1-\xi^2} \cdot \omega_n$

$= \sqrt{1-0.64} \times 100 = 60$

59. The equation of motion for a single degree of freedom system **[IES-1996]**

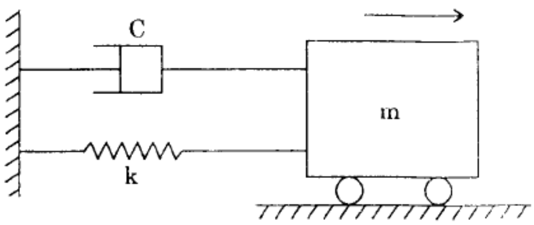
$4\ddot{x} + 9\dot{x} + 16x = 0$

The damping ratio of the system is

(a) $\frac{9}{128}$ (b) $\frac{9}{16}$ (c) $\frac{9}{8\sqrt{2}}$ (d) $\frac{9}{8}$

59. Ans. (b) $\omega_n = \sqrt{\frac{16}{4}} = 2$; $2\xi\omega_n = \frac{9}{4}$; $\xi = \frac{9}{4 \times 4} = \frac{9}{16}$

60. The figure shows a critically damped spring-mass system undergoing single degree of freedom vibrations. If m = 5 kg and k = 20 N/m, the value of viscous damping coefficient is



(a) 10 Ns/m (b) 20 Ns/m

(c) 4 Ns/m (d) 8 Ns/m **[IAS-2003]**

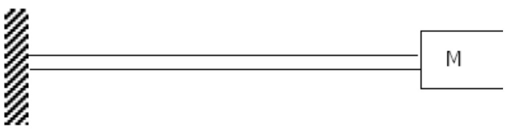
60. Ans. (b)

Critical dampling co-efficient = $2\,m\omega_n$

$= 2 \times m \times \sqrt{\frac{S}{m}}$

$= 2\sqrt{5}\,m = 2\sqrt{20 \times 5} = 20$ Ns/m

61. A mass M, of 20 kg is attached to the free end of a steel cantilever beam of length 1000 mm having a cross-section of 25 x 25 mm. Assume the mass of the cantilever to be negligible and E_{steel} = 200 GPa. If the lateral vibration of this system is critically damped using



a viscous damper, then damping constant of the damper is **[GATE-2004]**

(a) 1250 Ns/m (b) 625 Ns/m
(c) 312.50 Ns/m (d) 156.25 Ns/m

61. Ans. (a)

$$\delta = \frac{wl^3}{3EI} = \frac{mgl^3}{3E\frac{a^4}{12}} = \frac{4mgl^3}{Ea^4}$$

$$\omega_n = \sqrt{\frac{s}{m}} \times \sqrt{\frac{g}{\delta}} = \frac{a^2}{2}\sqrt{\frac{E}{ml^3}} = \frac{(0.025)^2}{2}\sqrt{\frac{200\times10^9}{20\times1^3}} = 31.25\,\text{cycle/s}$$

Therefore $c_c = 2m\omega_n = 2\times20\times31.25\,\text{Ns/m} = 1250\,\text{Ns/m}$

62. A mass of 1 kg is attached to the end of a spring with stiffness 0.7 N/mm. The critical damping coefficient of this system is **[IES-1994]**

(a) 1.40 Ns/m (b) 18.522 Ns/m (c) 52.92 Ns/m (d) 529.20 Ns/m

62. Ans. (c)

For critical damping, $\xi = 1 = \frac{c}{2m\omega_n}$, $c = 2\times1\times\sqrt{\frac{s}{m}} = 2\sqrt{\frac{700}{1}} = 52.92\,\text{Ns/m}$

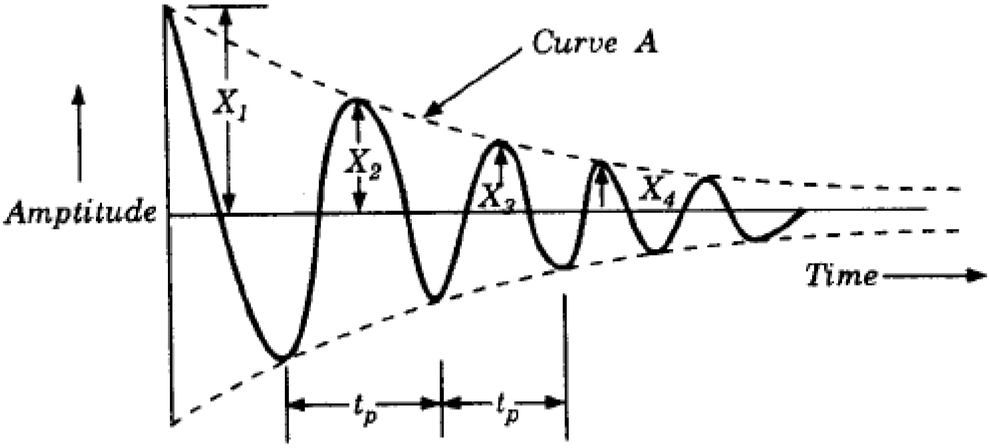
63. A spring-mass suspension has a natural frequency of 40 rad/s. What is the damping ratio required if it is desired to reduce this frequency to 20 rad/s by adding a damper to it?

(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{1}{2}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{4}$ **[IAS-2004]**

63. Ans. (a) $W_d = W_n\sqrt{1-\varepsilon^2}$ or $20 = 40\sqrt{1-\varepsilon^2}$ or $\varepsilon = \frac{\sqrt{3}}{2}$

Logarithmic Decrement

64. The amplitude versus time curve of a damped-free vibration is shown in the figure. Curve labelled 'A' is **[IES-1998]**



(a) a logarithmic decrement curve (b) an exponentially decreasing curve
(c) a hyperbolic curve (d) a linear curve

64. Ans. (a)

Frequency of under damped forced vibration

65. With symbols having the usual meanings, the single degree of freedom system, $m\ddot{x}+c\dot{x}+kx=F\sin\omega t$ represents **[IES-1993]**

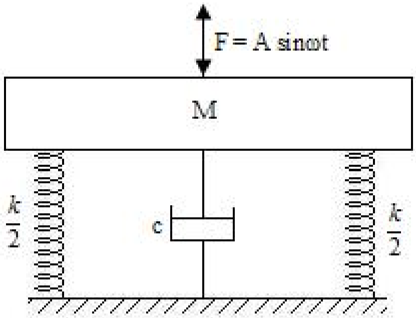
(a) free vibration with damping (b) free vibration without damping
(c) forced vibration with damping (d) forced vibration without damping

65. Ans. (c) Since the equation involves $c\dot{x}$ and $F\sin\omega t$, It means it is case of forced vibrations with damping.

66. The given figure shows vibrations of a mass 'M' isolated by means of springs and a damper. If an external force 'F' (=A sin ωt) acts on the mass and the damper is not used, then

(a) $\sqrt{\frac{k}{M}}$ (b) $\frac{1}{2}\sqrt{\frac{k}{M}}$

(c) $2\sqrt{\frac{k}{M}}$ (d) $\sqrt{\frac{k}{2M}}$

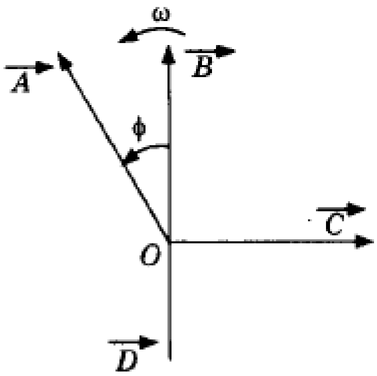


[IAS-1999]

66. Ans. (a) As damper is not used, c = 0, $m\frac{d^2x}{dt^2}+\left(\frac{k}{2}+\frac{k}{2}\right)x=0$ gives $\omega=\sqrt{\frac{K}{m}}$

67. The given figure depicts a vector diagram of forces and displacements in the case of Forced Damped Vibration. If vector A represents the forcing function P = $P_o$sin ω t, vector B the displacement y = Y sin ωt, and ϕ the phase single between them, then the vectors C and D represent respectively

(a) the force of inertia and the force of damping
(b) the elastic force and the damping force
(c) the damping force and the inertia force
(d) the damping force and the elastic force



[IES-1997]

67. Ans. (c) Inertia force is in phase with displacement but opposite in direction to acceleration, and damping force lags displacement by 90°.

68. In a forced vibration with viscous damping, maximum amplitude occurs when forced frequency is **[IES-1999]**

(a) equal to natural frequency (b) slightly less than natural frequency
(c) .slightly greater than natural frequency (d) zero

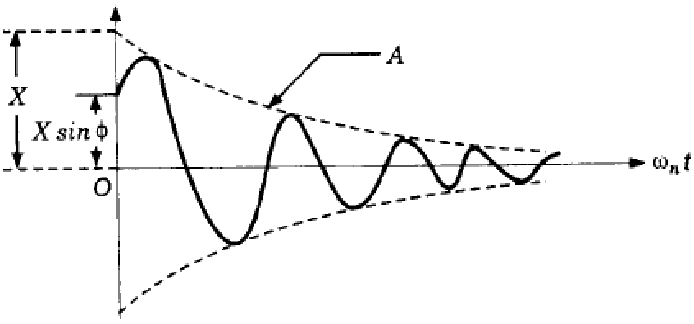
68. Ans. (a)

69. A damped free vibration is expressed by the general equation

$x=Xe^{-\xi\omega_n t}\sin\left(\sqrt{1-\xi^2}\,\omega_n t+\phi\right)$

which is shown graphically below:

The envelope A has the equation:



[IES-1997]

(a) Xe^{-t} (b) $X\sin\left(\sqrt{1-\xi^2}\right)\omega_n t$ (c) $e^{-\xi\omega_n t}$ (d) $Xe^{-\xi\omega_n t}$

69. Ans. (d)

70. When the mass of a critically damped single degree of freedom system is deflected from its equilibrium position and released, it will **[IES-1996]**
(a) return to equilibrium position without oscillation
(b) oscillate with increasing time period
(c) oscillate with decreasing amplitude (d) oscillate with constant amplitude.
70. Ans. (a)

71. For a harmonically excited single degree of freedom viscous damped system, which one of the following is correct? **[IAS-2007]**
(a) Inertia force leads damping force by 90° while damping force leads spring force by 90°
(b) Spring force leads damping force by 90° while damping force leads inertia force by 180°
(c) Spring force and damping force are in phase, and inertia force leads them by 90°
(d) Spring force and inertia force are in phase, and damping force leads them by 90°
71. Ans. (a) x=A cos (ωt-ϕ)

$$\frac{dx}{dt} = -\omega A\sin(\omega t-\phi) = \omega A\cos\left[90+(\omega t-\phi)\right]$$

$$\frac{d^2x}{dt^2} = -\omega^2 A\cos(\omega t-\phi) = \omega^2 A\cos\left[180+(\omega t-\phi)\right]$$

$$m\times\frac{d^2x}{dt^2}+c\frac{dx}{dt}+sx = F\cos(\omega t-\phi)$$

72. In a forced vibrations with viscous damping, maximum amplitude occurs when the forced frequency is **[IAS-1999]**
(a) equal to natural frequency (b) slightly less than natural frequency
(c) slightly greater than natural frequency (d) zero
72. Ans. (b)

73. The assumption of viscous damping in practical vibrating system is
(a) one of reality **[IAS 1994]**
(b) to make the resulting differential equation linear
(c) to make the resulting differential equatic1n non-liner
(d) to make the response of the mass linear with time
73. Ans. (a)

74. In a spring-mass system, the mass is 0.1 kg and the stiffness of the spring is 1 kN/m. By introducing a damper, the frequency of oscillation is found to be 90% of the original value. What is the damping coefficient of the damper? **[GATE-2005]**
(a) 1.2 N.s/m (b) 3.4 N.s/m (c) 8.7 N.s/m (d) 12.0 N.s/m
74. Ans. (c)

$$f_d = 0.9 f_n$$

$\Rightarrow$ $$\omega_d = 0.9\,\omega_n$$

$\Rightarrow$ $$\sqrt{\omega_n^2 - a^2} = 0.9\,\omega_n$$

Squaring $$\omega_n^2 - a^2 = 0.81\,\omega_n^2$$

$\Rightarrow$ $$0.19\omega_n^2 = a^2$$

$\Rightarrow$ $$0.19 \times \frac{s}{m} = \frac{c^2}{(2m)^2}$$

$\Rightarrow$ $$c^2 = 0.76\,sm$$

$\Rightarrow$ $$c = \sqrt{0.76 \times 1 \times 10^3 \times 0.1} = 8.717\ \text{Ns/m}$$

Magnification factor or Dynamic magnifier

75. In a system subjected to damped forced vibrations, the ratio of maximum displacement to the static deflection is known as **[IAS-2003]**
(a) Critical damping ratio (b) Damping factor
(c) Logarithmic decrement (d) Magnification factor
75. Ans. (d)

76. The ratio of the maximum dynamic displacement due to a dynamic force to the deflection due to the static force of the same magnitude is called the **[IAS 1994]**
(a) displacement ratio (b) deflection ratio (c) force factor (d) magnification factor
76. Ans. (d)

77. Under logarithmic decrement, the amplitude of successive vibrations are
(a) constant (b) in arithmetic progression **[IES-1992]**
(c) in geometric progression (d) in logarithmic progression
77. Ans. (c)

Statement for Linked Answer Questions 78 & 79:
A vibratory system consists of a mass 12.5 kg, a spring of stiffness 1000 N/m, and a dashpot with damping coefficient of 15 Ns/m.
78. The value of critical damping of the system is **[GATE-2006]**
(a) 0.223 Ns/m (b) 17.88 Ns/m (c) 71.4 Ns/m (d) 223.6 Ns/m
78. Ans. (d)

For critical damping, $C_c = 2m \times \sqrt{\frac{S}{M}} = 223.6\ \text{Ns/m}$

79. The value of logarithmic decrement is **[GATE-2006]**
(a) 1.35 (b) 1.32 (c) 0.68 (d) 0.66
79. Ans. (d)

Logarithmic decrement, $\delta = \dfrac{2\pi \times C}{\sqrt{C_c^2 - C^2}} = 0.42$

80. Logarithmic decrement of a damped single degree of freedom system is δ .If the stiffness of the spring is doubled and the mass is made half, then the logcrithmic decrement of the new system will be equal to **[IAS-1997]**

(a) $\frac{1}{4}\delta$ (b) $\frac{1}{2}\delta$ (c) δ (d) 2δ

80. Ans. (c)

Logarithmic decrement $(\delta) = \ln\left(\frac{x_n}{x_{n+1}}\right) = \frac{2\pi c}{\sqrt{c_c^2 - c^2}}$ $\quad c_c = 2m\omega_n = 2m\sqrt{\frac{s}{m}} = 2\sqrt{sm}$

$\delta = \frac{2\pi c}{\sqrt{4sm - c^2}}$ if s $\uparrow$ to double and m $\downarrow$ to half so $\quad$ sm = constant and δ remains the same.

81. A machine of 100 kg mass has a 20 kg rotor with 0.5 mm eccentricity. The mounting springs have stiffness 85 kN/m, and damping is negligible. If the operating speed is 20π rad/s and the unit is constrained to move vertically, the dynamic amplitude of the machine will be **[IES-1994]**

(a) 0.470×10^{-4} m (b) 1.000×10^{-4} m (c) 1.270×10^{-4} m (d) 2.540×10^{-4} m

81. Ans. (a) $\omega_n = \sqrt{\frac{s}{m}} = \sqrt{\frac{85\times1000}{120}} = 26.6,\ \frac{\omega}{\omega_n} = \frac{20\pi}{26.6} = 2.36$

Dynamic amplitude of machine =

$$D = \frac{me}{M}\left(\frac{\omega}{\omega_n}\right)^2 / \left[\left\{1-\left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(2\frac{\omega}{\omega_n}\right)^2\right] = 0.47\times10^{-4}\ \text{m}$$

Vibration Isolation and Transmissibility

82. In a vibration isolation system, if $\frac{\omega}{\omega_n} > 1$, then what is the phase difference between the transmitted force and the disturbing force? **[IAS-2007]**

(a) 0° (b) 45° (c) 90° (d) 180°

82. Ans. (d)

83. For effective vibration isolation, the natural frequency w of the system must be (w is the forcing frequency) **[IAS 1994]**

(a) $\omega/4$ (b) ω (c) 4ω (d) 10ω

83. Ans. (a)

84. A vibrating machine is isolated from the floor using springs. If the ratio of excitation frequency of vibration of machine to the natural frequency of the isolation system is equal to 0.5, then transmissibility of ratio of isolation is **[GATE-2004]**

$(a)\frac{1}{2}$ $(b)\frac{3}{4}$ $(c)\frac{4}{3}$ $(d)2$

84. Ans. (c)

$$\text{Transmissibility ratio, } \xi = \frac{\sqrt{1+\left(\frac{2c\omega}{\omega_n c_c}\right)^2}}{\sqrt{\left(\frac{2c\omega}{\omega_n c_c}\right)^2 + \left(1-\frac{\omega^2}{\omega_n^2}\right)^2}}$$

$$\text{If } \quad c = 0, \text{ then } \quad \xi = \frac{1}{\left(1-\frac{\omega^2}{\omega_n^2}\right)} = \frac{1}{1-(0.5)^2} = \frac{4}{3}.$$

85. High damping reduces the transmissibility if the non-dimensional frequency ratio $\frac{\omega}{\omega_n}$ (ω = forcing frequency, ω_n = natural frequency) **[GATE-1992]**

(a) is less than $\sqrt{2}$ (b) is greater than $\sqrt{2}$

(c) is less than $\frac{1}{\sqrt{2}}$ (d) is greater than $\frac{1}{\sqrt{2}}$

85. Ans. (b)

86. If $\omega/\omega_n = \sqrt{2}$, where ω is the frequency of excitation and ω_n is the natural frequency of vibrations, then the transmissibility of vibrations will be **[IES-1995]**

(a) 0.5 (b) 1.0 (c) 1.5 (d) 2.0

86. Ans. (b) Transmissibility of vibration is 1 when $\omega/\omega_n = \sqrt{2}$

87. Match List I (force transmissibility) with List II (frequency ratio) and select the correct answer using the codes given below the Lists:

List I	List II
	[IES-1994]
A. 1	1. $\frac{\omega}{\omega_n} > \sqrt{2}$
B. Less than 1	2. $\frac{\omega}{\omega_n} = \sqrt{2}$
C. Greater than 1	3. $\frac{\omega}{\omega_n} >> \sqrt{2}$
D. Tending to zero	4. $\frac{\omega}{\omega_n} < \sqrt{2}$

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

87. Ans. (b)

88. For a single degree of freedom viscous damped system, transmissibility is less than 1 if frequency ratio is **[IAS-2007]**

(a) Equal to 1 (b) < 1 (c) < $\sqrt{2}$ (d) > $\sqrt{2}$

88. Ans. (d)

89. Transmissibility is unity at two points. **[IAS-2004]**
Which one of the following is true for these two points?

(a) ω/ω_n is zero and $\sqrt{3}$ for all values of damping

(b) ω/ω_n is zero and $\sqrt{2}$ for all values of damping

(c) ω/ω_n is unity and 2 for all values of damping

(d) ω/ω_n is unity and $\sqrt{3}$ for all values of damping

89. Ans. (b)

90. When a shaking force is transmitted through the spring, damping becomes detrimental when the ratio of its frequency to the natural frequency is greater than

(a) 0.25 (b) 0.50 (c) 1.00 (d) $\sqrt{2}$ **[IES-1996]**

90. Ans. (c)

91. Consider the following statements:

1. When frequency ratio is < 2, the force transmitted to the foundations is more than the exciting force. **[IAS-2003]**
2. When frequency ratio is > 2, the force transmitted to the foundations increases as the damping is decreased.
3. The analysis of base-excited vibrations is similar to that of forced vibrations.

Which of these statements are correct?

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

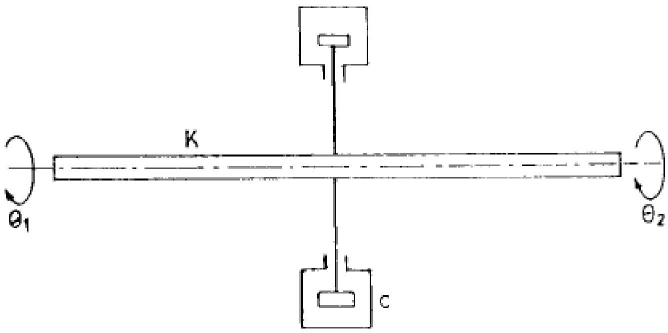
91. Ans. (c)

92. When a vehicle travels on a rough road whose undulations can be assumed to he sinusoidal, the resonant conditions of the base excited vibrations are determined by the

(a) mass of the vehicle, stiffness of the suspension spring, speed of the vehicle, wavelength of the roughness curve **[IES-2001]**
(b) speed of the vehicle only
(c) speed of the vehicle and the stiffness of the suspension spring
(d) amplitude of the undulations

92. Ans. (a)

93. Given figure shows a flexible shaft of negligible mass of torsional stiffness K coupled to a viscous damper having a coefficient of viscous damping c. If at any instant the left and right ends of this shaft have angular displacements θ_1 and θ_2 respectively, then the transfer function, $\theta_2/\ \theta_1$ of the system is



[IES-1995]

(a) $\frac{K}{K+c}$ (b) $\frac{1}{1+\frac{c}{K}s}$ (c) $\frac{1}{1+\frac{K}{c}s}$ (d) $1+\frac{K}{c}s$

93. Ans. (b)

Torsional Vibration

94. During torsional vibration of a shaft, the node is characterized by the **[IES-2001]**

(a) maximum angular velocity (b) maximum angular displacement
(c) maximum angular acceleration (d) zero angular displacement

94. Ans. (d)

95. In a multi-rotor system of torsional vibration maximum number of nodes that can occur is

(a) two (b) equal to the number of rotor plus one **[IES-1999]**
(c) equal to the number of rotors (d) equal to the number of rotors minus one

95. Ans. (d)

96. Assertion (A): 1be rotor system shown in Fig. A is equivalent to the rotor system shown in Fig. B in so far as torsional vibration is concerned. **[IES-1993]**

Fig. A

Fig. B

Reason (R): Each torsional system has two rotors carried by a shaft.
96. Ans. (d) Assertion A is not correct because two equivalent systems in regard to torsional vibrations are those which twist through exactly the same angle as the actual shaft, when equal and opposite torque are applied to the two rotors. Due to one rotor being restrained, above condition will not apply. However reason R is true since both systems in Fig. A & B have two rotors carried by a shaft.

98. Consider the following statements: **[IAS-2001]**
1. In forced vibrations, the body vibrates under the influence of an applied force.
2. In damped vibrations, amplitude reduces over every cycle of vibration.
3. In torsional vibrations, the disc moves parallel to the axis of shaft.
4. In transverse vibrations, the particles of the shaft moves approximately perpendicular to the axis of the shaft.
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1, 3 and 4 (c) 2, 3 and 4 (d) 1, 2 and 4
98. Ans. (d) 3 is false. In torsional vibrations, the disc moves in a circle about the axis of the shaft.

99. A shaft, supported on two bearings at its ends, carries two flywheels 'L' apart. Mass moment of inertia of the two flywheels are I_a and I_b, I being the polar moment of inertia of cross-sectional area of the shaft. Distance l_a of the mode of torsional vibration of the shaft from flywheel I_a is given by **[IAS-1998]**

(a) $l_a = \dfrac{LI_b}{I_a + I_b}$ (b) $l_a = \dfrac{LI_a}{I_a + I_b}$ (c) $l_a = \dfrac{LI_b}{I_a + I_b - I}$ (d) $l_a = \dfrac{LI_a}{I_a + I_b - I}$

99. Ans. (c)

100. Assertion (A): The longitudinal, transverse and torsional vibrations are simple harmonic. **[IAS-1996]**
Reason (R): The restoring force or couple is proportional velocity in the case of these vibrations.
100. Ans. (c) The restoring force or couple is proportional to displacement from the mean position.

Torsionally equivalent shaft

101. Two heavy rotating masses are connected by shafts of length l_1, l_2 and l_3 and the corresponding diameters are d_1, d_2 and d_3. This system is reduced to a torsionally equivalent system having uniform diameter d_1 of the shaft. The equivalent length of the shaft is equal to

(a) $l_1 + l_2 + l_3$ (b) $\frac{l_1 + l_2 + l_3}{3}$ **[IES-1997]**

(c) $l_1 + l_2\left(\frac{d_1}{d_2}\right)^3 + l_3\left(\frac{d_1}{d_3}\right)^3$ (d) $l_1 + l_2\left(\frac{d_1}{d_2}\right)^4 + l_3\left(\frac{d_1}{d_3}\right)^4$

101. Ans. (d)

102. Two heavy rotating masses are connected by shafts of lengths l_1, l_2 and l_3 and the corresponding diameters are d_1, d^2 and d^3. This system is reduced to a torsionally equivalent system having uniform diameter "d_1"of the shaft. The equivalent length of the shaft is

(a) $\frac{l_1 + l_2 + l_3}{3}$ (b) $l_1 + l_2\left(\frac{d_1}{d_2}\right)^3 + l_3\left(\frac{d_1}{d_3}\right)^3$ **[IES-1994]**

(c) $l_1 + l_2\left(\frac{d_1}{d_2}\right)^4 + l_3\left(\frac{d_1}{d_3}\right)^4$ (d) $l_1 + l_2 + l_3$

102. Ans. (c)

Answers with Explanation (Objective)

8.

Critical Speed or Whirling of Shaft

Objective Questions (IES, IAS, GATE)

1. Which one of the following causes the whirling of shafts?
(a) Non-homogeneity of shaft material (b) Misalignment of bearings
(c) Fluctuation of speed (d) Internal damping **[IES 2007]**
1. Ans. (a)

2. Whirling speed of a shaft coincides with the natural frequency of its **[IAS-1995]**
(a) longitudinal vibration (b) transverse vibration
(c) torsional vibration (d) coupled bending torsional vibration
2. Ans. (b)

3. Assertion (A): Every rotating shaft has whirling speeds
Reason (R): Eccentricity of rotors on rotating shafts is unavoidable.
3. Ans. (a) **[IAS 1994]**

4. Rotating shafts tend of vibrate violently at whirling speeds because **[IES-1993]**
(a) the shafts are rotating at very high speeds
(b) bearing centre line coincides with the shaft axis
(c) the system is unbalanced
(d) resonance is caused due to the heavy weight of the rotor
4. Ans. (d)

5. Whirling speed of shaft is the speed at which **[IAS-2002]**
(a) shaft tends to vibrate in longitudinal direction
(b) torsional vibration occur
(c) shaft tends to vibrate vigorously in transverse direction
(d) combination of transverse and longitudinal vibration occurs
5. Ans. (c)

6. A shaft carries a weight W at the centre. The CG of the weight is displaced by an amount e from the axis of the rotation. If y is the additional displacement of the CG from the axis of rotation due to the centrifugal force, then the ratio of y to e (where ω_c, is the critical speed of shaft and w is the angular speed of shaft) is given by **[IES-2001]**

(a) $\dfrac{1}{\left[\dfrac{\omega_c}{\omega}\right]^2+1}$ (b) $\dfrac{\pm e}{\left[\dfrac{\omega_c}{\omega}\right]^2-1}$ (c) $\left[\dfrac{\omega_c}{\omega}\right]^2+1$ (d) $\dfrac{\omega}{\left[\dfrac{\omega_c}{\omega}\right]^2-1}$

6. Ans. (b)

7. The critical speed of a rotating shaft depends upon **[IES-1996]**

(a) mass (b) stiffness (c) mass and stiffness (d) mass, stiffness and eccentricity.
7. Ans. (c)

8. A slender shaft supported on two bearings at its ends carries a disc with an eccentricity e from the axis of rotation. The critical speed of the shaft is N. If the disc is replaced by a second one of same weight but mounted with an eccentricity 2e, critical speed of the shaft in the second case is
(a) 1/2N (b) I/$\sqrt{2}$ N (c) N (d) 2N. **[IES-1995]**
8. Ans. (b)

9. A shaft has two heavy rotors mounted on it. The transverse natural frequencies, considering each of the rotors separately, are 100 cycles/see and 200 cycles/see respectively. The lowest critical speed is **[IES-1994]**
(a) 5367rpm (b) 6000rpm (c) 9360rpm (d) 12,000 rpm
9. Ans. (b) Lowest critical speed =6000 rpm.

10. Assertion (A): A statically and dynamically balanced system of multiple rotors on a shaft can rotate smoothly even at the 'critical speeds' of the system. **[IES-2001]**
Reason (R): Total balancing eliminates all the 'in plane' and 'out of plane' unbalanced forces of the system.
10. Ans. (d)

11. The critical speed of a shaft is affected by the **[IES-2000]**
(a) diameter and the eccentricity of the shaft
(b) span and the eccentricity of the shaft
(c) diameter and the span of the shaft (d) span of the shaft
11. Ans. (b)

12. Assertion (A): High speed turbines are run at a suitable speed above the critical speed of the shaft. **[IES-1998]**
Reason (R): The deflection of the shaft above the critical speed is negative, hence the effect of eccentricity of the rotor mass is neutralised.
12. Ans. (c)

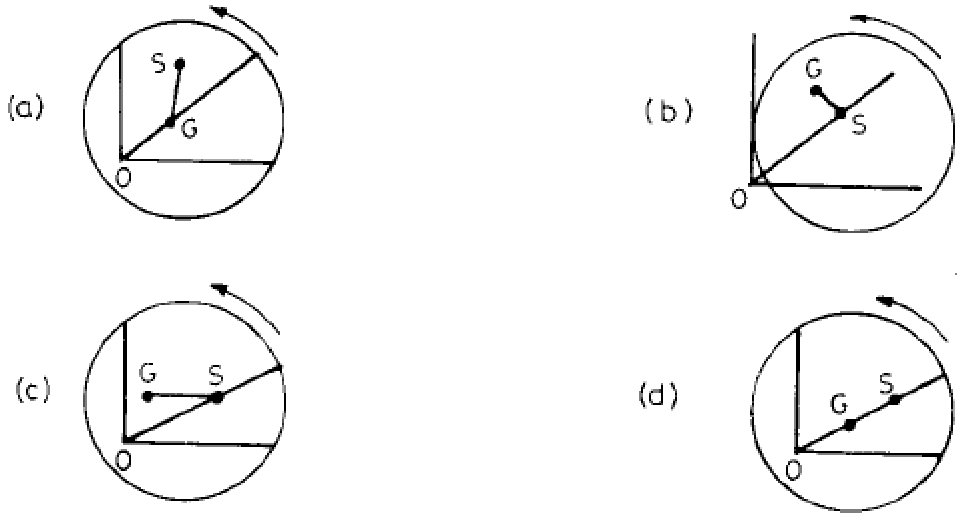
13. The critical speed of a uniform shaft with a rotor at the centre of the span can be reduced by
(a) reducing the shaft length (b) reducing the rotor mass
(c) increasing the rotor mass (d) increasing the shaft diameter **[IES-1998]**
13. Ans. (b)

14. Assertion (A): The critical speed of an elastic shaft calculated by the Rayleigh's method is higher than the actual critical speed. **[IES-2005]**
Reason (R): The higher critical speed is due to higher damping ratio.
14. Ans. (c)

15. A shaft of 50 mm diameter and 1 m length carries a disc which has mass eccentricity equal to 190 microns. The displacement of the shaft at a speed which is 90% of critical speed in microns is **[IES-2002]**
(a) 810 (b) 900 (c) 800 (d) 820
15. Ans. (a)

16. Let S and G be positions of centre of mass and geometric centre of a disc attached to a rotating disc with axis at O. Let the system be resisted by viscous damping. Then at the critical speed, the relative positions of O, G and S are given by

[IES-1994]



16. Ans. (d)

17. The danger of breakage and vibration is maximum? [IES-1992]
(a) below critical speed (b) near critical speed
(c) above critical speed (d) none of the above.
17. Ans. (b)

18. The rotor of a turbine is generally rotated at
(a) the critical speed [IAS-1999]
(b) a speed much below the critical speed
(c) 3 speed much above the critical speed
(d) a speed having no relation to critical speed
18. Ans. (c)

19. Consider the following statements
The critical speed of a shaft if affected by the
1. eccentricity of the shaft 2. span of the shaft 3. diameter of the shaft
Of these statements: [IAS 1994]
(a) 1 and 2 are correct (b) 1 and 3 are correct
(c) 2 and 3 are correct (d) 1, 2 and 3 are correct.
19. Ans. (c)

20. For lightly damped heavy rotor systems, resonance occurs when the forcing ω is equal to

$(a)\, 2\omega_{cr}$ $(b)\, \sqrt{2}\omega_{cr}$ $(c)\, \omega_{cr}$ $(d)\, \frac{1}{2}\omega_{cr}$ [GATE-1992]

Where ω_{cr} is the critical speed
20. Ans. (c)

21. A flexible rotor-shaft system comprises of a 10 kg rotor disc placed in the middle of a mass-less shaft of diameter 30 mm and length 500 mm between bearings (shaft is being taken mass-less as the equivalent mass of the shaft is included in the rotor mass) mounted at the ends. The bearings are assumed to simulate simply supported boundary conditions. The shaft is made of steel for which the value of E is 2.1 x 10^{11}Pa. What is the critical speed of rotation of the shaft? [GATE-2003]
(a) 60 Hz (b) 90 Hz (c) 135 Hz (d) 180 Hz
21. Ans. (b)

Here,

$$m = 10 \text{ kg} = \text{mass of rotar}$$
$$d = \text{diameter of shaft} = 30 \times 10^5 \text{ m}$$
$$l = \text{length of shaft} = 500 \times 10^{-3} \text{ m}$$
$$E \text{ for steel} = 2.1 \times 10^{11} \text{ N/m}^2$$
$$\Delta = \text{deflection of shaft} = \frac{mgl^3}{4gEI}$$
$$I = \frac{\pi}{64} d^4 = \frac{\pi}{64} \times (30 \times 10^{-3})^4$$
$$= 3.976 \times 10^{-8} \text{ m}^4$$
$$\Delta = \frac{mgl^3}{48EI}$$
$$= \frac{10 \times 9.81 \times (500 \times 10^{-3})^3}{48 \times 2.1 \times 10^{11} \times 3.976 \times 10^{-8}}$$
$$= 3.06 \times 10\text{–}5 \text{ m}$$
$$\omega_n = \sqrt{\frac{g}{\Delta}} = \sqrt{\frac{9.81}{3.06 \times 10^{-5}}} = 566.24 \text{ rad/s}$$
$$f_n = \frac{\omega_n}{2\pi}$$
$$= \frac{566.24}{2 \times 3.142} = 90 \text{ Hz.}$$

22. Critical speed of a shaft with a disc supported in between is equal to the natural frequency of the system in **[IES-1993]**
(a) transverse vibrations (b) torsional vibrations
(c) longitudinal vibrations (d) longitudinal vibrations provided the shaft is vertical.
22. Ans. (a)

23. If a spring-mass-dashpot system is subjected to excitation by a constant harmonic force, then at resonance, its amplitude of vibration will be **[IES-1999]**
(a) infinity (b) inversely proportional to damping
(c) directly proportional to damping (d) decreasing exponentially with time
23. Ans. (a)

24. Match List-I with List-II and select the correct answer using the codes given below the lists:
List-I List-II **[IES-1998]**
A. Node and mode 1. Geared vibration
B. Equivalent inertia 2. Damped-free vibration
C. Log decrement 3. Forced vibration
D. Resonance 4. Multi-rotor vibration

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

24. Ans. (b)

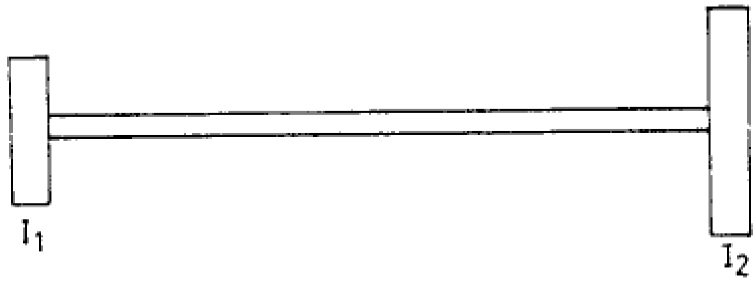
25. For steady-state forced vibrations, the phase lag at resonance is **[IAS-1996]**
(a) 0^0 (b) 45^0 (c) 90^0 (d) 180^0
25. Ans. (c)

26. A shaft has an attached disc at the centre of its length. The disc has its centre of gravity located at a distance of 2 mm from the axis of the shaft. When the shaft is allowed to vibrate in its natural bow-shaped mode, it has a frequency of vibration of 10 rad/s. When the shaft is rotated at 300 revolutions per minute, it will whirl with a radius of **[IES-1994]**

(a) 2 mm (b) 2.25 mm (c) 2.50 mm (d) 3.00 mm

26. Ans. (b)

27. In the two-rotor system shown in the given figure, ($I_1 < I_2$), a node of vibration is situated



(a) between I_1 and I_2 but nearer to I_1 (b) between I_1 and I_2 but nearer to I_2

(c) exactly in the middle of the shaft (d) nearer to I_1 but outside **[IES-1993]**

27. Ans. (b) Node of vibration is situated closer to rotor having high moment of inertia.

Answers with Explanation (Objective)

9.

Miscellaneous

Objective Questions (IES, IAS, GATE)

1. The mass moment of inertia of the two rotors in a two rotor system is 100 kg m^2 and 10 kg m^2. The length of the shaft of uniform diameter between the rotors is 110 cm. The distance of node from the rotor of lower moment of inertia is **[IES-2002]**
(a) 80 cm (b) 90 cm (c) 100 cm (d) 110 cm
1. Ans. (c)

2. Consider a harmonic motion x = 1.25 sin (5t –π/6) cm. 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. Amplitude (cm)	1. 5/2 π
B. Frequency (cycle/s)	2. 1.25
C. Phase angle (rad)	3. 1/5
D. Time period (s)	4. π /6

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

2. Ans. (b)

3. The pitching of a ship in the ocean is an oscillatory periodic motion. A ship is pitching 6° above and 6° below with a period of 20s from its horizontal plane. Consider the following statements in this regard:
   1. The motion has a frequency of oscillation (i.e. pitching) of 3 cycles/minute
   2. The motion has an angular frequency of 3.14 rad/s.
   3. The angular velocity of precession of ship's rotor is $\pi^2/300$ rad/s.
   4. The amplitude of pitching is π/30 rad.

Which of these statements are correct? **[IES-2000]**
(a) 1 and 2 (b) 1, 2 and 4 (c) 2, 3 and 4 (d) 1, 3 and 4
3. Ans. (b)

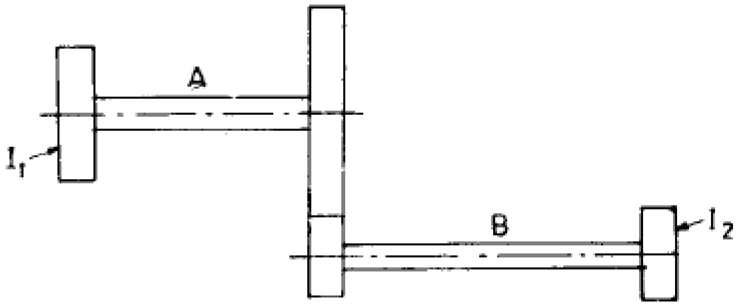
4. A rigid shaft when laid on horizontal parallel ways will not roll if the **[IES-1999]**
(a) centre of gravity falls on parallels (b) centre of gravity lies on the shaft axis
(c) horizontal moments are large (d) vertical moments are large
4. Ans. (b)

5. Two geared shafts A and B having moments of inertia I_a and I_b and angular acceleration α_a and α_b respectively are meshed together. B rotates at G times the speed of A.1f the gearing efficiency of the two shafts in η, then in order to accelerate B, the torque which must be applied to A will be **[IES-1998]**
(a) $I_a\alpha_a + G^2 I_b\alpha_b/\eta$ (b) $G^2 I_a\alpha_a/\eta$ (c) $G^2 I_b\alpha_a/\eta$ (d) $G^2 I_b\alpha_a/\eta$
5. Ans. (a)

6. In S.H.M., with respect to the displacement vector, the positions of Velocity vector and Acceleration vector will be respectively **[IES-1998]**
(a) 180° and 90° (b) 90° and 180° (c) 0° and 90° (d) 90° and 0°
6. Ans. (b)

7. Two links OA and OB are connected by a pin joint at 'O'. The link OA turns with angular velocity ω_1 radians per second in the clockwise direction and the link OB turns with angular velocity ω_2 radians per second in the anticlockwise direction. If the radius of the pin at 'O' is 'r', then the rubbing velocity at the pin joint 'O' will be
(a) $\omega_1\omega_2 r$ (b) $(\omega_1 - \omega_2)r$ (c) $(\omega_1 + \omega_2)r$ (d) $(\omega_1 - \omega_2)2r$ **[IES-1998]**
7. Ans. (c)

8. A torsional system with discs of moment of inertia I_1 and I_2 shown in the given figure, is gear driven such that the ratio of the speed of shaft B to shaft A is 'n'. Neglecting the inertia of gears, the equivalent inertia of disc on B at the speed of shaft A is equal to



[IES-1995]

(a) nI_2 (b) n^2I_2 (c) I_2/n^2 (d) I_2/n
8. Ans. (b)

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

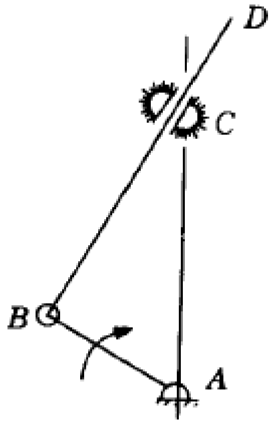
List I (Forces)	List II (Mathematical expressions)
A. Inertia Force	1. $C\frac{dy}{dt}$
B. Spring force	2. $M\frac{d^2y}{dx^2}$
C. Damping force	3. $M\omega^2R$
D. Centrifugal force	4. Ky

[IES-1993]

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

9. Ans. (b)

10. In the figure shown crank AB is 15 cm long and is rotating at 10 rad/s. C is vertically above A. CA equals 24 cm. C is a swivel trunnion through which BD (40 cm) slides. If ABCD becomes a vertical line during its motion, the angular velocity of the swivel trunnion at that instant will be
(a) Zero
(b) (100/25) rad/s
(c) (100/15) rad/s
(d) (100/10) rad/s



[IES-1997]

10. Ans. (a)

11. An axial flow fan balanced at one speed often exhibits substantial vibrational effects when operated at other speeds, mainly due to **[IES-1997]**
(a) primary critical speed effect (b) secondary critical speed effect
(c) unbalanced parts of the fan (d) aerodynamic unbalance
11. Ans. (d)

12. An electric lift is moving downwards with an acceleration of g/3. The vertical force between a passenger in the lift and its floor is equal to **[IES-1994]**
(a) 2/3 of the passenger's weight (b) 4/3 of the passenger's weight
(c) passenger's weight (d) 4/3 of the passenger's weight.
12. Ans. (a) When lift is moving down with acceleration of g/3, then vertical force between a passenger in lift and its floor = 2/3 of passenger's weight.

13. If a number of forces act on a rigid body, each force may be replaced by an equal and parallel force acting through a fixed point, together with a couple. For the rigid body to be in equilibrium,
(a) the resultant force at the fixed point must be zero **[IES-1994]**
(b) the resultant couple on the body must be zero
(c) both resultant force and couple must be zero
(d) none of the above need be zero.
13. Ans. (c) For rigid body to be in equilibrium, both resultant force and couple must be zero.

14. Jewel hearings are used in **[IES-1992]**
(a) contaminated atmosphere (b) low-torque applications
(c) fully immersed in water condition (d) high seed shafts
14. Ans. (b)

15. A ball A of mass m falls under gravity from a height h and strikes another ball B of mass m which is supported at rest on a spring of stiffness k. Assume perfectly elastic impact. Immediately after the impact **[GATE-1996]**
(a) the velocity of ball A is $\frac{\sqrt{2gh}}{2}$ (b) the velocity of ball A is zero
(c) the velocity of both balls is $\frac{\sqrt{2gh}}{2}$ (d) none of the above
15. Ans. (b)

Explanation. In a perfectly elastic collision between equal masses of two bodies, velocities exchange on impact.

Velocity just before impact = Velocity immediately after impact.

Before impact	**After impact**
$V_A = \sqrt{2gh}$	$V_A = 0$
$V_B = 0$	$V_B = \sqrt{2gh}$

16. $\frac{\partial^2 u}{\partial t^2} = C^2 \frac{\partial^2 u}{\partial x^2}$ represents the equation for **[GATE-1999]**

(a) Vibration of a stretched string
(b) Motion of a projectile in a gravitational field
(c) Heat flow in thin rod
(d) Oscillation of a simple pendulum

16. Ans. (a)