

# ESE 2020

PRELIMINARY EXAMINATION



# MECHANICAL ENGINEERING

## ESE TOPICWISE OBJECTIVE SOLVED PAPER-II



- Detailed Solution
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UPSC Engineering Service Examination 2020

**MECHANICAL ENGINEERING**  
**ESE TOPICWISE OBJECTIVE SOLVED**  
**PAPER-II**

**1995-2019**



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*Second Edition : 2018*

*Third Edition : 2019*

## PREFACE

It is an immense pleasure to present topic wise previous years solved paper of Engineering Services Exam. This booklet has come out after long observation and detailed interaction with the students preparing for Engineering Services Exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

Engineering Services Exam is a gateway to a immensely satisfying and high exposure job in engineering sector. The exposure to challenges and opportunities of leading the diverse field of engineering has been the main reason for students opting for this service as compared to others. To facilitate selection into these services, availability of arithmetic solution to previous year paper is the need of the day. Towards this end this book becomes indispensable.

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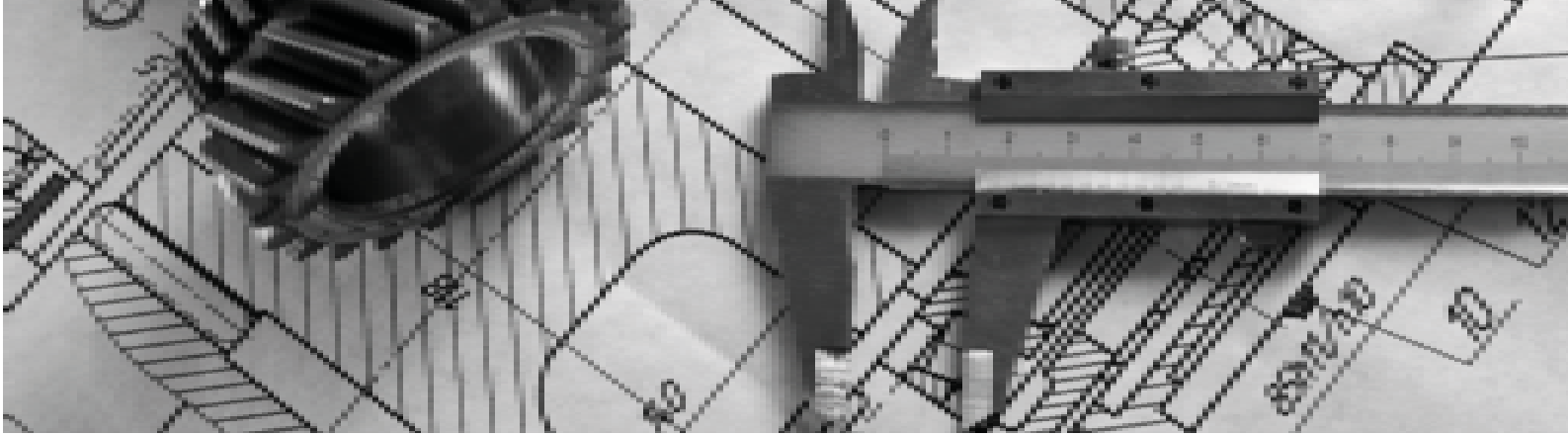
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# UNIT-1

# Theory of Machines

## SYLLABUS

Types of Kinematics pair, Mobility, Inversions, Kinematic Analysis, Velocity and Acceleration Analysis of Planar mechanisms, CAMs with uniform acceleration and retardation, cycloidal motion, oscillating followers; Vibrations - Free and forced vibration of undamped and damped SDOF systems, Transmissibility Ratio, Vibration Isolation, Critical Speed of Shafts. Gears - Geometry of tooth profiles, Law of gearing, Involute profile, Interference, Helical, Spiral and Worm Gears, Gear Trains - Simple, compound and Epicyclic; Dynamic Analysis - Slider - crank mechanisms, turning moment computations, balancing of Revolving & Reciprocating masses, Gyroscopes - effect of Gyroscopic couple on automobiles, ships and aircrafts, Governors.

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# 1

## ANALYSIS OF PLANAR MECHANISM

### IES - 2019

1. Which of the following statements are correct with respect to inversion of mechanisms?
1. It is a method of obtaining different mechanisms by fixing different links of the same kinematic chain.
  2. It is method of obtaining different mechanisms by fixing the same links of different kinematic chains.
  3. In the process of inversion, the relative motions of the links of the mechanisms produced remain unchanged.
  4. In the process of inversion, the relative motions of the links of the mechanisms produced will change accordingly.

Select the correct answer using the code given below.

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

### IES - 2018

2. **Statement I :**

In four-bar chain, whenever all four links are used, with each of them forming a turning pair, there will be continuous relative motion between the two links of different lengths.

**Statement II :**

For a four-bar mechanism, the sum of the shortest and longest link lengths is not greater than the sum of remaining two links.

3. Consider the following statements:
1. A kinematic chain is the combination of kinematic pairs joined in such a way that the relative motion between them is completely constrained.

2. The degree of freedom of a kinematic pair is given by the number of independent coordinates required to completely specify the relative movement.

Which of the above statements is/are correct?

- (a) 1 only                      (b) 2 only  
(c) Both 1 and 2              (d) Neither 1 nor 2

4. Consider the following statements:

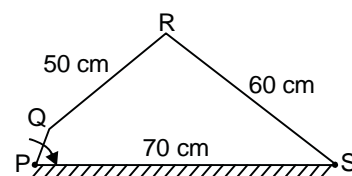
1. Gyroscopic effects generate forces and couples which act on the vehicles, and these effects must be taken into account while designing their bearings.
2. Rolling motion of a ship usually occurs because of the difference in buoyancy on the two sides of the ship due to a wave.

Which of the above statements is/are correct?

- (a) 1 only                      (b) 2 only  
(c) Both 1 and 2              (d) Neither 1 nor 2

### IES - 2017

5. In the 4-bar mechanism as shown, the link PQ measures 30 cm and rotates uniformly at 100 rev/min. The velocity of point Q on link PQ is nearly



- (a) 2.54 m/s                      (b) 3.14 m/s  
(c) 4.60 m/s                      (d) 5.80 m/s

6. Which of the following mechanisms are examples of forced closed kinematic pairs?
1. Cam and roller mechanism



2. Door-closing mechanism
3. Slider-crank mechanism

Select the correct answer using the code given below.

- (a) 1 and 2 only      (b) 1 and 3 only  
(c) 2 and 3 only      (d) 1, 2 and 3
7. A planer mechanism has 10 links and 12 rotary joints. Using Grubler's criterion, the number of degrees of freedom of the mechanism is
- (a) 1                      (b) 3  
(c) 2                      (d) 4
8. The number of instantaneous centres of rotation in a slider-crank quick return mechanism is
- (a) 10                      (b) 8  
(c) 6                      (d) 4

### IES - 2016

9. **Statement (I)** : In quick return motion mechanism, Coriolis acceleration exists.
- Statement (II)** : Two links in this mechanism oscillate with one sliding relative to the other.
10. Consider the following motions :
1. Piston reciprocating inside an engine cylinder
  2. Motion of a shaft between foot-step bearings
- Which of the above can rightly be considered as successfully constrained motion?
- (a) 1 only                      (b) 2 only  
(c) Both 1 and 2              (d) Neither 1 nor 2
11. Coriolis component of acceleration depends on
1. angular velocity of the link
  2. acceleration of the slider
  3. angular acceleration of the link
- Which of the above is/are correct?
- (a) 1 only                      (b) 2 only  
(c) 1 and 3                      (d) 2 and 3
12. In a circular arc cam with a roller follower, acceleration of the follower depends on
1. cam speed and location of centre of circular arc
  2. roller diameter and radius of circular arc
- Which of the above is/are correct?

- (a) 1 only                      (b) 2 only  
(c) Both 1 and 2              (d) Neither 1 nor 2

13. In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 200 mm. The lengths of the driving crank and the slotted bar are 100 mm and 500 mm, respectively. The length of the cutting stroke is
- (a) 100 mm                      (b) 300 mm  
(c) 500 mm                      (d) 700 mm

### IES - 2015

14. **Statement (I)** : Hooke's joint connects two non-parallel non-intersecting shafts to transmit motion with a constant velocity ratio.
- Statement (II)** : Hooke's joint connects two shafts the axes of which do not remain in alignment while in motion.
15. In a crank and slotted lever type quick return mechanism, the link moves with an angular velocity of 20 rad/s, while the slider moves with a linear velocity of 1.5 m/s. The magnitude and direction of Coriolis component of acceleration with respect to angular velocity are
- (a) 30 m/s<sup>2</sup> and direction is such as to rotate slider velocity in the same sense as the angular velocity
  - (b) 30 m/s<sup>2</sup> and direction is such as to rotate slider velocity in the opposite sense as the angular velocity
  - (c) 60 m/s<sup>2</sup> and direction is such as to rotate slider velocity in the same sense as the angular velocity
  - (d) 60 m/s<sup>2</sup> and direction is such as to rotate slider velocity in the opposite sense as the angular velocity
16. Which of the following are associated with Ackerman steering mechanism used in automobiles?
1. Has both sliding and turning pairs
  2. Less friction and hence long life
  3. Mechanically correct in all positions
  4. Mathematically not accurate except in three positions
  5. Has only turning pairs
  6. Controls movement of two front wheels

## ANSWER KEY

1. (a)	23. (b)	45. (a)	67. (d)	89. (d)
2. (c)	24. (d)	46. (a)	68. (c)	90. (c)
3. (c)	25. (c)	47. (d)	69. (a)	91. (a)
4. (c)	26. (a)	48. (c)	70. (d)	92. (b)
5. (b)	27. (c)	49. (d)	71. (d)	93. (**)
6. (a)	28. (d)	50. (a)	72. (b)	94. (a)
7. (b)	29. (c)	51. (a)	73. (c)	95. (d)
8. (c)	30. (a)	52. (d)	74. (a)	96. (c)
9. (c)	31. (b)	53. (b)	75. (b)	97. (b)
10. (b)	32. (c)	54. (a)	76. (a)	98. (c)
11. (a)	33. (b)	55. (b)	77. (a)	99. (a)
12. (c)	34. (a)	56. (c)	78. (b)	100. (a)
13. (c)	35. (c)	57. (a)	79. (c)	101. (d)
14. (d)	36. (d)	58. (d)	80. (a)	102. (a)
15. (c)	37. (c)	59. (c)	81. (c)	103. (c)
16. (a)	38. (c)	60. (a)	82. (d)	104. (c)
17. (b)	39. (c)	61. (c)	83. (c)	105. (c)
18. (b)	40. (c,d)	62. (a)	84. (b)	106. (a)
19. (a)	41. (d)	63. (d)	85. (a)	
20. (a)	42. (c)	64. (d)	86. (b)	
21. (d)	43. (d)	65. (b)	87. (c)	
22. (b)	44. (a)	66. (a)	88. (d)	

## EXPLANATIONS

**Sol-1: (a)****Sol-2: (c)**

For a four bar mechanism to form, sum of three links should be more than longest link. For inversion purpose, the sum of largest and smallest should be less than the rest two.

**Sol-3: (c)**

A kinematic chain is the combination of kinematic pairs joined in such a way that each link forms a part of two pairs and the relative motion between the links is completely or successfully constrained.

The degree of freedom of a kinematic pair is given by the number of independent coordinates required to completely specify the relative movement.

**Sol-4: (c)**

Rolling motion usually occurs because of the difference in buoyancy on the two sides of a ship due to a wave. This is a periodic couple and has a maximum value when the ship is on either side of the wave at the point of maximum slope and zero when the ship is at a peak or in the trough of the wave.

The gyroscopic effects generates forces and couples which act on the vehicles and other means of transport like ships, aeroplanes etc. These effects must be taken into account while designing them especially in selection of bearings etc.

**Sol-5: (b)**

The angular velocity of link PQ,

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 100}{60} \text{ rad/sec}$$

Velocity of point Q on link PQ,

$$V = \omega(PQ) = \frac{2\pi \times 100}{60} \times 0.30 \\ = 3.14 \text{ m/sec}$$

**Sol-6: (a)**

Forced closed mechanism require external force to maintain mechanical contact between links. Slider-crank mechanism does not requires such force.

**Sol-7: (b)**

Degree of freedom using grubler criterion,  
 $\text{DoF} = 3(n - 1) - 2J - h - F_r$   
 $= 3(10 - 1) - 2 \times 12 - 0 - 0 = 3$

**Sol-8: (c)**

No of instantaneous centre,

$$= {}^n C_2 = {}^4 C_2 = \frac{4 \times 3}{2} = 6$$

**Sol-9: (c)**

In quick return mechanism, slider moves on oscillating/rotating link, so Coriolis acceleration exist. But in this mechanism, one link rotates and other oscillates and slider a third link slides.

**Sol-10: (b)**

Successfully constraint motion means that the motion is constraint only in the presence of external force. The piston inside cylinder executes constraint motion due to it design and gudgeon pin. While foot step bearing requires a force to press the shaft in bearing to have constraint motion (rotation).

**Sol-11: (a)**

The expression for Coriolis component of acceleration,

$$= 2 V \omega$$

where V is sliding velocity of slider over oscillating link and ' $\omega$ ' is angular velocity of oscillating link in quick return mechanism.

**Sol-12: (c)**

The expression for acceleration of follower involve following parameters

- (i) Radius of flank of cam surface, ' $r_f$ '
- (ii) Least radius of cam profile or base circle radius ' $r_b$ '.
- (iii) Radius of roller ' $r_r$ '.
- (iv) Cam rotation speed ' $\omega$ '

**Sol-13: (c)**

Driving crank length

$$O_1A = 100 \text{ mm}$$

Slotted Bar length

$$O_2B = 500 \text{ mm}$$

$\therefore$  In triangle  $O_2O_1A$



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