2019

RANK IMPROVEMENT WORKBOOK

Mechanical Engineering

Theory of Machines

Answer Key of Objective & Conventional Questions

MADE EASY Publications

1 Mechanisms and Machines

LEVEL 1 Objective Questions

1. (c)
2. (c)
3. (a)
4. (a)
5. (c)
6. (a)
7. (d)
8. (d)
9. (d)
10. (a)
11. (c)
12. (d)
13. (d)

LEVEL 2 Objective Questions

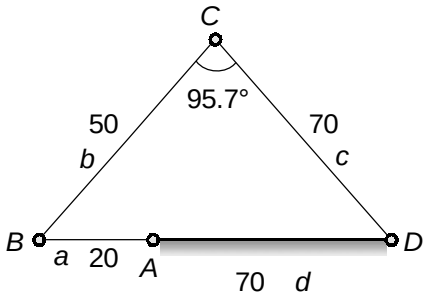
14. (6)
15. (1)
16. (c)
17. (1)
19. (c)
20. (c)
21. (b)
22. (a)
23. (b)
24. (b)
25. (1)
26. (a)
27. (180)

■■■■

LEVEL 3 Conventional Questions

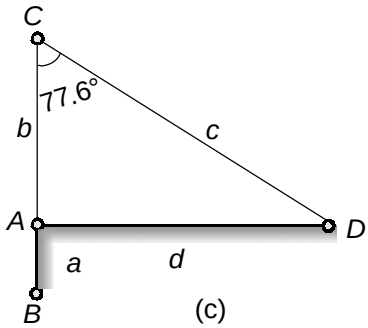
Solution : 28

In this mechanism



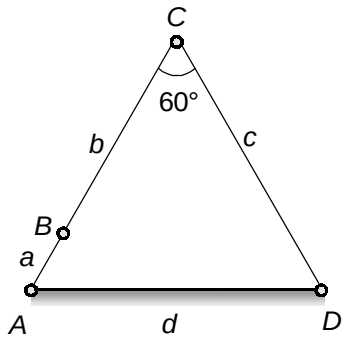
(a)

$\mu = 95.7°$



(c)

$\mu = 45.6°$



(d)

$\mu = 60°$

And the input angle, $\theta = 60°$

Solution : 29

The mechanism has three sub-chains:

(i) *ABC*, a slider-crank chain

(ii) *ABDE*, a four-bar chain

(iii) *AEFG*, a four-bar chain

(*DEF* is a locked chain as it has only three links.)

- As the length *BC* is more than the length *AB* plus the offset of 2 units, *AB* acts as a crank and can revolve about *A*.
- In the chain ABDE,

  Length of the longest link = 8, Length of the shortest link = 4, Length of the other links = 8 and 6

Since 8 + 4 < 8 + 6, it belongs to the class-I mechanism. In this case as the shortest link is fixed, it is a double-crank mechanism and thus *EF* and *AG* can revolve fully.

- In the chain *AEFG*,

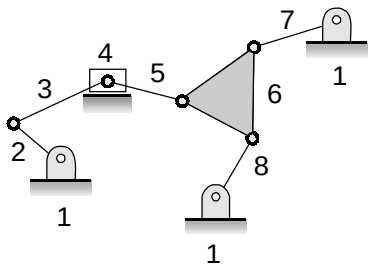
  Length of the longest link = 8, Length of the shortest link = 4, Length of the other links = 6 and 6

Since 8 + 4 = 6 + 6, it belongs to the class-I mechanism. In this case as the shortest link is fixed, it is a double-crank mechanism and thus *EF* and *AG* can revolve fully.

AS *DEF* is a locked chain with three links, the link *EF* revolves with the revolving of *ED*. With the revolving of *ED*, AG also revolves.

Solution : 30

(a) The mechanism has a sliding pair. Therefore, its degree of freedom must be found from Gruebler's criterion. Total number of links = 8



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

$$F = 3(N-1) - 2P_1 - P_2$$
$$= 3(8-1) - 2 \times 10 - 0 = 1$$

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

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

$\therefore$ Eeffective degree of freedom $= 3(N-1) - 2P_1 - P_2 - F_r$

$= 3(4-1) - 2 \times 4 - 0 - 1 = 0$

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

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2 Velocity & Acceleration Analysis

LEVEL 1 Objective Questions

1. (b)
2. (0.33)
3. (d)
4. (c)
5. (b)
6. (d)
7. (0)
8. (b)
9. (1)
10. (b)
11. (c)

LEVEL 2 Objective Questions

12. (67) (66.5 to 67.5)
13. (a)
14. (301.59)
15. (2.74)
16. (a)
17. (3)
18. (1000)
19. (45)
20. (2.69)
21. (8.386)
22. (a)

■■■■

LEVEL 3 Conventional Questions

Solution : 23

v_d = gd = 0.56 m/s

ω_{bq} = 5.63 rad/s counter-clockwise

ω_{ba} = 6.3 rad/s counter-clockwise

Velocity of rubbing at the crank pin

B = 0.0268 m/s

Solution : 24

v_s = 0.276 m/s

v_{pq} = 0.177 m/s

ω_{rs} = 0.279 rad/s clockwise

Solution : 25

v_d = 2.28 m/s

Solution : 26

α_{cd} = 33.25 rad/s^2

Solution : 27

$a_{A/0}$ = 3.507 × 10^3 mm/s^2

V_B = 2.3 × 4 = 9.2 m/s

a_B = 2.6 × 10^5 m/s^2

α = 6666.67 rad/s^2

Acceleration of mid point a_G = 2800 m/s^2

Solution : 28

By measurement V_R = vector O_1r = 1.61 m/s

ω_{DO_2} = 1.112 rad/s anticlockwise about O_2

Solution : 29

Length of crank = 25 cm

V = 4.1887 m/s

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3 Cams

LEVEL 1 Objective Questions

1. (c)
2. (c)
3. (c)
4. (a)
5. (a)
6. (c)
7. (c)
8. (c)
9. (c)
11. (c)
12. (b)

LEVEL 2 Objective Questions

13. (2.37)
14. (720)
15. (0.628)
16. (1.95)
17. (d)
18. (b)
19. (d)
20. (d)
21. (c)
22. (a)
23. (c)
24. (b)
25. (a)
26. (b)
27. (b)
28. (a)
29. (d)

■■■■

LEVEL 3 Conventional Questions

Solution : 30

v_{max} = 226.3 mm/s

f_{max} = 3.413 m/s^2

During descent

v_{max} = 216 mm/s

f_{max} = f = 0

Solution : 31

During descent

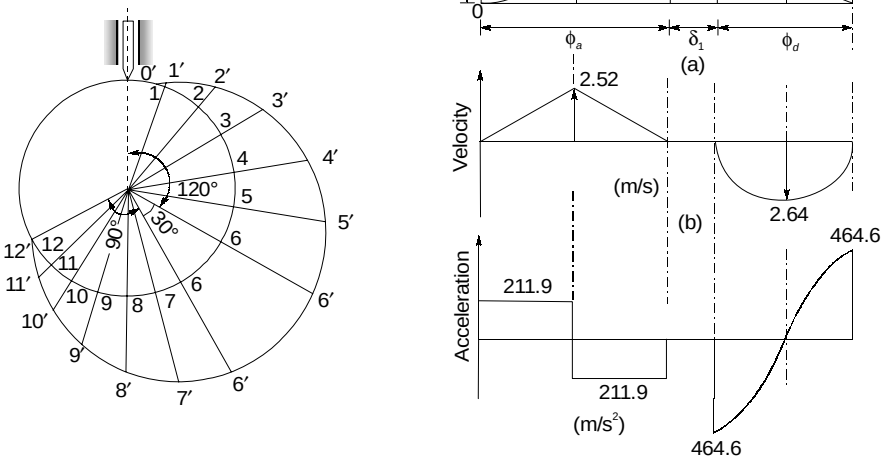
v_{max} = 824.7 mm/s

v_{max} = 549.8 mm/s

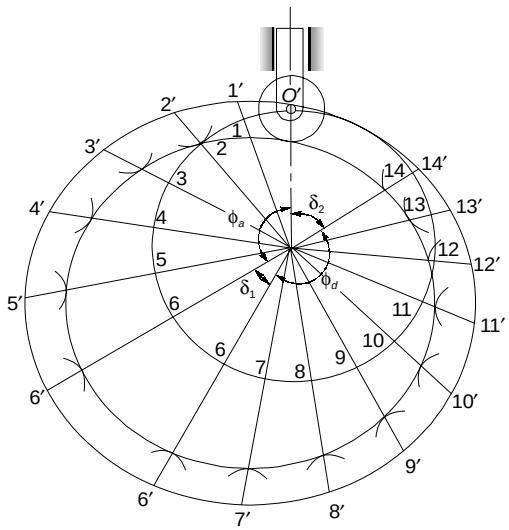
f_{max} = 38862 mm/s^2 = 38.882 m/s^2

f_{max} = 17272 mm/s^2 or 17.272 m/s^2

Solution : 32



Solution : 33



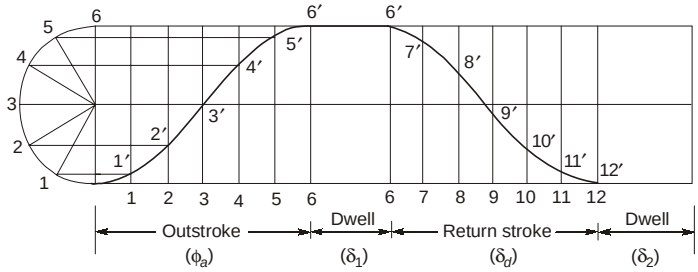
v_{max} = 360 m/s
f_{max} = 4320 mm/s^2 or 4.32 m/s^2

Solution : 34

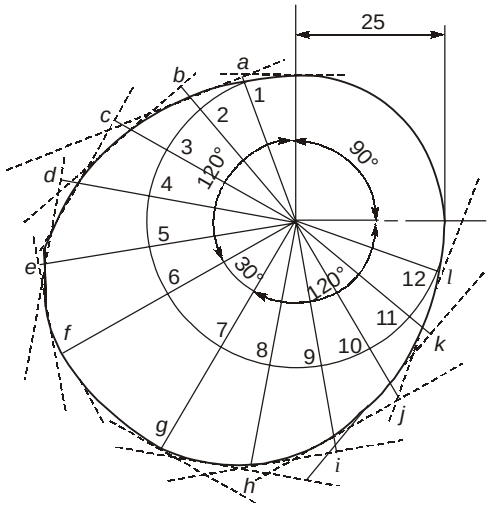
$\ddot{x}$ = 40 ω^2 cos θ
N = 609.9 rpm

Solution : 35

The displacement diagram for the given flat reciprocating follower movement will be as:



Given: ϕ_a = 120°, h(lift) = 20 mm, δ_1 = 30°, ϕ_d = 120°, δ_2 = 90°
Motion is SHM both during outward and inward stroke, minimum radius of cam (r_c) = 25 mm.
Construction:



1. First draw the displacement diagram now construct the cam profile as follows
2. Draw a circle with radius (r_c = 25 mm)
3. Take angles (ϕ_a, δ_1, ϕ_d and δ_2) in the counter clockwise direction if the cam rotation is assumed clockwise
4. Divide ϕ_a and ϕ_d into same number of parts as in the displacement diagram. (Example take 6 equal parts)
5. Draw radial lines (0-1, 0-2, 0-3,, etc. ....)
6. On the radial lines produced, take distances equal to the lift of the follower beyond the circumference of the circle with radius r_c, i.e., 1 - 1′, 2 - 2′, 3 - 3′, etc.
7. Draw the follower in all the positions by drawing perpendiculars to the radial lines at 1′, 2′, 3′, etc. In all the positions, the axis of the follower passes through centre O
8. Draw a curve tangential to the flat faces of the follower representing the cam profile.

Solution : 36

Radial component of cam force is given by;

F_r = 61 N

Torque = 0.651 N.m

Solution : 37

In this motion:

$(V_0)_{max}$ = 1.2 m/s
a = 72 m/s^2

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4 Gear and Gear Train

LEVEL 1 Objective Questions

1. (c)
2. (7.48)
3. (91)
4. (360)
5. (a)
6. (c)
7. (b)
8. (d)
9. (d)
10. (d)
11. (c)
12. (39207.076)

LEVEL 2 Objective Questions

13. (c)
14. (c)
15. (b)
16. (a)
17. (b)
18. (b)
19. (b)
20. (a)
21. (a)
22. (c)
23. (0.86)
24. (10.29)
25. (9.04)
26. (c)
27. (b)
28. (a)
29. (c)
30. (b)
31. (c)
32. (b)
33. (b)
34. (a)
35. (d)
36. (c)
37. (d)
38. (70)
39. (d)
40. (18)
41. (c)

■■■■

LEVEL 3 Conventional Questions

Solution : 42

Velocity of sliding = 57049 mm/min = 950.8 mm/s

Maximum velocity of sliding = 1017.1 mm/s

Solution : 43

Addendum of the wheel = 8.3 mm

r_a^2 = 30271

Addendum of the pinion = 14 mm

Arc of contact = 58.2 mm

Solution : 44

Length of arc of contact = 30.788 mm

n = 1.6334

Angle of action by the pinion, θ_p = 0.54 radian

θ_p = 30.95°

(a) = 0.388

(b) = 0.348

(c) = 0

Solution : 45

T = 49.44

n = 1.78

Solution : 46

Addendum, a = 0.8010 m

Stubbing required = 19.9% or 20%

Solution : 47

T_F = 72

T_S = 18

Speed of P, N_P = – 166.67 rpm

Therefore, speed of planet Gear P is 166.67 rpm in opposite direction to S and A.

Solution : 48

Speed of output shaft = – 50 rpm (clockwise)

Speed of output shaft = 39.5 rpm (clockwise)

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5 Flywheel and Governors

LEVEL 1 Objective Questions

1. (c)
2. (d)
3. (d)
4. (d)
5. (243.17)
6. (0.04)
7. (0.38)
8. (d)
9. (a)
10. (d)
11. (206.04)
12. (b)
13. (a)
14. (a)
15. (c)
16. (d)
17. (a)

LEVEL 2 Objective Questions

18. (d)
19. (323.6)
20. (991.735)
21. (183.33)
22. (22360)
23. (0.38)
24. (d)
25. (b)
26. (0.51)
27. (31.98)
28. (0.0444)
29. (51.3)
30. (31.4)(30 to 33)
31. (b)
32. (c)
33. (c)
34. (c)
35. (a)
36. (d)

■■■■

LEVEL 3 Conventional Questions

Solution : 37

m = 1217.4 kg

Solution : 38

I = 293.3 kg.m^2

Solution : 39

Power of motor = 4276.5 Watt = 4.28 kW

Solution : 40

Motor power = 0.3 kW

M = 988.68 kg

Solution : 41

N = 167 rpm

Range of speed = 4.163 rpm

Solution : 42

m = 5.2 kg

s = 32.72 N/mm

compression of the spring = 33.2 mm

Solution : 43

I = 1394.58 kg-m^2

Solution : 44

K = 0.678%

Solution : 45

N = 430.43 rpm

Solution : 46

Power of engine = 261.8 kW

I = 785.166 kg-m^2

α = 2.547 rad/sec^2

Solution : 47

Initial compression, S_1 = 10.03 cm

x_1 = 11.65 cm

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6 Balancing and Gyroscope

LEVEL 1 Objective Questions

1. (c)
2. (d)
3. (b)
4. (a)
5. (d)
6. (c)
7. (a)
8. (a)
9. (b)

LEVEL 2 Objective Questions

10. (d)
11. (c)
12. (a)
13. (a)
14. (a)
15. (a)
16. (a)

■■■■

LEVEL 3 Conventional Questions

Solution : 17

$v = 151$ km/h

Solution : 18

$m_{c1} = 3.13$ kg at 253°

$m_{c1} = 3.14$ kg

Solution : 19

$m_a = 17.37$ kg

$\theta_a = 294.6°$ or 294°36′

$l_d = -309$ mm

$l_b = -376$ mm

$l_c = -126$ mm

Solution : 20

$m_4 = 178.7$ kg

$\theta_4 = 248.2°$

$m_1 = 178.7$ kg $= m_4$

$\theta_1 = 201.8°$

Swaying couple = 3030.3 N.m

Variation in tractive force = 10100 N

Balance mass for reciprocating parts only = 74.46 kg

Maximum pressure on rails = 45326 N

Minimum pressure on rails = 23344 N

Velocity of wheels = 88.36 km/h

Solution : 21

$m_3 = 448$ kg

$m_2 = 438$ kg

Solution : 22

$R_1 = 4431.8$ N

$R_2 = 8223.8$ N

$R_3 = 2567.2$ N

$R_4 = 6359.2$ N

$R_1 = 8158.2$ N

$R_2 = 4366.2$ N

$R_3 = 6426.8$ N

$R_4 = 2632.8$ N

Solution : 23

Reaction at bearing, B = 98.6 N

Reaction at bearing, A = 59.4 N

Solution : 24

m_A = 9.67 kg, m_D = 7.89 kg

Angular position of the mass at D = 252.7° (w.r.t. B)

Solution : 25

m = 92.8 kg

θ = 201.48°

Solution : 26

Resultant = 8224.6 N

M = 40 kg

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7 Vibrations

LEVEL 1 Objective Questions

1. (d)
2. (d)
3. (d)
4. (a)
5. (a)
6. (3)
7. (b)
8. (d)
9. (d)
10. (d)
11. (b)
12.. (a)

LEVEL 2 Objective Questions

13. (b)
14. (a)
15. (1.11)
16. (c)
17. (b)
18. (2.28)
19. (0.56)
20. (26.74)
21. (1.9052)
22. (a)
23. (0.667)
24. (1)
25. (8)
26. (2)
27. (0.05)

■■■■

LEVEL 3 Conventional Questions

Solution : 28

$$\frac{1}{2}al\rho \times 2\dot{x}\ddot{x} + a\rho g \times 2x\dot{x} = 0$$

$$\ddot{x} + \frac{2g}{l}x = 0$$

Solution : 29

$A = 0.00298$ m $= 2.98$ mm

Solution : 30

$f_n = 2.85$ Hz

Solution : 31

$\delta = 0.693$

$C = 45.809$ Nm/rad

periodic time of oscillation $= 1.503 \times 10^{-3}$ sec

$f_n = 669.2$ Hz

Solution : 32

$$\omega_d = \sqrt{\frac{k_1 l_1^2 + mgl}{ml^2} - \left(\frac{Cl_2}{2ml^2}\right)^2}$$

Solution : 33

$N_c = 2598$ r.p.m

Solution : 34

$C = 400.824$ N/m/s

$\frac{f_d}{f_n} = 0.99$

$T_d = 0.32$ sec

Solution : 35

$\delta = 0.405$

Damping coefficient, $C = 32.745$ N.m.s/rad

$\omega_d = 4233.72$ rad/s

$T_d = 1.484 \times 10^{-3}$ s

Solution : 36

$F_T = 38.6$ N

$F_T = 367$ N

Amplitude of the forced vibration of the machine at resonance = 8.7 mm

Solution : 37

$C = 2970$ N-m/rad

Solution : 38

$A = 130$ mm

$\phi = 42.4897°$

Solution : 39

$k = 1.607$ N/mm

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