2019

RANK IMPROVEMENT WORKBOOK

## Mechanical Engineering

# Engineering Mechanics

Answer Key of Objective & Conventional Questions

MADE EASY Publications

# 1 System of forces, Centoriod, MOI

## LEVEL 1 Objective Questions

| | |
|---|---|
| 1. | (c) |
| 2. | (b) |
| 3. | (a) |
| 4. | (c) |
| 5. | (b) |
| 6. | (c) |
| 7. | (b) |
| 8. | (b) |
| 9. | (34) |
| 10. | (10.48) |
| 11. | (3.28) |
| 12. | (b) |
| 13. | (6) |
| 14. | 72.38 |
| 15. | (4.26) |
| 16. | (–9.5) |
| 17. | (5) |
| 18. | (a) |
| 19. | (c) |
| 20. | (b) |
| 21. | (b) |
| 22. | (a) |
| 23. | (b) |
| 24. | (a) |
| 25. | (b) |
| 26. | (b) |
| 27. | (c) |
| 28. | (b) |
| 29. | (c) |
| 30. | (b) |
| 31. | (c) |
| 32. | (b) |
| 33. | (c) |
| 34. | (a) |
| 35. | (c) |

## LEVEL 2 Objective Questions

| | |
|---|---|
| 36. | (c) |
| 37. | (d) |
| 38. | (b) |

## LEVEL 3 Conventional Questions

**Solution : 39**

Direction cosines, $l = \cos\alpha = -0.668$, $m = \cos\beta + 0.743$

Unit vector along $S_{PQ}$, $\bar{r} = -0.668i + 0.743j$

**Solution : 40**

Shown force vector = 72.97 N

$l = +0.548$

$m = -0.685$

$n = +0.48$

**Solution : 41**

Moment of the couple, $C = 30 \times 2 = +60$ Nm (ccw)

Couple vector, $C = 42.42j + 42.42i$ Nm

**Solution : 42**

The simplest resultant of the force system is 50 N ↓ acting at point (–12, 0, 8) m.

$F_R = -50j\text{ N} + \text{couple } C_R = +400i + 600k\text{ Nm}, |C_R| = 721\text{ Nm}.$

**Solution : 43**

Simplest resultant is 25.33 kN acting at a distance of 5.37 m from *A*.

**Solution : 44**

$$|F_R| = \sqrt{80^2 + 40^2} = 89.4\text{ N}$$

$C_R = 150$ Nm (*ccw*) resultant couple

If we take $\bar{x} = 0$, $\bar{y} = -1.875$ m

$\bar{y} = 0$, $\bar{x} = +3.75$ m

**Solution : 45**

Moment of inertia, $I_{xx} = 55.25\text{ cm}^4$.

**Solution : 46**

$I_{xy} = 300\text{ cm}^4$

$I_{\bar{x}\bar{y}} = -220\text{ cm}^4$

**Solution : 47**

$$\bar{y} = \frac{3}{8}R$$

Other distances $\bar{x} = \bar{z} = 0.$

**Solution : 48**

$$\bar{x} = 89.18 \text{ mm from } A$$

$$\bar{y} = 64.59 \text{ mm from } A$$

**Solution : 49**

Magnitude of the resultant force is equal to 45.6 N and acting at an angle of 132 with the horizontal i.e. East-West line.

**Solution : 50**

Magnitude of the resultant force

$$P = 85.15 \text{ kgf}$$

Angle of the resultant force = 273° 22′

**Solution : 51**

$$\bar{y} = \frac{V_1 y_1 + V_2 y_2}{V_1 + V_2} = 28.4 \text{ mm}$$

**Solution : 52**

$$h = 1.732\, r$$

**Solution : 53**

Now moment of inertia of the whole section about *X-X* axis,

$$I_{XX} = 1.824 \times 10^6 \text{ mm}^4$$

Now moment of inertia of whole section about its base *BC*,

$$= 4.815 \times 10^6 \text{ mm}^4$$

**Solution : 54**

$$\bar{y} = 2.8 \text{ cm}$$

$$I_{XX} = 117.51 \text{ cm}^4$$

$$I_{YY} = 498.3 \text{ cm}^4$$

■■■■

# 2 Equilibrium of Rigid Bodies

## LEVEL 1 Objective Questions

| | |
|---|---|
| 1. | (a) |
| 2. | (a) |
| 3. | (b) |
| 4. | (c) |
| 5. | (b) |
| 6. | (d) |
| 7. | (a) |
| 8. | (c) |
| 9. | (340) |
| 10. | (a) |
| 11. | (500) |
| 12. | (87.5) |
| 13. | (a) |

## LEVEL 2 Objective Questions

| | |
|---|---|
| 14. | (c) |
| 15. | (481) |
| 16. | (70.71) |
| 17. | (755.51) |
| 18. | (1911) |
| 19. | (c) |
| 20. | (c) |
| 21. | (c) |
| 22. | (b) |
| 23. | (b) |

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## LEVEL 3 Conventional Questions

**Solution : 24**

Component of 58.8 kN along horizontal direction

$$= 58.8 \times \sin\alpha = 5.85 \text{ kN}$$

**Solution : 25**

Tension, $T_3 = 500$ N

Tension, $T_2 = 353.6$ N

Tension, $T_1 = 683$ N

**Solution : 26**

$R_A = 601$ N

Reaction, $R_C = 333.5$ N

**Solution : 27**

$$x = \frac{WL}{2P}$$

Reaction at end $O$, $$R_0 = \left(P - \frac{W}{2}\right)\uparrow$$

**Solution : 28**

$$\alpha = 90^o$$

$$P_{min} = 660 \text{ N}$$

**Solution : 29**

Reaction, $$R_A = \left(W_1 - \frac{W_2 L_4}{L_3}\right)\uparrow$$

**Solution : 30**

$$P = 2.399 \text{ kN}$$

**Solution : 31**

$$R_{BV} = \frac{W}{4}$$

$$R_{AV} = \frac{3W}{4}$$

$$R_{AH} = \overrightarrow{0.25W}$$

$R_{BH} = \overleftarrow{W}/4$ (for equilibrium)

**Solution : 32**

$$R_A = 784.7 \ N$$

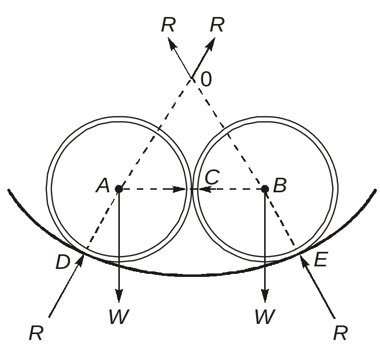
$$R_B = 315.9 \ N$$

**Solution : 33**

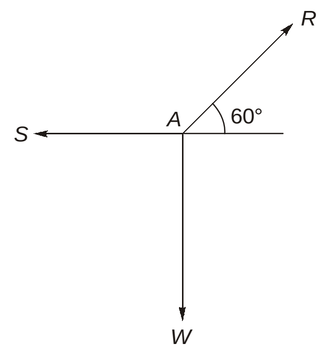
Radius of spheres = 50 mm

Radius of cup = 150 mm

The two spheres with centres *A* and *B*, lying in equilibrium, in the cup with *O* as centre are shown in figure (a). Let the two spheres touch each other at *C*, and touch the cup at *D* and *E*.




**(a)**




**(b)**

Let, $R$ = Reaction between the spheres and cup, and

$S$ = Reaction between the two spheres at *C*.

From the geometry of the figure, we find that,

$OD$ = 150 mm

and $AD$ = 50 mm

Therefore, $OA$ = 100 mm

Similarly $OB$ = 100 mm

We also find that, $AB$ = 100 mm

Therefore *OAB* is an equilateral triangle. The system of forces at *A* is shown in figure (b).

Applying Lami's equation at *A*,

$$\frac{R}{\sin 90^\circ} = \frac{W}{\sin 120^\circ} = \frac{S}{\sin 150^\circ}$$

$$\frac{R}{1} = \frac{W}{\sin 60^\circ} = \frac{S}{\sin 30^\circ}$$

$$\therefore \quad R = \frac{S}{\sin 30^\circ} = \frac{S}{0.5} = 2S$$

Hence the reaction between the cup and the sphere is double than that between the two spheres.

**Solution : 34**

$R_1$ = 134.2 *N*

$R_2$ = 240.8 *N*

$R_3$ = 154.9 *N*

$R_4$ = 622.5 N

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# 3 Kinematics of Point Mass and Rigid Bodies

## LEVEL 1 Objective Questions

1. (c)
2. (b)
3. (b)
4. (c)
5. (c)
6. (a)
7. (21.079)
8. (14)
9. (d)
10. (680)
11. (16)
12. (a)
13. (c)
14. (b)
15. (5)

## LEVEL 2 Objective Questions

16. (12)
17. (a)
18. (3.34)
19. (b)
20. (c)
21. (c)
22. (c)
23. (a)
24. (c)
25. (72.11)
26. (c)
27. (10)
28. (1400)
29. (a)
30. (c)
31. (b)
32. (a)
33. (c)
34. (c)
35. (b)
36. (b)
37. (c)

■■■■

## LEVEL 3 Conventional Questions

**Solution : 38**

$$S = 1.5t^2 = 1.5 \times 29.856^2 = 1337.1 \text{ m}$$

**Solution : 39**

Radius of curvature, $R = 100$ m

Normal acceleration, $a_n = 4$ m/s$^2$.

**Solution : 40**

Maximum angular velocity, $\omega = 2.09 \times 10^{-2}$ rad/s

$\alpha_1 = 6.98 \times 10^{-4}$ rad/sec$^2$

$\alpha_2 = 10.45 \times 10^{-4}$ rad/s$^2$

**Solution : 41**

Angular acceleration, $\alpha = -0.333$ rad/s$^2$

$t = 26$ seconds

$\theta = 112.64$ radians

**Solution : 42**

Angular velocity, $\dot{\theta} = -3\pi \sin 4\pi t$

Angular acceleration $\ddot{\theta} = -12\pi^2 \cos 4\pi t$

**Solution : 43**

$V = 7.2$ m/s at $t = 6$ s

$S = 10.8$ m

**Solution : 44**

Velocity, $v_4 = 29.697$ m/s

$S_4 = 40.697$ m

$a_4 = 16.348$ m/s$^2$

**Solution : 45**

Tangential acceleration, $a_t = 4.905$ m/s$^2$

Normal acceleration, $a_n = 17.01$ m/s$^2$

Velocity, $V = 4.124$ m/s

Acceleration $a = 17.70$ m/s$^2$

**Solution : 46**

$v = 18 + 0 - 0 = 18$ m/s

$a = 6$ m/s$^2$

$t = 0.5$ sec

**(iii)** Maximum speed of the particle

The maximum speed of the particle may now be found out by substituting $t = 0.5$ second in equation (ii),

$$v_{max} = 18 + 6 \times 0.5 - 6\,(0.5)^2$$
$$= 19.5 \text{ m/s}$$

**Solution : 47**

$$V = \frac{672}{400} = 1.68 \text{ m/sec}$$

**Solution : 48**

$$a = 5.8 \text{ m/sec}^2$$
$$T_A = 38.88 \text{ N}$$
$$T_B = 21.47 \text{ N}$$

**Solution : 49**

$$a_0 = \frac{g}{1 + \frac{m_1}{4}\left(\frac{1}{m_2} + \frac{1}{m_3}\right)}$$

**Solution : 50**

$$t = \left[\frac{2L}{(g + a_0)\sin\theta\cos\theta}\right]^{1/2}$$

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# 4 Dynamics of Rigid Bodies, Momentum, Collision

## LEVEL 1 Objective Questions

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

## LEVEL 2 Objective Questions

15. (b)
16. (c)
17. (a)
18. (a)
19. (1)
20. (4)
21. (b)
22. (b)
23. (a)
24. (b)
25. (a)
26. (c)
27. (a)
28. (b)
29. (a)
30. (c)
31. (b)

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## LEVEL 3 Conventional Questions

**Solution : 32**

$$\bar{a} > 0.35\,g$$
$$\bar{a} > 0.3\,g$$

**Solution : 33**

Cable Tension, $T = 5533.95$ N

$P = 572.65$ N

**Solution : 34**

$t = 3.76$ second.

**Solution : 35**

$T = 29.62$ N

$F = 71.74$ Newton

**Solution : 36**

Linear acceleration of mass centre of cylinder,

$$\bar{a} = \frac{2}{3} g \sin\theta$$

$$\alpha = \frac{2\mu g \cos\theta}{R}$$

**Solution : 37**

Angular acceleration, $\alpha = 7.842$ rad/s$^2$

Tension in string, $T = 27.17$ N

**Solution : 38**

Gap between the two after 1 second

$S_1 - S_2 = 0.2785$ m.

**Solution : 39**

Vertical reaction, $N = 0.95mg$

$F = 0.1875$ mg

Coefficient of friction, $\mu = 0.1974$

**Solution : 40**

Angular acceleration, $\alpha = 5.2083$ rad/s$^2$

$O_X = \overrightarrow{156.25}$ N.

**Solution : 41**

Loss of KE = 1.05 Nm.

**Solution : 42**

$$T = \frac{mg}{6}$$

$$v = \sqrt{\frac{4gh}{3}}$$

**Solution : 43**

The sphere rolls with translational velocity $\frac{6v_0}{7}$ in the forward direction.

**Solution : 44**

$$v = \frac{mv_0}{M + m}$$

$$\omega = \frac{mv_0(h - R)}{\left(\frac{2}{5}M + m\right)R^2}$$

$$h = \left(\frac{\frac{7}{5}M + 2m}{M + m}\right)R \approx \frac{7}{5}R$$

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# 5 Work and Energy

## LEVEL 1 Objective Questions

| | |
|---|---|
| 1. | (b) |
| 2. | (a) |
| 3. | (c) |
| 4. | (b) |
| 5. | (c) |
| 6. | (b) |
| 7. | (b) |
| 8. | (b) |
| 9. | (c) |
| 10. | (b) |



## LEVEL 2 Objective Questions

| | |
|---|---|
| 11. | (9.8) |
| 12. | (d) |
| 13. | (d) |
| 14. | (0.0001) |
| 15. | (b) |
| 16. | (a) |
| 17. | (50) |
| 18. | (c) |
| 19. | (c) |
| 20. | (a) |
| 21. | (b) |
| 22. | (c) |
| 23. | (c) |
| 24. | (a) |

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## LEVEL 3 Conventional Questions

**Solution : 25**

Reaction at $D$, $R_D$ = 466.66 N.

$F_B$ = 350 N ↑

**Solution : 26**

$P_1$ = 1.5 P

**Solution : 27**

Force, $P$ = 381.4 N.

**Solution : 28**

Speed of flywheel after punching = 215.44 rpm

**Solution : 29**

Putting the value of $k$ = 62.5 Nm

**Solution : 30**

Work done in rolling the wheel up the plane by 3 m

$U_{1-2}$ = 79.29 Nm

Angular velocity, $\omega$ = 26.54 rad/s

**Solution : 31**

$T$ = 150 N

**Solution : 32**

$P$ = 707 N

**Solution : 33**

$P$ = 1 kN

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# 6 Plane Trusses

## LEVEL 1 Objective Questions

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



## LEVEL 2 Objective Questions

11. (d)
12. (b)
13. (b)
14. (c)
15. (a)
16. (b)
17. (b)
18. (11.5
19. (b)

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## LEVEL 3 Conventional Questions

**Solution : 20**

$$F_{BD} = 0.866P \text{ (Compression)}$$

**Solution : 21**

$$R_{AV} = 1.5\text{ W}$$

**At *E*:** Reaction $R_{EV} = 0.5\text{ W}\uparrow$

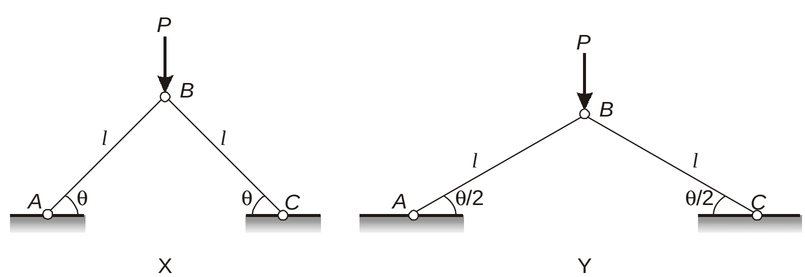
$$R_{EH} = R_{AH} = 2.6\text{ W (for balancing)}$$

**Joint *D*** $F_{BD} = 2\text{ W}\uparrow (T)$

**Solution : 22**

$$F_{GF} = 6\text{ kN (Tension)}$$
$$F_{BC} = 6.667\text{ kN (Compression)}$$
$$F_{GC} = 1.2\text{ kN } (T).$$

**Solution : 23**




As both are symmetric frames having only difference in degree of inclination thereby forces in each will be

For frame *X*: $F_{AB} = F_{BC} = -\dfrac{P}{2\sin\theta}$

**For frame *Y*:** $F_{AB} = F_{BC} = -\dfrac{P}{2\sin\dfrac{\theta}{2}}$

Similarly deflection of point *B* will be

**For frame *X*:** $F_{AB} = F_{BC};\ \Delta_B = -\dfrac{P}{2\sin^2\theta}\dfrac{l}{AE}$

**For frame *Y*:** $F_{AB} = F_{BC};\ \Delta_B = -\dfrac{P}{2\sin^2\dfrac{\theta}{2}}\dfrac{l}{AE}$

As sine is an increasing function thereby $\sin\theta/2 < \sin\theta$.

$\therefore$ Force in $X <$ Force in $Y$

$\Rightarrow$ $\Delta_B$ in $X < \Delta_B$ in $Y$

**Solution : 24**

$$F_{BD} = -\frac{40}{\sqrt{3}} \text{ kN} = -23.09 \text{ kN} = 23.09 \text{ kN (compressive)}$$

**Solution : 25**

$\Rightarrow$ 5

**Solution : 26**

$$F_{BF} = 2.6 \text{ kN}$$

**Solution : 27**

$$P_{AB} = 13.16 \text{ tf (Compression)}$$
$$P_{AG} = 11.4 \text{ tf (Tension)}$$
$$P_{DE} = 8.84 \text{ tf (Compression)}$$
$$P_{FE} = 7.66 \text{ tf (Tension)}$$
$$P_{BC} = 11.66 \text{ tf (Compression)}$$
$$P_{BG} = 2.6 \text{ tf (Compression)}$$
$$P_{GC} = 8.37 \text{ tf (Tension)}$$
$$P_{GF} = 5.91 \text{ tf (Tension)}$$
$$P_{FC} = 3.46 \text{ tf (Tension)}$$

| S.No. | Member | Magnitude of force in *tf* | Nature of force |
|---|---|---|---|
| 1 | *AB* | 13.16 | Compression |
| 2 | *AG* | 11.4 | Tension |
| 3 | *DE* | 8.84 | Compression |
| 4 | *FE* | 7.66 | Tension |
| 5 | *BC* | 11.66 | Compression |
| 6 | *BG* | 2.6 | Compression |
| 7 | *DF* | 0 | - |
| 8 | *CD* | 8.84 | Compression |
| 9 | *GC* | 8.37 | Tension |
| 10 | *FG* | 5.91 | Tension |
| 11 | *FC* | 3.46 | Tension |

**Solution : 28**

Now tabulate these results as given below:

| S.No. | Member | Magnitude of force in kN | Nature of force |
|---|---|---|---|
| 1 | *AD*, *DB* | 7.08 | Tension |
| 2 | *AC*, *CB* | 11.19 | Compression |
| 3 | *CD* | 10.0 | Tension |

**Solution : 29**

The value of *W*, which would produce the force of 15 tones is the member *AB*

$$W = 5 \text{ tf}$$

**Solution : 30**

$$P_{CD} = 2 \text{ kN (Tension)}$$
$$P_{CG} = 1.7 \text{ kN (Tension)}$$

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# 7 Friction

## LEVEL 1 Objective Questions

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

## LEVEL 2 Objective Questions

13. (b)
14. (81.17)
15. (a)
16. (1)
17. (c)
18. (330)
19. (c)
20. (0.5)
21. (d)
22. (380.2)
23. (22.50)
24. (a)
25. (a

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## LEVEL 3 Conventional Questions

**Solution : 26**

$$\theta = 14°20'$$

**Solution : 27**

$$\text{Number of turns, } n = 2.32 \text{ turns}$$

**Solution : 28**

resolving the forces vertically, $P = 232.3$ N

**Solution : 29**

$$P = 18.35 \text{ kgf}$$

$$\alpha = 68° 57'$$

**Solution : 30**

resolving the forces horizontally,

$$P = 180.4 \text{ kgf}$$

**Solution : 31**

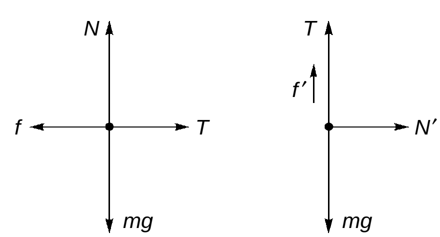
$$W_A = 262.3 \text{ N}$$

**Solution : 32**

If no force is applied, the block $A$ will slip on $C$ towards right and the block $B$ will move downward. Suppose the minimum force needed to prevent slipping is $F$. Taking $A + B + C$ as the system, the only external horizontal force on the system is $F$. Hence the acceleration of the system is

$$a = \frac{F}{M + 2m} \quad \text{...(i)}$$

Now take the block $A$ as the system. The forces on $A$ are




(i) tension $T$ by the string towards right,
(ii) friction $f$ by the block $C$ towards left,
(iii) weight $mg$ downward and
(iv) normal force $N$ upward

For vertical equilibrium $N = mg$

As the block moves towards right with an acceleration $a$,

$$T - f = ma$$

or, $$T - \mu mg = ma \quad \text{...(ii)}$$

Now take the block $B$ as the system. The forces are

(i) tension $T$ upward,

(ii) weight $mg$ downward,
(iii) normal force $N'$ towards right, and
(iv) friction $f'$ upward

As the block moves towards right with an acceleration $a$,

$$N' = ma$$

As the friction is limiting, $f' = \mu N' = \mu\, ma$

For vertical equilibrium, $T + f' = mg$ ...(iii)

Eliminating $T$ from (ii) and (iii),

$$a_{min} = \frac{1-\mu}{1+\mu}g$$

When a large force is applied the block $A$ slips on $C$ towards left and the block $B$ slips on $C$ in the upward direction. The friction on $A$ is towards right and that on $B$ is downwards. Solving as above, the acceleration in this case is

$$a_{max} = \frac{1+\mu}{1-\mu}g$$

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