34 Years
Previous Solved Papers

GATE 2021

Mechanical Engineering

- Fully solved with explanations
- Topicwise presentation
- Analysis of previous papers
- Thoroughly revised & updated

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GATE - 2021 : Mechanical Engineering Topicwise Previous GATE Solved Papers (1987-2020)

1st Edition : 2008
2nd Edition : 2009
3rd Edition : 2010
4th Edition : 2011
5th Edition : 2012
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8th Edition : 2015
9th Edition : 2016
10th Edition : 2017
11th Edition : 2018
12th Edition : 2019

13th Edition : 2020

Preface

B. Singh (Ex. IES)

Over the period of time the GATE examination has become more challenging due to increasing number of candidates. Though every candidate has ability to succeed but competitive environment, in-depth knowledge, quality guidance and good source of study is required to achieve high level goals.

The new edition of **GATE 2021 Solved Papers : Mechanical Engineering** has been fully revised, updated and edited. The whole book has been divided into topicwise sections.

At the beginning of each subject, analysis of previous papers are given to improve the understanding of subject.

I have true desire to serve student community by way of providing good source of study and quality guidance. I hope this book will be proved an important tool to succeed in GATE examination. Any suggestions from the readers for the improvement of this book are most welcome.

B. Singh (Ex. IES)
Chairman and Managing Director
MADE EASY Group

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Theory of Machines

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UNIT IV

Theory of Machines

Syllabus : Displacement, velocity and acceleration analysis of plane mechanisms; dynamic analysis of linkages; cams; gears and gear trains; flywheels and governors; balancing of reciprocating and rotating masses; gyroscope.

Vibrations : Free and forced vibration of single degree of freedom systems, effect of damping; vibration isolation; resonance; critical speeds of shafts.

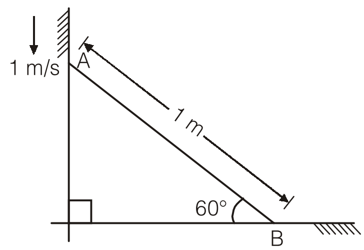
Analysis of Previous GATE Papers

Exam Year	1 Mark Ques.	2 Marks Ques.	3 Marks Ques.	5 Marks Ques.	Total Marks
1987	–	–	–	–	**–**
1988	–	–	–	–	**–**
1989	–	–	–	1	**5**
1990	–	–	–	–	**–**
1991	–	–	–	–	**–**
1992	–	1	–	–	**2**
1993	–	2	–	–	**4**
1994	1	–	–	–	**1**
1995	–	3	–	–	**6**
1996	–	2	–	2	**14**
1997	1	–	–	1	**6**
1998	1	1	–	–	**3**
1999	1	2	–	1	**10**
2000	1	1	–	–	**3**
2001	2	1		1	**9**
2002	–	–	–	–	**–**
2003	3	6	–	–	**15**
2004	2	8	–	–	**18**
2005	2	6	–	–	**14**
2006	3	9	–	–	**21**
2007	1	6	–	–	**13**
2008	1	3	–	–	**7**
2009	2	4	–	–	**10**
2010	5	3	–	–	**11**

Exam Year	1 Mark Ques.	2 Marks Ques.	Total Marks
2011	1	3	**7**
2012	2	1	**4**
2013	3	2	**7**
2014 Set-1	2	3	**8**
2014 Set-2	2	3	**8**
2014 Set-3	2	4	**10**
2014 Set-4	2	3	**8**
2015 Set-1	1	2	**5**
2015 Set-2	2	2	**6**
2015 Set-3	3	3	**9**
2016 Set-1	2	3	**8**
2016 Set-2	1	2	**5**
2016 Set-3	3	3	**9**
2017 Set-1	1	3	**7**
2017 Set-2	2	4	**10**
2018 Set-1	3	3	**9**
2018 Set-2	2	3	**8**
2019 Set-1	3	3	**9**
2019 Set-2	1	5	**11**
2020 Set-1	4	2	**8**
2020 Set-2	2	3	**8**

1 Displacement, Velocity and Acceleration

1.1 A rod of length 1 m is sliding in a corner as shown in figure. At an instant when the rod makes an angle of 60 degrees with the horizontal plane., the velocity of point A on the rod is 1 m/s. The angular velocity of the rod at this instant is

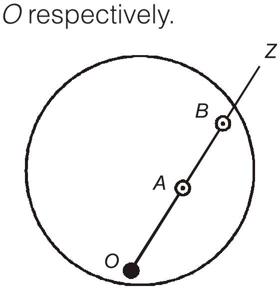


(a) 2 rad/s (b) 1.5 rad/s
(c) 0.5 rad/s (d) 0.75 rad/s

[1996 : 2 Marks]

Common Data Questions Q.1.2 and Q.1.3

The circular disc shown in its plan view in the figure rotates in a plane parallel to the horizontal plane about the point O at a uniform angular velocity ω. Two other points A and B are located on the line OZ at distances r_A and r_B from O respectively.



1.2 The velocity of point B with respect to point A is a vector of magnitude

(a) 0
(b) ω ($r_B - r_A$) and direction opposite to the direction of motion of point B
(c) ω ($r_B - r_A$) and direction same as the direction of motion of point B.
(d) ω ($r_B - r_A$) and direction being from O to Z.

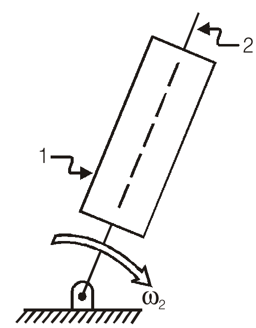
[2003 : 2 Marks]

1.3 The acceleration of point B with respect to point A is a vector of magnitude

(a) 0
(b) ω ($r_B - r_A$) and direction same as the direction of motion of point B.
(c) ω ($r_B - r_A$) and direction opposite to be direction of motion of point B.
(d) ω^2 ($r_B - r_A$) and direction being from Z to O.

[2003 : 2 Marks]

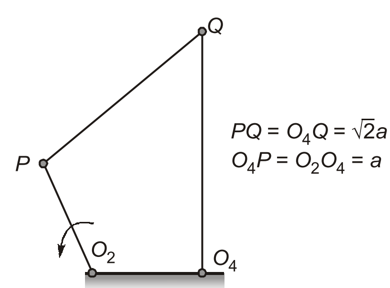
1.4 In the figure shown, the relative velocity of link 1 with respect of link 2 is 12 m/s. Link 2 rotates at a constant speed of 120 rpm. The magnitude of Coriolis component of acceleration of link 1 is



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

[2004 : 2 Marks]

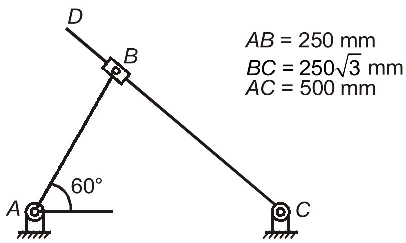
1.5 The input link O_2P of a four bar linkage is rotated at 2 rad/s in counter clockwise direction as shown below. The angular velocity of the coupler PQ in rad/s, at an instant when $\angle O_4O_2P = 180°$, is



(a) 4 (b) $2\sqrt{2}$
(c) 1 (d) $1/\sqrt{2}$

[2007 : 2 Marks]

1.6 For the configuration shown, the angular velocity of link AB is 10 rad/s counter clockwise. The magnitude of the relative sliding velocity (in ms^{-1}) of slider B with respect to rigid link CD is



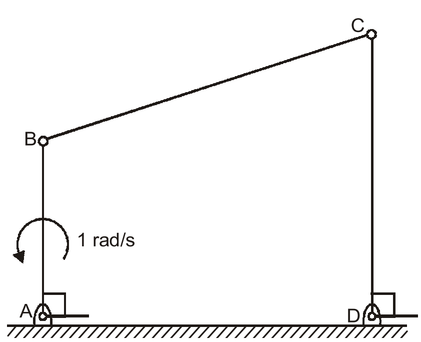
(a) 0 (b) 0.86
(c) 1.25 (d) 2.50

[2010 : 2 Marks]

1.7 There are two points P and Q on a planar rigid body. The relative velocity between the two points
(a) should always be along PQ
(b) can be oriented along any direction
(c) should always be perpendicular to PQ
(d) should be along QP when the body undergoes pure translation

[2010 : 1 Mark]

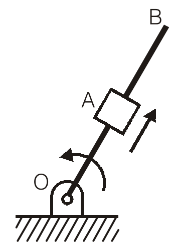
1.8 For the four-bar linkage shown in the figure, the angular velocity of link AB is 1 rad/s. The length of link CD is 1.5 times the length of link AB. In the configuration shown, the angular velocity of link CD in rad/s is



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

[2011 : 2 Marks]

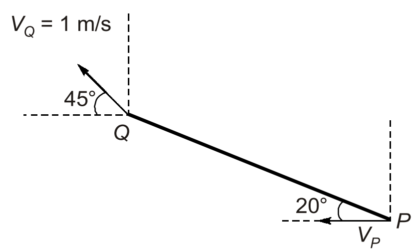
1.9 A link OB is rotating with a constant angular velocity of 2 rad/s in counter clockwise direction and a block is sliding radially outward on it with an uniform velocity of 0.75 m/s with respect to the rod, as shown in the figure below. If OA = 1 m, the magnitude of the absolute acceleration of the block at location A in m/s^2 is



(a) 3 (b) 4
(c) 5 (d) 6

[2013 : 1 Mark]

1.10 A rigid link PQ is 2 m long and oriented at 20° to the horizontal as shown in the figure. The magnitude and direction of velocity V_Q, and the direction of velocity V_P are given. The magnitude of V_P (in m/s) at this instant is



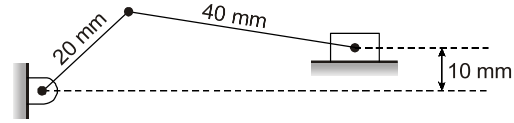
(a) 2.14 (b) 1.89
(c) 1.21 (d) 0.96

[2014 : 1 Mark, Set-1]

1.11 A rigid link PQ of length 2 m rotates about the pinned end Q with a constant angular acceleration of 12 rad/s^2. When the angular velocity of the link is 4 rad/s, the magnitude of the resultant acceleration (in m/s^2) of the end P is _______.

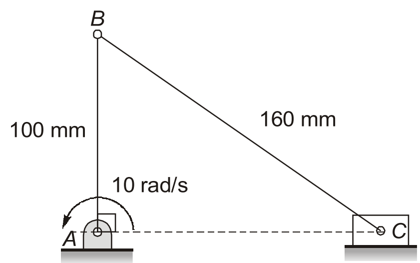
[2014 : 2 Marks, Set-2]

1.12 An offset slider-crank mechanism is shown in the figure at an instant. Conventionally, the Quick Return Ratio (QRR) is considered to be greater than one. The value of QRR is _______.



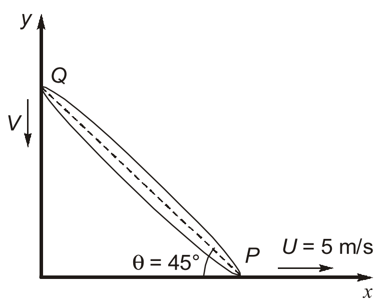
[2014 : 2 Marks, Set-1]

1.13 In the figure, link 2 rotates with constant angular velocity ω_2. A slider link 3 moves outwards with a constant relative velocity $V_{Q/P}$, where Q is a point on slider 3 and P is a point on link 2. The magnitude and direction of Coriolis component of acceleration is given by clockwise. The magnitude of linear velocity (in m/s) of the piston at the instant corresponding to the configuration shown in the figure is _______.



[2017 : 1 Mark, Set-2]

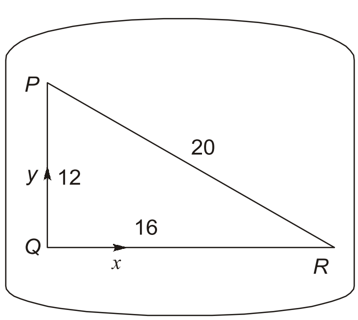
1.20 A rigid rod of length 1 m is resting at an angle θ = 45° as shown in the figure. The end *P* is dragged with a velocity of *U* = 5 m/s to the right. At the instant shown, the magnitude of the velocity *V* (in m/s) of point *Q* as it moves along the wall without losing contact is



(a) 5
(b) 6
(c) 8
(d) 10

[2018 : 2 Marks, Set-2]

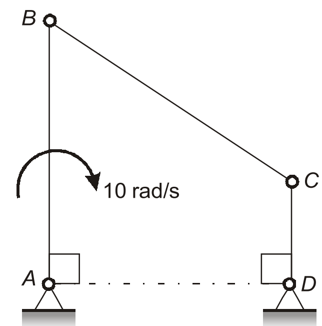
1.21 In a rigid body in plane motion, the point *R* is accelerating with respect to point *P* at 10∠180° m/s^2. If the instantaneous acceleration of point *Q* is zero, the acceleration (in m/s^2) of point *R* is



(a) 8∠233°
(b) 10∠225°
(c) 10∠217°
(d) 8∠217°

[2018 : 2 Marks, Set-2]

1.22 In a four bar planar mechanism shown in the figure, *AB* = 5 cm, *AD* = 4 cm and *DC* = 2 cm. In the configuration shown, both *AB* and *DC* are perpendicular to *AD*. The bar *AB* rotates with an angular velocity of 10 rad/s. The magnitude of angular velocity (in rad/s) of bar *DC* at this instant is



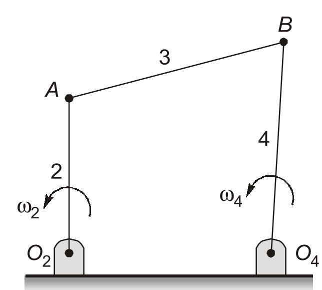
(a) 10
(b) 25
(c) 15
(d) 0

[2019 : 2 Mark, Set-1]

1.23 A four bar mechanism is shown in the figure. The link numbers are mentioned near the links. Input link 2 is rotating anticlockwise with a constant angular speed ω_2. Length of different links are:

$O_2O_4 = O_2A = L, \quad AB = O_4B = \sqrt{2}L$

The magnitude of the angular speed of the output link 4 is ω_4 at the instant when link 2 makes an angle of 90° with O_2O_4 as shown. The ratio $\frac{\omega_4}{\omega_2}$ is _______ (round off to two decimal places).



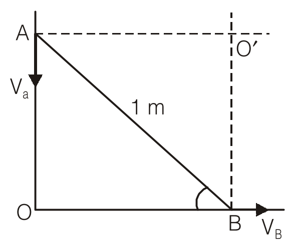
[2019 : 2 Mark, Set-2]

Answers Displacement, Velocity and Acceleration

1.1 (a)	1.2 (c)	1.3 (d)	1.4 (a)	1.5 (c)	1.6 (d)	1.7 (c)	1.8 (d)	1.9 (c)
1.10 (d)	1.11 (40)	1.12 (1.25)	1.13 (a)	1.14 (1)	1.15 (b)	1.16 (d)	1.17 (243.310)	
1.18 (0.266)	1.19 (1)	1.20 (a)	1.21 (d)	1.22 (b)	1.23 (0.79)			

Explanations Displacement, Velocity and Acceleration

1.1 (a)



$$V_a = O'A \times \omega$$

Here, O' is instantaneous centre of rotation.

$$1 = 1 \cos 60° \times \omega$$

or $$\omega = \frac{1}{\cos 60°} = \frac{1}{0.5} = \textbf{2 rad/s}$$

1.2 (c)

Linear velocity of A and B are ωr_A and ωr_B respectively.

$\because \quad r_B > r_A$

$\therefore \quad \omega r_B > \omega r_A$

Velocity of B with respect to A

$$(\vec{V}_{B/A}) = \overrightarrow{\omega r_B} - \overrightarrow{\omega r_A}$$

$\omega(r_B - r_A)$ in the direction of motion of point B.

1.3 (d)

Acceleration of point B with respect to point A.

$$\overrightarrow{a_{B/A}} = \vec{a}_B - \vec{a}_A$$

$$= \overrightarrow{\omega^2 r_B} - \overrightarrow{\omega^2 r_A}$$

$$= \omega^2 (r_B - r_A) \text{ in direction from } Z \text{ to } O.$$

1.4 (a)

Velocity of link 1 with respect to 2

$$V_{1/2} = 12 \text{ m/s}$$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 120}{60} = 12.566 \text{ rad/s}$$

$\therefore$ Corioli's component of acceleration

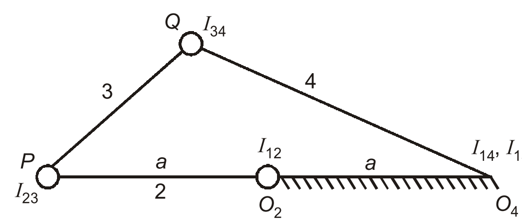
$$= 2V_{1/2}\omega = 2 \times 12 \times 12.566 \approx \textbf{302 m/s}^2$$

1.5 (c)

Method I:

When

$\angle O_4 O_2 P = 180°$



$$I_{13} \begin{cases} I_{12}\, I_{23} \\ I_{14}\, I_{34} \end{cases}$$

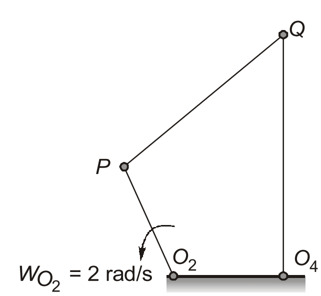
Applying angular velocity theorem at I_{23}.

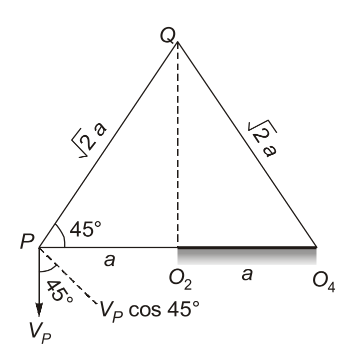
$$\omega_2(I_{23}I_{12}) = \omega_3(I_{23}I_{13})$$

$$2(a) = \omega_3(2a)$$

$$\omega_3 = 2/2 = \textbf{1 rad/s}$$

Method II:





The given four bar linkage is converted into isosceles triangle as shown above.

$$V_P = O_2P \times \omega_{O_2P}$$
$$= a \times 2 = 2a \text{ m/s}$$

Velocity V_P also has two components, in which one component will be perpendicular to link,

$$PQ = V_P \cos 45°$$
$$= 2a \times \frac{1}{\sqrt{2}} = \sqrt{2}a \text{ m/s}$$

$\because$ Angular velocity of link PQ,

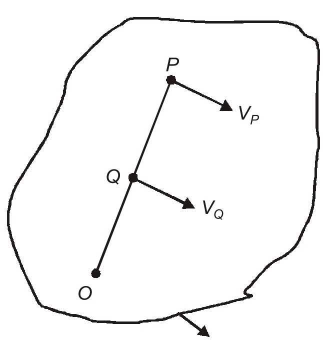
$$\omega_{PQ} = \frac{V_P \cos 45°}{PQ} = \frac{\sqrt{2}\,a}{\sqrt{2}\,a}$$
$$= 1 \text{ rad/sec}$$

1.6 (d)

As AB is perpendicular to slider for given condition, so sliding velocity of slider equals to velocity of link AB

$$= \omega \times AB = 10 \times 0.25 = \textbf{2.5 m/s}$$

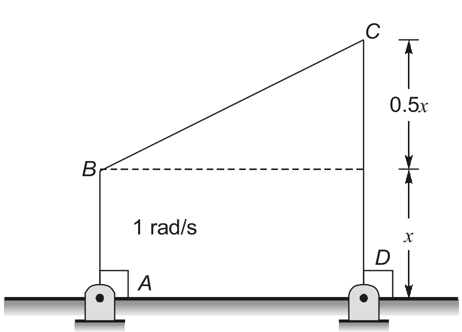
1.7 (c)



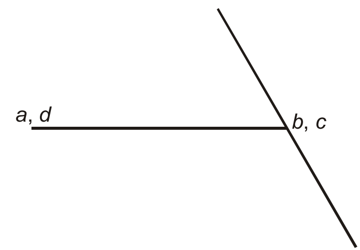
Planar rigid body.

V_{PQ} = Relative velocity between P and Q.
$V_{PQ} = V_P - V_Q$ Always perpendicular to PQ.

1.8 (d)



Let length of link AB is x velocity diagram;



$$v_b = v_c$$

(As per from velocity dia)

$$AB \times \omega_{AB} = CD \times \omega_{CD}$$
$$1 = \left(\frac{CD}{AB}\right) \times \omega_{CD}$$
$$1 = 1.5 \times \omega_{CD}$$
$$\omega_{CD} = \frac{2}{3} \text{ rad/s}$$

1.9 (c)

$\vec{a}_{A/B}$

Acceleration of the block at $A = \vec{a}_{cr} + \vec{a}_r$

$$= \overrightarrow{2\omega V} + \overrightarrow{\omega^2 r}$$

$\Rightarrow \quad r = OA$

$\Rightarrow \quad 2\omega V = 2 \times 2 \times 0.75 = 3 \text{ m/s}^2$

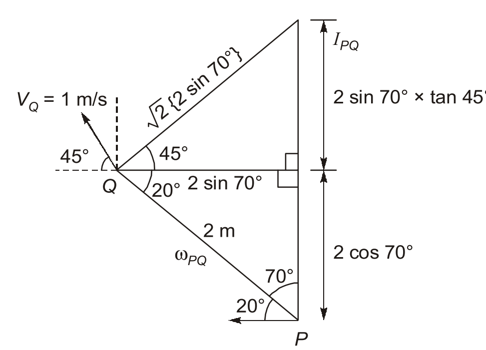
$\Rightarrow \quad \omega^2 r = 2^2 \times 1 = 4 \text{ m/s}^2$

As Corioli's component and radial component are perpendicular to each other.

So, $\quad |\vec{a}_{abs}| = \sqrt{3^2 + 4^2} = \textbf{5 m/s}^2$

1.10 (d)

<u>Method I:</u>



$$\therefore \quad \omega_{PQ} = \frac{V_P}{PI_{PQ}} = \frac{V_Q}{QI_{PQ}}$$

$P.I_{PQ}$ = Distance between P and I_{PQ}

$= 2 \cos 70° + 2 \sin 70° \times \tan 45°$

$= 2.56$ m

$$5 = 1\cos 45^\circ \times \omega$$

$$\omega = \frac{5}{\cos 45^\circ}$$

$$V_Q = IP \times \omega$$

$$= 1\sin 45^\circ \times \frac{5}{\cos 45^\circ}$$

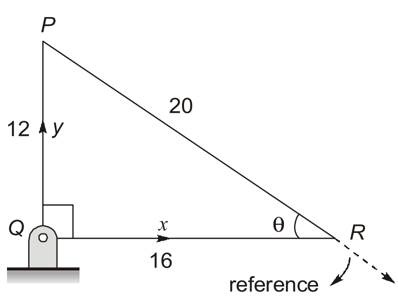
$$= \frac{5}{\tan 45^\circ} = 5 \text{ m/s}$$

Note: Here student is getting right answer by chance, (because $\angle = 45^\circ$). But concept is wrong. Because, we should take distance perpendicular to velocity, not parallel, so

$$V_p = IP \times \omega = r_p \times \omega$$

and $$V_Q = IQ \times \omega = r_Q \times \omega$$

1.21 (d)



As acceleration of point Q is zero, therefore we can assume this rigid body PQR is hinged at Q at this instant.

$$\vec{a}_{RP} = \vec{a}_R - \vec{a}_P$$

is given as 10 m/s^2 at an angle of 180°, that means only radial acceleration is there at that instant and reference is PR

$$a_{RP} = (RP)\omega^2 = 10$$

$$\Rightarrow \quad 20\omega^2 = 10$$

$$\Rightarrow \quad \omega = \frac{1}{\sqrt{2}}$$

Since point R has only radial acceleration, so total acceleration is only radial, therefore tangential acceleration is zero.

Therefore $\alpha_{body} = 0$

$$a_R = QR(\omega^2) = 16 \times \frac{1}{2} = 8 \text{ m/s}^2$$

and will be in the horizontal backward direction, but our reference is along PR, so the angle of it from reference is $(180 + \theta)$

from ΔPQR

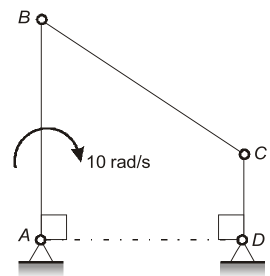
$$\tan\theta = \frac{12}{16}$$

$$\Rightarrow \quad \theta = 36.8698^\circ$$

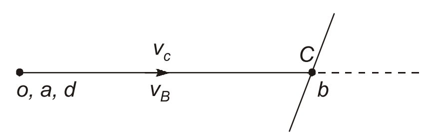
So, $180 + 36.8698 = 216.8698 \simeq 217^\circ$

So answer is **8∠217°**

1.22 (b)



Velocity diagram:

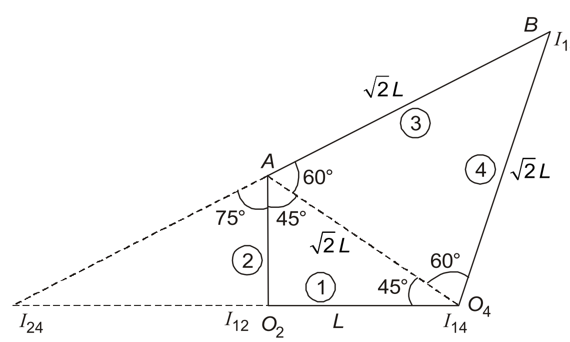


$$V_C = V_B = (AB) \times \omega_{AB}$$

$$= 0.05 \times 10) = 0.5 \text{ m/s}$$

$$\omega_{CD} = \frac{V_C}{CD} = \frac{0.5}{0.02} = 25 \text{ rad/s}$$

1.23 Sol.



According to Arnold's Kennedy theorem,

$$\Rightarrow \quad \tan 75^\circ = \frac{(I_{24}I_{12})}{(L)}$$

$$(I_{24}I_{12}) = (L\tan 75^\circ) = 3.732\,L$$

$$(I_{24}I_{14}) = 4.732\,L$$

$$\omega_2 \times (I_{24}I_{12}) = \omega_4\,(I_{24}I_{14})$$

$$\frac{\omega_4}{\omega_2} = \frac{I_{24}I_{12}}{I_{24}I_{14}}$$

$$\frac{\omega_4}{\omega_2} = \left(\frac{3.732}{4.732}\right) = 0.7886$$

■■■■