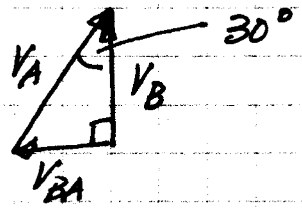
① $\omega_2 = \dfrac{\bar{V}_A}{\bar{R}_A} = \dfrac{12 \text{ in/s}}{24 \text{ in}} = 0.5 \text{ rad/s} = 4.8 \text{ RPM CCW}$



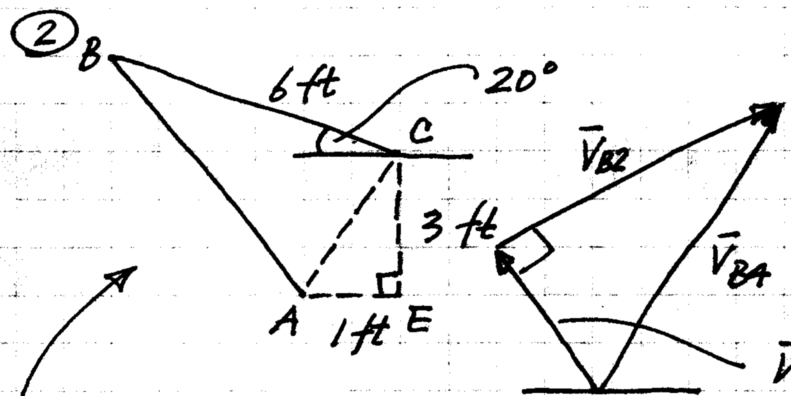
FROM DISPLACEMENT DIAGRAM

∴ FROM LAW OF SINES:

$$V_{BA} = \sqrt{[V_A^2 + V_B^2 - 2(V_A)(V_B)(\cos 30°)]}$$
$$= \sqrt{(12)^2 + (10.4)^2 - 2(12)(10.4)(\cos 30°)}$$
$$= 6.0 \text{ in/s}$$

so, $\bar{V}_{BA} = 6.0$ in/s @ 180° FROM HORIZONTAL.

②



$\bar{V}_{B4/B2} = \delta$ ft/min

$$\bar{V}_{B4} = \bar{V}_{B4/B2} + \bar{V}_{B2}$$

$\bar{V}_{B2}$ is $\perp$ TO $\overline{AB}$; $\bar{V}_{B4}$ is $\perp$ TO $\overline{BC}$

$$AC = \sqrt{[AE^2 + CE^2]} = \sqrt{(1)^2 + (3)^2} = 3.16 \text{ ft}$$

$$\measuredangle CAE = \tan^{-1}\left(\frac{CE}{AE}\right) = \tan^{-1}\left(\frac{3}{1}\right) = 71.57°$$

$$\therefore \measuredangle ACE = 90° - 71.57° = 18.43°$$

now, $\measuredangle BCE = 20° + 90° = 110°$

and, $\measuredangle BCA = \measuredangle BCE - \measuredangle ACE = 110° - 18.43° = 91.57°$

$$AB = \sqrt{AC^2 + BC^2 - 2(AC)(BC)\cos(\measuredangle ACB)}$$

$$AB = \sqrt{(3.16)^2 + (6)^2 - 2(3.16)(6)\cos(91.57°)}$$

$$= 6.86 \text{ ft}$$

$$\measuredangle BAC = \sin^{-1}\left\{\frac{6}{6.86}\sin(91.57°)\right\} = 60.96°$$

$$\measuredangle CBA = \sin^{-1}\left\{\frac{3.16}{6.86}\sin(91.57°)\right\} = 27.42°$$

$\therefore \measuredangle BAE = \measuredangle CAE + \measuredangle BAC = 71.57° + 60.96° = 132.53°$

$\therefore$ THE REMAINING $\measuredangle$ IS $47.47°$ $(180° - 132.53°)$ ON THE VELOCITY DIAGRAM AND THE INTERIOR ANGLE WILL BE $62.53°$ $(180° - 70° - 47.47°)$.

$\therefore V_{B4} = \left(\frac{V_{B4/B2}}{\cos 62.53°}\right) = 17.43$ ft/min @ 70° FROM HORIZONTAL

now, $\omega_4 = \frac{V_{B4}}{R_{BC}} = \frac{17.43}{6} = 2.89$ rad/sec (CW)

$= 0.46$ RPM (CW)

(3.61)

$\underline{r}_o + \underline{r}_1 + \underline{r}_2 + \underline{r}_3 = 0$ (a)

from which

$-r_o + r_1 e^{j\theta_1} + r_2 e^{j\theta_2} + r_3 e^{j\theta_3} = 0$ (b)

Substituting $e^{j\theta} = \cos\theta + j\sin\theta$, we obtain

$-r_o + r_1(\cos\theta_1 + j\sin\theta_1) + r_2(\cos\theta_2 + j\sin\theta_2)$

$+ r_3(\cos\theta_3 + j\sin\theta_3) = 0$ (c)

Equating the imaginary parts of c,

$r_1\sin\theta_1 + r_2\sin\theta_2 + r_3\sin\theta_3 = 0$ (d)

Equating the real parts of c,

$-r_o + r_1\cos\theta_1 + r_2\cos\theta_2 + r_3\cos\theta_3 = 0$ (e)

Position:

Equations d and e may be solved simultaneously to find position angles θ_2 and θ_3 if θ_1 is given. There are two assembly configurations.

Angular velocity:

Equation b is differentiated with respect to time to obtain

$j\omega_1 r_1 e^{j\theta_1} + j\omega_2 r_2 e^{j\theta_2} + j\omega_3 r_3 e^{j\theta_3} = 0$ (f)

Multiplying equation f by $(e^{-j\theta_3}/j)$:

$\omega_1 r_1 e^{j(\theta_1-\theta_3)} + \omega_2 r_2 e^{j(\theta_2-\theta_3)} + \omega_3 r_3 = 0$ (g)

Substituting $e^{j\theta} = \cos\theta + j\sin\theta$ in eqn. g,

$\omega_1 r_1[\cos(\theta_1-\theta_3) - j\sin(\theta_1-\theta_3)] + \omega_2 r_2[\cos(\theta_2-\theta_3) - j\sin(\theta_2-\theta_3)]$

$+ \omega_3 r_3 = 0$ (h)

Equating the imaginary parts of h:

$\omega_1 r_1\sin(\theta_1-\theta_3) + \omega_2 r_2\sin(\theta_2-\theta_3) = 0$ from which

$\omega_2 = -[\omega_1 r_1\sin(\theta_1-\theta_3)]/[r_2\sin(\theta_2-\theta_3)]$ (i)

Equating the real parts of h:

$\omega_3 = -[\omega_1 r_1\cos(\theta_1-\theta_3) + \omega_2 r_2\cos(\theta_2-\theta_3)]/r_3$ (j)

There are several possible methods. From equation d,

$\sin\theta_3 = \frac{1}{r_3}(-r_1\sin\theta_1 - r_2\sin\theta_2)$ (k)

Equation k may be used to eliminate θ_3 in equation e: The result is

$f(\theta_2) = 0 = r_o - r_1\cos\theta_1 - r_2\cos\theta_2$

$- r_3\cos[\arcsin(-\frac{r_1}{r_3}\sin\theta_1 - \frac{r_2}{r_3}\sin\theta_2)]$ (l)

Since the arcsin is double valued, both the computed result and 180° minus the computed arcsin should be considered. The solutions may be obtained using a calculator programmed to solve $f(\theta_2) = 0$, yielding $\theta_2 = 288.3°$ and $11.8°$. For the second value, using equation k,

$\theta_3 = \arcsin(-\frac{2}{3}\sin 60° - \frac{4.5}{3}\sin 11.8°) = -62.1$ and $242.1°$

The second value applies to the configuration in the sketch.

From equation i,

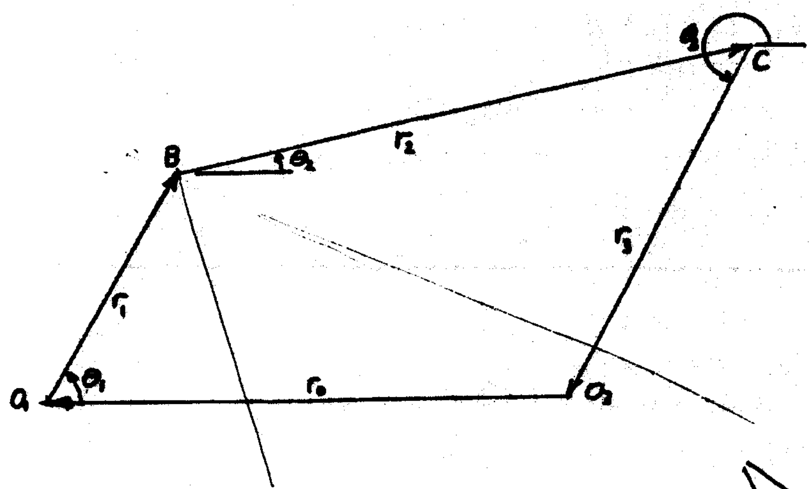
$\omega_2 = -[-50\times2\times\sin(60-242.1)]/[4.5\times\sin(11.8-242.1)]$

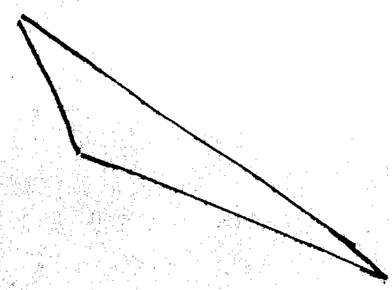
$= 1.06$ rad/s cc

From equation j,

$\omega_3 = -[-50\times2\times\cos(60-242.1) + 1.06\times4.5\times\cos(11.8-242.1)]/3$

$= -32.3$ (32.3 rad/s cw)





See figure.

$ob = \omega_1 r_1 = 50 \times 2 = 100 \perp O_1B$

$bc \perp BC$ $\quad oc \perp O_3C$

$bc = 5$ $\quad oc = 97$

$\omega_2 = bc/BC = 5/4.5 = 1.1$ rad/s cc

$\omega_3 = oc/O_3C = 97/3 = 32.3$ rad/s cw